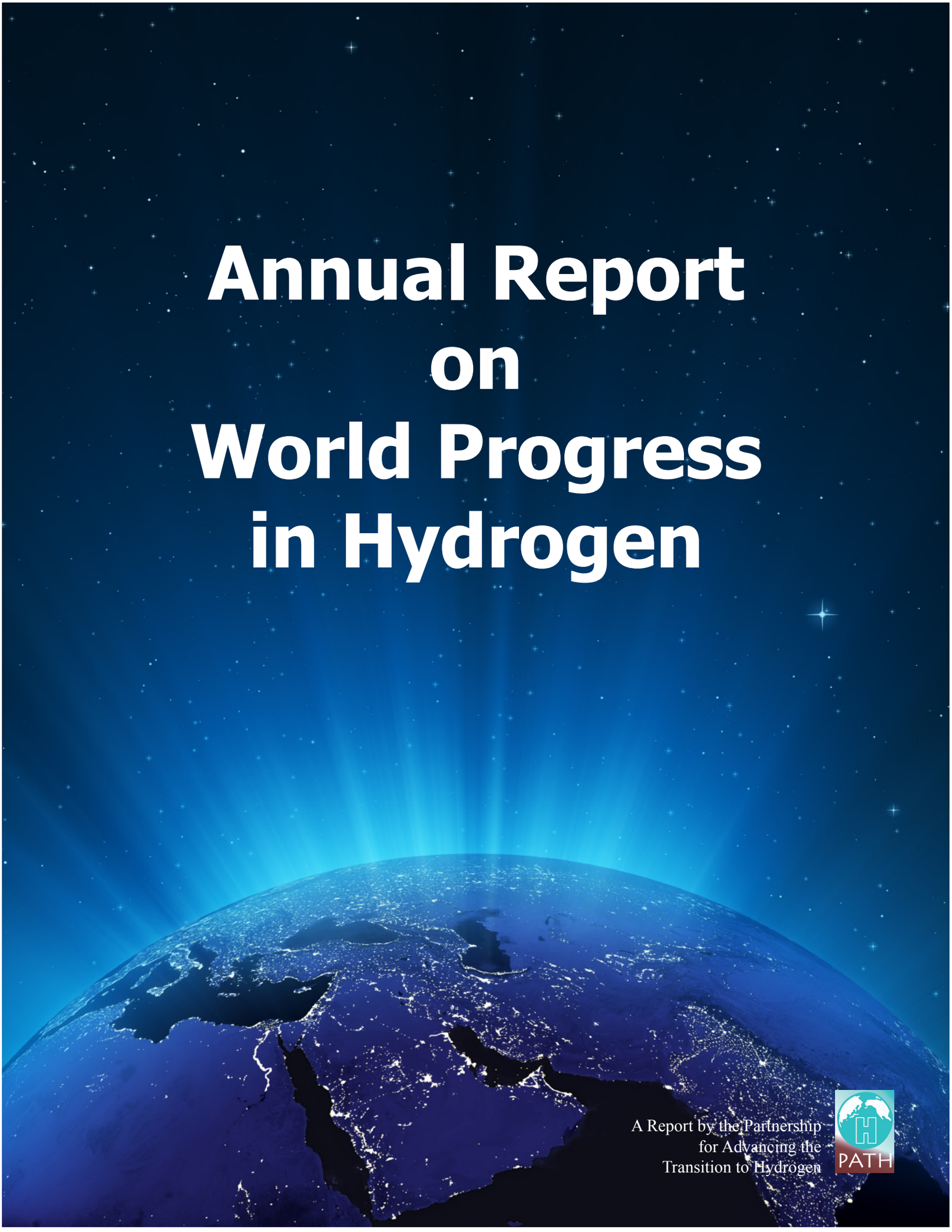
Annual Report on World Progress in Hydrogen



A Report by the Partnership
for Advancing the
Transition to Hydrogen

PATH

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Annual Report on World Progress in Hydrogen

A Report by the Partnership for Advancing the
Transition to Hydrogen (PATH)

June, 2011

This Report was developed in part by data contributions provided by PATH Associations.

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Table of Contents

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Part I: Introduction

Acknowledgements

The Partnership for Advancing the Transition to Hydrogen (PATH) is grateful for support from its members and affiliates. This Report would not be possible without their contributions. In particular, this work could not be made possible without significant financial support from the International Association for Hydrogen Energy (IAHE). PATH's Annual Report on World Progress in Hydrogen was published by the Technology Transition Corporation.

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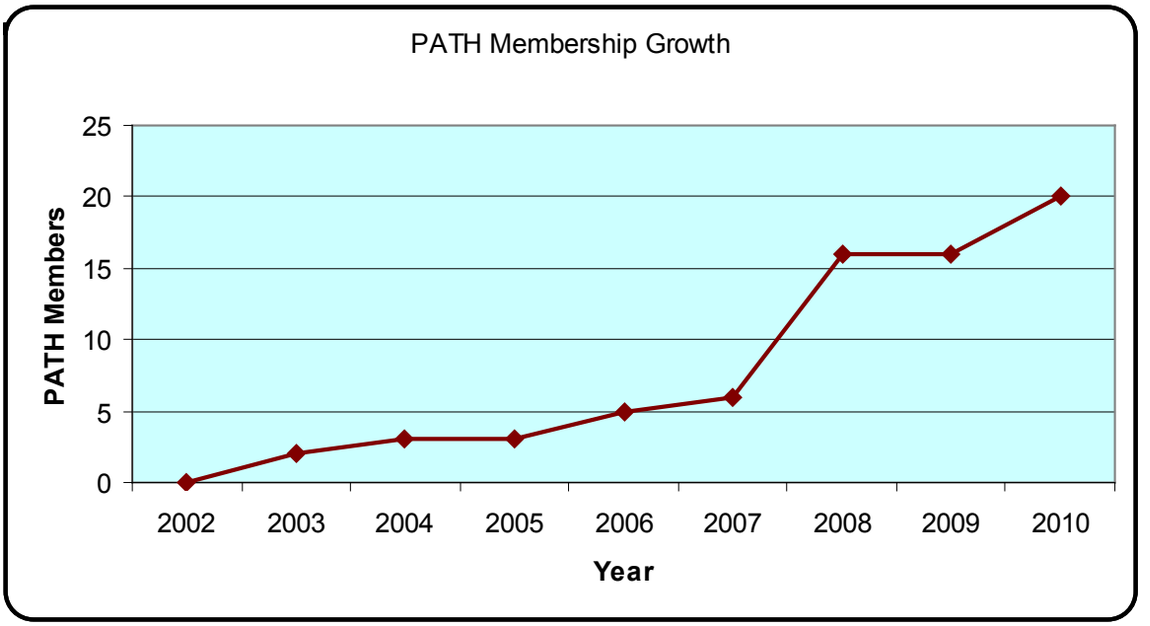
Special Thanks to...

Purpose of Report

In today's evolving market economy, finding up-to-date information about the current state of hydrogen and fuel cell development can be a difficult task. Hydrogen programs are advancing at different paces as a result of internal country politics, resource availability, and public perception. This presents added challenges to businesses looking to expand opportunities & ventures, impacting local economies and industry momentum. In response, the Partnership for Advancing the Transition to Hydrogen (PATH) has undertaken a comprehensive assessment of the state of the global hydrogen and fuel cell industry in the form of this Annual Report. This Report serves as the go-to source for information in the world's hydrogen and fuel cell community.

This Report is intended to provide a broad level picture of the current state of the global hydrogen and fuel cell industry. The issues that will be addressed in this Report include:

- Hydrogen and fuel cell development projects
- Government funding & initiatives
- Production
- Manufacturing
- Technology Deployment
- Education
- Events
- Public perception
- Employment
- International Partnerships
- Status of PATH associations and recent developments

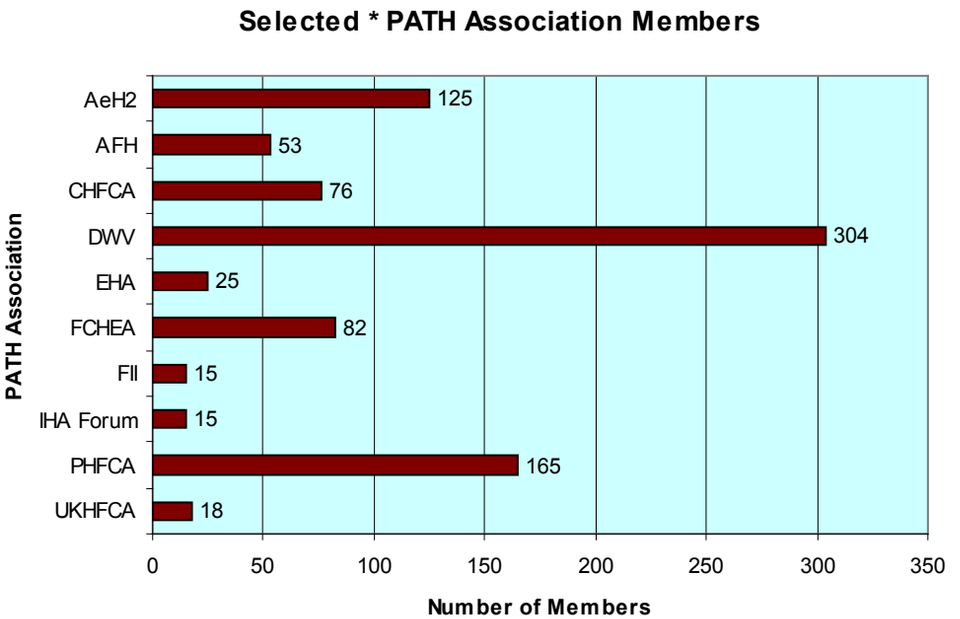


About PATH

The Partnership for Advancing the Transition to Hydrogen (PATH) is a not-for-profit international coalition of hydrogen associations established in 2002 that seeks international cooperation to help advance the transition to hydrogen as a potentially carbon-free energy carrier and a solution to energy and environmental issues across the globe (www.hpath.org). Today, 20 associations and partnering organizations, across 5 continents belong to PATH, representing 79% of the world's GDP, 40% of the global population and a majority of the world's interest in hydrogen and fuel cells.

PATH's program consists of three major areas of focus:

1- Strengthening communications and outreach efforts amongst the global hydrogen community by providing a voice for hydrogen advocates in all countries.
2- Sharing information among partners through newsletters, website activities, funded projects and comprehensive reports.
3- Developing International Codes & Standards for the safe use of hydrogen.



PATH's Mission

PATH's mission is to spread a vision of the hydrogen economy globally and to facilitate its implementation. As countries and economies are beginning to take the first steps along this commercialization road, PATH seeks to develop an international community of interest in hydrogen to share knowledge, demonstrate that hydrogen systems are safe, reliable & affordable, and meet the unique requirements that each country may impose on these systems.

*Not all PATH associations submitted membership data

Centers of Global Hydrogen Progress

PATH Associations

- Argentina: Asociación Argentina del Hidrógeno
- Australia: Australia Association for Hydrogen Energy
- Brazil: Development Commerce Transport (DCT) Energia (Interim Member*)
- Canada: Canadian Hydrogen and Fuel Cell Association
- China: China Association for Hydrogen Energy
- Taiwan Assn. for Hydrogen Energy and Fuel Cell
- EU: European Hydrogen Association
- France: Association Française de l'Hydrogène
- Germany: Deutscher Wasserstoff- und Brennstoffzellenverband
- Italy: Italian Hydrogen Forum
- Italy: Italian Hydrogen and Fuel Cell Association
- Japan: Hydrogen Energy Systems Society
- Malaysia: Universiti Teknologi Malaysia (Interim Member*)
- Mexico: Sociedad Mexicana del Hidrógeno
- New Zealand: Massey University Centre for Energy Research (Interim Member*)
- Poland: Polish Hydrogen and Fuel Cell Association
- North Africa: Sahara Wind (Interim Member*)
- Spain: Asociación Española del Hidrógeno
- United Kingdom: U.K. Hydrogen and Fuel Cell Association
- United States: Fuel Cell and Hydrogen Energy Association

Definitions and Acronyms

AAHE: Australian Association of Hydrogen Energy
ACRE: Australian Centre for Renewable Energy
AeH2: Spanish Hydrogen Association*
AFH2: French Hydrogen Association*
BIPV: Building Integrated Photovoltaic
C&S: Codes & Standards
CDER: Renewable Energy Development Center (Algeria)*
CEI: Clean Energy Initiative (Australia)
CEP: Clean Energy Partnership
CHA: Canadian Hydrogen Association
CHFCA: Canadian Hydrogen and Fuel Cell Association
CHP: Combined Heat & Power
CNETHPC: National Centre on Hydrogen & Fuel Cell Technology Experimentation (Spain)
CO_2: Carbon Dioxide
CTFCA: Canadian Transportation and Fuel Cell Alliance
DMFC: Direct Methanol Fuel Cell
DWV: German Hydrogen and Fuel Cell Association*
EHA: European Hydrogen Association
EREC: European Renewable Energy Council
EU: European Union
FCHEA: Fuel Cell & Hydrogen Association (USA)
FCH-JU: Fuel Cell and Hydrogen Joint Undertaking (European Union)
FCUK: Fuel Cells United Kingdom
FCV: Fuel Cell Vehicle
FII: Italian Hydrogen Forum
GEF: Global Environment Facility
H2&FC: Hydrogen and Fuel Cells
H2FCC: Hydrogen & Fuel Cells Canada
HESS: Hydrogen Energy Systems Society (Japan)
HRS: Hydrogen Refueling Station
IAHE: International Association for Hydrogen Energy
IEA: International Energy Agency
IHE: Institute Hydrogen Economy (Malaysia)
IHFCA: Italian Hydrogen & Fuel Cell Association
INER: Institute of Nuclear Energy Research (Taiwan)
IPHE: The International Partnership for the Hydrogen Economy
IRAP: Industrial Research Assistance Program (Canada)
ITRI: Industrial Technology Research Institute (Taiwan)
JTI: Joint Technology Initiative (European Union)
kWh: Kilowatt Hour
MNRE: Ministry of New and Renewable Energy (India)
NEDO: New Energy & Industrial Technology Development Organization (Japan)
NHA: National Hydrogen Association (USA)
NHER: National Hydrogen Energy Roadmap (India)

NIP: National Innovation Program (Germany)
NRCC: National Research Council Canada
PATH: Partnership for Advancing the Transition to Hydrogen
PCHE: Pakistan Chapter for Hydrogen Energy
PEFC: Polymer Electrolyte Fuel Cell
PEM: Polymer Electrolyte Membrane
PEMFC: Polymer Electrolyte Membrane Fuel Cell
PHFCA: Polish Hydrogen & Fuel Cell Association
R&D: Research & Development
RCS: Regulations, Codes & Standards
SDTC: Sustainable Development Technology Canada
SHFCA: Scottish Hydrogen and Fuel Cell Association
SMH: Mexican Hydrogen Association*
SOFC: Solid Oxide Fuel Cell
TTC: Technology Transition Corporation (USA)
UKHA: United Kingdom Hydrogen Association
UKHFCA: United Kingdom Hydrogen & Fuel Cell Association
USD: United States Dollar
UTM: Universiti Teknologi Malaysia
WHEC: World Hydrogen Energy Conference
WHTC: World Hydrogen Technologies Conference

**translated*

List of Figures, Tables & Graphs

Methodology

As the voice of hydrogen and fuel cell communities in their respective countries, each association contributed relevant information on the following topics:

- Association Information: Number of members, recent activates and relevant news
- National Information: Recent H2&FC infrastructure developments
- Market Data: H2&FC use on industrial level
- Education: H2&FC related academic courses, degrees and on campus research
- Employment: Established information on H2&FC job employment
- Public Perception
- Miscellaneous: relevant information not yet included

PATH Annual Report on World Progress in Hydrogen

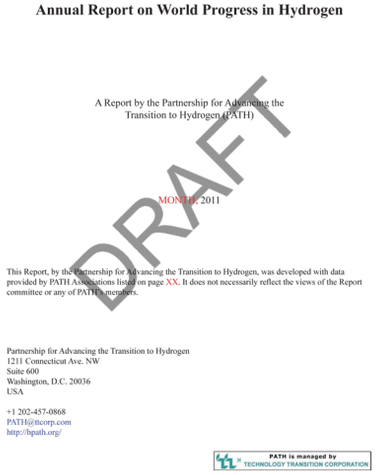
REPORT WORKSHEET

Dear Hydrogen & Fuel Cell Colleagues-
Thank you for taking time to complete the following data collection activity in support of PATH's Annual Report. If your association has data requested in this worksheet or otherwise appropriate for the report in a different format, do not hesitate to submit it in its original form. We are asking that data be submitted by **15 April.** Completion of this worksheet is a compulsory exercise for maintaining your Association's active participation in PATH.

1 - General Information about the Association

Association Name
Website
Main Representative's Name
Representative's Title at Association
Representative Telephone
Representative Fax
Representative email
Representative Primary Location (City, Country)

2 - Association Information



Annual Report on World Progress in Hydrogen

A Report by the Partnership for Advancing the Transition to Hydrogen (PATH)

DRAFT

MONTH, 2011

This Report, by the Partnership for Advancing the Transition to Hydrogen, was developed with data provided by PATH Associations listed on page XX. It does not necessarily reflect the views of the Report committee or any of PATH's members.

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PATH is managed by TECHNOLOGY TRANSITION CORPORATION

As part of the data collection process, representatives from each association were given an interactive PDF worksheet (also accessible to all PATH members via a member's only password-protected section of the website) to be completed over the course of 3 months. These packets served more as guidelines for desired information rather than required formal paperwork. Most representatives elected to submit existing reports and documents that contained relevant data rather than re-transcribing information for submission.

In addition to PATH member associations providing data, energy agencies and national governments were also contacted to provide information directly, as were some corporate firms with a large presence in specific regions. Hydrogen organizations that are not PATH members but PATH affiliates were also asked to contribute. Information was also obtained from some of the other international hydrogen and fuel cell associations, including:

- The International Association for Hydrogen Energy
- The International Partnership for the Hydrogen Economy
- The International Energy Agency

After being internally revised, a final draft was supplied to all PATH members for their comments, corrections and suggestions. The final Report was released in June 2011.

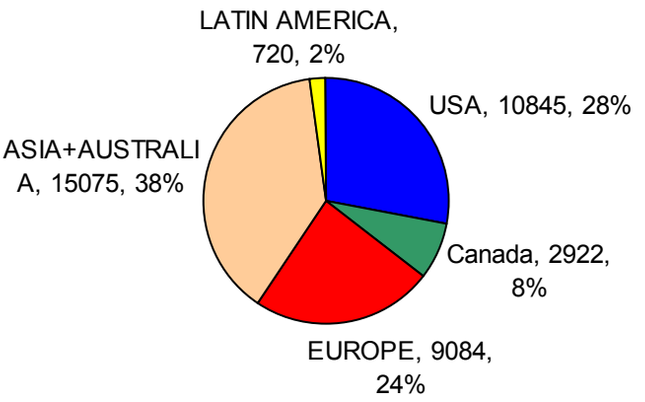
Executive Summary

The global hydrogen energy and fuel cell industry stands to be one of the most significant players in technology innovation, economic expansion and global progression in the 21st century. The world's energy solution portfolio is expanding as hydrogen and fuel cells' role increases. Around the world, progress in developing, producing and deploying hydrogen and fuel cell products and infrastructure is becoming a greater present day reality rather than a future aspiration. As these technologies move from the R&D stages of development to commercialization, the vision of a hydrogen revolution is becoming a reality.

The rate of progress in this industry is made complex because different segments of the industry are advancing at different rates across wide geographical regions. In some areas, the concept of 'advancement' means tangible forward progress in the public eye, while in other regions it simply translates to maintaining the foundation on existing infrastructure and achievements. Overall, however, hydrogen and fuel cells are becoming more practical, more innovative, and more familiar as an alternative energy technology of today rather than a futuristic possibility of tomorrow.

While the growth of the global hydrogen and fuel cell market is occurring, measuring the level of successful implementation is less precise. It has been predicted that the world's hydrogen and fuel cell market will grow to $16 billion (USD) by 2017[1] while others estimate that it will grow to $26 billion by 2020[2].

Global Hydrogen & Fuel Cell Jobs



Global spending on hydrogen and fuel cell innovation exceeded $5.6 billion in 2008 and is growing in manufacturing, research & development demonstrations and other market sectors. Global revenues in hydrogen and fuel cells are expected to range between $3.2 billion and $9.2 billion in 2015 and between $7.7 billion and $38.4 billion in 2020, respectively. By 2050, one prediction suggests that the industry could grow to as high as $180 billion[3]. Today, hydrogen and fuel cells are responsible for up to 40,000 jobs worldwide when taking into account direct and indirect jobs created by the industry. Of that total, roughly 1/3 of those positions are directly attached to the implementation of those technologies[4].

Across the globe, waves of innovative hydrogen and fuel cell technologies are introduced through advanced commercial demonstration programs. Canada is a prime example in commercial demonstrations of fuel cells. In British Columbia, a fleet of hydrogen fuel cell buses is operational and has helped make this modern age transportation available. Similar programs throughout Europe have brought fuel cell buses to Germany, Italy, and Spain as well as a number

of other transportation projects focused on demonstrating the feasibility of hydrogen and fuel cell-powered vehicles in Europe. The Zero Regio Project (recently concluded) was a demonstration program responsible for introducing a small fleet of FCVs used for personal use over the course of 95,000+ km. FCV progress has gained sufficient viability that 31 automakers are currently designing and manufacturing hydrogen fuel cell vehicles across the globe.

In Asia, personal transportation is a staple of hydrogen and fuel cell development. With the support of the Prime Minister of Malaysia, The Universiti Teknologi Malaysia recently launched a fuel cell motorbike demonstration. In China, 90 fuel cell passenger vehicles, 6 fuel cell buses, and 100 fuel cell sightseeing trolley cars were showcased at the Expo 2010 Shanghai event. Research labs in Taiwan are actively involved in a project working with the private sector to develop fuel cell scooters for personal use. There are currently over 15 countries around the world who have fuel cell buses in use for public transportation.

Hydrogen and fuel cell infrastructure promise to enhance lucrative cross-border market development opportunities. To help increase its energy independence while expanding its export portfolio, Japan has taken on fuel cell export manufacturing and intends to market its products to Germany, a country with a rapidly increasing fuel cell demand. Throughout Europe, the EU has facilitated joint programs incorporating multiple national governments as well as private corporations with headquarters based countries apart. In North Africa, private ventures are harnessing the ubiquitous renewable sources provided in the Sahara Desert to power communities and produce hydrogen, which may be transported to markets across the Mediterranean.

Despite the progress made, there are still challenges that must be overcome by this community. One key example is whether fueling infrastructure should be built before the vehicles that will use them, or visa versa? In many places around the world, hydrogen and fuel cell development faces this ‘chicken and egg’ scenario. Cross border market development standards are also slowly developing along with international trade standards for manufacturing and industry best practices standards, but more uniform standards across the industry are still needed.

Endnotes

1.“Hydrogen Technology Roadmap” Australian Government, Department of Resources, Energy and Tourism, 2008.
2. http://www.carbontrust.co.uk/news/news/press-centre/2009/Pages/carbon-trust-launches-uk-bid.aspx
3. http://www.carbontrust.co.uk/news/news/press-centre/2011/Pages/acal-fuel-cell.aspx
4. “A Compendium of Job Estimates in the Fuel Cell Industry” FuelCells2000, March 2011

PART II: World Progress Report

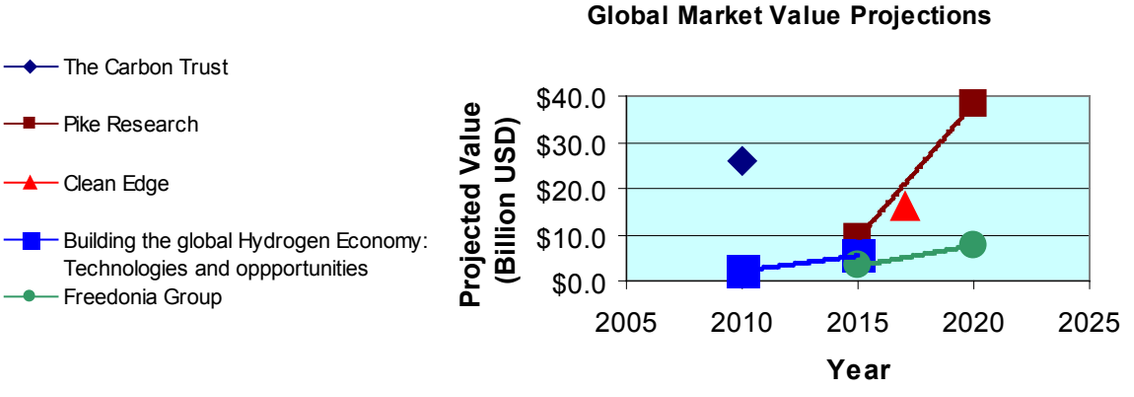
WORLD OVERVIEW

Market Worth

Progress towards commercialization of hydrogen and fuel cell technology has been made across the inhabited world. Global spending in this technology exceeded $5.6 billion in 2008 and is growing in manufacturing, research & development, demonstrations, and other key market sectors. According to the Freedonia Group and Pike Research[1], it is projected that global revenues in hydrogen and fuel cells combined will be between $3.2 billion and $9.2 billion in 2015 and between $7.7 billion and $38.4 billion in 2020, respectively. The global hydrogen and fuel cell market could be worth over $180 billion in 2050[2]. Revenues in the fuel cell sector are projected to grow at a rate of 26% over the next decade. By comparison, other renewable energy sectors are expected to grow at slower rates, such as solar (12%), biofuels (10%) and wind (6%)[3]. Additionally, in 2009 the global fuel cell market grew 41%, compared to 2008, and the industry shipped roughly 24,000 fuel cell systems[4].

Employment

Along with increasing financial market knowledge, global statistics on employment are also more readily available for the hydrogen and fuel cell industry. It is estimated that there are currently 13,272 jobs around the world directly related to hydrogen and fuel cells with another 25,764 indirectly related, bringing the total to nearly 40,000 jobs worldwide[5]. By 2019, there may be as many as 700,000 jobs worldwide employed by the hydrogen and fuel cell industry[6].



New Developments

While this Report is focused on major regions throughout the world where substantial advances in new hydrogen and fuel cell technologies and businesses are advancing, there are smaller, less publicized, or recently organized centers of hydrogen development that are notable.

The Pakistan Chapter for Hydrogen Energy (PCHE) at the University of Balochistan, Quetta, Pakistan is one example of how hydrogen technologies are beginning to gain traction in that part of the world. In a heavily-populated and rapidly developing country with increasing energy demands, hydrogen and fuel cell technologies stand to play a large role in energy solutions and economic enhancement. 2011 marks the inaugural year at the University of Balochistan when

hydrogen courses are being incorporated into the curriculum. The PCHE is planning a number of workshops and conferences in 2011 to discuss hydrogen energy, environmental problems and technology development, despite Pakistan having no infrastructure including fuel cell vehicles, fork lifts, fueling stations and portable or stationary fuel cell generators.

In Algeria, renewable energy is becoming an increasingly significant component of the country's economic strategy and culture. Feed-in tariffs for wind, solar and hydroelectric plants are already under consideration by the Algerian government. The national government's Centre de Dévéloppement des Energies Renouvelables (CDER) has divisions dedicated to solar, wind, biomass and hydrogen & fuel cell development.

In Latin America, a growing population and an increase in energy demand as well as GDP has made hydrogen a focus in many countries. Argentina, Brazil and Mexico are among the hydrogen and fuel cell leaders in the region. The national governments in Argentina and Brazil are both aggressively supporting research and development in hydrogen and fuel cell technologies through legislation, tax benefits and direct financial support.

The Patagonia Wind Project is an example of a recent demonstration project in southern Argentina for harnessing electricity via wind energy to generate electrolysis for producing hydrogen, which could then be used to power rural communities in Patagonia. That project is now complete, but plans for installing additional wind farms in the region remain. Asociación Argentina del Hidrógeno (Argentine Hydrogen Association, www.aah2.org.ar) provides the voice for the hydrogen and fuel cell community in Argentina).

Hydrogen and fuel cells have also gained ground in countries that have a strong energy base in conventional fuel sources. In 2006, India published its National Hydrogen Energy Roadmap outlining its intentions to complete infrastructure for roughly 1,000 MW capacity of hydrogen based power generation by 2020 along with one million hydrogen fueled vehicles across the country. While still short of these goals, funding for these projects suggests strong national commitment to hydrogen and fuel cells. This progress is under the authority of the Indian Ministry of New and Renewable Energy (MNRE). Fuel cells in India are also used as backup power for telecommunications facilities and mobile backup power units[7]. The Indian Hydrogen Association (www.hydrogenindia.com) was established in 2009 to provide a central focus on activities related to commercialization of hydrogen technology in India.

Endnotes

1. "Assessment of the Economic Impact of the Canadian Hydrogen and Fuel Cell Sector" Ference Weicker & Company, BC Ministry of Small Business, Technology and Economic Development, March 26, 2010
2. http://www.carbontrust.co.uk/news/news/press-centre/2011/Pages/acal-fuel-cell.aspx
3. "Assessment of the Economic Impact of the Canadian Hydrogen and Fuel Cell Sector" Ference Weicker & Company, BC Ministry of Small Business, Technology and Economic Development, March 26, 2010
4. "Industry Review 2010" FuelCellToday, 2010
5. "A Compendium of Job Estimates in the Fuel Cell Industry" FuelCells2000, March 2011
6. "Fuel Cells Today Industry Review 2010" Fuel Cell Today, 2010
7. "Fuel Cells: Emerging Markets" FuelCellToday, Industry Review 2009

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With Australia's unique position in the South Pacific and ample sources of renewable energy, including solar, wave/tidal, and wind, the country has become increasingly recognized internationally as a leader in production of hydrogen and fuel cell products. As Australia works to reduce its reliance on fossil-based fuels, the Department of Resources, Energy and Tourism has created the Clean Energy Initiative (CEI) to promote zero emission technologies and implement a range of renewable energy programs. The current CEI program budget of $5 billion (AUS) includes carbon capture & storage as well as solar initiatives including the Australian Solar Institute and the Australian Centre for Renewable Energy (ACRE). The ACRE conducts research and development on biofuels, geothermal power, wind energy, electric storage, and technology integration and deployment. 7% of Australia's energy needs are currently supplied from renewable energy sources[1]. While the CEI does not explicitly work on hydrogen or fuel cells, progress in advancing renewable energy sources to the marketplace benefits hydrogen and fuel cells as a potential energy carrier. As conveyed in its National Hydrogen Study, Australia has a grand opportunity to develop hydrogen infrastructure to a level that will allow it to replace fossil-based fuels as a primary energy export[2].

In spite of progress made in renewable energy in Australia, the 2008 Hydrogen Technology Roadmap published by the Department of Resources, Energy and Tourism cautiously warns that "Australia risks significant competitive disadvantage in the global hydrogen and fuel cell markets and industry growth if it is simply left to market forces to prepare for their introduction locally." Progress in Australia is being delayed by similar challenges present in other countries. The Roadmap goes on to warn that "…Australia has some world-class technology strengths in specific hydrogen, fuel cell and system integration areas, but the ability of Australia to exploit these is compromised by current energy market and innovation system weaknesses."

To address this issue, the Roadmap outlines tasks necessary for hydrogen and fuel cell industry growth. Many of the goals enumerated have already been met, including the establishment of a hydrogen and fuel cell association, which was realized with the formation of the Australian Association for Hydrogen Energy (AAHE) in late 2009 (www.HydrogenAustralia.org). The Roadmap also emphasized the importance of continued participation and engagement with the international hydrogen and fuel cell community. Australia has also seen robust policy formation and legislative progress in renewable and clean energy. AAHE hopes for more explicit hydrogen and fuel cell legislation that would be a stronger show of support and a more practical implementation of the Roadmap's goals. Also still needed is the development of a clear set of regulations, codes, & standards market development in the supply chain & business sectors as well as large scale support from existing companies for extensive demonstrations projects, similar to the case in Canada, which will subsequently lead to expanded commercialization.

Research and Development on hydrogen technologies at academic institutions is a focus in Australia's alternative energy commitment. A sampling of hydrogen research projects include[3]:

- "Development of Zero Emission Coal Technology (Incorporating Enhanced H2 Generation, CO2 Capture ad Fuel Cell Integration)"- Dr. Andrew Harris, The University of Sydney and the University of New South Wales: $300,000 (AUS)/ 4 years
- "Gasification Technology for the Production of Hydrogen"- Dr. Jorge Beltramini, Prof. Max Lu, & Mr. Akshat Tanksale, The University of Queensland and the ARC Centre for Excellence for functional Nanomaterials: $300,000 (AUS)/ 5 years
- "Efficient and Practical Hydrogen Fuelled Vehicle Technologies"- Dr. Michael Brear, Prof. Will Ducker, Dr. Chris Manzie, Prof. Dragan Nesic and Prof. Harry Watson, The University of Melbourne, ford Motor Company of Australia, Haskell Australasia and University of North Florida: $3 million (AUS)/ 3 years
- "Electric drive systems for low emission vehicles"- Dr. Stephen Collocott, CSIRO Materials Science and Engineering: $950,000 / 5 years

2010 saw significant business infrastructure development, as the AAHE hosted its first workshop addressing sustainable transport, infrastructure development, and international policy in November. The AAHE has also established working groups to address various topics including standards & regulations and renewable hydrogen. The establishment of a hydrogen and fuel cell industry association is just one of many goals outlined in the 2008 Hydrogen Technology Roadmap[4]. In the near future, the industry aims to establish infrastructure in order to build towards the goal of "effectively exploiting emerging hydrogen and fuel cell market and supply-chain opportunities"[5] globally.

Australia has served as host to several noted international hydrogen/renewable conferences; including the 17th World Hydrogen Energy Conference (WHEC) is Brisbane, Queensland in June 2008, and EcoGen 2010 (Sydney, NSW, September 2010), which also served as the venue for the AAHE's official launch. Joining Dr. Andrew Dicks, President of the AAHE for the launching event, were Jeff Serfass, former President of the U.S. National Hydrogen Association and General Manager of PATH, Janice Larson, Director of Renewable Energy Development for the Government of British Columbia (Canada), and the Honourable Clover Moore MP, Lord Mayor of Sydney who announced that Sydney will also play host to the 2015 World Hydrogen Technologies Conference (WHTC). In the lead-up to WHTC in 2015, expect a number of new demonstration projects showcasing the roles hydrogen and fuel cell technology plays in meeting Australia's long-term energy needs.

Endnotes

1. "Energy in Australia 2011" Australian Department of Resources, Energy and Tourism, 2011
2. "Towards Development of an Australian Scientific Roadmap for the Hydrogen Economy" Australian Academy of Science, March 2008 http://www.science.org.au/reports/documents/hydrogen.pdf
3. "Australian Hydrogen Activity 2008" Australian Department of Resources, Energy and Tourism, Dr A. L. Dicks, Dr J. Bradley and D. T. Alexander, Department of Chemical Engineering, The University of Queensland, 2008
4. "Hydrogen Technology Roadmap" Australian Department of Resources, Energy and Tourism, 2008
5. "Hydrogen Technology Roadmap" Australian Department of Resources, Energy and Tourism, 2008

CANADA

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Canada has solidified its standing as a global leader in the hydrogen and fuel cell industry from research & development to commercialization to technology deployment. With support from provincial governments and as homes of the industry's leading manufacturers of fuel cell/electrolysers and hydrogen production facilities, notable centers of activity have developed in Ontario and British Columbia.

In Ontario, the Hydrogen Village (www.HydrogenVillage.ca) project has been in operation since April 2004. It is a public-private partnership funded by Village members, the government of Ontario, and Natural Resources Canada (NRCan), Canada's Energy Agency, to raise awareness about hydrogen and fuel cells through market introduction of this technology in powering various stationary, portable, and transportation applications within a community of greater Toronto.

Elsewhere, the Canadian Transportation and Fuel Cell Alliance (CTFCA) was a seven year, $33 million (CAN) program funded and managed by NRCan to oversee development of hydrogen refueling stations and support development of hydrogen-fueled vehicles through development and demonstration initiatives. CTFCA operated from 2001-2008.

In British Columbia, the Hydrogen Highway, was launched in March 2004 with $10 million (CAN) of financial support by the BC Transit Authority. The BC Hydrogen Highway is part of a larger campaign known as H2i (www.PoweringNow.ca), and it promotes long distance travel of hydrogen-fueled vehicles. The primarily highway is along provincial route 99 between Vancouver and Whistler, BC, a distance of approximately 125 km. The BC Hydrogen Highway is part of the much-longer West Coast Hydrogen Highway, spanning over 1,700 miles from the US-Mexico border in Southern California to British Columbia. In BC alone, hydrogen refueling stations have been installed in greater Vancouver and Whistler to make travel possible for hydrogen vehicles. A hydrogen refueling station has also been installed in BC's capital of Victoria for a total of eight refueling stations in the province since the inauguration of the Hydrogen Highway project seven years ago.

During the Vancouver Olympics in February 2010, the world's largest fuel cell bus fleet was deployed in Whistler, BC and shuttled spectators between games in Vancouver and the ski resort. The Olympics provided the ideal venue to showcase to the world community the potential hydrogen/fuel cell infrastructure offers as a contemporary alternative to the fossil-based vehicles the public is familiar with on a large scale.

The majority of the Canadian hydrogen and fuel cell industry's visible progress is in the form of these ambitious demonstration projects. While the more well-known projects include the aforementioned Toronto Village, BC Hydrogen Highway, and public transportation projects in British Columbia, there are notable hydrogen production projects throughout the country. On

Ramea Island, hydrogen is being produced from wind power and put into compressed storage. A similar project is taking place on Prince Edward Island. In Bella Coola, hydrogen is being produced from a hydro plant. Elsewhere in North Vancouver, hydrogen is being produced from by-product systems. Through the CTFCA, $867,000 (CAN) was funded by the Government of Canada to test the use of fuel-cell packs developed by General Hydrogen Corporation in tugs that tow baggage between the airport terminal and airplanes at Vancouver International Airport. The project was in cooperation between Air Canada and its Vancouver Ground Support Equipment site. In another example, fuel cell forklifts are in use, principally by Wal-Mart in Alberta, for material handling.

According to the International Partnership for the Hydrogen and Fuel Cell Economy (IPHE), approximately 3 million tons of hydrogen is produced annually in Canada. The country is the largest producer per capita of hydrogen in the Organization of Economic Co-Operation and Development (OECD). Production of hydrogen in Canada has come from a wide array of resources, including renewable (e.g. wind, solar, hydropower, biomass, etc), fossil-based sources (e.g. natural gas, oil, coal) and nuclear. According to the IPHE, Canada's most likely source for large-scale hydrogen production in the near-term will be the result of electrolysis[1].

Competing alternative energy storage technologies include conventional batteries, flywheels, compressed air and pumped hydro.

As a result of these projects and programs around the country, hydrogen and fuel cells are becoming more recognizable. Job estimates in the hydrogen and fuel cell industry in Canada range from 1,200[2] to more than 2,900[3]. In both scenarios, roughly 1/3 of those jobs are directly related to hydrogen and fuel cells while the remainder is indirectly related. The majority of these jobs are the result of manufacturing stationary fuel cells and portable fuel cells for vehicles. Conservative estimates predict that there will be nearly 9,000 jobs by 2020 and a total of 12,500 by 2030[4]. Other long term projections estimate that there will be 14,469 and 43,594 jobs created directly and indirectly by the Canadian hydrogen and fuel cell industry by 2020, respectively[5].

Recently, H2&FC activities in Canada have shifted away from a demonstration and application focus. Academic and government laboratory R&D funding and activities have increased despite overall government funding and support decreasing. NRCan contributes $500,000 (CAN) to fund projects dedicated to industry and government collaboration as well as in-house R&D. Another organization, Sustainable Development Technology Canada (SDTC), contributes $2 million (CAN) to hydrogen demonstration projects. Small and medium sized enterprises with a hydrogen or fuel cell focus are supported by the National Research Council Canada's (NRCC) Industrial Research Assistance Program (IRAP), which totals $1 million (CAN).

Government support of hydrogen and fuel cells has been essential to past successes in Canada and will play a vital role in the future direction of the industry of future projects. A feed-in-tariff in British Columbia may soon include the use of fuel cells as energy efficiency devises, qualifying them for additional tax incentives and other benefits. Canada currently holds a 16% market share in the global commercial hydrogen and fuel cell market. If this market share holds, the Canadian hydrogen and fuel cell market is estimated to be worth between $1.2 and $6.1 billion (CAN) by 2020[6].

In the global arena, Canada has taken leading roles in harmonization of

international safety codes and standards through two prominent organizations; the ISO Technical Committee 197 (Hydrogen Technologies) (has chaired the Technical Committee) and the International Energy Agency Hydrogen Implementing Agreement Task 19. Task 19 group members look specifically into the properties of hydrogen that impact safety.

The national industry representative for hydrogen and fuel cells is the Canadian Hydrogen and Fuel Cells Association (CHFCA). Two formerly independent associations, the Canadian Hydrogen Association and Fuel Cells Canada (FCC), merged on January 1, 2009 to combine initiatives and focus industry efforts. Since its formation, the CHFCA has hit the ground running, organized workshops in May 2010, submitting budget proposals, increasing industry visibility through social media outreach and remaining an active player on the international stage. Since its merger, the CHFCA has hosted two conferences, Hydrogen + Fuel Cells 2009 and 2011 in Vancouver. Canada will also serve as host to the 19th World Hydrogen Energy Conference (WHEC) in Toronto, ON June 2-7, 2012 (www.WHEC2012.com).

In early 2011, the CHFCA submitted a federal budget request for tax incentives and grants for the commercial installation of fuel cells and hydrogen fueling infrastructure to make hydrogen and fuel cell use in the commercial sector more attractive. As of April 2011, no decision on that budget request has been made as a vote of no-confidence and an election is in progress in the Canadian government. If the proposal passes, however, British Columbia will become the first province in Canada to acknowledge hydrogen and fuel cells officially as energy efficiency technologies.

"…more needs to be done but we must take encouragement from small steps in the right direction".

- Terry Kimmel, VP CHFCA

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As home to the world's greatest population, China has found itself increasingly seeking alternative energy systems to help sustain both its massive energy needs and the financial ambitions of its people. The central Chinese government has undertaken support for technology and science programs that generate progress through R&D programs including hydrogen and fuel cells.

FCVs at Expo 2010 Shanghai

China has had multiple opportunities to showcase its progress in hydrogen and fuel cell development at various industry demonstrations and other prominent events. The Expo 2010 Shanghai China event held from May 1-October 31 attracted over 73 million visitors during that 6-month period and showcased China's innovative technology in the marketplace, including those associated with hydrogen and fuel cells. Specifically, 90 fuel cell passenger vehicles, six fuel cell busses, and 100 fuel cell sightseeing trolley cars were available for testing and display. Also on display at the Expo was a by-product hydrogen purification plant, the opening of the Anting Hydrogen Refueling Station (stationary), along with a mobile hydrogen refueling station. The 2008 Summer Olympic games in Beijing also served as a prime venue for promoting China's commitment to commercializing hydrogen fuel cell vehicles. During that event, 20 Passat Lingyu FCVs were used as demonstration passenger cars. That demonstration lasted 68 days, over which time, 76,000+ km were driven in over 970 driving demonstrations. Additionally, during the first six months of 2009, an agreement with the California Fuel Cell Partnership (U.S.) brought 16 Passat FCVs to the United State, which were driven 37,000+ km in U.S. demonstrations. One vehicle was driven over 4,100 km alone[1].

China's progress in development of hydrogen and fuel cell technology is on par with overall global development. In 1996, China first received an international grant, from the Global Environment Facility (GEF) for fuel cell vehicle deployment. More recently, GEF committed to a five-year fuel cell bus demonstration project in Shanghai and Beijing with an estimated cost of $32 million[2] (US). A H2/CNG filling station is currently under construction in the Shanxi province. In addition to operating in rural areas, hydrogen and fuel cells also operate in Guangzhou, Beijing, Shanghai, Suzhou City and the Fengzian District.

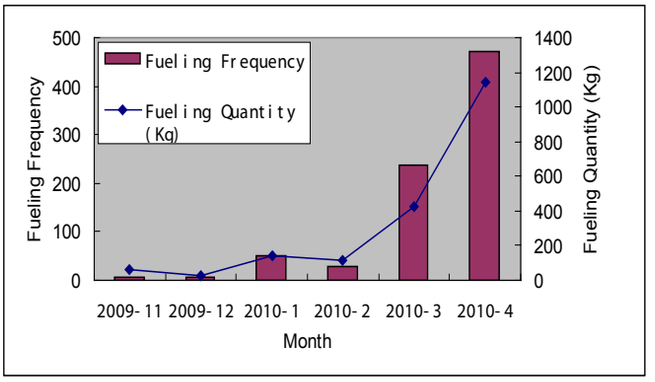
China's primary sources of energy today are coal (about two-thirds) with the remaining divided between oil, hydroelectric, natural gas and nuclear[3]. China's abundant wind and solar resources in the drier hinterlands and biomass in the densely-populated coastal cities provide promising sources for hydrogen production.

FCVs at Beijing Olympics 2008

Mainland China's two leading centers of academic curriculum development include Tsinghua University (Beijing), and Wuhan University of Technology. Tsinghua University is the home headquarters of mainland China's premiere hydrogen association, the China Association for Hydrogen Energy (CAHE), and presided by Dr. MAO Zong Qiang, a professor in the university's Institute of Nuclear Energy Technology. Wuhan University of Technology maintains a robust fuel cell program as part of its curriculum.

Regional advances in hydrogen and fuel cell technology are common throughout Chinese industry. Similarly to Japan, the island of Taiwan relies heavily on energy imports. Consequently, the island has taken a great interest in energy storage technologies and alternative energy sources. To that extent, hydrogen and fuel cells have become increasingly important to Taiwan's energy portfolio. The Taiwanese government implemented a Renewable Energy Development Bill to encourage renewable energy innovation including production and storage. Of its energy research budget, 20% is dedicated to hydrogen and fuel cell research taking place at government institutes such as the Industrial Technology Research Institute (ITRI) and the Institute of Nuclear Energy Research (INER)[4].

Fueling Stations Use



As the first HRS in Shanghai, Anting Station has been operating about three years.

In November 2010, the Green Energy Development Center Feng Chia University, Taichung in Taiwan hosted the 2010 Asian Bio-Hydrogen Symposium and the 2010 Asia-Pacific Economic Cooperation (APEC) Advanced Bio-Hydrogen Technology Conference. The focus of this multifaceted sustainable energy evennt was on utilizing hydrogen produced from organic waste decomposition as a contributing segment in Asia's overall energy solutions. The Conference was sponsored by the Taiwan Department of International Cooperation, National Science Council & Bureau of Energy and the Ministry of Economic Affairs. Representatives from dozens of institutes from Asia, Europe and the Americas participated.

At the forefront of hydrogen and fuel cell development in Taiwan is the Joint Center for Advanced Energy Research at the MingDao University. At the center of H2&FC research at MingDao is a government-sponsored fuel cell scooter program. The University has partnered with the largest scooter manufacturer in Taiwan, Kwang Yang Motor Co. Ltd., to develop and put into demonstration a fleet of 8 fuel cell scooters in the next year (currently on going). Eventually, this program is intended to lead to subsequent projects with markets that will target commuters throughout Southeast Asia, where scooters serve as a primary means of personal transportation. Other potential markets include recreational motorcycles in the United States and Europe.

Two organizations represent the hydrogen and fuel cell industry in China. The China Association for Hydrogen Energy (CAHE) represents mainland China's interests in hydrogen energy while the Taiwan Association for Hydrogen Energy and Fuel Cells provides a more focused view of hydrogen and fuel cell activities on the island and is based in MingDao University.

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In assessing the global hydrogen and fuel cell industry, it is an necessary to view European progress both in terms of the individual nations and in terms of the continent as a whole. This Report contains data for specific countries within Europe in their individual sections. This section however will provide a high-level summary of European programs, incentives and efforts in hydrogen and fuel cells.

Europe as a whole has arguably the most advanced infrastructure in the industry. There are currently scores of projects and demonstrations of hydrogen fuel cell applications, in the transportation, stationary, and portable arenas. Moreover, there are at least 22 associations in Europe providing local, national, and multi-national voices for mass-deployment of hydrogen and fuel cell products on the continent.

Europe's largest association for hydrogen interests is the multi-national European Hydrogen Association (EHA, www.h2euro.org), presided by Ian Williamson as its President. Mr. Williamson also serves as PATH's Vice Chairman, both positions he has held since 2010. The EHA in turn, is composed of 19 national associations plus several of Europe's major hydrogen producing companies. A complete list of EHA members may be found on its website at http://www.h2euro.org/eha/about-eha/eha-members. Moreover, several of Europe's countries are active in multinational hydrogen and fuel cell organizations, including the North Atlantic Hydrogen Association (www.newenergy.is/naha) and PATH.

Fuel Cell Europe (www.FuelCellEurope.org) serves as Europe's leading voice on fuel cells. Members include the leading fuel cell and electrolyser companies in Europe and as well as leading university and research institutions on the continent.

Significant projects of note in Europe include the opening of hydrogen highways, including:

- Germany – NRW Hydrogen HyWay: launched by the German state government in North Rhine-Westphalia in March 2008 (total length: 230 km)
- Italy – Motorway of Brennero: one of Europe's first hydrogen highways (total length: approximately 100 km).
- Spain – Three hydrogen refueling stations opened in 2010 along the A-23 highway between the cities of Huesca and Zaragoza (total length: approximately 65 km)
- Norway – HyNor: Established in 2003 between Oslo and Stavanger; opened on May 11, 2009. 4 hydrogen fueling stations are currently operational along the route with three more planned to be open in 2011 for a total of 7 stations (total length: approximately 580 km).

- Sweden – formerly known as Hyfuture: a hydrogen highway is planned in western Sweden. Hydrogen Sweden is leading the efforts to implement it.
- Denmark – Hydrogen Highway Link Network: begun in 2005 by the Nordic Transportpolitical Network the purpose is to link 15 hydrogen refueling stations across Denmark to create a country-wide hydrogen highway

The Hydrogen Highways (both planned and operational) in Norway, Sweden and Denmark constitute a broader alliance known as the Scandinavian Hydrogen Highway Partnership (SHHP). The SHHP collaboration began in June 2006 and culminated in the ceremonial hydrogen vehicle bridge crossing between Malmo, Sweden and Copenhagen, Denmark on November 30, 2009. The vehicle crossing was led by the EHA with support of European hydrogen and fuel cell sponsors and featured vehicles from Daimler, Ford, General Motors/Opel, Honda, Hyundai, Kia Motors, Renault/Nissan alliance, and Toyota. The bridge served several purposes; linking the hydrogen highways as well as symbolic transition into a hydrogen age for transportation. The event was also timed to be held immediately before the commencement of the 15th United Nations Climate Change Conference of the Parties (COP15) in Copenhagen.

Plans are being made for additional stations to be built in the near future[1]. Station construction coincides with automakers' expected 2015 rollout date of FCVs. Across Europe, hydrogen is being produced from conventional fossil fuels, by-product systems and renewable energy sources including biomass, wind and solar. It is currently estimated that the European hydrogen and fuel cell industry supports over 9,000 jobs; 3,000+ directly and 6,000+ indirectly[2].

A number of large scale projects were only possible with support from multiple nations as a joint venture. The Zero-Regio Project, being one such project, completed its six year operation in May 2010. The program included 16 partners, including the European Commission, from four European Union countries. Beginning in November 2004, the Zero-Regio project was dedicated to developing a transportation system based on hydrogen-driven fuel cell cars. Among its achievements, the Zero-Regio program affectively utilized an above and below ground pipeline to supply fueling stations with by-product hydrogen, developed 700 bar refueling technology, integration with existing service station infrastructure while exceeding first generation FCV performance expectations. The program also put a spotlight on infrastructure short falls, particularly the necessity for uniform standards and practices throughout the industry across political borders[3]. This theme also holds true throughout Europe.

In Europe, progress is being made in portable applications as well. In January 2011, the HyLIFT-DEMO project was unveiled to demonstrate the effectiveness and reliability of 30 hydrogen fuel cell-power forklifts in real time applications. The demonstration was co-funded by the European Joint Undertaking for Fuel Cells and Hydrogen FCH JU. The fuel cell systems were developed by Denmark-based H2 Logic and DanTruck A/S produced the forklift vehicles. The purpose of the demonstration is to raise visibility for these machines in terms of usability, safety, and convenience of refueling in preparation a planned market introduction and deployment of the forklifts by 2013. The forklifts were displayed at this year's CeMAT Logistics Fair,

Hannover, Germany in May 2011[4].

HyChain

The HYCHAIN MINI-TRANS project is another example of European countries working together to advance the use of hydrogen fuel cell products into society. Coordinated by Air Liquide with 24 partners, HYCHAIN is in the final year of its 5-year program. The program consists of providing over 50 hydrogen fuel cell powered products to the public in 4 test regions, including the Rhône-Alpes part of France, Soria, Spain, North Rhine-Westphalia, Germany, and Modena, Italy. Test products include motor scooters, minibuses, wheelchairs, and small utility vehicles[5].

HyFleet:CUTE

HyFleet:CUTE is an experiment in public transportation that features buses running on fuel cells and supported by infrastructure powered by stationary fuel cells (€18.5 M).

HyFleet:CUTE is the premiere hydrogen-power bus project, operating 47 buses in 10 cities across Europe, as well as in parts in Asia and Australia. The project was commissioned and financially sustained by the European Commission's 6th Framework Research Programme and currently is comprised of 31 partnering organizations, including those in government, industry, and academia. Buses in operation include hydrogen ICE engines as well as those running on fuel cells. The project will compare the benefits, negatives, and financial implications for each technology[6].

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France maintains one of Europe's most robust hydrogen and fuel cell programs, with R&D projects, participation in safety codes and standards organizations, government participation in the International Partnership for the Hydrogen and Fuel Cell Economy, country association representation in the European Hydrogen Association (EHA), and representation in the Partnership for Advancing the Transition to Hydrogen.

In 2003, the Association Française de l'Hydrogène (AFH2) hosted the EHA's first hydrogen conference. The hydrogen and fuel cell technology outreach campaign in France is part of a broader renewable energy platform adopted in that country. Nuclear power remains a key component to France's clean energy program and is responsible for nearly 80% of the entire country's electric production. But clean energy is not the only focus; energy efficiency is also a cornerstone of France's energy portfolio. Overall, the entire country has become 17% more efficient between 1990 and 2007. This includes increased efficiency in industry consumption of ~19%, household consumption of ~21% and transportation of ~12%[1]. Hydrogen and fuel cell innovation serves as an integral component of France's energy future.

Stationary Fuel Cell at French Railway Station

Like most European countries, hydrogen and fuel cell deployment are past the R&D stage and in the late demonstration stage. However, there are still ongoing R&D projects, particularly those that integrate H2&FC utilization into modern-day applications. One such example is in the city of Gagny, where an ElectraGen stationary fuel cell is being used as backup power for a signaling station for the French railway. The station can provide up to 12 hours of backup power in the event of a total electrical loss on the existing electric grid[2].

In 2009, AFH2, in partnership with ADEME (Government Agency), founded the French Hydrogen and Fuel Cell Platform, HyPAC, gathering 80 members (laboratories, industrial companies and local representatives involved in hydrogen technologies in France). Since the launch of HyPaC, two General Assemblies were organized in 2009 and two in 2010. In 2010, HyPAC produced a Roadmap for the deployment of hydrogen technologies in France and initiated a working group dedicated to developing industry codes and standards. This is of particular importance not only in France, but also in Europe and throughout the global hydrogen & fuel cell industry. Simultaneous with HyPAC's foundation, AFH2, launched the "Observatoire français de l'hydrogène et des piles à combustible" (e.g. "French Observatory of Hydrogen and Combustible

Batteries") in collaboration with Ademe and Alphéa Hydrogen. This project gathered updated information concerning activities in France in hydrogen technologies (e.g.- demonstrations, conferences and congresses, exhibitions, bibliography) and is organizing a database.

It is estimated that there are currently over 400 jobs in the hydrogen and fuel cell industry in France, the majority of which are in research settings at universities and government or company laboratories. Also responsible for a large portion of hydrogen and fuel cell jobs are fuel cell manufacturing jobs. It is projected by some estimates that industry employment level will grow to 3,000+ by 2020.

AFH2, participated in several exhibitions in 2009 and 2010 such as the "Renewables exhibitions" in Lyon and Paris and the "Pollutec exhibitions", also in Lyon and Paris. In December 2009, AFH2 organized, in collaboration with the "Palais de la découverte" and the "Région Rhône-Alpes", an exhibition dedicated to hydrogen technologies for the general public as well as students in Lyon. Additionally, AFH2 representatives participated in the World Hydrogen Energy Conference (WHEC) 2010 in Essen, the Fuel Cell & Hydrogen Energy 2011 Conference in Washington DC and EHA Board meetings throughout 2010. AFH2 has 49 members in fields ranging from hydrogen storage to policy development to system integration to research to manufacturing and distribution & to safety and training.

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Germany has one of the most actively expanding hydrogen and fuel cell programs in the world. Both the public and private sectors have invested heavily to advance this technology. The renewable energy industry in Germany has created roughly 370,000 total jobs. In 2010, renewable energy consumption saved roughly 210 million tons of CO2 and roughly 11% of the total energy consumption.

Germany's commitment to alternative energy solutions is rooted in its pronounced commitment to address climate change head on. The Federal government has passed legislation committed to reducing CO2 emissions by 250 million tons through 2020[1]. To do this, substantial commitments have been made to support renewable energy use and improved energy efficiency. Specifically, the Renewable Energies Sources Act and the Combined Heat and Power Act guarantee special fuel cell bonus and feed-in tariff rates in support of new technologies and infrastructure. As the world's largest current producer of biogas worldwide, Germany has also passed the Gas Grid Ordinance, specifically aimed at stimulating the use of biogas in fuel cell applications.

In addition to substantial support from the Federal government, a very comprehensive public funding strategy is in place. Established in 2006, the National Hydrogen and Fuel Cell Technology Innovation Program (NIP) has a budget of € 1.4 billion to bolster technology development. 50% of these funds are split between the Federal Ministry of Transport, Building and Urban Affairs and Federal Ministry of Economics and Technology and the remaining 50% is funded by industry stakeholders. The purpose of NIP is to prepare hydrogen and fuel cell products for entry into the marketplace through late-stage R&D projects and demonstrations. R&D projects are funded through the contributions of the Federal Ministry of Economics and Technology while the demonstrations are funded by the Federal Ministry of Transport, Building, and Urban Affairs.

NIP is managed by the National Organization for Hydrogen and Fuel Cell Technology (NOW). NOW serves as the central hub for industry, government and academia for strengthening Germany's hydrogen and fuel cell program. It is a federally-owned agency tasked with providing the leadership needed to execute the German government's hydrogen and fuel cell implementation strategy.

In the policy arena, Germany has passed legislation to advance hydrogen production from renewables such as biofuels including waste sewage from water treatment centers and gas from pyrolysis in plants.

Germany's alternative energy commitment is not just centered on financial programs, but it also includes a range of infrastructure-based programs. The Clean Energy Partnership (CEP) aims to prove the feasibility of hydrogen fuel as a broader usage of renewable energy resources by showing that hydrogen fueling stations are practical, reliable and safe[2]. Germany also has a large scale program, Callux, to showcase the feasibility of combined heating and power (CHP) units in residential settings (€ 80 M).

14 May 2010, Essen Germany

Hydrogen and fuel cell buses are either currently in use or have been in use in Munich, Berlin, Hamburg, Nuremburg, Furth, Cologne, Oberstdorf, Barth, Messe Düsseldorf, Herten, Bottrop and Stuggart. In addition to buses, other hydrogen or fuel cell technologies are being used across the country in Potsdam, Saxony, Rhine-Main, Rhine-Rhur, Bremen- Oldenburg, Frankfurt, Papenburg, Rostock, Bavaria, Baden-Württemberg, Lake Constance, Brandenburg, Hessen, Cuxhaven, Aachen, and Dertmund- among others[3].

With over 350 companies and organizations comprising the bulk of the hydrogen and fuel cell industry, Germany possesses roughly 70% of Europe's share of fuel cell demonstration units[4]. By 2015, it is estimated that Germany will account for more than one third of the demand of all European fuel cells[5]. Its current fuel cell supplier network already has well over 100 specialized companies. Competing energy storage technologies include oil, natural gas and coal.

Apart from federal and state governments' support, the private sector has also played an important role in hydrogen and fuel cell innovation and implementation. There are currently over 65 organizations and/or institutions conducting fuel cell technology research projects throughout Germany. In support of international research and development projects, German industry and state agencies will contribute € 2 billion over the next 10 year outside their borders[6].

The Deutscher Wasserstoff- und Brennstoffzellen-Verband (DWV), the German Hydrogen and Fuel Cell Association, has played an active role in moving the hydrogen industry forward in Germany as well as Europe. The DWV is also prominently represented in the European Hydrogen Association (EHA). Since it's formation in 1996, the DWV has grown to 304 members and has co-authored a number of key publications on European renewable energies and hydrogen technology. The DWV is frequently an active player on the world stage as participants and presenters in international exhibitions and conferences. General information is available to the public by press release, regular newsletters, an annual report, an annual press conference and non-periodic publications. "DWV-Mitteilungen" is a bulletin for its members with contributions provided by its members. As the voice of the industry in Germany, the DWV also actively participated in political lobby work and weighs in on relevant upcoming legislation on both the federal and state level.

DWV served as host of the 18th World Hydrogen Energy Conference in Essen Germany in June 2010. HANNOVER MESSE (www.hannovermesse.de) is also an annual trade show hosted in Germany with hydrogen and fuel cell products prominently featured among its exhibits.

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Hydrogen and fuel cells have a long history in Italy. As a leader in European Union programs to curb emissions and increase energy efficiency, Italy has established a prominent role for itself in the clean technology innovation and market transformation international community.

Hydrogen and fuel cell buses are currently in operation in Brescia, Milan, Mantova, Perugia, Rome, and Belzano. Italy also has an extensive refueling network throughout the country, including in Tuscany, Lombardy, Abruzzo and Veneto. Hydrogen at these stations is produced from renewable sources, as well as natural gas and electrolysis.

Fuel Cell Vehicles in Lombardy, Italy

While the Italian hydrogen and fuel cell industry has a number of programs throughout the country, there are several high profile projects that will be addressed in this section. In February 2010, the President of Italy's Lombardy region inaugurated the first combined hydrogen- natural gas mixture station. The station in Milan is an excellent example of intermediate transition technologies between traditional fossil-based energy sources and clean energy infrastructure. Another program, Clean Hydrogen in European Cities, utilizes 3 hydrogen buses for use as public transportation in Milan. Other projects testing fuel cell vehicles on public roads include the "H2 Power Hydrogen in Fuel Gas" project in Perugia and the Hychain Project in Modena.

In addition to demonstrations and real world application projects, Italy also has a strong research and development commitment to help produce new technologies and promote green energy. The Hydrogen Research Center in Lazio specializes in research; specifically on power systems based on renewable energy-produced hydrogen and the analysis of energy carriers in general. Of particular interest is the "Marine hydrogen for usable and sustainable land energy" project at Polo Territoriale Universitario di Trapani. That project intends to develop a system for the production, storage and distribution of hydrogen from wave energy for use in public transportation buses.

Two noted organizations that provide a collective voice for Italy's hydrogen and fuel cell community are: Forum Italiano dell'Idrogeno ("The Italian Hydrogen Forum," FII) and L'Idrogeno italiano & Alimenta Cellula Associazione ("the Italian Hydrogen and Fuel Cell Association," H2IT).

FII formed in 1997, and was one of the original founders of the European Hydrogen Association in 2000. FII (www.h2forum.it) continues as a non political, non-profit organization dedicated to promoting the development of hydrogen as an energy carrier and for fostering contacts and exchanges with international partners. It primarily serves the academic community for hydrogen and fuel cell curriculum development in Italy. H2IT (www.h2it.org) serves as the government and industry voice in Italy. Over 100 members have joined the organization and it is dedicated to stimulating and developing the market for the use of hydrogen. In January 2011, the H2IT Board of Directors produced a detailed outline for the association's 2011 activities. These goals include developing short term policy proposals in order to promote hydrogen and fuel cell technologies at the federal and local levels as well as organize an Italian hydrogen and fuel cell conference to be held in May and support other various hydrogen and fuel cell events to be held around the country throughout the year.

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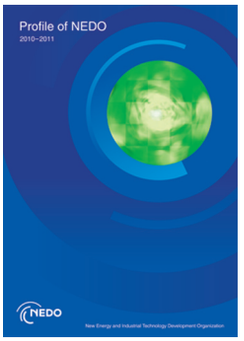
Commercialization of hydrogen and fuel cell infrastructure in Japan is best described as a rapidly developing industry dominated by large corporations with specific market goals backed by a supportive government offering robust financial and resource support. Because the country relies heavily on imported oil and nuclear sources for power, energy issues remain a centerpiece of legislation and policy making. As part of this effort, the New Energy & Industrial Technology Development Organization (NEDO, www.nedo.go.jp) is responsible for promoting research and development of new energy technologies and programs to hasten product rollout. Accordingly, NEDO works with the government, public, industrial and academic sectors. While the Japanese government is investing in the whole spectrum of alternative and renewable energy options, hydrogen and fuel cells are a particular focus for the island nation. Part of NEDO's work is dedicated to developing residential fuel cell systems for export to nations with an elevated and growing demand for fuel cells, such as Germany[1].

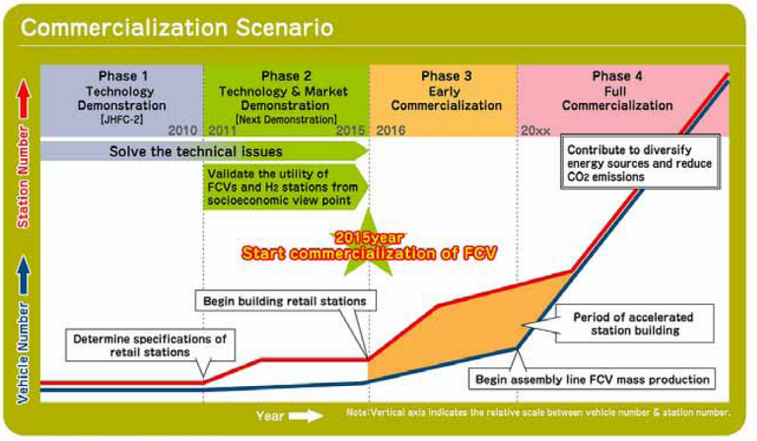
Behind Japan's commitment to hydrogen and fuel cells is a strong dedication to promoting renewable energy and energy efficiency. Japan's goals are to reduce national energy dependency and increase energy self–sufficiency from 18% to 70% as well as reducing daily life CO2 emissions by 50%[2]. Implementation of a strong hydrogen and fuel cell program is a key factor in achieving these goals.



Between 2008 and 2010, the Japanese government invested around ¥ 24 billion (~$285 million USD) per year on hydrogen and fuel cell research[3]. In 2009, elections brought a new party to power in Japan, the Democratic Party of Japan. Among its many goals, the Democratic Party of Japan immediately sought to establish a strong and fast-paced movement towards clean and efficient energy. This includes a 25% reduction of greenhouse gases by 2020 (based on 1990 levels), the introduction of a feed-in tariff scheme for all types of renewables regardless of quantity, and elevating the total national portion of renewables used as an energy source to at least 10%[4].

Japan has a number of programs in place to promote hydrogen and fuel cell use. By 2030, the Japanese government intends to have 2.5 million Solid Oxide Fuel Cell (SOFC) units for use in small scale stationary commercial settings[5]. To accomplish this, ¥ 1.20 billion (~$14.4 million USD) has been allocated for a SOFC development between 2008 and 2012. Similarly, mobile fuel cell technology intended for fuel cell vehicles (FCV) are also receiving substantial support. One research program devotes ¥ 2.0 billion (~24 million USD) between 2008 and 2014 to the development of Polymer Electrolyte Fuel Cells (PEFC) - known elsewhere in the world as Proton Exchange Membrane Fuel Cell (PEMFC). As with many new and promising technologies, these programs are only getting larger and more expansive. The predecessor program in PEFC development in practical settings received ¥ 4.69 billion (~56 million USD) in funding between 2005 and 2009[6].

While technology innovation is integral to hydrogen and fuel cell development, proper infrastructure is needed to support these technologies. A ¥ 9.0 billion (~$110 million USD) project from 2005 to 2009 established a working group to develop a set of Codes & Standards for the new industry[7]. The purpose of this program was to not only establish a firm foundation for manufacturing and development, but to also ensure safety and efficiency once these technologies are introduced to the public. This work is relevant not only to the H2&FC market in Japan, but also around the world. The need for harmonious regulations, codes and standards for the introduction of hydrogen and fuel cell products across borders is becoming more and more relevant.



In addition to significant government support, corporations are investing heavily in promoting hydrogen and fuel cell technologies. Toshiba is developing a Direct Methanol Fuel Cell (DMFC) for stationary and backup power to put into use as soon as possible. They are also planning on developing a universal hydrogen-fueled charger to power small electronic devices, such as smart phones[8]. The largest challenge is to sufficiently reduce the device's size without compromising its ability to operate and power a modern electronic device.

Honda Motor Company is one of the world's leaders in the automotive industry when it comes to fuel cell development. Honda is open about its understanding of the limitations of electric battery vehicles, especially when compared to the longer lasting fuel cell driven vehicles. Since the 1980s, Honda has been engaged in research and development programs dedicated to progressively building increasingly smaller, lighter and more efficient fuel cells. In the mean time, they have developed fuel cells that withstand minimum starting temperatures of -13°C with a range of 280 miles. In 2008, the Honda Clarity was launched and there are currently eight of those vehicles in use in the US and another eight in Japan[9].

The Hydrogen Energy Systems Society (HESS) is the industry representative for hydrogen and fuel cells in Japan. Formed in July of 1973, HESS is one of the oldest hydrogen and fuel cell associations to date. HESS operates out of Yokohama University as a center for research and development, refining hydrogen energy systems that utilize renewable energy sources. Quarterly workshops attract between 70 and 100 attendees to exchange information on infrastructure, production, transportation, storage and other topics vital to affecting change in the direction of promoting the hydrogen economy.

Endnotes

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MALAYSIA

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The introduction of hydrogen and fuel cell technology in Malaysia is still in its formative stages. Thus far, the majority of H2&FC-related work has been confined to R&D projects in labs and test sites. However, two hydrogen plants have been installed by Air Product and Chemicals, Inc. (www.airproducts.com) based on steam reformation of methane where hydrogen is recovered from petrochemical processes. No government incentive programs currently exist that are directly dedicated to H2&FC research or work, but a national status report and roadmap for green technology is expected to be published by the Malaysian government in the near future. Similarly to the four 'Asian Tiger' economies (e.g. Taiwan, Hong Kong, South Korea, and Singapore), Malaysia aspires to move from a resource and agriculture-driven economy to a manufacturing industrial economy[1]. This, combined with its intent on developing sustainable infrastructure by 2020, makes hydrogen and fuel cells a potentially strategic and lucrative market for the Malaysian people.

As with most nations whose hydrogen and fuel cell industry still has yet to enter a large-scale demonstration stage, other renewable energy technologies dominate the spotlight. Solar energy has found a home at a number of universities across the country. In 2005, the Malaysian government backed a Building Integrated Photovoltaic (BIPV) System program jointly funded with the Global Environment Facility (GEF) a total of RM 80 million between 2005 and 2010, along with private sector contributions. The GEF contributed RM 16 million. Similar paths from research to application are taking place in the biodiesel and biomass fields. To encourage renewable energy development and innovation, the Malaysian government has implemented tax exemptions for more renewable energy technologies.

A large portion of H2&FC R&D in Malaysia is done through the Universiti Teknologi Malaysia (UTM), where the Institute Hydrogen Economy (www.ihe.utm.my, IHE) is based. IHE's founders have over two decades of experience in hydrogen and fuel cells. Despite this, the Institute was only formally created in 2009. The Institute focuses on hydrogen production, purification systems, hydrogen storage materials, design & prototyping of application systems, testing & standardizing of system components and various other aspects that fall under the umbrella of general hydrogen research. In March 2011, IHE held a Strategic Planning Workshop

to settle on a 5-year term direction strategy for the Institute. As it is part of the Universiti Teknologi Malaysia, the IHE contributes a number of hydrogen and fuel cell related courses to the academic curriculum. Courses include operations and safety, financial modeling, materials development and systems operations.

Endnotes

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Mexico has played an increasingly role towards the advancement of hydrogen and fuel cell products in Latin America. In the Trade and Climate Change Report published by the United Nations Environment Program and World Trade Organization, Mexico was cited among the top five emerging nations for exports of renewable energy products[1]. One of Mexico's commitments is to reduce electricity generation from fossil fuels by 25% through use of renewable energy sources. This movement towards renewable energy is backed by $250 million (USD) from the Energy Transition and Sustainable Energy Use Fund. Mexico also received $500 million (USD) from the Clean Technology Fund, which is managed by the World Bank[2].

Mexico's climate and geographical position places the country in a highly favorable position to harness energy from renewable sources, including biomass, geothermal, wind, and hydropower. In fact, these sources contributed to the production of 17.5% of Mexico's overall energy supply in 2010. This included 14% from hydroelectric power, 2% from geothermal, 1.4% wind and 0.1% biomass[3]. In Mexico's arid northern regions, the potential to harness solar power is great, much like the solar projects in Arizona and Southern California in the United States. These renewable energy sources have the potential to replace conventional fuels (e.g. offshore drilling in the Gulf of Mexico, etc.) for hydrogen production in Mexico.

Development of hydrogen and fuel cell products will play an important role in Mexico in several ways. Today, oil reserves not only provide a power source in Mexico, but are also an important export product for the nation's economy. But oil production peaked in 2004 and has declined since then. It is becoming increasingly important for Mexico to develop new technologies to power the country, but also to fill a potentially growing void in the country's economy.

The hydrogen and fuel cell market in Mexico is mainly used as backup power for telecommunications. Companies outside of Mexico are also taking interest in developing fuel cell applications for industrial use[4]. In its Emerging Markets report in 2009, FuelCellToday suggests that Mexico has the potential to become a major exporter of fuel cell products.

To advance the implementation of hydrogen and fuel cell technology in Mexico, the Sociedad Mexicana del Hidrógeno (SMH, "Mexican Hydrogen Society,") was established and acts as the primary source of information exchange and collaboration in the country for this community. Each year, it hosts the International Hydrogen Congress, a conference known throughout the Americas and abroad as a premier event for the hydrogen and fuel cell community in Latin America. The next such Congress will be held in Cuernavaca, Mexico from 20-23 September 2011 (http://www.iie.org.mx:8080/SitioGENC/hydrogen2011/).

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NORTH AFRICA

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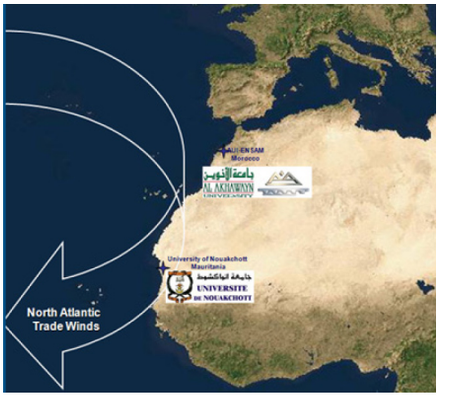
One of the most ambitious programs from renewable energy sources is taking place in North Africa. The coastal African nations of Morocco and Mauritania are climatologically ideally situated at the edge of the vast Sahara Desert to the east and the Atlantic Ocean to the west. This convergence, combined with large daily variations of temperatures, set up a natural climate boundary which serves to generate great winds that blow across these two countries. These winds are reliable. The Sahara Wind-Hydrogen Development Project (www.saharawind.com) aims to harness the power of these winds by establishing wind farms in strategically-placed areas of the desert, thereby generating substantial electricity to power communities directly as well as provide the power needed for electrolysis for hydrogen production. The hydrogen may then be sold to European markets abroad for profit.

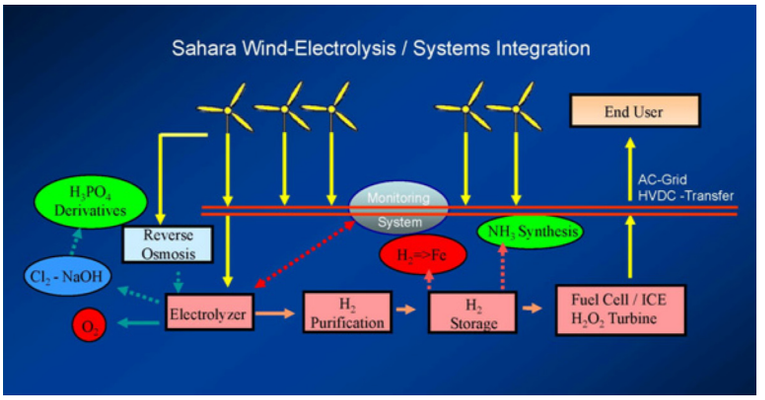
In order for success to be achieved, hydrogen storage must be economical. As there is limited infrastructure in the region to support such an ambitious endeavor, the first phase of the Sahara Wind project involves academic development and local demonstrations. The second phase involves large scale implementation and integration with existing industry infrastructure. With these two phases in mind, one of the program's priorities is to strengthen the relationship between academia and industry.



North Africa Winds

The academic phase of the project will be predominately based out of two sites; the Al Akhawayn University of Morocco (www.aui.ma) and the University of Nouakchott in Mauritania (www.univ-ukc.mr). Not only will these universities house much needed research in prototype development, storage systems integration and other necessary technologies for the project, but they are also to be used as demonstration sites for one of the integral goals of the project; the "Green Campus Concepts". In this project, 5 kW wind turbines will be installed on the campuses to supply power to the local grid as well as to a 30 kW pressurized alkaline electrolyser to produce hydrogen. This hydrogen is then stored under 12 bars of pressure to be used in a 1.2 kW fuel cell that will be used to provide power to the grid during low wind levels and to stabilize the grid when needed. These campus demonstrations will showcase the feasibility of a large scale equivalent for North Africa and surrounding markets.

Since it began installing wind measurement equipment in 1993, Sahara Wind has not only contributed valuable mechanical infrastructure, but it has also established meaningful business development and policy infrastructure with its partners. At the start of the 21st century, Sahara Wind officially became an incorporated organization, connecting the private sector (the Morocco Utility company ONE) and the public sector (Moroccan Ministry of Energy) to supply the European Union and other Mediterranean nations with additional energy. Sahara Wind plans on producing an additional 720 MW of energy to the existing 280 MW per year by 2012. By 2020, the goal is to produce 1+ GW[1]. If these goals are to be met, increased grid capacity will be required.



Support for the Sahara Wind Project comes from multiple nations and organizations. The most notable supporting member is a NATO Science for Peace & Security contract (SfP-9826290). The project aims to not only provide power. It also aims to develop infrastructure, generate business opportunities, expand upon academic achievements and improve cross-border political relations. It is also viewed as a more comprehensive national development undertaking with economic, environmental, energy, and political interests. Other international partners include: the U.S. Department of State, the German Ministry of Economic Affairs and Energy, the French Commisariat à l'Energie Atomique, Gif-sur-Yvette, and the International Centre for Hydrogen Energy Technologies which is supported by the Turkish Ministry of Energy and Natural Resources.

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POLAND

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Hydrogen and fuel cell progress in Poland has recently been focused on education and outreach-based activities. 2010 saw the formation of the first Department of Hydrogen and Energy on the university level in Poland at the AGH University of Science & Technology in Krakow. It also saw the formation of the "Best Thesis in the Field of Hydrogen Technology & Fuel Cells" contest, set to take place nationally on an annual basis. A prototype fuel cell vehicle was also developed at the Krakow University of Technology based on the Melex chassis with a four-stroke engine from a Fiat 126p. The fuel cell engine is being developed for use in public transportation buses. Additionally, the Military University of Technology in Warsaw is currently developing technology to produce hydrogen from natural gas.

As it is a developing industry still in its early stages, there are limited funding sources to support new research projects for hydrogen and fuel cells in Poland. There are currently no national or regional programs specifically dedicated to hydrogen or fuel cell technology innovation or development. Outside the laboratory, hydrogen is used most actively in the chemical industry as a raw material to produce ammonia and hydrogen chloride. It is also used in hardening plant oil or for petrol synthesis.

Since its formation in 2004, the Polish Hydrogen and Fuel Cell Association (PHFCA) has moved to educate the public and energy industry on hydrogen energy, fuel cells and their related technologies. Every two years, the association holds the Polish Fuel Cells and Hydrogen Forum to showcase recent developments in the industry. The PHFCA is heavily involved in higher education at the university level at Technical universities and institutions. Outreach efforts include an annual PHFCA bulletin. The PHFCA will also participate in the Polish EU Presidency conference "Strategic Energy Technology Plan: SET- Plan" in November 2011.

SPAIN

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In Spain today, hydrogen and fuel cell stakeholders are heavily focused on research and development projects. It is currently competing with advanced batteries and water pump plants as the premier advanced energy storage technology. There are currently a number of demonstration programs that are ongoing throughout the country. In Soria, 12 hydrogen fuel cell-powered vehicles make up the Spanish portion of the European HyChain (www.hychain.org) program. The Hércules program in Sevilla is developing hydrogen fuel cell vehicles specially powered by hydrogen produced from solar energy. Across the country, smart grids with integrated fuel cells are being implemented. Other programs are developing PEMFCs and SOFCs for portable and stationary use, respectively.

Education is a primary component of Spain's long-term implementation strategy. There are currently over 65 courses across the nation in higher education dedicated to hydrogen and fuel cell subjects at over 45 institutions. The National Center on Hydrogen and Fuel Cell Technology Experimentation (CNETHPC) in Puertollano was created as part of the implementation of the Spanish Roadmap of Scientific and Technological Facilities. The Centre is the result of collaboration between the Spanish Ministry of Science & Innovation and the Castilla-La Mancha Regional Government and is dedicated to developing new and innovative hydrogen and fuel cell technologies[1].

It is currently estimated that there are 280 jobs directly related to the hydrogen and fuel cell industry in Spain.

The Spanish Hydrogen Energy Association (AeH2) has 43 private and public company members and 82 individual members. It also has over a dozen research institutions and research members. AeH2 also maintains a database of hydrogen and fuel cell activities taking place in the industry throughout the country. These activities include initiatives, programs, or other business agendas dedicated to advancing the hydrogen and fuel cell industry. AeH2 participated in the International trade fair for Energy and the Environment, Genera 2009 and Genera 2010, as well as the alternative fuel and vehicle fair in Valladolid, Spain in 2009 and 2010. AeH2 frequently hosts hydrogen and fuel cell seminars, including "Hydrogen and Fuel Cells Users" (2009) and "Hydrogen and Electric Cars" (2010). In 2011, AeH2 plans on attending Genera 2011 and the H2 Power Expo 2011. Spain will also be the host country for the 21st World Hydrogen Energy Conference (WHEC) in Zaragoza in 2016.

Endnotes

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UNITED KINGDOM

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Even before it signed the 1997 Kyoto Protocol, alternative energy growth in the United Kingdom had been a priority for the UK energy industry, a commitment that has continued through the last 13 years and continues today beyond. In keeping with this commitment, in 2009, greenhouse gas emissions decreased 8.7% compared to 2008. Roughly 35% of greenhouse gas emissions were from the energy supply sector, 22% from transportation, 15% from business and 14% from residential fossil fuel use. The energy supply sector alone has reduced greenhouse gas emissions by 28% and businesses have reduced emissions by 24%[1]. This notable decrease in UK emissions in 2009 can be attributed to a decrease in consumption in all energy sectors as well as a shift in energy production type. Nuclear power and other renewables are being used in place of coal and natural gas power. These alternatives become especially attractive as they also hold new financial benefits.

The United Kingdom has adopted a long term view on the implementation and utilization of hydrogen energy and fuel cells between now and 2050. There are currently hydrogen related programs at 1 in 9 universities and fuel cell programs in 1 in 20 universities, creating over 340 jobs in those local communities[2]. In the next few years, fuel cells will be used at demonstration events to showcase their versatility, reliability and clean energy capacity. At the 2012 Olympics, to be held in London, UK hydrogen and fuel cell stakeholders intend to demonstrate fuel cells as a reliable and environmentally-friendly technology. One notable planned demonstration is for a fleet of approximately 50 hydrogen-powered taxis will be in operation, along with 150 hydrogen-powered public buses. As many as 6 hydrogen refueling stations are planned to be installed to accommodate this number of vehicles in operation.

Between 2012 and 2020, fuel cells will be utilized in supermarkets and other distribution settings, much in the same way they are used in the US and other countries today. Fuel cell forklifts and palette trucks using hydrogen fuel cells provide a financial benefit both in the electricity and labor hours saved as well as units moved due to increased efficiency. The UK government also suspects that over the next decade, stationary power generators will be utilized in small island communities where extending existing electric grid infrastructure is difficult and costly. It is expected that the world fuel cell market might be greater than $26 billion (USD) by 2020, of which the UK might have a market share of roughly $1 billion[3].

By 2030, the UK expects hydrogen energy and fuel cells will be common throughout the marketplace. Hydrogen-fueled vehicles will be readily available to consumers, if auto companies choose to move forward with commitments to manufacture them. By 2050, hydrogen is projected to play a significant role in the United Kingdom's energy portfolio with infrastructure including a central pipeline, electric storage centers and refueling stations operational. It is expected that the world fuel cell market might be greater than $180 billion by 2050[4], of which the UK might have a market share of roughly $19 billion[5].

There are a number of prominent universities offering programs in hydrogen and fuel cell education. The University of Ulster, Belfast is home to the HySAFER Centre (http://hysafer.ulster.ac.uk), which focuses on safety standards for hydrogen infrastructure. In May 2011, they offered a short course entitled "Progress on Hydrogen Safety: Hydrogen Technologies and Infrastructure." The Sir Joseph Swan Center at Newcastle University (www.ncl.ac.uk/energy/research/themes/csd/fuelcellandhydrogen.htm) offers a state-of-the-art research program on hydrogen storage as well as a comprehensive scope of fuel cell technologies from hydrogen fuel cells (high-temperature) to microbial fuel cells (low temperature). The program also addresses key challenges remaining for mass-commercialization of fuel cells. The University of Birmingham's Centre for Hydrogen and Fuel Cell Research (www.fuuelcells.bham.ac.uk) is part of the school's College of Engineering & Physical Sciences. Formed in 2000, the center maintains an advanced program for the study of fuel cell technologies in two primary areas: solid oxide fuel cells, and proton exchange membrane fuel cells. The Center is also home to the country's first hydrogen fueling station and fully hydrogen fuel cell-powered house (both in 2008). In addition to R&D activities, the Centre has also written publications and holds patents in designing of fuel cell products. The Cass School of Business in London also maintains a research program on market introduction of hydrogen and fuel cell technology.

The UK Hydrogen Fuel Cell Association (UKHFCA, www.ukhfca.co.uk) is a new organization created from a merger between Fuel Cells UK (FCUK) and the UK Hydrogen Association (UKHA) in early 2010. In the midst of restructuring and re-focusing itself and its goals, the UKHFCA continues to act as the coordinator between industry, public perception, and national goals. Another association in the United Kingdom representing the regional interest of Scotland is the Scottish Hydrogen & Fuel Cell Association (SHFCA, www.shfca.co.uk).

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UNITED STATES OF AMERICA

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The United States has long been recognized as the global leader in development of hydrogen and fuel cell technology. Hydrogen fuel cells were used as far back as the 1960s during NASA's Apollo space program as a means to power the spacecraft and to make use of its byproducts for manned missions: drinking water and heating the inside of the capsule. Since then, hydrogen and fuel cell products have become increasingly more important to the daily lives of the American people. Hydrogen and fuel cells offer the American people, as they do other nations, two important benefits over conventional petroleum-based fuels: energy security and a cleaner environment.

But the U.S. is not without its share of challenges for mass-commercialization. The challenges include: public education and outreach, significant public and private investment in infrastructure, cost competitiveness with other energy sources, uniform codes and standards to ensure safety of the products, and broad academic curriculum development to educate the next generation of engineers for designing safe, reliable, and cost competitive equipment.

For mass-commercialization of hydrogen and fuel cells for transportation in the U.S., it is important to consider the following points:

- Convenience of refueling stations,
- Cost of refueling compared with conventional fossil-based fuels,
- Cost of hydrogen vehicles,
- Public perception of vehicle integrity.

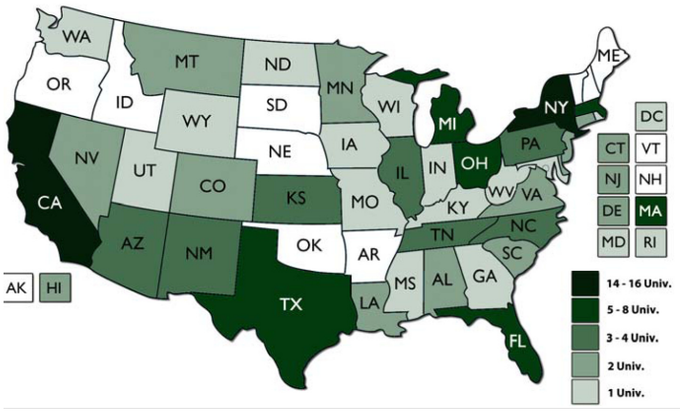
Convenience of Refueling Stations

In addressing the first bullet point above, the U.S. has undergone an aggressive campaign in the last decade, funded in part by the U.S. Department of Energy and state and local governments, to create hydrogen highways along heavily-traveled interstate routes. Mostly begun in the mid-2000s, the results of four noted projects below to date have yet to be determined.

California Hydrogen Highway Network (CaH2Net) – Initiated in 2004 by Former Governor Arnold Schwarzenegger, CaH2Net is a public-private partnership managed by the California Air Resources Board (ARB) to work with industry partners to lead hydrogen vehicle demonstrations and install hydrogen refueling stations along California's highways such that vehicles running on hydrogen fuel are able to reach other stations without the chance of running out of fuel. The California Hydrogen Blueprint Plan was created with input from various industry and environmental stakeholders to define where these stations should be installed throughout the state. $6.5 million was set aside in the 2005 state budget, with an additional 6.5 million in 2006 and $6.09 million in 2007[1]. Since then, nearly 30 stations have been established, mostly in Southern California, with several stations operating in Oakland and Sacramento. The stations primarily serve demonstration projects. In October 2010, the California Energy Commission announced it has awarded a total of $19 million to fund infrastructure needed for the installation of 11 additional refueling stations[2]. ARB estimates by 2017, between 50-100 refueling stations

will be operational[3]. It should be noted that since 2007, three stations have been decommissioned as the terms of their funding for demonstrations has expired. By the end of 2011, ARB projects 8 refueling stations will be open for public use, with possibly as many as 20 stations in operation to the general public by 2013[4]. The California Hydrogen Highway is a broader segment of a much larger planned continuous Hydrogen Highway beginning at the U.S.-California/Mexican border and extending through the Pacific Northwest, terminating in British Columbia, Canada.

Florida – In 2005, as part of the Florida Energy Technologies Act, Former Florida Governor Jeb Bush announced plans for a hydrogen highway to be created along Interstate 4 between Tampa and Orlando during a ground breaking for the state's first hydrogen refueling station. The site was provided by Progress Energy and was to serve as a test platform for the operation of a refueling station for real-time applications in Florida along the route[5]. Unfortunately to date, the hydrogen highway has not materialized.



East Coast Hydrogen SuperHighway – In 2010, SunHydro announced plans to establish a hydrogen highway beginning in Portland, Maine and terminating in Miami, Florida. 9 stations would operate along the route and will be designed to produce hydrogen from solar power and electrolysis. The first station opened at the Proton Energy Systems' parking lot in Wallingford, Connecticut in October 2010. Proton Energy is a partner with SunHydro in this effort. The final result remains to be seen.[6]

South Carolina – Two hydrogen refueling stations opened in South Carolina in March 2009: Aiken (capacity of 80 kg of hydrogen) and Columbia (current capacity of 120 kg) creating a 60-mile hydrogen highway along Interstate 20.[7]

According to the National Hydrogen Association's U.S. Market Report in 2010, 61 known hydrogen refueling stations were in operation across the United States[8].

Cost of Refueling Compared with Conventional Fossil-Based Fuels

According to the U.S. Market Report, the U.S. Department of Energy has calculated that hydrogen produced from current methods may be sold for $3 - $6 (USD) per kilogram without taxes. That is equivalent to $9.14 - $18.27 per gallon. When taking into the fact that hydrogen vehicles may travel twice the distance on a gallon of hydrogen compared with conventional fuels, the cost of hydrogen on the low end becomes close to the U.S. national average cost of gasoline (e.g. $3.84/gallon as of the week of May 30, 2011)[9].

Cost of Hydrogen Vehicles

The cost of hydrogen vehicles remains a key obstacle in mass-production of this product. Today's hydrogen vehicles typically cost about ten times the cost of conventional vehicles[10]. In the United States, as in other countries, the average citizen cannot afford to purchase a hydrogen vehicle. Despite this, leading auto manufactures including General Motors, Honda, and Toyota

have affirmed continuation of their hydrogen/fuel cell programs to design and develop more affordable equipment to lower the cost of these vehicles.

Public Perception of Vehicle Integrity

The United States has maintained an active role in development of Codes and Standards to ensure hydrogen and fuel cell products are safe for public use. In addition, non-profit associations at the national and regional levels have maintained outreach programs to educate community leaders, government officials, students at university and secondary schools, and other potential end-users about the safety of the vehicles. A number of public transit agencies have operated hydrogen-powered buses as a means of introducing commuters to the benefits of this technology in a safe and familiar way. It is estimated that there are approximately 210 light-duty hydrogen powered vehicles in the United States[11].

Beyond vehicle use alone, progress in being made to introduce hydrogen-powered forklifts to retail stores. Walmart has partnered with Plug Power, Inc. to use their GenDrive machines at two of distribution centers.

In July 2010, Boeing unveiled the Phantom Eye UAV hydrogen-powered aircraft, an unmanned spy place powered by hydrogen[12].

R&D into commercialization of motorcycles, scooters, and tractors are also underway.

Education and Employment

The U.S. Market Report states that 130 universities and institutions of higher learning maintain academic courses in hydrogen and fuel cell technology. Of those, 9 offer advanced degrees in the study of hydrogen and fuel cell products[13].

Data for an exact number of jobs in the U.S. hydrogen and fuel cell industry is difficult to come by. The U.S. Market Report estimated the number to be approximately 7,000 in 2008, but that total did not include jobs associated with non-PEM sectors of the fuel cell industry or military, portable, or transportation fuel cell applications. Despite this, the Report projects the total employment to reach approximately 58,000 – 182,000 by the year 2020[14].

National/Regional Non-Profit Hydrogen and Fuel Cell Organizations

The U.S. maintains a number of national and regional non-profit organizations to serve the interests of the hydrogen and fuel cell communities, spread out across vast distances of the country.

Fuel Cell and Hydrogen Energy Association (FCHEA) - The Fuel Cell and Hydrogen Energy Association (www.fchea.org) provides the collective voice of the fuel cell and hydrogen community in the United States. The organization was launched on November 1, 2010 as a result of a merger between the (U.S.) National Hydrogen Association (since 1989) and U.S. Fuel Cell Council (since 1998). The organization consists of 86 members, including leading fuel cell/electrolyser manufacturers, hydrogen/energy suppliers, public utilities, auto manufacturers, government agencies, national laboratories, and universities. The FCHEA serves as the focal point for advancing information exchange and reaching out to key target audiences to solve market challenges for the fuel cell and hydrogen industry in the United States. The FCHEA is headquartered in Washington, DC, USA.

Hydrogen Education Foundation (HEF) - The Hydrogen Education Foundation (www.hydrogeneducationfoundation.org) was incorporated in 2006 and remains a key partner for hydrogen and fuel cell education and outreach in the United States. Its purpose is "to promote clean hydrogen energy technologies through student scholarships, innovative national competitions, and educational programs to encourage environmental stewardship, improve energy security, and create green jobs." Today, the HEF manages three outreach programs: the H-Prize (www.hydrogenprize.org), the Hydrogen Student Design Contest (www.hydrogencontest.org), and the H2 & You public outreach program (www.h2andyou.org). It has also managed the Proton Energy Scholarship Program in the past (http://protonenergyscholarship.org). The HEF is headquartered in Washington, DC, USA.

Council for Hydrogen Energy Implementation (CHEI) - Originally started in 2003 as the New Mexico Hydrogen Business Council, then later becoming the Mountain States Hydrogen Business Council in 2006, today the organization is known as the Council for Hydrogen Energy Implementation (CHEI, www.council4hydrogenenergy.org). CHEI is a regional organization comprised of 18 industry members, plus reciprocal, honorary, and affiliate arrangements with an additional 8 organizations, primarily serving the interests of stakeholders in the western part of the country.. Its purpose is to "promote the business interests of its members, facilitate joint efforts and to advocate for state, regional and federal legislative activities that remove or mitigate barriers to the commercialization of hydrogen energy." CHEI is headquartered in Santa Fe, New Mexico, USA.

South Carolina Hydrogen & Fuel Cell Alliance - The South Carolina Hydrogen & Fuel Cell Alliance (www.schydrogen.org) is a public-private partnership of 16 organizations in South Carolina that work together to promote and advance hydrogen and fuel cell technology in the state. The organization was launched in 2006 and headquartered in Columbia, South Carolina, USA.

California Fuel Cell Partnership (CaFCP) - The California Fuel Cell Partnership (www.fuelcellpartnership.org) was launched in 1999 to bring together California's state government agencies with the state's auto manufacturers, fuel cell developers, and public utilities to promote the commercialization of hydrogen and fuel cell products in California. Today, the organization consists of 30 such stakeholders. The CaFCP is headquartered in West Sacramento and maintains a second office in Los Angeles.

Additional U.S. Involvement

In addition to these organizations above, the U.S. Department of Energy maintains a seat on the International Partnership for the Hydrogen and Fuel Cell Economy (www.IPHE.net).

The U.S. also maintains representation with the Partnership for Advancing the Transition to Hydrogen through the Fuel Cell and Hydrogen Energy Association.

Finally, the United States maintains an active Codes and Standards program through its involvement with the International Organization for Standardization (e.g. ISO TC 197).

Future Prospects

Like many other countries, the United States was not immune from the Great Recession of 2007-2010. As a result, the U.S. hydrogen and fuel cell program has seen its share of the federal budget cut in recent years. These cuts have affected state budgets as well, which have served to significantly impede progress made over the last decade to commercializing hydrogen products.

As government support for funding hydrogen and fuel cell-related programs continues to be reduced, it will become increasingly more important for industry stakeholders to affirm their support and work to advance these projects. This Report will need future revisions on the state of the U.S. hydrogen and fuel cell industry as events surrounding public funding continues to unfold.

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Part III: Closing

Summary & Conclusions

While the first decade of the 21st century saw great progress made on a global scale, successful implementation of a hydrogen and fuel cell economy is far from complete. It still requires a continued and steady commitment by industry, government, and academia, including significant levels of private investment from energy companies, automotive manufacturers, public utilities, and public investment from governments and academic institutions and research organizations.

Today, the hydrogen and fuel cell industry has become a multi-billion dollar industry and continues to attract the attention of the public through participation in large global technology expos and public events like the Olympic Games. Moreover, with governmental support at the national and local levels, and strategic partnerships between industry and research organizations, hydrogen highways have emerged in parts of North America, Europe, and Asia.

Known hydrogen and fuel cell associations exist on 5 continents and demonstration and public outreach campaigns exist on all 6 inhabited continents, as do universities offering programs in the field for the world's next generation of engineers, communications & marketing, and business professionals.

Among challenges the community still face includes:

- Cost:

o Fuel – The cost of hydrogen fuel still is higher than conventional fuels. But as the world's supply of non-renewable fossil-based fuel supplies increasingly become more expensive to tap, there will be a tipping point between the cost of producing hydrogen and the cost of petroleum supplies. In addition, as technology improves and becomes more widespread for harnessing renewable energy, the cost of producing hydrogen will continue to decrease.

o Fuel cells – Fuel cells engines are expensive compared to conventional internal combustion engines. Even today, a hydrogen fuel cell vehicle is approximately ten times the cost of a conventional vehicle, which keeps them generally out of the price range of what most people can afford.

- Accessibility to refueling stations – While significant steps have been taken to implement refueling stations and hydrogen highways connecting cities in regions of North America, Europe, and Asia, the number of refueling stations that sell hydrogen compared to fossil-based fuels is quite small. Commercialization of hydrogen-fueled products requires a significant undertaking by leading energy companies in order to make the fuel more readily available.
- Storage – With hydrogen's extremely low boiling temperature, storing the fuel requires designing tanks strong enough to hold the fuel without it escaping. Engineers are also looking into use of metal hydrides and other chemical compounds for keeping hydrogen from escaping at higher temperatures. Designing sufficient hydrogen storage tanks is especially important for transportation and mobile applications. Stationary applications may use hydrogen stored in cryogenic tanks either in the compressed gaseous, liquid, or slush state.
- Codes and Standards – Development of codes and standards for the design and performance of hydrogen products and fuel cells is a vital component to successful commercialization of this technology. It requires safety officers and code officials from around the world to communicate, exchange information, and work together to design products that are safe and user-friendly for the general public. In some countries without a significant investment in hydrogen and fuel cell infrastructure, it requires educating and training workshops targeting those safety officers and code officials, and winning their endorsements before proceeding with a commercialization plan in their countries.

• Public perception – With the industry still in its infancy, a large segment of the population perceive hydrogen to be a dangerous fuel. Convincing a skeptical public otherwise involves a massive outreach campaign. It requires participation in public events (e.g. Olympic Games, Exhibitions, etc.) and reaching out to the public with examples of how this technology benefits and improves their every-day lives, while ensuring the products are safe. This may be done by reaching out to and educating the media, who have the potential to reach out to an exponentially larger audience than those at specific functions and events. Educating key national, local, and community leaders is also a significant component to success in this capacity.

• 'Renewable' Debate – As hydrogen is an energy carrier rather than an energy source, it must be obtained from an energy source. Hydrogen and fuel cell technologies offer a clean alternative to carbon-based fuels and may work in concert with renewable fuels (e.g. solar, wind, hydropower, etc.) to transition the globe towards power from clean energy, rather than work independently from renewable sources. In the long term, the use of renewable sources for electrolysis should be the ultimate goal for creating cheap and abundant supplies of hydrogen.

• Economics – Stakeholders should continue to remain committed to implementation of hydrogen and fuel cell infrastructure. In the recent global economic downturn, governments and industry alike continue to cut budgets, putting the progress made in the last decade at serious risk. Successful commercialization of hydrogen and fuel cell products ensures thousands, perhaps millions, of jobs around the world in the years ahead. Continued commitments to continuing the program by governments, industry, and research organizations also helps avoid delays in transitioning global energy supplies from carbon-based to clean and renewable energy based and moves all nations who work towards it ensured energy security.

For continued information on developments around the world throughout the year, readers of the Report are encouraged to access PATH's website, www.HPATH.org, along with those of its Associations, which are as follows:

- Argentina: Asociación Argentina del Hidrógeno, www.aah2.org.ar
- Australia: Australia Association for Hydrogen Energy, www.hydrogenaustralia.org
- Brazil: Development Commerce Transport (DCT) Energia (Interim Member*)
- Canada: The Canadian Hydrogen and Fuel Cell Association, www.h2fcc.ca
- China:
  - China Association for Hydrogen Energy
  - Taiwan Association for Hydrogen Energy
- European Union: European Hydrogen Association, www.h2euro.org
- France: Association Française de l'Hydrogène , www.afh2.org
- Germany: Deutscher Wasserstoff- und Brennstoffzellen-Verband (DWV), www.dwv-info.de
- Italy:
  - Italian Hydrogen and Fuel Cell Association, www.h2it.org
  - Italian Hydrogen Forum, www.h2forum.it
  - Japan: Hydrogen Energy Systems Society of Japan, http://hess.co.jp
  - Malaysia: Universiti Teknologi Malaysia (Interim Member*)
  - Mexico: Sociedad Mexicana del Hidrógeno , www.smh2.mx
  - New Zealand: Massey University Centre for Energy Research (Interim Member*)
  - Poland: Polish Hydrogen and Fuel Cell Association, www.hydrogen.edu.pl
  - Sahara Wind (Interim Member*), www.sarahawind.com
  - Spain: Asociación Española del Hidrógeno, www.aeh2.org
  - United Kingdom: U.K. Hydrogen and Fuel Cells Association, www.ukhfca.co.uk
  - United States: Fuel Cell and Hydrogen Energy Association, www.fchea.org

Additional information may be found at:

- International Partnership for the Hydrogen and Fuel Cell Economy, www.IPHE.net
- International Association for Hydrogen Energy, www.IAHE.org
- Hydrogen fueling stations worldwide, http://h2stations.org/

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Appendix - 2011 Events

2011

13 – 16 February: Fuel Cell and Hydrogen Energy 2011, Washington DC, USA,
http://www.FCHEA.org

2 – 4 March: 7th International Hydrogen & Fuel Cell Expo, Tokyo, Japan
http://www.fcexpo.jp/en

15 – 18 May 2011: Hydrogen + Fuel Cells 2011: Canadian Hydrogen and Fuel Cell Conference, Vancouver, BC, Canada
http://www.hfc2011.com

9 – 10 June: Fuel Cells & Hybrid Devices for Commercial and Military Applications, Boston, MA
http://www.knowledgefoundation.com/viewevents.php?event_id=258&act=evt#oid

19 – 22, June: International Conference on Hydrogen Production, Thessaloniki, Greece
http://www.ich2p.org/ich2p11/index.php?conference=ich2p11&schedConf=ich2p11

29 – 20 June: Energy Path Conference: *Educationally-focused with topics to include Hydrogen*, Lehigh Valley, PA
http://energypath.org/energypath2011/Home.aspx

28 June – 1 July: European Fuel Cell Forum: Lucerne, Switzerland
http://www.efcf.com

1 – 16 September: International Conference on Hydrogen Safety, San Francisco, CA.
http://www.fuelcelltoday.com/events/event/2011-09/International-Conference-on-Hydrogen-Safety

14 – 16 September: Fourth World Hydrogen Technologies Convention, Glasgow, Scotland.
http://www.whtc2011.org.uk

14 – 16 September: Scottish Hydrogen & Fuel Cell Association Annual Conference 2011, Glasgow, Scotland
http://www.shfca.org.uk/event/198

27 – 29 September: Broadband World Forum, Paris, France
http://www.broadbandworldforum.com/manual/exhibitors/air_bbwf2010

25 – 26 October: Nordic Hydrogen and Fuel Cell Conference, Malmo, Sweden
http://www.malmokongressbyra.se/hydrogen_and_fuel_cells_conference/welcome

November: Strategic Energy Technology Plan: SET- Plan, Poland.

31 October – 3 November: Fuel Cell Seminar & Exposition 2011: Walt Disney World Resort, Orlando, Florida, USA
http://www.fuelcellseminar.com

22 – 23 November: International Conference on Fuel and Hydrogen Technology, Kuala Lumpur, Malaysia
http://www.ukm.my/icfcht2011

1 – 5 December: International Association for Hydrogen Energy Hydrogen and Fuel Cells Conference, Cancun, Mexico
http://www.zingconferences.com/index.cfm?page=conference&intConferenceID=79&type=conference

12 – 15 December: HYPOTHESIS IX: The Next Hydrogen Power Theoretical and Engineering Solutions International Symposium San José, Costa Rica
http://www.hypothesis.ws

2012

29 February – 2 March: 8th International Hydrogen & Fuel Cell Expo: FCExpo11, Tokyo, Japan
http://www.FCExpo.jp

23 – 27 April: Eighteenth Group Exhibit Hydrogen. Laatzen, Germany
http://www.h2fc-fair.com/hm12

3 – 7 June: 19th World Hydrogen Energy Conference (19th WHEC): Toronto, ON, Canada
http://www.whec2012.com

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NOTE: This list of references contains all policy papers, conference presentations, industry studies, market reports etc. that were used as reference or support materials at any point during the production of this Report. As many of these were used to confirm common knowledge information, some of the documents listed here will not be found referenced on any country content pages in this Report. For data specific references for information contained in the Report, refer to endnotes relevant to each country's summary.

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