IPHE Workshop Report

International Hydrogen Fuel Cell Technology and Vehicle Development Forum

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Galaxy Hotel Shanghai
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Introduction

The International Hydrogen Fuel Cell Technology and Vehicle Development Forum co-sponsored by the Ministry of Science and Technology of the People's Republic of China (MOST) and the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) took place in Shanghai from 21 to 22 September 2010. The forum was co-organized by the National Fuel Cell Vehicles & Powertrain Research & Engineering Center/Tongji University and the U.S. Department of Energy (DOE) Argonne National Laboratory, and co-endorsed by the Science and Technology Commission of Shanghai Municipality and the Shanghai New Energy Automotive Promotion Office. Mr. Zhang Zhihong, Deputy Director-General of the Department of High and New Technology Development and Industrialization, MOST, Ms. Nilgün Parker representing IPHE from the Federal Ministry of Transport, Building and Urban Development of Germany and Mr. Lu Xiaochun, Deputy Director of Science and Technology Commission of Shanghai Municipality delivered the address respectively at the opening ceremony.

Figure 1 Opening ceremony

Present at the forum were representatives from 18 member government agencies and research institutions, including Australia, Brazil, Canada, China, the European Commission, France, Germany, Iceland, India, Italy, Japan, the Republic of Korea, New Zealand, Norway, the Russian Federation, the Republic of South Africa, the United Kingdom and the United States , representatives from automobile manufacturers such as Honda, GM and SAIC,

representatives from energy and gas industries such as Shell, Linde, Air Liquide and Air Products as well as journalists from the People's Daily, Jiefang Daily, Xinmin Evening News and Xinhua News. More than 80 representatives from around the world came together for presentations and discussions about the technical development, demonstration and commercialization of hydrogen and fuel cell-powered vehicles as well as the development of hydrogen energy infrastructure in the perspectives of governments, academia and industry. The 1.5 day agenda included 23 presentations and 2 expert panel discussions covering 5 topics. After the conclusion of the forum, representatives visited the fuel cell vehicle demonstration base and hydrogen refueling station for EXPO Shanghai 2010 and took a ride in the demonstrated fuel cell buses, cars and sightseeing trolleys.

Representatives at the forum indicated with a touch of optimism that even with the financial crisis, the technical development, demonstration and commercialization of hydrogen energy and fuel cells is on track around the world, with fuel cell vehicles being promoted for commercialization in the near future. The forum not only provided an opportunity for governments and industrial players to share their experiences in hydrogen energy and fuel cell technologies, but also conveyed again to the public the confidence in promotion of technical development and commercialization of hydrogen energy and fuel cells, further advancing the commercialization progress of fuel cell vehicles.

Figure 2 Representatives at the forum

This report summarizes the forum in terms of government policies, industrial perspectives and demonstration progress.

Part 1: Government policies

Governments around the world attach great importance to hydrogen energy and fuel cell technologies and continue to make investments in technical development and demonstration.

Dr. Sunita Satyapal and Mr. Fred Joseck from the U.S. Department of Energy (DOE) presented the U.S. government's support of technical development of hydrogen energy and fuel cells and the technical development progress of fuel cells as well as hydrogen production and transportation. To advance the commercialization of fuel cells, in view of technical barriers (including the cost and durability of fuel cells, hydrogen cost and hydrogen storage capacity) as well as economic and systemic barriers (including standards, regulations, domestic production and supply basis, public awareness and acceptance, infrastructure for hydrogen production and transportation infrastructure), the U.S. government has implemented a series of policies and programs to support the development and deployment of fuel cells. In 2010, the DOE appropriated a fund amounting to USD40 million from the American Recovery and Reinvestment Act of 2009 ARRA to support 12 fuel cell projects and plans to deploy 1,000 fuel cells. Several demonstration activities are being conducted to validate technical maturity, e.g. in the recent validation activities for fuel cell vehicles and infrastructure, altogether 152 fuel cell vehicles and 24 hydrogen refueling stations were involved, demonstrating a total driving distance of up to 2.8 million miles, a total driving time up to 114,000 hours, efficiency up to 53-59% and hydrogen production and refueling exceeding 134,000Kg. The DOE also strives to facilitate the development of standards and regulations and the education of legislators and the general public. With the support from the DOE, many research institutions and companies are making significant progress in fuel cell, hydrogen production and transportation technologies, e.g. in 2010, the mass production cost of fuel cells (500,000 units/year) has been reduced by 15% since 2009 to USD51/KW; the service life of fuel cell MEA exceeds 7,300 hours (original target of 5,000 hours); and the hydrogen transportation cost has been substantially reduced.

Mr. Zheng Fangneng, Director of the Division of Energy and Transportation, the Department of High and New Technology Development and Industrialization, MOST, presented China's national hydrogen energy strategy and electric vehicle development program. Mr. Zheng pointed out that the hydrogen energy is the keystone of China's future energy development strategy. The National Program for Medium- and Long-Term Scientific and Technological Development

(2006-2020) focuses on the development of large-scale hydrogen energy utilization and a distributed energy supply system as well as research on high-efficiency and low-cost hydrogen production technology by utilizing fossil and renewable energies, economic and efficient hydrogen storage and transportation technologies, basic key fuel cell component manufacturing and fuel cell stack integration technologies, fuel cell power generation, and vehicle power system integration technologies, thus establishing technical codes and standards on hydrogen energy and fuel cells. Regarding China's electric vehicle development program, Mr. Zheng emphasized that a common understanding has been reached for the transformation of vehicle energies and power systems, however it must be recognized that for the development of fuel cell vehicles, a range of challenges must be dealt with, such as cost, service life, hydrogen production and hydrogen sourcing. It is imperative to make breakthroughs in core technologies such as cells (including fuel cells), powertrain and electric control and reduce the cost with project funding support and industry-university alliances. It is necessary for the infrastructure for electrification of urban transportation to be planned and constructed according to the urban energy and transportation characteristics. It is important to create new commercialization modes of electric vehicles and promote the industrialization of electric vehicles through the electric vehicle demonstration areas in place (such as Chongming Island demonstration project and Jiading International Automobile City).

The Fuel Cell and Hydrogen Joint Undertaking (FCH JU) is being implemented in the EU as supported by the governments of EU member countries. Mr. Enrique Giron from FCH JU presented the objectives and current progress of this program. The objective of the FCH JU is to promote the development of hydrogen and fuel cell technologies in preparation for commercialization in 2015. According to the total budget of FCH JU, an investment of at least Euro 940 million will be made from 2008 to 2013, including Euro 467 million in cash from the EU, Euro 20 million in cash and Euro 450 million in assets from industries and Euro 3 million in cash from research institutions. By application, 32-36% of funding will be used in transportation and infrastructure, 34-37% in stationary power generation and cogeneration, 10-12% in hydrogen production and transportation, 12-14% in early market development and 6-8% in cross-applications. By project nature, 31-35% of funding will be used in R&D support, 41-46% in demonstration and the balance in support actions and long-term research. H2moves Scandinavia and Clean Hydrogen in European Cities (CHIC) are two major ongoing demonstration projects under FCHJU.

Dr. Stian Nygaard representing IPHE from the Research Council of Norway presented the development of fuel cell projects in IPHE partner countries. In Germany, under the NIP project, an investment amounting to Euro 1.4 billion will be made from 2007 to 2016 in development of hydrogen energy and fuel cell technologies, including 50% from the government (Euro 200 million in R&D and Euro 500 million in demonstration respectively) and 50% from industry. In Canada, in British Columbia, 7 hydrogen refueling stations have been put into operation, including the world's largest hydrogen refueling station with a supply capacity of 1000kg/day to serve the world's largest fuel cell bus fleet (20 buses). In Brazil, an investment budget amounting to USD27 million is made in 5 applications for development of hydrogen energy and fuel cell technologies. Fuel cell buses will be deployed in Sao Paulo and Rio de Janeiro starting from 2010. In Iceland, under the Smart-H2 project, 27 fuel cell cars have been put into demonstration operating from 2007 to 2010 and currently 22 fuel cell cars remain in operation. In Norway, 4 hydrogen refueling stations are already operating and another 4 hydrogen refueling stations will be put into operation in 2010 and 2011. In the UK, 3 fuel cell buses are put into demonstration operation in London and 6 projects of hydrogen refueling stations and fuel cell taxis will be completed by 2012. According to IPHE, hydrogen energy and fuel cell technologies will play an increasingly important role in the energy and transportation systems of the future and the successful commercialization of hydrogen energy and fuel cell technologies relies on the international cooperation and experience sharing between all countries.

Dr. Haruhisa Koguchi from ANRE, METI presented the R&D of fuel cell vehicles and hydrogen energy in Japan. The support from the Japanese government effectively promotes the technical development of fuel cell vehicles and hydrogen energy in Japan. Starting from 2006, almost every year new projects or policies are implemented (such as Science and Technology Basic Plan, New National Energy Strategy, Basic Energy Plan, Cool Earth - Innovative Energy Technology, Next-Generation Automobile Fuel Initiative and Hatoyama Initiative) to support the technical development of fuel cell vehicles and hydrogen energy as regulated and supported by METI and NEDO. Dr. Koguchi presented the commercialization roadmap of fuel cell vehicles in Japan with the objective of 2,000 fuel cell vehicles on the road and 15 hydrogen refueling stations put into operation by 2015 and further 2 million fuel cell vehicles on the road and 1,000 hydrogen refueling stations put into operation by 2025.

Part 2: Industrial perspectives

The automobile and energy industries are ready for commercialization of fuel cell vehicles and have made significant progress.

In 2009, 7 automobile manufacturers, Daimler, Ford, GM/Opel, Honda, Hyundai/Kia, Renault/Nissan and Toyota, jointly published an open letter to energy companies and government agencies, indicating that starting from 2015, there will be a significant number of fuel cell vehicles launched to the market, therefore it is imperative to construct a hydrogen infrastructure, especially in the major markets such as Europe (Germany), U.S., Japan and Korea. In the forum, GM and Honda again indicated their confidence in commercialization of fuel cell vehicles by 2015.

Mr. George P. Hansen from GM presented GM's electrification strategy with a focus on hydrogen energy and fuel cell vehicles - "coexistence rather than simple substitution". The basic guideline of GM's electrification strategy is from hybrid vehicles through plug-in hybrid vehicles to pure electric vehicles and fuel cell electric vehicles. Currently GM is conducting the world's largest-scale fuel cell fleet market testing under a leasing arrangement where 119 vehicles are put into demonstration operation in the U.S., Europe and Asia, with a cumulative driving distance up to 2 million km. GM and SAIC are jointly developing the Roewe 750 platform-based fuel cell vehicles "Shanghai," which has the same fuel cell driving system as the Chevrolet Equinox. These fuel cell vehicles were used as the VIP vehicles at EXPO Shanghai 2010. GM's next-generation fuel cell driving system (Gen2), which are halved in size and weight with a service life more than 10 years as compared to the current system (Equinox Fuel cell) and are designed for more applications with the potential to substantially reduce the cost, will be launched to the market in 2015. The objective of GM's fuel cell system R&D projects is to reduce the content of platinum as a precious metal to 10g per vehicle and to reduce the cost of membrane materials through development of non-PFSA base materials. For vehicle hydrogen storage systems, GM prefers a 700bar 4 cylinder hydrogen storage system.

Mr. Takashi Moriya from Honda R&D Co. Ltd. presented the development progress of fuel cell electric vehicles at Honda. Honda holds that the fuel cell vehicles are the ultimate energy solution and Honda is committed to R&D of fuel cell vehicles. The environment-friendly FCV Clarity cars from Honda taking into account the driving performance will be equivalent to "zero emission" and

"comfort". To achieve a sustainable hydrogen energy society and the promotion of fuel cell electric vehicles, actions must be taken to enhance the construction of a hydrogen energy infrastructure and to increase social awareness of hydrogen energy.

Mr. Zhang Tong, General Manager of Shanghai Fuel Cell Vehicle Powertrain Co. Ltd., and Mr. Huang Chendong from SAIC respectively presented the R&D progress of fuel cell vehicles in China as well as the demonstration operation of fuel cell vehicles designed and manufactured by China at 2008 the Beijing Olympic Games, EXPO Shanghai 2010, and in California. Mr. Huang presented SAIC's fuel cell development roadmap. The fuel cell vehicles demonstrated at EXPO Shanghai 2010 are G2 which mainly address safety and reliability. Abundant data and experience is gained through demonstration. The G3 fuel cell vehicles to be introduced in 2013 will focus on improved performance, and the G4 fuel cell vehicles to be introduced in 2015 will focus on reduced cost. It is noteworthy that shortly after the conclusion of the forum, SAIC formally published its strategic objective for fuel cell vehicles - provide 50 fuel cell cars for its management's commuting by 2013 and achieve industrialization of fuel cell vehicles by 2015, with 1,000 fuel cell vehicles at the unit price of within RMB500,000 launched to the market in the pilot cities such as Beijing, Shanghai and Dalian.

Now that the automobile industry is ready for commercialization of fuel cell vehicles by 2015, will be a sufficient infrastructure in place to meet the demand? The world top 3 industrial gas groups, i.e. Linde, Air Liquide and Air Products, were present at the forum. Currently, approximately 80% of hydrogen refueling stations around the world are supplied by these 3 industrial gas groups and they made clear their points of view in the forum.

Fred Zheng, China Chief Representative of Hydrogen Solutions, The Linde Group, presented Linde's leading experience in construction of hydrogen energy infrastructure, mainly including the hydrogen refueling station, hydrogen compression and refueling technologies, in particular the innovative ionic liquid compressor technology which has been incorporated in hydrogen refueling stations (such as the hydrogen refueling station in Berlin). Mr. Patrick Sanglan from Air Liquide presented Air Liquide's hydrogen energy R&D and demonstrations. At Air Liquide, R&D covers hydrogen refueling stations as well as 70MPa high pressure composite hydrogen storage tanks and fuel cell products, and Air Liquide is actively exploring the market segments for commercialization of hydrogen energy and fuel cell products. Ms. Wendy Zhou from Air Products presented Air Products' basic information and its hydrogen energy system. Air Products is the world's largest hydrogen manufacturer with its

extensive patented technologies to secure its leading position in hydrogen fuel applications. Since 1993 Air Products has been actively involved in hydrogen fuel applications, with its footprint in more than 100 hydrogen refueling stations and more than 65,000 refueling. Linde, Air Liquide and Air Products all are large international groups dealing in industrial gases with extensive technologies and experience in hydrogen production, storage, transportation and use, enabling the quick product development for hydrogen infrastructure required by fuel cell vehicles. They believe that the hydrogen infrastructure is reliable and secure in terms of technology and safety; with improved technology and increased production, the cost will be cut down. In terms of the relationship between infrastructure and vehicles, joint efforts are required for market development and the governments' role in this respect is significant. The representative from Shell also expressed the same perspective during the expert panel discussion.

Besides the automobile and energy industries, experts from research institutions also expressed their interest in commercialization of hydrogen energy and fuel cells in the forum.

Prof. Michael Wang from the DOE Argonne National Laboratory presented an energy and emission benefit analysis for hydrogen fuel cell technology. Prof. Wang conducted a detailed analysis of energy benefits and reduced greenhouse gas emissions for hydrogen production, fuel cell vehicles, Combined Heat And Power (CHP) and Combined Hydrogen, Heat and Power (CHHP). He pointed out that hydrogen fuel cell vehicles provide a high energy benefit and help to reduce greenhouse gas emissions. The technical development of renewable hydrogen energy resources will maximize the benefit. At the same time, early market applications of fuel cells will contribute to emission reduction to a certain extent. Dr. Ulrich Buenger from LBST presented an environmental benefit analysis for hydrogen fuel cells used in transportation in Europe, the recent development progress and next development steps of hydrogen fuel cells in Europe and the agenda of hydrogen refueling stations in Germany. Dr. Buenger particularly conducted a detailed analysis of the annual expansion plan of hydrogen refueling stations in Germany from 2010 to 2020. According to the plan, there will be 1,000 hydrogen refueling stations (currently 16 hydrogen refueling stations) and 500,000 fuel cell vehicles (currently 50 fuel cell vehicles) in place in Germany by 2020.

Part 3: Demonstration progress

Fuel cell vehicle demonstration projects achieve significant results and commercialization is approaching.

In the forum, representatives from China, U.S., Japan and Europe presented several major fuel cell vehicle demonstration projects around the world.

Ms. Catherine Dunwoody from the California Fuel Cell Partnership (CAFCP) presented the plan and progress of fuel cell market development in California. In California, the focus is placed on the demonstration of fuel cell cars and buses, public education and legislation. In California, 350 fuel cell cars or buses have been operated since 1999. Today, 150 fuel cell cars or buses are in operation; there are 24 hydrogen refueling stations in operation, including 3 public stations; there are 7 stations under construction and 11 stations ready for construction. The plan is to have 40 new hydrogen refueling stations put into operation during 2009-2014 to serve 4,000 fuel cell cars and 60 fuel cell busies. It is expected to have 450, 4,200 and 54,300 fuel cell cars in 2012, 2013-2015 and 2016-2018 respectively. The development of fuel cell buses has 3 phases: test (15-17 fuel cell buses in 2011), large-scale demonstration (20-60 fuel cell buses in 2012-2014) and commercialization (60-150 fuel cell buses in 2015-2017).

Mr. Jinichi Tomuro from ENAA presented the progress of Japan Hydrogen & Fuel Cell Demonstration Project (JHFC) in 2009. Under the JHFC project, another 3 hydrogen refueling stations have been put into operation in 2009. So far there are 15 hydrogen refueling stations in operation in Japan, among which 4 are capable of refueling at 70MPa. From December 2002 to December 2009, under this project, the total driving distance of fuel cell cars registered 1,100,000km, with the hydrogen refueled up to 20.5t; the total driving distance of fuel cell buses registered 290,000km, with the hydrogen refueled up to 28.4t. In 2009, validation was conducted for long driving distances (1,100km) and 2 refueling of fuel cell vehicles, showing that the fuel cell vehicles can reach the continuous driving distance of conventional gasoline vehicles. The analysis also indicates that with the upgrading of hydrogen refueling stations from 35MPa to 70Mpa, efficiency only declines by 1-2% (mainly due to some electricity consumption by the high pressure compressor and pre-cooling system).

Ms. Monika Kentzler from EvoBus GmbH presented demonstration projects implemented in Europe. Under the HyFLEET:CUTE

demonstration project implemented in 2006-2009, 32 Benz fuel cell buses were put into operation in 7 European cities, Perth, and Beijing, and 14 hydrogen internal combustion engine MAN buses were put into operation in Berlin. This is the world's largest hydrogen energy bus fleet so far. Upon the completion of this project in 2009, the driving distance of fuel cell buses registered 2,600,000km, with the driving time up to 140,000 hours; the driving distance of hydrogen internal combustion engine buses registered 430,000km, with the driving time up to 30,000 hours. In 2010, the new CHIC (Clean Hydrogen in European Cities) demonstration project was launched. Under this project, during 2010-2016, 26 fuel cell buses will be put into operation in 5 cities (with 2 hydrogen refueling stations in each city). In addition, under the NIP project in Germany, the Clean Energy Partnership (CEP) has been running since 2002; at the end of 2010, there will be more than 50 fuel cell cars in demonstration operation; in early 2011, there will be 10 fuel cell buses and 4 hydrogen internal combustion engine buses put into demonstration operation.

After the conclusion of the forum, the representatives visited the EXPO hydrogen refueling station and the fuel cell vehicle maintenance base and took a ride in the fuel cell buses, cars and sightseeing trolleys. There are 196 fuel cell vehicles in operation at EXPO (including 90 fuel cell cars, 6 fuel cell buses and 100 fuel cell sightseeing trolleys), operated for nearly 6 months after the opening of EXPO. For the fuel cell sightseeing trolleys put into operation in the elevated footpath and Beihuan Road alone, as of 20 September, the total driving distance registered 487,629km, involving 8,883 trips and 1,540,138 passengers. During the forum, Prof. Wang Zhe from the National Fuel Cell Vehicle & Powertrain Research & Engineering Cente/Tongji University presented the plan of post-EXPO fuel cell vehicle demonstration operation in Shanghai and the plan for the Chongming Island demonstration project. According to Prof. Wang, the positioning of Chongming Island as a world-class eco-friendly island provides the potential for zero-emission transportation systems and also provides the opportunity for promotion of new energy vehicles. The relatively isolated location and moderate driving distance make Chongming Island suitable for large-scale application of new energy vehicles. In view of the low vehicle population in Chongming Island at present, with the support by legislation and supportive policies, the application of new energy vehicles will be promoted. The plan aims to achieve zero emission from public service and private vehicles and to have 100,000 electric vehicles (pure electric and fuel cell vehicles) put into operation in Chongming Island by 2020.

Figure 3 Representatives visiting EXPO new energy vehicle base

Figure 4 Representatives in fuel cell sightseeing trolleys

Conclusion and Next Steps

Overall the forum indicated that hydrogen and fuel cell technologies have been recognized around the world and governments and industries around the world have enhanced the R&D and demonstration of hydrogen energy fuel cell vehicles for reduced cost and improved performance of fuel cell vehicles. With significant progress made in relevant technologies in recent years, the representatives are confident in the future of fuel cell vehicles. Nevertheless, along the journey to industrialization of fuel cell vehicles, there are still rigorous challenges to be dealt with: the stability and durability of key components have to be improved and the cost has to be reduced; on the other hand, the infrastructure (such as hydrogen refueling stations) has to be in place for large-scale application of fuel cell vehicles. As discussed by representatives in the forum, at the early stage of industrialization, the government's key role in R&D and demonstration support shall be emphasized. Government policies provide support in development of the fuel cell industry; more importantly, they provide a guideline, indicating the government's affirmation of the fuel cell vehicle industry and ensuring public acceptance and further market penetration of fuel cell vehicles. To achieve the industrialization of fuel cell vehicles, the representative's call for enhanced cooperation between government agencies, research institutions and industries around the world to bring about synergies in R&D, demonstration, legislation and marketing and overcome the bottlenecks in the way, jointly promoting the global development of fuel cell vehicles.