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WORLDWIDE PROMOTION AND DEPLOYMENT OF FUEL CELL VEHICLES

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Abstract

Fuel cell vehicles are an important part of vehicle related R&D programs worldwide since many years. Many scientists and car manufacturers see them as an optimal long-term solution for clean and efficient individual mobility. A series of large scale demonstration projects on passenger cars, buses, two wheelers and material handling vehicles are running worldwide. Against the background of the current economic boundary conditions and the situation of the vehicle industry in general, new technology options for the future have become even more important for the long term strategies. Looking on the current trends at the moment there seems strong interest (especially in the U.S.) in the probably more immediate solution with plug-in hybrid vehicles. The following paper provides an up-to-date, neutral and comprehensive overview on current trends in fuel cell vehicles worldwide, and provides an insight in current R&D programs and strategies.

Keywords: fuel cell vehicles, R&D programs, deployment, international energy agency, demonstration projects, trends, overview

1 Introduction

The current individual mobility is strongly related to fossil fuels causing a valuable amount of the CO2 emissions worldwide and in many cases coming from politically unstable regions Fuel cell vehicles offer unique advantages concerning energy efficiency, reduction of emissions and reduced use of petroleum. They are not limited by thermodynamic restrictions of combustion processes. Therefore many scientists and car manufacturers see them as an optimal long-term solution for clean and efficient individual mobility.

The International Energy Agency (IEA) actively supports the development and market introduction of these new vehicle technologies. The Implementing Agreement on Hybrid and Electric Vehicle Technologies and Programs (IA-HEV) includes an Annex XIII on “fuel cells for vehicles” which complements the ongoing activities on battery and hybrid vehicles within the IA-HEV. As the implementing agreement of advanced fuel cells (IA-AFC) is as well working on vehicle based fuel cell technology a close cooperation has been established in order not to duplicate work.
The IA-HEV has direct access to information from national, industrial and scientific representatives. The results of the Annex will accompany R&D

activities of its members and initiate an intensive information exchange. This international cooperation reduces the danger to overlook technological trends or results in the global development process and allows the combination of strengths from different partners in a coordinated R&D process.
Throughout the last decades a lot of R&D was done in order to improve the performance of fuel cell vehicle components, and prototype vehicles were tested under real life conditions. The latest generation of fuel cell vehicles shows significant improvements in terms of driving range, reliability and availability, power density and cost. These cars have not entered the mass market yet. To validate R&D progress these cars are tested in large scale demonstration projects since several years.
The following paper provides an up-to-date, neutral and comprehensive overview on current trends in fuel cell vehicles worldwide, and provides an insight in current R&D programs and strategies.

2 Current R&D Programs

Fuel cells for vehicles have been an inherent part of R&D programs worldwide for many years. Whereas large scale demonstration and fleet testing programs started in the US (FreedomCAR and Fuels Partnership), Canada (the Vancouver Fuel Cell Vehicle program), Japan (JHFC Project) and within the 6th European Research Framework Program, additional RD&D programs are now promoted worldwide. The formation of a joint technology initiative (JTI) on hydrogen and fuel cells in Europe is maybe the most prominent among these new initiatives.
A JTI is a public-private partnership for industrial research at European level. Over the next six years (beginning in 2008), the European Commission and industry will invest almost €500 million each into the initiative, with the aim of accelerating the development of hydrogen and fuel cell technologies and bringing them to the market by 2020. The JTI will focus its efforts on four main areas:

- Transportation and hydrogen refuelling infrastructure
- Hydrogen production and distribution
- Stationary power generation and combined heat and power (CHP)
- Early markets [1].

Furthermore, Germany recently started the "National Innovation Program for Hydrogen and Fuel Cell Technology" (NIP). Under the NIP, additional €500 million assistance has been earmarked for this technology over the next ten years. Up to €1.4 billion is available during the period 2007 to 2016 taking into account the complementary funds from industry and users. More than 50% of the total budget is earmarked to the transport sector. Generally, about 65 percent of the available resources should be used in demonstration projects (lighthouse projects). Projects within the NIP Program follow a bottom up strategy with a maximum promotion of 50% [2].
In 2004, Canada launched the B.C. Hydrogen Highway project which is currently entering the final phase with the construction of a filling station in Whistler where a fleet of 20 FC-Buses is planned [3].
China started phase I of its "Demonstration Project for Fuel Cell Bus Commercialization" in Beijing in 2006. Phase II of the project started in Shanghai in 2007 and goes on until 2010. A fleet of twelve buses will be in operation. Beside these examples, a series of demonstration projects for both passenger cars and buses are running worldwide.

The US FreedomCAR is a partnership between the US Department of Energy, car manufacturers (Chrysler, Ford, GM) and fuel companies (ExxonMobil, Shell, BP, …). Under this effort, fuel cells are being developed by various organizations (industry and national labs) and then integrated in vehicles by car makers. A large demonstration program at several sites in US and with more than fifty fuel cell vehicles is funded jointly by DOE and industry to determine the state of the technology. Data from each vehicle is collected daily and analyzed to verify efficiency of fuel cells, fuel economy of vehicles, range, degradation, performance, and other factors.
Under the umbrella of the California Fuel Cell Partnership - CFCP (founded in 1999) which promotes fuel cell vehicle commercialization demonstration programs in six areas provide an array of driving conditions, climates and geography to collect a range of experiences. California with its strict regulatory framework conditions for cars is a candidate for an early fuel cell vehicle market.
Similar to the programs in the US and Japan in Germany in May 2008 the Clean Energy Partnership CEP started its second phase. Leading oil- gas and energy companies, technology

suppliers as well as the majority of German vehicle manufacturers are participating in this innovative project to establish a hydrogen region in the area of Hamburg–Berlin
Until 2010 the project is concentrating on validating technology under everyday conditions and will particularly push ahead with the further development of technologies that are essential for hydrogen's market entry at a later date. Concrete steps are increasing the vehicle fleet up to 40 cars, expanding the fleet of public busses in Hamburg and Berlin and the opening of three new filling stations in Berlin and in Hamburg HafenCity. A first major milestone is the enlargement of the Berlin vehicle fleet by ten GM/Opel HydroGen4 with 700bar-vessel system [6].

3 Trends in the market - and examples for interesting niche markets

After an overoptimistic perspective on the future of fuel cell vehicles in the mid/late 90s, fuel cell passenger cars and buses of the latest generation are currently under field testing programs. Latest results of fleet testing show significant improvements for those vehicles in terms of driving range, reliability and availability. All these fuel cell vehicles feature improvements in stack and system design that result in higher reliability and considerable higher energy densities in terms of weight although improvements in terms of volume are rather small.
In 2008 a limited number of fuel cell vehicles were released to "real" costumers for lease mainly in the U.S. and Japan and Germany. This can be seen as a next step towards fuel cell vehicles in early markets and therefore fuel cell mass production.
Beside the classical passenger car and heavy duty vehicle market (auxiliary power units - APU), two markets seem especially interesting for fuel cells. Material handling is a large electric vehicle market with almost 900k sales per year and has high potential for the use of FC technology. Battery Electric vehicles are an immanent part of material handling processes. Battery electric vehicles in shift operation have the need of a rather extensive battery charging equipment. The handling of heavy battery packs is time consuming and needs special handling equipment. Fuel cell powered vehicles can be refueled in a very short time without the need of additional handling equipment. Early market applications like the fuel cell forklift market will help develop the technology and supply chain required for successful fuel cell cars, and educate customers to the advantages of fuel cells and hydrogen. For instance Plug Power announced it will supply 220 GenDrive fuel cell modules for installation in new Yale lift trucks that will be deployed at a new distribution center under construction by Central Grocers, Inc., in Joliet, Il.
Also the market for Scooters (2wheelers), especially in Asia, seems very promising [5]. The Taiwan Fuel Cell Partnership is strongly promoting fuel cell for two wheelers. But also densely populated areas in Europe would strongly benefit from the introduction of fuel cell powered two wheelers as there are more than twenty million two wheelers running in Europe at the moment.
Currently, in the U.S. there seems to be a strong interest in the more immediate solution with plug-in hybrid vehicles. It is perceived that even taking into account the high cost of batteries, the plug-in hybrids would be much less expensive that fuel cell vehicles and also a completely new fuelling infrastructure would not be necessary. As a result of this, more funding is going towards the plug-in hybrid and battery development than for fuel cell vehicles. GM for example, is counting on its range extender EV flagship vehicle (Volt) to show that the company is in the forefront of advanced green technology vehicles.
Currently the automotive industry is facing a very difficult period. In combination with a worldwide financial crisis this also means a hard time for fuel cell vehicle developers, nevertheless all major automotive companies still have fuel cell vehicles on their roadmaps to a sustainable mobility.

4 Future potential for hydrogen and fuel cell vehicles

Against the background of steadily rising Green House Gas (GHG) emissions, imminent and visible climate change and increasing dependence on energy resources from politically unstable regions, policymakers set ambitious goals to secure energy supply and to reduce GHG emissions, including those from the transport sector. Long term energy carrier scenarios for the transport sector in Western Europe [4] show that the contribution of Biofuels to the total fuel consumption is limited whereas hydrogen is theoretically able to fulfil the future demand of a carbon neutral energy carrier.

A variation of different parameters shows that the analysis is especially sensitive to CO2 (compulsory) reduction targets: under a 50% CO2 reduction target compared to 1990 basis until 2100, a remarkable role of hydrogen and FCVs seems realistic. In this scenario Biofuels and hybrid technology can be interpreted as a bridging technology to a fuel cell powered transport future.

If even stricter CO2 reduction targets of about 60% are expected (accepted), a hydrogen market share of 20% is predicted for 2050.
Fuel cell technology also is an interesting option for heavy duty applications. When looking on long distance freight transport with trucks a future transport system with pure battery electric propulsion seems rather unlikely from today's perspective. A real breakthrough in battery technology would be needed to fulfil the requirements for long distance freight transport. This offers a chance for hydrogen and fuel cell technology in the long distance transport sector, whereas improvements of fuel cell technology are needed to fulfil the requirements of this application.
When reading the analysis one should also keep in mind that meeting the cost targets for sustainable hydrogen fuel and fuel cell stacks is still a big challenge as well as the chicken-or-egg problem for the hydrogen infrastructure is still an unsolved question.
Nevertheless, CO2 reduction targets seem an effective tool for stimulating hydrogen market introduction. In the near term, fuel cell vehicles might lose relevance to plug-in hybrid vehicles under this scenario. Fuel cell technology improvements and the production of affordable hydrogen from renewable resources accompanied and stimulated by research programs and large scale demonstration projects will open a chance for fuel cell vehicles in the future.

5 Technological challenges

When looking in to the future potential of fuel cell technology in the automotive sector one should be aware of the technological hurdles that have still to be overcome. Large scale demonstration programs are necessary to show and improve fuel cell technology for everyday use. In addition to these programs a lot of basic research on various topics such as material research (membranes, catalysts, bipolar plates, …), stack design, system integration, control strategies, hydrogen storage materials and many more will be necessary.
At the moment with an upcoming "hype" on lithium battery technology and vehicle applications such as Plug-in hybrids batteries and fuel cells are often seen as a sort of concurrent. When having a look on a fuel cell vehicle system one can see that both are partners in such a system. Combing the strengths of both may result in systems such as a Plug-In Fuel Cell Hybrid Transit Bus unveiled by the start up Proterra (Golden, CO). This prototype was also presented in March 2009 at the annual meeting of National Hydrogen Association conference in Columbia, SC (USA) and is a good example of how the strengths of fuel cells and batteries can be combined in a vehicle system.

6 Conclusion

Currently, new R&D programs focusing on large scale testing and on market introduction of fuel cell technology especially in the transport sector have either started or have entered a next stage. Remarkable improvements of the latest generation of fuel cell vehicles have been demonstrated in the latest fleet tests. Extended driving range, higher power density and better reliability are promising for the future.
Car manufacturers recently started to lease FCVs to real customers taking the next step towards market introduction. Also early niche markets such as scooters in Taiwan or material handling vehicles such as tow trucks and fork lifts seem interesting for the fuel cell industry. Even in times of an automotive crises companies such as Honda and GM-Opel started to test their latest fuel cell vehicle generation in within large scale demonstration projects in the US, Europe and Japan.
Beside large scale demonstration projects necessary for technology validation under every-day-use testing conditions policy makers and industry should not forget about basic research that will be necessary to overcome the technological hurdles on the way to a successful market introduction of fuel cell vehicles.
The current discussion on limiting GHG emissions, and the resulting CO2 reduction targets seem an effective tool for stimulating hydrogen market introduction. There is going to be a strong competition from plug-in hybrid vehicles in the short term, but fuel cell vehicles fuelled by hydrogen produced from renewable sources are an interesting option from the stand point of emissions and GHG.
At the moment there is a very strong interest in Plug-In hybrid technology and battery electric

vehicles in general especially in the USA. Batteries similar to fuel cells still suffer from technological hurdles such as energy density, reliability and last but not least cost. Battery and fuel cell technology should be seen as partners on the road towards a sustainable mobility and transport sector.
The work of the IEA IA HEV annex XIII "fuel cells for vehicles" gives an actual and broad overview of ongoing R&D efforts worldwide and provides unbiased information to policy makes of the member countries.

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