'Hydrogen is a choice'

A substantial part of the European fleet could drive on hydrogen by 2030. Policy incentives for technology deployment, harmonization of legislation, more R&D, and a lower sales price for hydrogen vehicles are the necessary prerequisites. But it will only happen if Europe makes an explicit choice for hydrogen as a long-term solution.

By Annemieke van Roekel

'Transport on the basis of hydrogen is a choice. A hydrogen economy will not come about by itself. It is the option with the best outlook in terms of emission reductions and security of supply, but it is also the most difficult to introduce. If we make a conscious choice, it is possible that a substantial number of cars and trucks will be equipped with fuel cells and will use hydrogen in 25 years time.' That is the opinion of Harm Jeeninga, hydrogen specialist at the Netherlands Energy Research Centre (ECN) in Petten, which cooperates with the hydrogen research laboratory of the European Commission, GCO, also in Petten.

'We should not lose sight of the fact that the hydrogen vehicles on the road at the moment are still prototypes,' says Jeeninga about the current state of affairs. 'Serialized production is out of the question as yet, and the cost of prototypes is still very high. The sales price can be reduced by more R&D, but the research efforts must be in line with deployment - the number of hydrogen vehicles that are actually on the road.'

According to the HyWays study, a EU roadmap for the introduction of hydrogen, there need to be some ten million hydrogen cars on the European roads to reach an acceptable sales price. According to Jeeninga, price reduction could be accelerated if the automobile sector opts to outsource the production of components, such as fuel cells, to specialized companies. 'More hydrogen vehicles will lead to lower prices. In view of what drivers are prepared to spend on expensive navigation systems, they should be prepared to pay a little more for a clean hydrogen car.'

According to Jeeninga, Europe is too much focused on the Kyoto CO_2 emission reduction targets that have a relatively short timeline. Consequently, the national governments are prone to choose measures that bear fruit in the short term. Hydrogen does not fit that mould, as it will only become cost effective in about 25 years time. ECN is one of the research institutes that is involved with the plans of the European Industry Commissioner, the German Günter Verheugen, to set aside 470 million euros for research into hydrogen cars over the coming years (see box). Industry is supposed to match that funding.

Air quality

One of the main benefits of fuel cell vehicles is that they do not produce harmful emissions. When you convert the colourless and non-toxic hydrogen gas into electricity and heat, you only produce water vapor. Passenger vehicles and trucks on hydrogen could therefore have a significant positive influence on the air quality in densely populated and urban areas. However, hydrogen must be produced first and that process requires energy. Hydrogen (H2) can be obtained from water (H2O) by means of electrolysis, whereby oxygen is released, or it can be 'reformed' from natural gas or other fossil sources. Hydrogen is also the most important auxiliary in oil refining. Depending on the way hydrogen is produced, it can be seen as a CO_2-neutral 'fuel', or more appropriately, energy carrier.

In a fuel cell, which, like the solar panel, was applied first in space travel, electricity is generated when hydrogen and oxygen react. The electric current drives an electromotor. A number of hydrogen cars that have been introduced in the market so far - usually as a prototype or test model - have a modified combustion engine into which it is possible to inject hydrogen as well as petrol. The combination of hydrogen/fossil fuel is a temporary solution whilst there is no hydrogen infrastructure.

The BMW Hydrogen 7 is an example of a model that combines fossil fuels with hydrogen, and a limited number were introduced a few years ago. The Mazda RX-8 also runs on a combination of hydrogen and petrol. Both models use a combustion engine and are used as

Hydrogen vehicles from the Hychain Minitrans project. Photos: Frank Koch

Tanking electricity with the Toyota Prius. Photo: Bart Willemsen

lease cars by a small group of selected clients. 'From the point of view of emissions, the use of hydrogen in a normal petrol engine is preferable over fossil fuels,' says Jeeninga, 'but it is preferable to convert the hydrogen with the highest efficiency. With a fuel cell you can realize an additional energy efficiency of 40%.'

The first hydrogen car with a fuel cell will be introduced on the market in 2008 by Honda. The Honda FCX Clarity has a range of 400 kilometers and will be available as a lease car; the lease costs amount to $600 per month. Mass production is out of the question for the time being, due to the lack of hydrogen fuelling stations. In 2008, General Motors will also introduce a fuel cell vehicle. The test model is based on the Chevrolet Equinox, and will be tried out in three American cities by a selected group of users such as politicians and business people.

Compulsory Fuel Cell

It is not surprising that the US puts a lot of effort into the development of fuel cell cars. California introduced legislation that compels automobile manufacturers to introduce a minimum number of fuel cell vehicles on the market, and this number increases each year. European laws do not make a distinction between hydrogen cars with or without a fuel cell. Some automobile manufacturers in the US are lobbying to get hydrogen models with combustion engines included in the Californian legislation.

According to Jeeninga, the strict laws as enacted in California are not without risk. 'The American innovation strategy is based on introducing new technologies that have not yet been fully developed. If the American car manufacturers do not meet the strict government requirements, they have to pay a hefty fine. But technological progress is hard to predict. If they are not able to achieve the expected breakthroughs, car manufacturers may not be able to meet the requirements, despite the major investments they make. This may lead to very high costs if technological developments remain behind. It may reduce the support for a technology that is still at a vulnerable stage. This happened before with the electric car, which was pushed into the market through regulation. For various reasons, targets were not met and the introduction failed.'

Jeeninga points out that innovation policy in Europe is usually more cautious. 'New unproven technologies are put on the market with the necessary protection and in the form of pilot

European ambitions

In October 2007, the European Commission (EC) approved the funding of the Joint Technology Initiative (JTI) on hydrogen and fuel cell technologies. This JTI - which includes both the private and the public sector (the European Commission) - is given a central task in developing and deploying hydrogen technologies. The companies involved include many of the major players in the hydrogen sector, such as Shell, Fiat, Volkswagen, Rolls Royce, Gaz de France, BP, and so on. The companies have set up a legal entity for the purpose of participating in the JTI, called New Energy World - Fuel Cell and Hydrogen for Sustainability.

Public-private partnerships such as the JTI are regarded by experts as necessary to realize a transition towards a hydrogen economy. Research is too complex to be performed by individual companies or research institutes, says a spokesman of Kellen, the company that carries out the project management of the European Hydrogen and Fuel Cell Technology Platform (HFP). HFP is responsible for carrying out the hydrogen JTI.

Brussels, which aims at commercialization of hydrogen vehicles by 2015, co-finances the JTI with €470 million over a 6-year period. The money comes from the Seventh Framework Programma (FP7), a financial instrument for R&D in various research fields aims at a transition towards cleaner technologies. The budget for energy research within FP7 amounts to € 2.3 billion for the period 2007-2013. The private sector is also expected to put up €470 million.

Hydrogen motorbike from the Hychain Minitrans project. Photo: Frank Koch

projects and policy support schemes, to enable them to withstand competition from established technologies in the early phase of market introduction.'

CUTE

Hydrogen-powered bus transport can also help reduce air pollution in many urban areas. Hydrogen buses have been running in European cities for more than ten years, starting in Hamburg and Oslo. In 2001, the European project Clean Urban Transport for Europe (CUTE) started as a large-scale demonstration project. Now Citaro fuel-cell powered, low-noise buses from DaimlerChrysler are in operation in nine European cities: Luxembourg, London, Porto, Amsterdam, Stockholm, Hamburg, Stuttgart, Madrid, and Barcelona. In a number of cities, hydrogen is produced on site - in Madrid and Stuttgart from methane, and in Amsterdam, Barcelona, Stockholm and Hamburg by means of electrolysis powered by sustainable electricity. In Iceland too, which has major plans for realizing a hydrogen economy for its vehicle and fishing fleet, an experiment is being carried out with hydrogen buses.

Jeeninga believes that the CUTE project presents a misleading picture from an innovation perspective. He refers to the fact that the buses are prototypes. 'These are modifications of existing models. More prototypes will need to follow before the technology is ready for the market. Another cause for concern is that there is as yet insufficient competition between the providers and that the same type of bus runs in all the cities.'

It is a moral obligation that Japan, the US, and Europe are taking the lead in

Innovative hydrogen truck

During the most recent European Road Transport Show, one of the largest industrial vehicle fairs in Europe, the TERTS Innovation Award was awarded to the Hytruck, a light truck fully powered by hydrogen. The Hytruck C8HE is a converted Mitsubishi Canter distribution truck, whose engine, gears, rear axle, and fuel tank have all been completely replaced by a hydrogen-electrical propulsion system. 'What is new about the Hytruck is the combination of proven technologies of light fuel cells, high-tech electronics, high-yield wheel motors, and lithium-ion phosphate batteries that absorb and give off energy quickly,' explains Eric Beers, one of the initiators.

Photo: Bart Willemsen

The Hytruck is equipped with a 16 kW fuel cell; a maximum of six kilos of hydrogen is stored under high pressure in the tank. The efficiency is high and is optimized further with two electric motors, fitted directly in the back wheels, which recoup kinetic energy during braking; they store this energy in the battery. Many hybrid vehicles use this principle. For the Hytruck this leads to an efficiency improvement of more than 70% compared to diesel.

The Hytruck company has by now sold three prototypes, one to steel company Corus. Beers: 'Corus produce hydrogen as a residual product in their industrial process, so they have cheap fuel available. However, it is essential to filter the contaminations from the industrial hydrogen first. Corus is currently researching methods for purifying their residual gases.'

According to Beers, the Hytruck has a range of approximately 350 kilometers. 'A full tank costs approximately €35, but that could be much cheaper if residual gases were used.'

Worldwide, truck manufacturers are developing hydrogen trucks, but they are at an experimental stage. 'Our advantage is that we are a new company and we do not have to earn a return on our investment in other clean technologies first,' says Beers. He expects that with a fleet of twenty thousand distribution vehicles, the Dutch market has enough potential for the Hytruck C8HE. Hytruck would break even with the production and sales of some hundred vehicles per year, says Beers. The Hytruck C8HE prototype was realized with a government subsidy.

realizing a transport sector on hydrogen, Jeeninga believes. Those are the countries with a large transport sector, where emissions and fuel consumption have led to major problems. Whilst California is at the global forefront with strict legislation to force businesses to produce hydrogen transport, Japan and Europe are making progress in the area of fuel-cell technology. According to Jeeninga, the developments in Japan are less accessible, but he suspects that they are at least at the same level as Europe from a technological point of view. Europe could learn important lessons from the Japanese strategy, believes Jeeninga. 'They have carried out some successful demonstration projects, but they are now at a stage where they are wondering about the next steps in vehicle deployment.'

In Europe, Germany, which has a large automobile industry and is strongly dependent on energy imports, leads the field of hydrogen technology and has the greatest ambitions. Germany is one of the few countries in Europe with its own hydrogen program. The western state North Rhine-Westphalia is one of Europe's most important regions for fuel-cell technology. Foreign producers, such as Hydrogenics from Canada, IdaTech (US) and Ceramic Fuel Cells (Australia), have set up in this region because of the availability of industrial networks. One of these networks is the NRW Fuel Cell and Hydrogen Network, which has several hundred German and foreign companies and research institutes as members representing the entire hydrogen chain. The cooperation is focused on new methods of storing and producing hydrogen gas, and on applying fuel cells in diverse sectors, ranging from transport and industry to energy provision. The government of North Rhine-Westphalia wants to put itself on the map as the international centre of hydrogen technology, and finances some sixty fuel-cell and hydrogen projects with a sum of €74 million.

North Rhine-Westphalia, together with three other regions in Italy, France and Spain, is participating in the Hychain Minitrans project that is focused on small hydrogen vehicles with fuel cells to a capacity of 10 kW. One of the objectives of this project is the introduction of the 'early adopter products', such as midi buses, scooters, wheelchairs, utility cars and cargobikes, telecommunication, and flexible filling stations. The project-based sales of those projects, which appeal initially to a small consumer market, must eventually create a market for mass production. The project costs €37 million, to which the EU contributes €17 million. The objective is to close the gap between R&D and market development. The project runs until 2010. ■

Hydrogen from gas waste

Between 10 and 20% of the hydrogen gas produced in Germany is burnt as waste gas in torches. 'This is an enormous waste of energy,' says Dr. Frank Koch from the EnergieAgentur in North Rhine-Westphalia. 'This hydrogen could provide the fuel for some 100,000 hydrogen cars.'

Germany produces 7 billion Nm3 (billion cubic meters at normal pressure of 1 bar and 25 °C) of H2 as a by-product each year, out of a total hydrogen production of 22 bn Nm3. Germany is by far the largest hydrogen producer in the European Union (with a share of 25%), followed by the Netherlands (12.5%).

If industrial hydrogen gas is purified it can be used very well in fuel cell applications, according to Koch. 'We are now calculating the precise amounts of hydrogen produced and consumed. From this study we will be able to determine exactly how much hydrogen is available for fuel cell technology.'

Pollution of the hydrogen can be a problem for fuel cells. 'Purifying costs are not a problem,' Koch says, 'as they only increase the price of hydrogen by a few cents per kilogram. Our purification technologies are state-of-the-art.' Most of the hydrogen comes from refineries, steam reformers, where natural gas (CH_4) is transformed into CO, CO_2 and H_2, and the chlorine-industry, where salt is turned into chlorine with hydrogen as by-product. Most of the hydrogen is re-used in the chemical, food and glass industry. The presence of a 230 kilometers long pipeline in the Ruhr Area could help to realize a hydrogen infrastructure for transport applications. Koch: 'This pipeline is designed to connect several chemical plants in this area but it could be used to supply fuelling stations as well. This could be the start of a hydrogen infrastructure.'

The Frankfurt area now takes part in Zero Regio, a demonstration project for hydrogen infrastructure financed by the European Commission. 'We are very much looking forward to the 18th World Hydrogen Energy Conference in Essen in 2010, which is a milestone to us. We plan to build fuelling stations before 2010, so they can act as a showcase for hydrogen.'

Hydrogen minibus from the Hychain Minitrans project. Photo: Frank Koch