Lessons for Low-Power Fuel Cell Vehicles from a Demonstration Project: Results of Techno-Economic, Safety, Environmental and Social Assessment of the EUHYCHAIN MINI-TRANS Project

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Lessons for Low-Power Fuel Cell Vehicles from a Demonstration Project: Results of Techno-Economic, Safety, Environmental and Social Assessment of the EU-HYCHAIN MINI-TRANS Project

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1 The Hychain Project

The HYCHAIN MINI-TRANS project is an Integrated Project funded through the 6th Framework Programme of the European Union. It is one of the leading hydrogen demonstration projects of the European Commission's Transportation and Energy Division and is the first demonstration project of this nature to be implemented. The project, with a network of 24 European partners, runs from January 2006 to July 2011 under the co-ordination of Air Liquide.

The HYCHAIN MINI-TRANS Project allows citizens from four European Community regions to test a group of 53 small urban vehicles including small utility vehicles and midi-buses, wheelchairs, scooters and cargo-bikes, all powered by hydrogen fuel cells. This project also demonstrates the use of innovative logistics for hydrogen distribution. The four partner regions are: Rhône-Alpes in France (Grenoble Alpes Métropole Agglomeration Community), Castilla y León region in Spain (city of Soria), North Rhine Westphalia in Germany (region of Emscher-Lippe) and the city of Modena in Italy. Public and private fleets are currently operating the vehicles in every-day use: municipal services, public transport, last-mile logistics and personal transport by people with disabilities.

The following four-step approach has already been implemented: (1) the project started from existing prototypes of five low-power fuel cell applications that were optimised in design and functionality, (2) pre-commercial manufacturing lines were set up to reduce costs as well as to improve quality, (3) the required hydrogen distribution logistics and services (transport, distribution, dispensing) were established based on an even exchange of innovative refillable storage solution and (4), a network of comparable subprojects using the common demonstration vehicles are being implemented in the four participating regions.

Technical deployment is complemented by socio-economic research targeted at overcoming the main current barriers, such as stakeholder awareness and public acceptance, certification, training, etc. Dissemination and exploitation activities provide the framework for maintaining the momentum and triggering a sustainable market growth in several lines of applications.

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2 Technology Assessment as Part of Innovation Activities

HYCHAIN assesses the results of the project in five different dimensions:

- *technical* (e.g. component performance, maintenance needs)
- *economic* (life-cycle costs of vehicles and of hydrogen logistics)
- *safety* issues
- *environmental* (well-to-wheel analysis and environmental impact analysis) and
- *social* (user perceptions and public acceptance of the technology).

The assessment is mostly based on data collected through an on-line system that centralises the data resulting from daily operation of the vehicles and associated hydrogen infrastructure. Based on this assessment, a forecast of HYCHAIN MINI-TRANS evolution, as well as innovation and policy-oriented conclusions will be carried out at the end of the project.

The presented poster gives insights into the first results of the five assessment dimensions, focusing mainly on the technological, environmental and user perception assessment. The following sections present some first results. At the time of poster presentation, further data on the deployment of most vehicles will be included into the assessment.

3 Status of Deployment Phase

The deployment phase of the HYCHAIN MINI-TRANS vehicles started in May 2009 when the first two midi-buses were delivered to the public transport company Vestische in the Emscher-Lippe region. Till the deadline of this abstract, 21 vehicles have been deployed (3 midi-buses, 6 cargo-bikes, 7 wheelchairs and 5 utility vehicles, see Figure 1). All other planned vehicles have been manufactured and are awaiting distribution from May 2010.

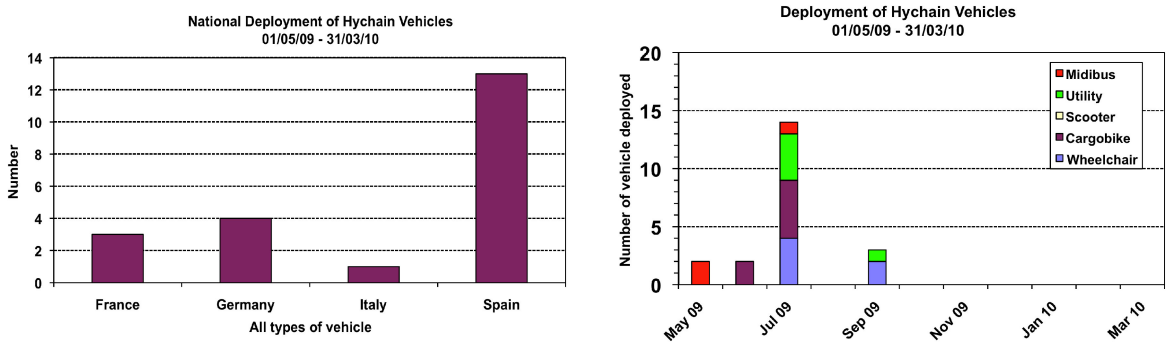

Figure 1: Deployment of HYCHAIN MINI-TRANS vehicles (by country and by type).

4 First Results of Technological Performance Monitoring

Figure 2 illustrates cumulative figures for the number of journeys and driven distance over all vehicles. As can be seen, most journeys done so far were journeys of the midi-buses (584 journeys = 83% of total). Furthermore, midi-buses dominate the distances travelled by 94% (21,900 from 23,350 km in total). The remaining distance was driven by utility vehicles (1,200 km in 60 journeys) followed by cargo-bikes (252 km in 60 journeys). Although all wheelchairs are deployed, no journeys have been made, due to user selection problems.

None of the vehicles have been running since December. In the case of the midi-buses, this is due to technical problems which are unrelated to the hydrogen and fuel cell components. All other vehicles are not able to be used at temperatures below of 5° Celsius which means they had to stop their operation. When presenting the final poster, updated figures up to April 2010 will be shown.

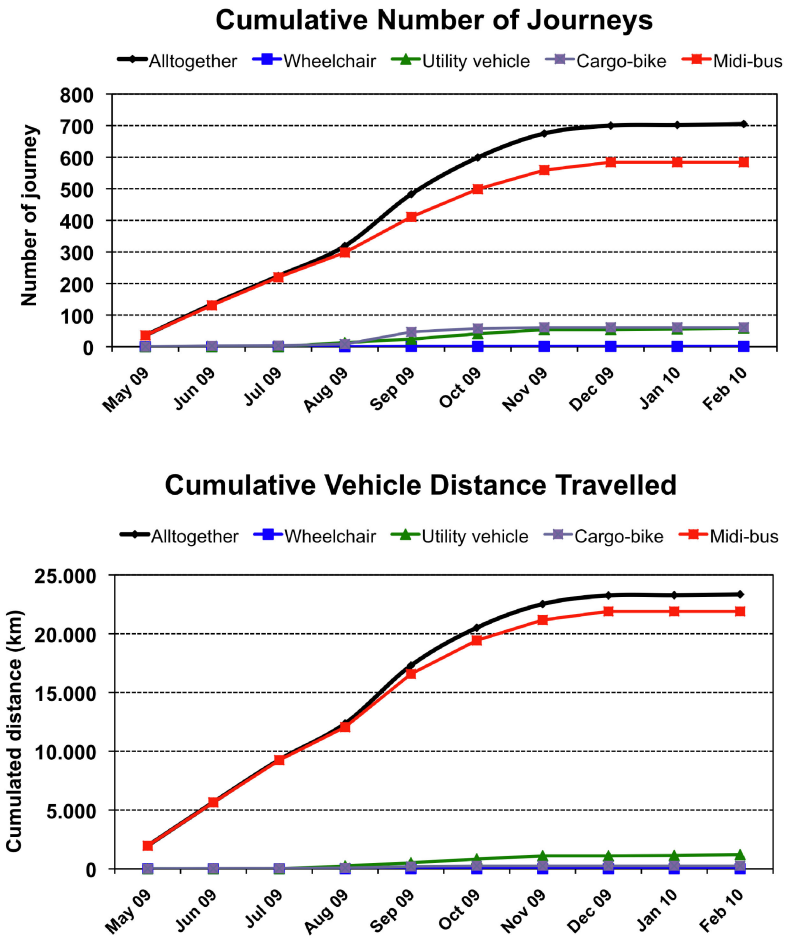

Figure 2: Cumulative number of journeys and distance travelled since start of deployment.

Figure 3 gives a more detailed view on the three midi-buses in operation. Two of them are used for public transport in the Emscher-Lippe region (7 days a week), one in the Spanish city Soria (5 days a week). The buses show a real success story of HYCHAIN MINI-TRANS (11,200 and 10,020 km driven by the buses in Germany; 820 km in Spain). They have a technical availability of 72 – 75%, which is more than initially expected. The target for the next months is to achieve a higher range since the German operating company wants to enhance the buslines to cover a larger area in their region. Currently a range of 130 – 138 km can be achieved, while the theroetical range, calculated for standard conditions, is 176 km.

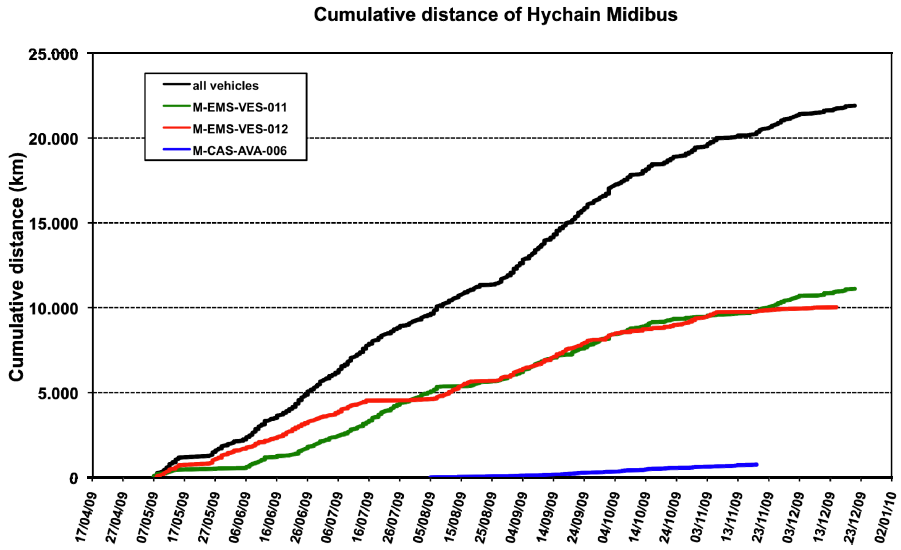

Figure 3: Distance travelled by the midi-buses in operation in Germany ("EMS") and Spain ("CAS").

Finally, Figure 4 illustrates the effect of the operation in different conditions. The cargobikes are used in the centre of the cities or at the premises of companies with distances ranging between one and five kilometres. The minibuses have a higher range between 10 and 90 kilometres. Whereas the German buses are operating in the countryside driving distances between 50 and 80 km per journey, the Spanish bus is operated within the city of Soria covering distances between 5 and 25 km per journey on average.

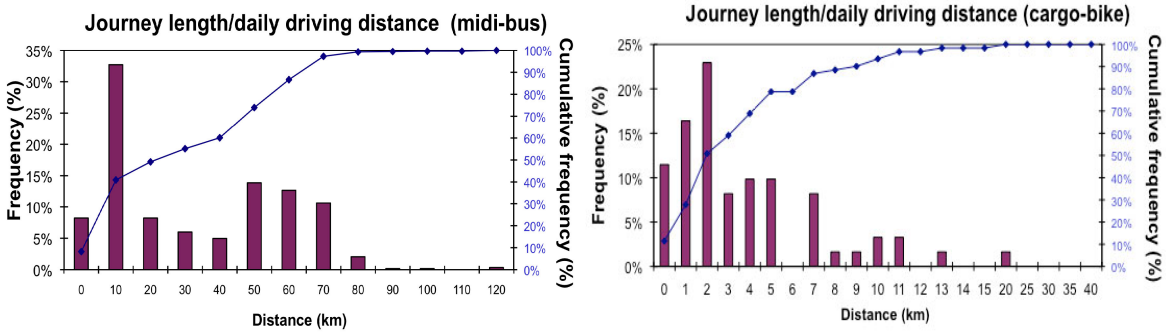

Figure 4: Journey length and daily driving distances of cargo-bike (left) and midi-bus (right).

5 First Results of the Well-to-Wheel and Environmental Impact Analysis

The environmental assessments performed in HYCHAIN MINI-TRANS are divided into a Well-to-Wheel (WtW) assessment of the hydrogen production plus an Explorative Environmental Impact Assessment (EEIA) of those parts of the vehicle that markedly differ from the reference vehicles.

The *WtW analysis* assesses the energy consumed from hydrogen production to its use in the fuel cell vehicle – and corresponding CO_2 emissions – in order to get information about the

energy use and environmental impacts of hydrogen production and use within HYCHAIN technologies. This data is compared to the corresponding reference technology (ICE vehicles and electric vehicles). The process chain can be segmented as:

- *Well-to-gate*: actual industrial H_2 supply by Air Liquide
- *Gate-to-tank*: HYCHAIN hydrogen logistics and distribution by vehicle
- *Tank-to-wheel*: specific operation figures of the vehicles

As Figure 5 shows, the greenhouse gases (GHG) emissions evaluated for a HYCHAIN midi-bus are an estimated 345 g eq. CO_2/km, considering a 200 km range. The GHG emissions calculated for the reference midi-bus (electric vehicle) are rather similar (348.5 g eq. CO_2/km), considering a European electricity mix and a 100 km effective battery range.

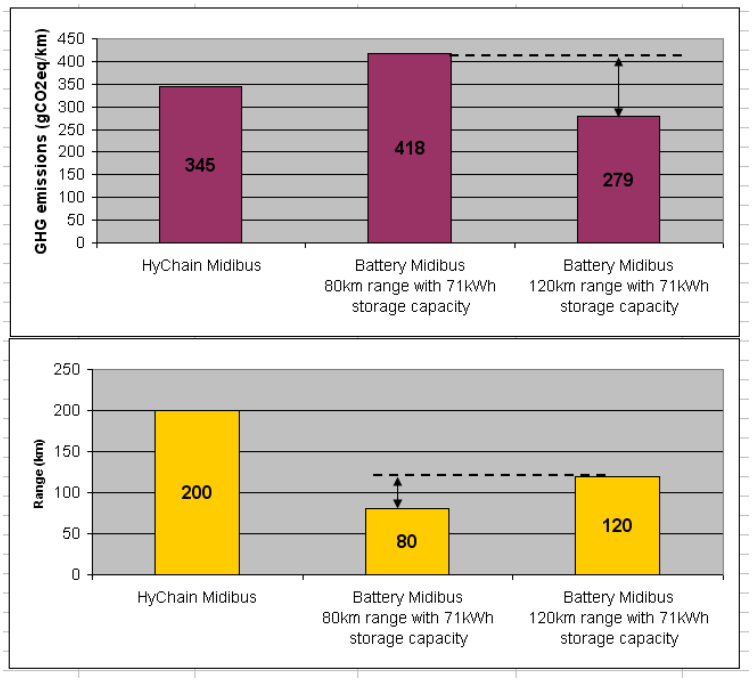

Figure 5: Hychain and reference electric midibus range and corresponding GHG emissions.

HYCHAIN's Explorative Environmental Impact Assessment aims at identifying the major impacts related to the life-cycle of HYCHAIN applications from production to decommissioning and disposal. The assessment will be restricted to those parts of the HYCHAIN Vehicles that markedly differ from the reference vehicles (ICEs and Electric vehicles).

The study of environmental impacts will focus on:

- fuel cell manufacturing
- manufacturing of hydrogen storage and distribution equipment
- disposal or recycling of the storage technologies and fuel cells after their life time.

The environmental aspects assessed include the use of fossil and primary energy, consumption of scarce materials such as platinum and yttrium, GHG emissions as well as other pollutant emissions (NO_x, SO_2, CO, PM, NMVOC, …) and their associated environmental impacts.

The EEIA study is in the process of collecting and processing the data related to the manufacturing processes of all components. First results will be presented at the conference.

6 First Results of the User Perception

The first inquiries on user perception started in the early fall 2009 with the midi-bus drivers located in the Emscher-Lippe region. The issues within the driver questionnaire cover personal experiences satisfaction with the bus, safety and maintenance aspects of the vehicle, training units and preparations courses, attitudes and knowledge and finally sociodemographic data. The sample insisted of 32 male drivers with an average age of 45.29 years and a solid experience as a bus driver of more than 10 years for 96.9% of all respondents. At the time the survey was conducted, most of the drivers drove the vehicle on a regular basis of several times a week (42%) or several times a month (36%).

As one example of the results, Figure 6 shows the drivers' satisfaction with the midi-bus overall performance. 44% of the drivers are satisfied with the vehicle's overall performance (14 drivers), yet 22% of the interviewees declare themselves to be rather unsatisfied (7 drivers), while one third were undecided (10 drivers). Due to the fact that the buses were operated in regular service from the beginning, these results are quite acceptable.

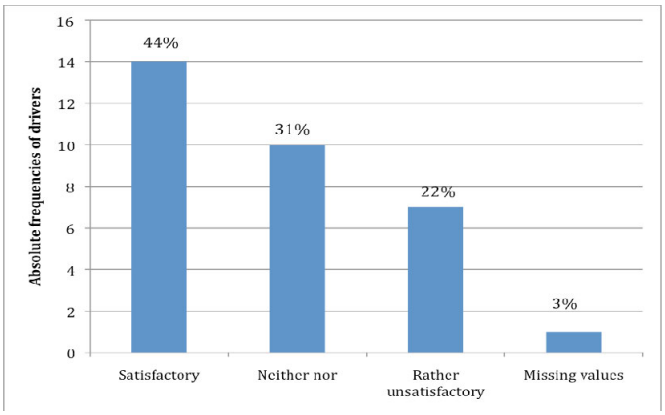

Figure 6: Frequencies of drivers' satisfaction with the midi-bus overall performance (n=32).

7 Conclusions

In sum, the HYCHAIN project is in the process of assessing the data resulting from daily operation of the vehicles and associated hydrogen across five different dimensions: technical, economic, safety, environmental and social. Based on this assessment, a forecast of HYCHAIN MINI-TRANS evolution, as well as innovation and policy-oriented conclusions will be carried out at the end of the project.

The presented poster gives insights into the first results of the five assessment dimensions, focusing mainly on the technological, environmental and user perception assessment. At the time of poster presentation, further data on the deployment of most vehicles will be included into the assessment. The outlook for future demonstration and early market initiatives will be analysed in the light of these results.