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ALT-HY-TUDE PROJECT: THE 2 FIRST HYDROGEN / HYTHANE® REFUELING STATIONS IN FRANCE

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ABSTRACT

Hydrogen is recognised as an attractive solution in order to reduce greenhouse gases emissions and urban pollution, to which road transport is a great contributor. But there are still today numerous barriers related to the introduction of hydrogen in the current vehicle fuel pool. The blend of natural gas and hydrogen, sometimes referred to under the name Hythane®, represents a relevant and pragmatic transition solution to massively introduce hydrogen in the public transportation system (buses), by taking advantage of the synergies with the NGV technology and infrastructure.

This paper presents the ALT-HY-TUDE project lead by the Research Division of Gaz de France, which intends to demonstrate the use of Hythane® as an environmental friendly fuel. The objectives are to:

- assess the relevance of Hythane® as a short term transition towards hydrogen,
- provide immediate benefits with reduction of urban pollution and greenhouse gases,
- take advantage of synergy with NGV infrastructure and vehicle technologies.

The project is developed in two cities in France that have a strong environmental policy and wish to lead the path of innovation towards hydrogen: Dunkerque, in the North of France and Toulouse in the South-West.

The subjects studied in the project deal with:

- hydrogen production and the Hythane® refuelling stations,
- improvement of the NGV engine and buses for hydrogen/natural gas blend: bench tests are carried on in order to find the best engine performance trade-off in term of emissions, efficiency and reliability, for several hydrogen contents in the blends,
- technico-socio-economic assessment of Hythane® as clean fuel.

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1. CONTEXT AND OBJECTIVES

Hydrogen is recognised as an attractive solution in order to reduce greenhouse gases emissions and urban pollution. The transport vehicles is one of the main sectors responsible for primary fossil energy consumption and CO2 emission. In this field, hydrogen is considered to have a great potential as "friendly environmental" fuel, especially when hydrogen is produced from renewable primary resources (like wind power or biomass) providing then maximum CO2 savings.

But there are still today numerous barriers related to the introduction of hydrogen in the current vehicle fuel pool. Vehicle technology still requires consequent technological breakthroughs while infrastructure has to be demonstrated and deployed, with the adequate regulatory framework and agreement from the society.
Therefore transition solutions are of crucial importance to help address these various barriers and start commercial activities in this field in the short to medium term, taking advantages of current engine technologies and cleanest resources (like natural gas). Two possible examples are:

- the H2 internal combustion engines -simple or hybridised- that can pave the way for future fuel cell propulsion systems,
- the small scale natural gas reformers, as a transitional step towards CO2 neutral hydrogen production means.

The ALT-HY-TUDE[1] project led by Gaz de France intends to demonstrate the use of an innovative fuel, Hythane® -a blend of natural gas and hydrogen- as a relevant and pragmatic transition solution to massively introduce hydrogen in the public transportation system (buses), by taking advantege of the synergies with the NGV technology and infrastructure.

Some years ago, the blend of NG and 20% of H2 in volume -with the brand name Hythane®- was extensively assessed and demonstrated in Montréal (Canada) in the field of the Euro-Québec project. Two buses from NOVABUS ran in the city for a period of nine months. The 20% H2 portion (i.e. 7% in terms of energy) was identified in that case of operation as the optimum in terms of efficiency, pollutant emission, and costs [1]; the CO2 emissions were reduced by 7,5% by an increase of the efficiency, the NOx were cut by 40% without any increase of unburned hydrocarbons in the exhaust fumes [2].

These buses were operated afterwards by SUNLINE in Palm Springs (California, USA) where they are still commercially in operation with new Cummins-Westport engines. No incident has been reported up to now.

Recently an Hythane® demonstration has started in Europe; in Malmö (Sweden) led by Sydkraft Gas AB (E.On Group). First, 8% vol. of H2 (which equivalent to 2% only in energy) was added to the natural gas without any change in the VOLVO-engine; the buses run well. In the next step of the demonstration the blend with 20-25% vol. H2 will be tested.

In the ALT-HY-TUDE project, with the new IRISBUS-IVECO stoichiometric engine technology, using available and proven NGV technologies adapted to the new fuel will also allow to maintain the low local pollution -NOx, CO and unburned hydrocarbons- and to satisfy the stringent future regulations (Euro V), while substantially lowering fuel consumption.

The objectives of the ALT-HY-TUDE project can be summarised as:

- assess the relevance of Hythane® as a short term transition solution towards hydrogen,
- provide immediate benefits with reduction of urban pollution and greenhouse gas emissions,
- take advantage of synergy with NGV infrastructure and vehicle technologies.

The project is developed in two cities in France that have a strong environmental policy and wish to lead the path of innovation towards hydrogen: Dunkerque, in the North of France and Toulouse in the South-West.

[1] ALT-HY-TUDE is the acronym of « ALternative of Transport with HYthane® in ToUlouse and DunkerquE ».

2. PROGRAMME DESCRIPTION

The ALT-HY-TUDE project runs from mid-2005 to 2008. The launch of the effective stations and buses operation is planned by the end of 2006.

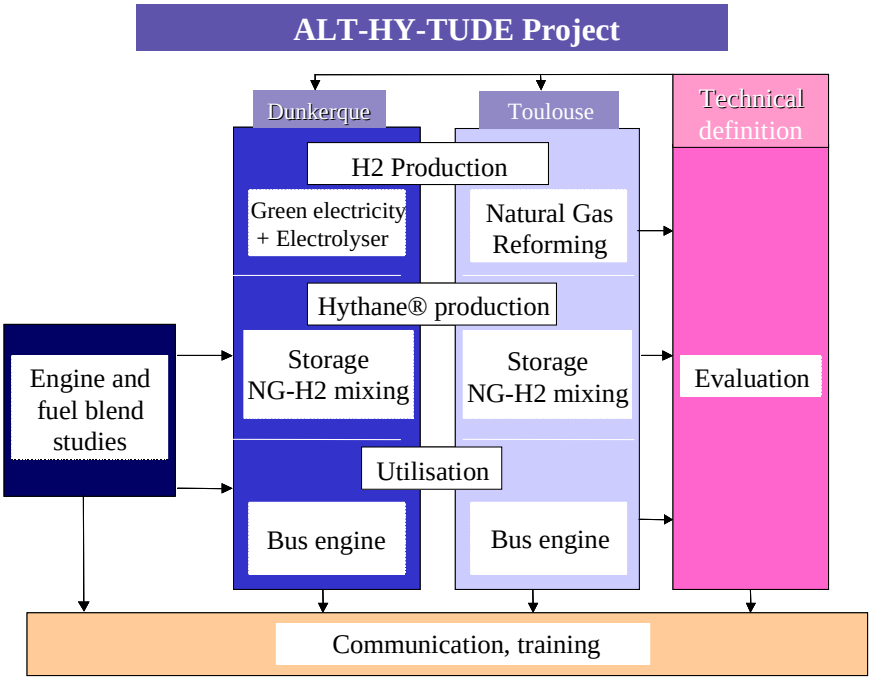

Figure 1. Programme description.

In both cities of Dunkerque and Toulouse, the hydrogen is produced locally at the refuelling station and mixed to the compressed natural gas:

- Dunkerque: H2 is produced by a small electrolyser fuelled with “green” electricity and virtually coupled with a wind turbine, filling 2 buses,
- Toulouse: an innovative natural gas reformer produces the H2, filling 3 buses.

Regulatory file including safety studies on the refuelling stations and the vehicles is a major issue that is already being worked on with local authorities.

2.1 Hydrogen production and the Hythane® refuelling stations

The demonstration of the two new refuelling stations takes place by the existing NGV stations in order to take advantage of the NGV infrastructures, e.g. the compressed NG and the bus depot. The NGV stations are modified to build the new Hythane® refuelling stations by adding the H2 generator, the mixing equipment, the filling terminal, and the measurement and safety devices. One notable difference between the two stations is the means of H2 production: two ways of decentralised production are explored using different resources: water electrolysis with green electricity and NG reforming.

2.1.1. The Hythane® station in Dunkerque: electrolysis

The Region of Dunkerque has a great potential of wind power as renewable energy resources which is already partly exploited. This potential will be used for the production of the hydrogen at the refuelling station by means of a small electrolyser supplied with that “green” electricity. Therefore a reduction of CO2 emissions compared to NGV are induced considering the whole energy chain analysis. Electrolysis is known as the typical solution for sustainable development although its costs are very high today.

The electrolyser provided by HYDROGENICS has a capacity of H2 production of 4 Nm3/h designed to fill the two Hythane® buses of the demonstration. The H2 is afterwards compressed and stored in cylinders before the filling with the compressed NG and H2 is requested by the bus operator.

2.1.2. The Hythane® station in Toulouse: NG reforming

The production of H2 by reforming of NG is today the cheapest way which is currently used for mass production of industrial hydrogen (30.000-125.000 Nm3/h of H2). This way is considered as the best solution to provide H2 in the transition phase while the market of the H2-energy is growing. The coupling with CO2 sequestration can besides enhance its environmental performance while keeping it competitive with other carbon free production ways. However the reforming at small scale (10-100 Nm3/h of H2) is attractive and may be less expensive than the delivery of cylinders by trucks. Today new technologies come on the markets with innovative concepts and architecture, that can drastically cut down investment costs compared to the state of the art. Such a solution will be assessed in the Toulouse refuelling station.

The reformer provided by Air Products and Gaz de France will have small H2 production capacity (between 5 and 30 Nm3) designed for filling the three Hythane® buses of the demonstration. The H2 is afterwards compressed and stored in cylinders before the filling with the compressed NG and H2 is requested by the bus operator.

2.2 Improvement of the NGV engine and buses for hydrogen fuel

The two cities are providing new NGV buses from IRISBUS-HEULIEZBUS for the demonstration (figure 2). These NGV buses are equipped with the new stoichiometric engine CURSOR 8 from Iveco. Its properties are described in the table 1. The storage tanks of these buses are Dyneteck bottles which are adapted to pure H2 storage.

Figure 2. Future Hythane® bus in Toulouse, operated by Tisséo Réseau Urbain.

The use of Hythane® implies an adaptation of the NGV buses to the new fuel which includes a modification of the mapping of the engine.

The first task aims at optimising the CURSOR 8 engine tuning for a blend of natural gas with 20% vol. of hydrogen, taking into account technical parameters like the efficiency (fuel consumption, power), the pollutant emissions (mainly NOx) and the reliability of the engine (knocking, misfiring). Another approach will concern the study the optimum H2 content in the blend for this type of engine. The tests will be carried on in laboratories on test benches, with both types of natural gas distributed in France (the type H “high calorific NG” and the type B “low calorific NG” distributed in the North of France).

The outcomes (optimised tuning) will be applied to the engine on the buses and the results obtained on test benches will be checked with trial tests on the buses with no passengers in a first step in order to test reliability of the solution.

ENGINE	Reference	CURSOR 8
	Displacement	7.8 litres
	Maximum power	200 kW at 2000 rpm (reference A)
		154 kW at 2100 rpm (reference B)
	Maximum torque	1100 N.m at 1100 rpm (reference A)
		900 N.m at 950 rpm (reference B)
	Super charging	cooling turbo
TANKS	Number	8 bottles of 155 litres
	Capacity	1240 litres (300-400 km depending on the line and the NG)
	Operation pressure	200 bars
	Lifetime	20 years

Table 1. Technical data sheet of the NGV buses from IRISBUS.

In the meantime the necessary process of approval for this new type of Hythane® buses will be followed with the French Administration (both the Ministry of Transport and the Ministry of Economy).

2.3 Assessment of Hythane® as a clean fuel

The demonstration in parallel in Dunkerque and Toulouse allows to gather comparable and reliable data. The assessment will be applied to every step of the energy chain;

- production of H2 (electrolysis and NG reforming); reliability of the generator, flexibility, efficiency, H2 gas quality, maintenance and repair,
- operation of the stations,
- operation of the buses,

and on several items;

- environmental performances; the usual ADEME[2] protocols for clean transport will be applied to the Hythane® buses (stationary tests with standardised runs) (NOx, CO, unburned hydrocarbons, CO2),
- energetic performances,
- safety feedback,
- and general public acceptability.

The results will be used for life-cycle assessment (LCA), and technical-economic comparison of the current fuels for buses (Diesel, NGV, Hythane®). The safety assessment will be also processed as a crucial item for the general success of the operation.

3. EXPECTED RESULTS

The ALT-HY-TUDE project will evaluate the potential of the Hythane® fuel in France:

- quantify the environmental advantages (greenhouse gases, local pollutants) and the benefits (efficiency),
- understand the technical and regulatory challenges linked to the introduction of hydrogen in a French station and on board a vehicle,
- analyse two different ways of hydrogen production; small scale natural gas reforming and electrolyser supplied with green electricity,

[2] ADEME : French Agency for the Environment and the Energy Management.

- achieve a costs analysis on the whole chain and compare it to other possible approaches using hydrogen,
- communicate on an innovative way allowing to introduce quickly an important fraction of hydrogen into the vehicle fuel pool.

4. PARTNERSHIP

All necessary stakeholders have been involved in the project; urban communities, utility suppliers, refuelling station operators, technology developers, bus operators, bus manufacturer, universities, engineering companies and safety experts. The goal is not only to gather the right competencies to achieve the various parts of the project but also to start building a hydrogen expert community covering all aspects of the energy chain.

The table 2 shows the organization of the consortium with the 14 partners:

Gaz de France: coordinator	
GNVert: refueling station studies, modification, operation & maintenance	
INERIS: regulatory aspects, safety studies	
EGIM: engine studies	
IRISBUS: vehicles modification & validation	
CONNEX: pollutant measurements	
Dunkerque	**Toulouse**
H2 Développement: local coordinator & green H2 production	**IMFT**: local coordinator & engines studies
Communauté Urbaine de Dunkerque	**SMTC-Tisséo**: public transport Authority
DK Bus Marine: bus operation	**Tisséo Réseau Urbain**: bus operation
Hydrogenics: H2 generation (electrolyser), station design and supply	**Air Products**: H2 generation (reformer), station design and supply, back-up

Table 2. Presentation of the partners.

Acknowledgments
The ALT-HY-TUDE project is funded by the ADEME (French Agency for the Environment and the Energy Management) and the FEDER (European Funds for the Regional Development) for the operation in Dunkerque.

5. REFERENCES

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