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NATURALHY

"Preparing for the Hydrogen Economy by Using the Existing Natural Gas System as a Catalyst"
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Towards a Hydrogen Economy

Gordon Adam, former MEP, Barbara Lowesmith, Loughborough University of Technology, U.K. and Dave Pinchbeck, General Secretary, GERG - The European Gas Research Group

It must be 20 years or so since I drove a hydrogen powered vehicle. If I had not known, I would not have been able to spot the difference from driving a normal car. Only steam came out of the exhaust. No pollution and no CO2.

In those days the European interest in hydrogen was as an energy vector related to oil prices and the possible exhaustion of oil and gas supplies. Hydrogen was seen as having the potential to keep road transport moving. I even saw a drawing of what a hydrogen aeroplane might look like. The hydrogen programme of those days went onto the back burner as oil and gas supplies eased. Time has moved on. The concerns are now focused on reducing carbon dioxide emissions and hydrogen is back into the research programmes of the European Union.

My general attitude to energy supply has always been that it makes sense to examine and, where possible, exploit all energy sources. So, I have in those general terms supported research work that the EU has undertaken into the contribution that hydrogen might make. But it was not until I was asked to become a member of the Strategic Advisory Committee of the NATURALHY project that I became aware of the huge range of issues that have to be investigated before a hydrogen economy could become a reality. Clearly, anything approaching another "Hindenburg" disaster must be avoided. It is an interesting question as to how far that disaster affected the development of air transport.

Putting to one side the question of how the hydrogen is produced, for hydrogen to be used on any sizeable scale raises huge questions in relation to its transportation. Can it be transported in the existing natural gas grid system? If so, that would save a huge investment expenditure. Might it be possible to transport both hydrogen and natural gas together? Can they be readily separated along the system? More intriguingly, can a hydrogen/natural gas mixture be used as an interim stage towards hydrogen on its own, but with the advantage of reducing the carbon content of the gas? Could, in fact, such mixtures be used in existing appliances which burn natural gas?

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EDITORIAL

With this sixth Newsletter on the NATURALHY project we would like to update you on the progress of our project, which investigates the potential of the existing natural gas system for the delivery of hydrogen. The main objective of the project is to identify and if possible remove the potential barriers inhibiting the development of hydrogen as an energy carrier, using the existing natural gas system as a catalyst for change. As a first logical step in the transition towards the hydrogen economy, the project focuses on using the existing natural gas grid for the delivery of hydrogen/natural gas mixtures from the perspective of the "greening of gas" but also perhaps to deliver 'pure' hydrogen where necessary. The addition of hydrogen to natural gas affects the chemical and physical properties of the gas and will have an impact on the safety aspects related to the transmission, distribution and en use of the gas. In the main article of this issue we focus on the values of the NATURALHY research programme placed in a historical context by Dr. Gordon Adam, former Member of the European Parliament and a member of the NATURALHY Strategic Advisory Committee. Dr. Adam, C. Eng., MIMMM, FEI, served as a Member of the European Parliament from 1979-2004 and Vice-President Energy, Research & Technology Committee 1984-1999. He is currently a Senior Advisor, Energy Policy Consulting; European Advisor, Major Energy User's Council and Chairman, Northumbria Energy Efficiency Advice Centre.
The second article in this issue provides an overview of the current status of the Naturalhy project and relates the latest results of the Work Packages to the overall objectives of the Naturalhy project.
If you have any questions or would like to discuss certain aspects of the NATURALHY-approach with us, than please react through our website www.naturalhy.net.

The project coordination team
Gjalt Tiekstra, Folkert Koopman and Friedrich Vollink

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High pressure gas jet fire test at the Spadeadam test site

The NATURALHY Project is part of the European Hydrogen and Fuel Cell Technology Platform. It has been established to find out if hydrogen can help to make it possible to end human induced climate change caused by the emission of carbon dioxide. Can hydrogen provide the means for fuelling a clean transport system and does it also have the potential to mix with or act as a replacement for natural gas at some point in the future? The objective of NATURALHY is to determine to what extent we can use the existing EU wide natural gas pipeline system to deliver hydrogen. This involves an evaluation of the technical, environmental, safety and economic aspects of transporting natural gas/hydrogen mixtures. It also considers aspects of utilisation of both natural gas/hydrogen mixtures and hydrogen which has been withdrawn selectively from the mixture in the pipeline.

As it happens I live close to the former British Gas Engineering Research Station at Killingworth on the outskirts of Newcastle upon Tyne in the North East of England. About 2 hours drive away is the gas testing site at Spadeadam - a name which in my school days meant a rocket testing site. It is now well hidden in the huge Kielder Forest on the borders of Cumbria and Northumberland. I visited the site a few weeks ago to witness some of the testing. What happens if hydrogen or a mixture of hydrogen and natural gas ignites and there is an explosion? Obviously the safety standards for natural gas transmission systems have already been established. But for hydrogen or a mixture will the existing systems be adequate? The test site is operated by Advantica which was part of British Gas prior to privatization and more recently part of National Grid which operates the UK gas transmission system.

The tests at Spadeadam are part of the safety package of the NATURALHY project. The aim is to assess any change in risk to the public caused by adding hydrogen to natural gas. In particular, the tests are assessing any change in the consequences of a gas escape – in terms of the fire or explosion hazard. I witnessed a fire following an intentional escape of gas at 60 bar (60 times normal atmospheric pressure), typical of the pressure in transmission pipelines. The thermal radiation and heat loads from the fire were being measured. In other experiments, the gas accumulation and explosion severity is being assessed, for example, whether a gas escape in the home might result in a more severe explosion if hydrogen was added. Earlier indications are that some hydrogen can be added without a significant difference in the scale of hazard presented.

As I drove home in the evening I reflected on the test I had witnessed. The fire I saw was only part of the extensive NATURALHY project scope, The fatigue, corrosion, permeability, burst resistance, joint leakage of both steel and polymer pipes, all these features have to undergo rigorous investigation, as well as the application of the gas mixtures to existing natural gas appliances and even gas meters.

Using the existing European gas grid to transport hydrogen mixed with natural gas is going to involve a formidable amount of work, not only in setting engineering standards, but also to gain public and customer acceptance. There is a whole range of issues to be addressed from the high volume transmission pipelines, to the low pressure distribution grid, to the point of end use in the home, office or factory, for which separation of hydrogen, via novel membranes, may be crucial.

I do not know if the hydrogen economy will ever become a reality. I expect, in some form or other, it will, but have no idea when. Obviously if existing natural gas pipeline systems can be used that will be a great advantage, but it cannot be assumed that the extensive investigations and testing that is currently going on under the NATURALHY programme will give a simple answer "yes". Ultimately much will depend on how comfortable people will feel. Would I, for instance, be comfortable with the AGA cooker and the combi central heating boiler being fed by a gas mixture or by hydrogen alone? That will be the ultimate test for public acceptance.

In the meantime, it is reassuring to know that the vast experience of the European gas industry, with support from the oil industry, linked to the exhaustive detail with which the issues are being investigated by leading experts throughout the European Union, has been mobilised in this project to look in exhaustive detail at all the ramifications that must be resolved before a hydrogen economy can become a reality.

I am much the layman on the advisory committee but my interest in hydrogen has remained since my involvement with the earlier programme. Even this week that I am writing these notes I was at a conference where a possible design of a hydrogen powered aeroplane was shown – much like a drawing I saw in DG Research those many years ago – and in the press an announcement that Honda are to produce a hydrogen powered car next year. ❖

Dr. Gordon Adam
MEP (retired)
Member of Naturalhy SAC

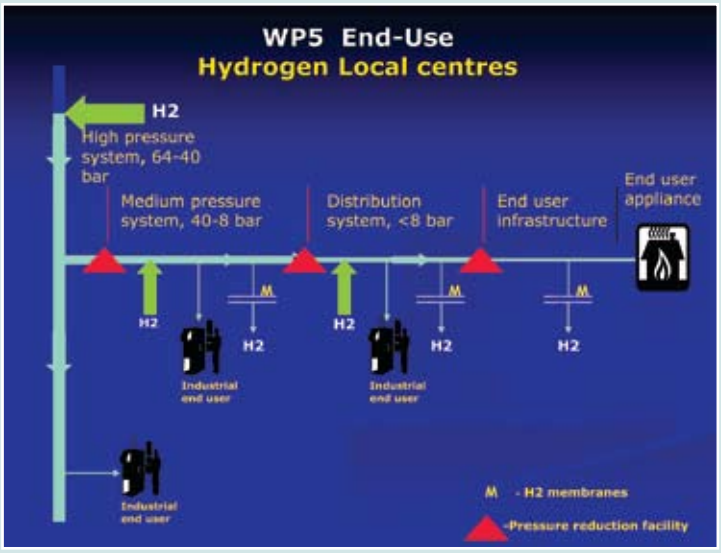
A brief overview of Naturalhy status

NATURALHY is an EU integrated project that for the first time, examines in depth the feasibility of adding hydrogen to natural gas networks as a means of greening natural gas operations and also accelerating the distribution and use of hydrogen. The approach is simply to ask "to what extent can we use the existing EU wide natural gas pipeline system to deliver hydrogen?"

In trying to answer this, we immediately raise many other fundamental questions:

- How much hydrogen can be tolerated by each part of the grid network (high and medium pressure steel pipes, low pressure plastic pipes, the associated components, the end user infrastructure and, in particular, gas appliances)?
- What are the safety implications related to the transmission, distribution and use of the gas bearing in mind the excellent safety record of natural gas operations over many decades?
- What are the long term integrity management implications? Hydrogen may diffuse into the material and change the mechanical properties (e.g. hydrogen enbrittlement of steel, leading to an accelerated growth of micro cracks).
- How can we ensure that we supply end users with gas that meets the contractual specifications so that safety, appliance performance and billing accuracy are guaranteed?
- How can we separate hydrogen from the mixture in the pipeline to accommodate those end user customers wishing to use pure hydrogen?
- What are the quantifiable benefits of adding hydrogen to the natural gas network in terms of efficiency, the environment, employment and socio-economic factors?

The Naturalhy concept is illustrated below in a simplified scheme showing addition of hydrogen into the natural gas (NG) grid and separation of hydrogen at various points depending on scale and application. The source and production of the hydrogen is not within the scope of the project, nevertheless it is considered as part of the project's life cycle analysis.



Over the past three years, the Naturalhy partners (39 organisations) have been researching these issues and working towards establishing the fundamental data required to develop a Decision Support Tool that will enable gas operators to calculate feasibility, benefits and costs of introducing hydrogen into their NG networks.

A high degree of interaction has been vital between the various work packages, each considering specific issues, in order to assess the effect on the integrated Naturalhy scheme.

Some promising early results have been obtained in key areas:

- It is not yet possible to say conclusively what level of hydrogen may be safely added to existing NG networks. However, current indications are that it may be possible under ideal conditions to transport in excess of 30% hydrogen in high pressure transmission lines with existing steel materials. However, in the same way as a chain is only as trong as its weakest link, the maximum level of hydrogen will depend on a careful analysis of impacts across the whole gas chain.
- The modern pre-mixed domestic boilers tested in the Naturalhy project can tolerate mixtures containing more than 50% hydrogen in NG, apparently with slightly lower NOx levels. These are potentially very important results, obtained both in laboratory tests and in year-long field trials. However it must be borne in mind that these results are derived using new pre-mixed boilers and many of the domestic appliances in use across Europe are not new, are not of the pre-mixed design and are not subject to rigorous maintenance. Moreover there is a large variation in quality in the NG used within EU countries and consequently this would lead to a significant variation in maximum allowable hydrogen. Taking these factors into account, the maximum allowed percentage of hydrogen in NG might turn out to be 10% or less. It is however too early to make a definitive statement.
- Data on the safety of NG/hydrogen mixtures in confined and unconfined locations have been obtained from large scale explosion tests at the unique Spadeadam facility. These tests determine empirical factors that can be applied to the predictions of existing NG models or hydrogen models to account for the differences in the consequences of release resulting from the presence of hydrogen. Current preliminary results indicate that mixtures of up to 20% hydrogen in natural gas will bring no significant increase in risk. This work is of paramount importance in assuring both gas operators and health and safety regulators that the addition of hydrogen to NG will not compromise safety.
- Integrity management tools have been developed for NG/hydrogen mixtures. When used in conjunction with data from the other work packages and from the pipeline operator these tools will provide the pipeline operator with information about the additional measures required to maintain an acceptable level of integrity for his pipeline system when adding hydrogen.

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These results are of importance in assessing the economic consequences of mixing hydrogen with natural gas, and also to convince pipeline operators that the Naturalhy approach is worth adopting.

- Carbon based membranes have been found to have the capability of separating hydrogen from NG/hydrogen mixtures at high flow rates to give around 90% hydrogen purity, while very pure hydrogen (>99.9%) have been obtained with laboratory scale thin Pd membranes. These could prove to be crucial results for those cases where end-users wish to withdraw hydrogen selectively from the gas mixture.
- Life cycle analysis is an essential means of determining the overall benefits of distributing hydrogen via the European NG pipeline system. A baseline scenario development covering the entire gas network system has been completed so that comparisons may now be made between existing operations and systems modified by the addition of hydrogen.

It is extremely important to remember that these are preliminary results and that we must remain cautious until the testing and development programmes are complete.

The project is now in a critical phase and its outcome relies on the development of the Decision Support Tool (DST), the main project deliverable. To provide a full answer to the key question, it will be necessary to integrate results from all of the technical work packages to provide a PC-based interactive system. It is planned that a preliminary version of the DST will be trialled by gas operators in the Netherlands, Greece and Portugal.

Naturalhy is setting the state-of-the-art in researching the detailed impact that hydrogen addition could have on the existing natural gas network system in Europe and the project has attracted strong interest from international gas operators and gas research organisations. The project incorporates an international Strategic Advisory Committee consisting of many commercial, governmental and policy organisations and has also forged strong links with European, US and Asian organisations interested in the intricacies of delivering hydrogen to end-users. ❖

Kosta Komodromos and Ashok Bhattacharya
Oxford University,
WP5 Leader

Experimental Test Rig for Vapour cloud explosions at Spadeadam

Testing of domestic boiler with NG/hydrogen

UPCOMING EVENTS

June 1-4, 2008 18th European Symposium on Computer Aided Process Engineering
Palais des Congrès, Lyon, France

June 15-19, 2008 the 17th **W**orld **H**ydrogen **E**nergy **C**onference (WHEC) 2008,
Brisbane Convention and Exhibition Centre, Queensland Australia

October 8-10, 2008 the **I**nternational **G**as Union **R**esearch **C**onference (IGRC) 2008,
Cité des Sciences et de l'Industrie Paris, France

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