THE SAFE USE OF THE EXISTING NATURAL GAS SYSTEM FOR HYDROGEN (OVERVIEW OF THE NATURALHY-PROJECT[1])

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ABSTRACT

The transition period towards the situation in which hydrogen will become an important energy carrier will be lengthy (decades), costly and needs a significant R&D effort. It's clear, therefore, that the development of a hydrogen system requires a practical strategy within the context of the existing assets. Examining the potential of the existing, extensive natural gas chain (transmission - distribution - end user infrastructures and appliances) is a logical first step towards the widespread delivery of hydrogen.

The project will define the conditions under which hydrogen can be mixed with natural gas for delivery by the existing natural gas system and later withdrawn selectively from the pipeline system by advanced separation technologies. Membranes will be developed to enable this separation. The socio-economic and life cycle consequences of this hydrogen delivery approach will be mapped out.

By adding hydrogen to natural gas, the physical and chemical properties of the mixture will differ from "pure" natural gas. As this may have a major effect on safety issues and durability issues (which also have a safety component) related to the gas delivery and the performance of end use appliances, these issues are particularly addressed in the project.

The project is executed by a European consortium of 39 partners (including 15 from the gas industry). In this project, set up under the auspices of GERG, The European Gas Research Group, there are leading roles for N.V. Nederlandse Gasunie (NL), Gaz de France (F), TNO (NL), ISQ (P), the Universities of Loughborough and Warwick (UK) and Exergia (GR). Guidance will be provided by a Strategic Advisory Committee consisting of representatives from relevant (inter)national organizations.

The project started on 1st May 2004 and will run for 5 years. The European Commission has selected the Integrated Project NATURALHY for financial support within the Sixth Framework Programme.

1.0 INTRODUCTION

Hydrogen is foreseen as an important energy carrier. However, the very significant technical, economic and institutional changes required to establish the full hydrogen economy will take several decades to implement. These changes will concern all individual elements of the energy system: production, delivery, storage, conversion and end-use applications. These elements are interrelated and interdependent and, as a consequence of this, there is a "chicken and egg" dilemma regarding market segment development and how supply and demand will push or pull these activities.

In any transition scenario for the full hydrogen economy and in all variants of hydrogen economies, there must be a connection between the hydrogen production and the appliances powered by hydrogen. The distance between the hydrogen production and the appliances will range from several centimeters to several thousands of kilometers depending on production, whether centralized,

[1] Further information on the project and the possibility to be included in the mailing list for the regular Newsletter are available on the project website www.naturalhy.net

decentralized or hybrid, and its use. For many situations, pipelines are favorable to, for instance, delivery by trucks. For economic and safety reasons, pipelines will have an important role in connecting hydrogen production facilities and consumers and also in matching the patterns of hydrogen production and demand.

Transmission and distribution of gas is the core business of several partners of the NATURALHY-Project. Hence, they have made a preliminary examination of the possibilities of using their existing gas systems as the connection between hydrogen production and appliances powered by hydrogen. In fact, it is an obvious and pragmatic step to assess the existing situation for adaptation to new opportunities, and in this way to break the "chicken and egg" dilemma.

The NATURALHY-project, prepared by all stakeholders involved and, crucially, including the main gas industry aims to investigate comprehensively the practical means of transition from the existing natural gas infrastructure to the hydrogen economy.

The basic principle investigated in the NATURALHY-Project concerns the addition of hydrogen to natural gas within the existing natural gas system including the high and medium pressure transmission systems, the distribution system, the end-user infrastructures and end-user appliances. The mixture should be suitable for direct use in the existing end-user appliances. Membranes to be developed within the project will enable the extraction of hydrogen from the mixture so that it can be used for hydrogen appliances and for supplying hydrogen to fuel stations for road transport applications. This approach is explained in Fig.1.

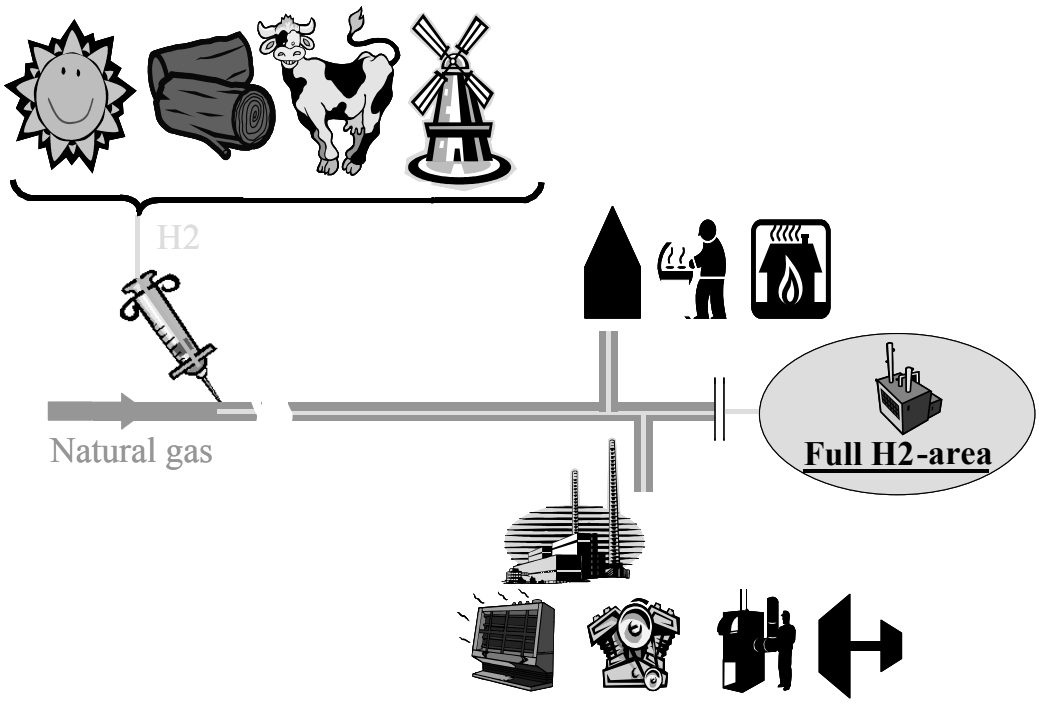

Figure 1. The NATURALHY approach: addition of hydrogen to natural gas in the existing natural gas system, and use of the mixture as well as separation of hydrogen by membranes

The addition of hydrogen to natural gas in the existing natural gas system may result in different chemical and physical properties compared to "pure" natural gas. The impact of added hydrogen on the combustion properties necessitates appropriate actions to mitigate the consequences for, *inter alia*, the performance of end-user appliances, with regard to aspects such as flashback, unintended gas release, efficiency and lifetime; and safety related to all aspects of the supply chain from production

up to an including consumption. In addition, hydrogen might also affect the material properties of pipeline systems, which could have an effect on safety.

This paper presents an overview of the project. The paper presented at this conference by Mrs. I. Allait and Mr. J. Heerings gives further details on the NATURALHY programme concerning pipeline durability and integrity, while the paper presented by Professor G. Hankinson explains the safety programme included in NATURALHY.

2.0 PROJECT OBJECTIVES

If urgent progress is to be made towards developing hydrogen as a realistic energy option, a practical strategy must be adopted within the context of the existing, extensive natural gas system. Advantage should be taken from the extensive experience of the natural gas industry, particularly with regard to its excellent safety record. The NATURALHY approach is the only realistic solution to large-scale distribution of hydrogen in Europe in the next 30 to 50 years. The main basis of this view is that:

- Significant financial and economic benefits can arise from the use of the existing European infrastructure with its inherent economic value of several hundreds of billions of EUROs.

- Using the existing gas infrastructure for the change to the full hydrogen economy will accelerate the transition rate and the innovation in all relevant fields.

Further to this vision, the NATURALHY project aims to identify and solve the barriers for progressively introducing hydrogen into natural gas networks and to support the development of a roadmap towards the full hydrogen economy by the EU-funded Integrated Project HYWAYS. Gaining experience with testing key components of full hydrogen systems will speed up the transition process.

Safety is the key issue in the NATURALHY project, and is represented by the following set of objectives:

- To define the technical conditions under which hydrogen can be accommodated in the existing natural gas system with acceptable risks, to avoid leakage and significant degradation of the system and consequences for the end-users.

- To assess the current situation of standards and regulations regarding hydrogen/natural gas mixtures and to identify necessary modifications and to initiate required changes.

- To develop a Decision Support Tool for the assessment of the suitability of an existing natural gas system (transmission, storage, distribution, end-user infrastructure and end-user appliance) for mixtures of hydrogen/natural gas and to develop models to determine the economic and environmental aspects of the whole chain from sustainable hydrogen production up to and including end-user appliance.

- To motivate all stakeholders in the whole chain, from production up to and including end-use, to welcome hydrogen. Such stakeholders consist of, among others, the public, end-users, manufacturers of appliances, owners and operators of gas transmission grids, hydrogen producers, local, regional and national authorities, manufacturers of all kinds of equipment and components for gas, etc. This objective will be met in cooperation with IP HYWAYS and the NoE HYSAFE.

In addition, the following coherent and complementary objectives have been defined:

- To analyse the socio-economic aspects of transitional natural gas/hydrogen systems and the full hydrogen system and compare these with current natural gas and related systems, with

particular reference to job creation and maintenance, capital investment and total economic costs.

- To carry out life-cycle assessment as a means of comparing the major resource inputs and environmental outputs of current natural gas and related systems, transitional natural gas/hydrogen systems and the full hydrogen system, including methods of hydrogen production.

- To develop innovative devices (membranes) to separate hydrogen from hydrogen/natural gas mixtures. These devices will enable an early establishment of full hydrogen growth centres that will help to advance a gradual transition to the full hydrogen economy.

3.0 PARTICIPANTS

Table 1. List of organizations participating in the NATURALHY-project

Participant name	**Part. short name**	**Country**
N.V. Nederlandse Gasunie	GASUNIE	NL
Högskolan i Borås	UCB	SE
BP Gas Marketing Limited (BP)	BP	UK
Commissariat à l'énergie atomique (CEA)	CEA	F
Compagnie d'Etudes des Technologies de l' Hydrogène	CETH	F
Computational Mechanics International Ltd	CMI	UK
The European Association for the Promotion of Cogeneration	COGEN	B
Centro Sviluppo Materiali Spa	CSM	I
DBI Gas- und Umwelttechnik GmbH	DBI-GUT	D
Public gas corporation S.A.	DEPA	EL
Danish Gas Technology Centre	DGC	DK
Energy Research Centre of the Netherlands	ECN	NL
EXERGIA, Energy and Environment Consultants S.a	EXERGIA	EL
Technische Universität Berlin	TU BERLIN	D
Gaz de France	GDF	F
General Electric PII Ltd	GE PII	UK
GERG - The European Gas Research Group	GERG	B
The Health and Safety Executive	HSE (UK)	UK
Istanbul Gaz Dagitim Sanayi ve Ticaret A.S	IGDAS	TR
Institut Français du Pétrole	IFP	F
Instituto de Soldadura e Qualidade	ISQ	P
University of Leeds		UK
Loughborough University		UK
Tubitak Marmara Research Center Energy Systems and Environmental Research	MRC	TR
Naturgas Midt-Nord I/S	MIDT-NORD	DK
Netherlands Standardization Institute	NEN	NL
National Technical University of Athens	NTUA	EL
Norwegian University of Science and Technology	NTNU	NO
Planet - Planungsgruppe Energie und Technik Gbr	PLANET	D
Ecole Nationale d'ingénieur de Metz	ENIM	F
SAVIKO Consultants ApS (Saviko Roskilde ApS)	SAVIKO	DK
Shell Hydrogen B.V		NL
STATOIL ASA	STATOIL	NO
SQS Portugal - Sistemas de Qualidade de Software, Lda	SQS	P

Total S.A	TOTAL	F
Netherlands Organisation for Applied Scientific Research	TNO	NL
X/ Open Company Limited	TOG	UK
Transco plc (part of National Grid Transco plc)	TRANSCO	UK
University of Warwick	WPTG	UK

4.0 PROJECT APPROACH

A set of Work Packages (WP), each covering a well-defined issue or set of issues, has been established within the NATURALHY project. Although closely integrated, they have been defined in such way that they can mainly be executed independently from the other Work Packages.

Technical activities are focussed on existing situations/materials/constructions/circumstances /equipment in relation to the specific physical properties of hydrogen/natural gas mixtures. In fact, the bigger part of these activities is dedicated directly to "safety" and to pipeline durability and integrity aspects, which are strongly related to safety.

With regard to technical aspects, the main focal points of the projects are:

- the high and medium pressure natural gas transmission system;
- the natural gas distribution system;
- the end-user infra structure and appliances;
- membranes for the selective withdrawal of hydrogen from hydrogen/natural gas mixtures.

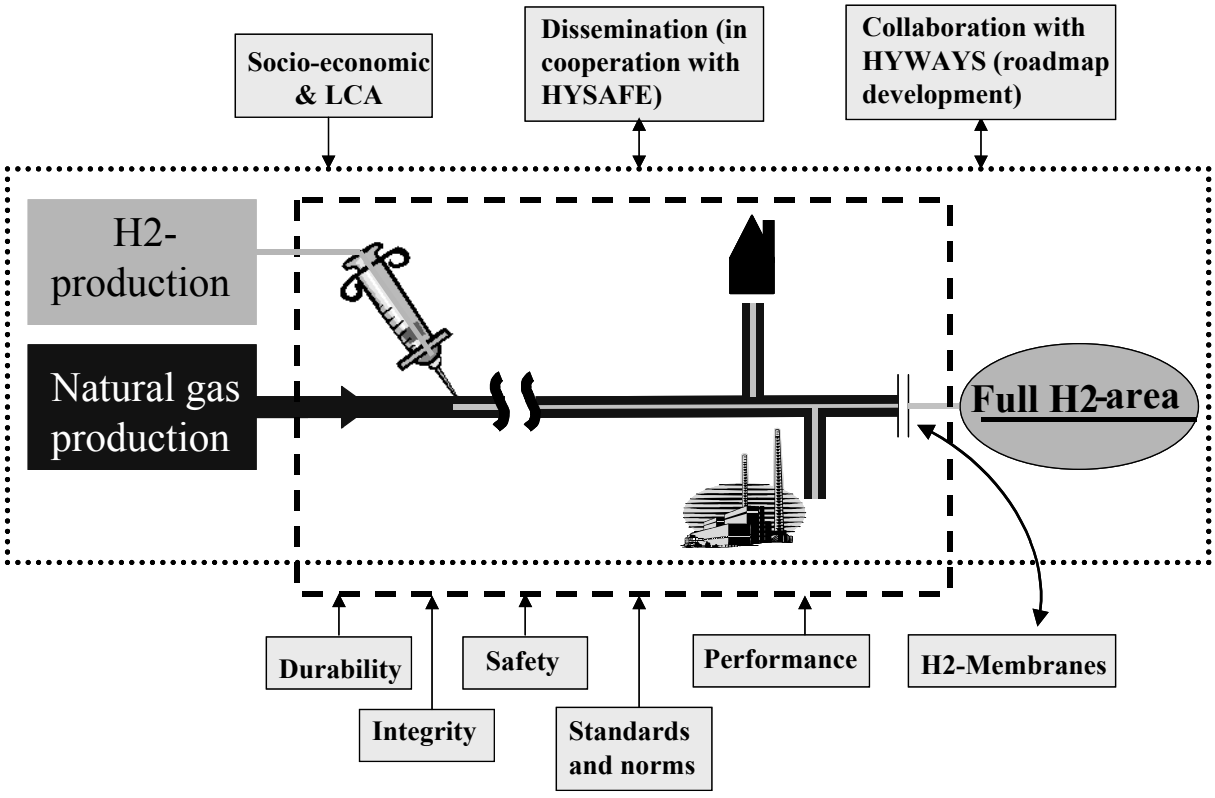

Figure 2. The approach of the NATURALHY-project

And, for all non-technical issues (upper part of figure 2):

The whole chain is taken into account, from production down to and including end-use, covering

- various sustainable hydrogen production facilities and processes, and
- natural gas exploitation.

The Life-cycle and Economic Analyses concern the use of the existing gas system for hydrogen/natural gas mixtures and the full hydrogen situation with a new, dedicated hydrogen infrastructure. The existing situation will be the reference case.

The potentials of the existing natural gas system during the transition towards the full hydrogen economy will be mapped out. In addition, the means (including membranes) for local full hydrogen areas (growth centres) will be developed, based on the separation of hydrogen from hydrogen/natural gas mixtures at/near the location of the end-user.

Table 2 details the distinct Work Packages in the NATURALHY-Project and the organizations coordinating the activities within these packages.

Table 2: NATURALHY Work Packages

Number	**Work Package (Work package leader)**
WP1	Socio-economic and Life Cycle Analysis (Warwick University)
WP2	Safety (Loughborough University)
WP3	Durability (Gaz de France)
WP4	Integrity (TNO)
WP5	End Use (Warwick University)
WP6	Decision Support Tool (ISQ)
WP7	Dissemination (Exergia)
WP8	Project management (Gasunie Engineering & Technology)

The technical Work Packages 2, 3, 4, 5 and 6 originate from the impact of hydrogen on safety, because the properties of hydrogen differ significantly from natural gas.

Within the framework of Work Package Safety, large-scale experiments are foreseen related to domestic and industrial utilization (confined & vented explosions), transmission and distribution (pipeline rupture fires), transmission, distribution and operational sites (jet fires and vapour cloud explosions). In fact, experiments are planned which are similar to the experiments on which the current safety models for natural gas are based, but with different concentrations of hydrogen added to the natural gas.

In addition to differences in the combustion properties already mentioned, the diffusion of hydrogen into pipeline materials can have a negative effect on the mechanical properties of the material (embrittlement of steel pipelines). Consequently, activities have been defined regarding the acceptability of corrosion defects and sharp defects contained in these brittle zones, to update the associated assessment criteria (WP3) and the maintenance procedures, repair techniques and equipment to assess the integrity of pipelines in presence of hydrogen and natural gas mixtures (WP4).

The sensitivity required of monitoring equipment used to find defects for the case when hydrogen is added to natural gas is higher than in the case of “pure” natural gas and the smallest defect might be critical in the situation of hydrogen/natural gas. Additionally, the question of permeation of hydrogen/natural gas mixtures through the wall of polymer pipelines is also considered in the NATURALHY project.

During approximately the first half of the project, attention will be dedicated to acquiring the basic information concerning safety, durability, pipeline integrity, and the performance of end-user appliances. This information will be used for the development of the "Decision Support Tool" (the main technical Deliverable). The "Decision Support Tool" will comprise, *inter alia*, a set of guidelines, tests procedures, criteria, models and material data; this will be necessary to predict and judge the consequences of adding hydrogen to natural gas regarding durability, safety, economic and life cycle assessment aspects of the transmission and distribution systems and end-user infrastructure and appliances. The Decision Support Tool will enable any given gas system to be assessed for its suitability for carrying hydrogen/natural gas mixtures.

Getting the support of all stakeholders is crucial in this project. So, over the whole length of the project, the Work Package "Dissemination" will concentrate on attracting the attention of public, authorities and gas companies to the projects aims, objectives and results. Regarding the communication with the public and decision makers about safety aspects, there will be an arrangement with NoE HYSAFE (see the paragraph "Co-operation").

5.0 PLANNING AND BUDGET

The execution of the NATURALHY project actually started on 1st May 2004, and will run for 5 years. The total project budget exceeds 17 M EURO, while the European Commission's contribution within the Sixth Framework Programme amounts to 11 M EURO.

6.0 CO-OPERATION

In order to establish a platform for dissemination and to encourage public awareness and understanding, a strategic advisory board has been defined consisting of global leading entities from politics, decision makers, regulators, normalisation and authorities active in the said fields, such as International Energy Agency, International Gas Union, UK Health and Safety Executive, Dutch ministry of economic affairs, European Natural Gas Vehicle Association, US Department of Energy, International Hydrogen Energy Association, the Wuppertal Institute, NUON, European Commission, the Carbon Trust, Bellona and HYWAYS and HYSAFE and is chaired by the former chairman of CEN.

The NATURALHY consortium cooperates with IP HYWAYS regarding the development of roadmaps and timelines to the hydrogen economy and with NoE HYSAFE regarding the communication towards the public and decision makers about safety aspects of the transmission, distribution and use of hydrogen/natural gas mixtures. Furthermore, there will be a connection with the Dutch project "Vergroening van Gas" financially supported within the EET-programme.

7. ACKNOWLEDGEMENT

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