



A practical step towards “hydrogen”: The conditions under which the existing natural gas system can be used for mixtures of hydrogen and natural gas (the NATURALHY -project)

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ABSTRACT

Hydrogen is foreseen as an important energy carrier and an essential element for global sustainable development. However, there are many significant challenges for implementing all the components of a complete energy system based on hydrogen. Despite these challenges, there is global interest in hydrogen. The transition towards the situation in which hydrogen is an important energy carrier will be lengthy (decades), costly and needs a significant effort for R&D. The development of a hydrogen system requires a practical strategy within the context of an existing, extensive natural gas system which has resulted from substantial capital investment over a long period of time.

The NATURALHY-project aims to define the conditions under which the existing natural gas system (transmission and distribution system, end user infrastructure and end user appliances) can be used for mixtures of natural gas and hydrogen. Innovative membranes will be developed to selectively withdraw hydrogen from a hydrogen/natural gas stream.

As the physical and chemical properties of mixtures of hydrogen and natural gas may differ significantly from “pure” natural gas, the NATURALHY -project addresses particularly the safety, durability and integrity issues related to the transmission, distribution and end use of such mixtures.

A European consortium of 39 partners (15 from gas industry) has been assembled, and guidance will be provided by a Strategic Advisory Committee consisting of representatives from relevant (inter)national organisations. The execution of the project started on 1st May 2004, and takes 5 years.

The European Commission has selected the NATURALHY -project for financial support within the Sixth Framework Programme.



INTRODUCTION

Hydrogen is foreseen to become 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 appliance powered by hydrogen. The distance between the hydrogen production and the appliance will range from several centimetres to several thousands of kilometres depending on production, whether centralised, decentralised or hybrid, and its use. For sure, pipelines will be an important part of this connection.

Given the strong political stress on the implementation of hydrogen as an important energy carrier, several companies united in the NATURALHY project whose core business is the transmission and distribution of gas, and who want to prepare themselves to the situation that hydrogen will actually be offered for transmission and distribution. An obvious and pragmatic first step is to examine the possibilities presented by the existing natural gas system for adaptation to new opportunities.

More over, it is important to assess the contribution of the existing assets because:

- 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 accelerates the transition rate and innovations in all relevant fields.

This vision is also supported by the United States Department of Energy as reported in the National Hydrogen Energy Roadmap (April 2-3, 2002): “*Vision of hydrogen delivery: A national hydrogen supply network will evolve from the existing fossil fuel-based infrastructure to accommodate both centralized and decentralized production facilities*”.

From previous preparatory experiments it is already known that the existing system will not be suitable for 100% hydrogen and that even 50% hydrogen added to natural gas will be too much to compromise safety and acceptable effects on pipeline durability. Nevertheless, in



view of its enormous capacity, its extent, and its availability on the short term it is worth examining what the natural gas system offers to the implementation to hydrogen, especially during the transition period.

OBJECTIVES

For urgent progress towards developing hydrogen as a realistic energy option, a practical strategy must be adopted within the context of the existing, extensive natural gas system. In the view of the NATURALHY-partners, this is the only realistic solution to large-scale distribution of hydrogen in Europe in the next 30 to 50 years. Further to this vision, the NATURALHY-project aims to prepare stakeholders by identifying and solving the barriers for progressively introducing hydrogen to natural gas networks and to support the development of a roadmap towards the full hydrogen economy by Integrated Project HYWAYS (also funded by the European Commission within FP6). Gaining experience with testing key components of full hydrogen systems will speed up the transition process.

The NATURALHY-project will achieve these aims by means of the following set of coherent and complementary 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 develop a Decision Support Tool for the assessment of the suitability of an existing natural gas system (transmission, storage, distribution, end user infra structure 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 appliances.
- 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 advance a gradual transition to the full hydrogen economy.



- 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 Integrated Project HYWAYS and the Network of Excellence HYSAFE.
- To assess the current situation of standards and regulations regarding hydrogen/natural gas mixtures, to identify necessary modifications and to initiate required changes.

APPROACH

Figure 1 shows the field of activities of the NATURALHY-project:

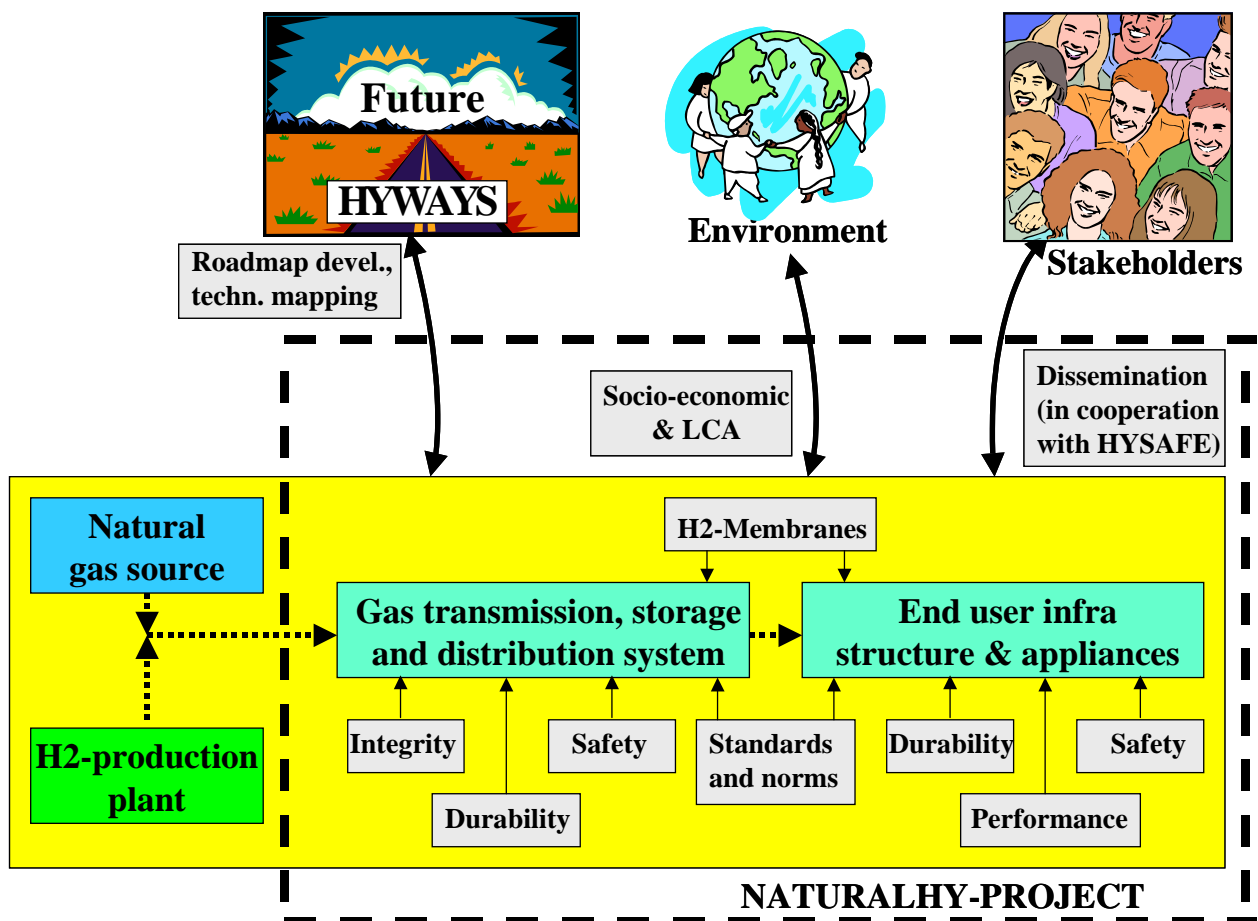


Figure 1: The approach of the NATURALHY-project

- The attention for safety, durability, integrity and performance (the technical aspects) in this project focuses at:



- Gas transmission system;
- Gas distribution system;
- End-user infra structure and appliances, and membranes to selectively withdraw hydrogen from hydrogen/natural gas mixtures.
- And, for all non-technical issues (life cycle assessment, dissemination, and roadmapping as indicated in upper part of Figure 1), emphasis is on:
 - The whole chain including:
 - Various sustainable hydrogen production facilities and processes, and
 - Natural gas exploitation is taken into account.

The technical activities are focussed on existing situations/materials/constructions/circumstances/equipment in relation to the specific physical and chemical properties of hydrogen/natural gas mixtures.

The chemical and physical properties of hydrogen differ significantly from those of natural gas and so the properties of mixtures will also differ from “pure” natural gas. In this respect, the main fields in which these changes are relevant are safety, durability, pipeline integrity and the performance of the end user appliances. For safety and appliance performance, it is important to realise that

- the explosion limits of hydrogen/air mixtures are much wider than for natural gas;
- the ignition energy for hydrogen is much less than for natural gas;
- the latent energy per unity of volume of natural gas is about 3 times of that of hydrogen;
- the flame velocity of hydrogen is much higher than for natural gas;
- the radiation of hydrogen flames is much less than from natural gas flames.

As a consequence of this, the impact on safety aspects by the addition of hydrogen to the transmission and distribution has to be assessed. Within the work programme on the safety aspects, it will be necessary to investigate to what extent mixtures of hydrogen/natural gas behave differently from “pure” natural gas: large scale experiments with different percentages hydrogen added to natural gas will be carried out (such experiments were previously carried out for the preparation of the natural gas safety models). The approach is to adapt these existing safety models for hydrogen/natural gas mixtures. For a more detailed description of the activities planned within the NATURALHY-project regarding “Safety”, the authors would like to refer to the paper presented by Professor Geoff Hankinson at this Conference.

It is well-known that the diffusion of hydrogen into the pipeline material can have a negative effect on the mechanical properties of the material (embrittlement of steel pipelines).



Consequently, activities have been defined within the NATURALHY-project regarding the acceptability of corrosion defects and sharp defects contained in these brittle zones, to update the associated assessment criteria and the maintenance procedures, repair techniques and equipment required to assess the integrity of pipelines in presence of hydrogen and natural gas mixtures.

The necessary sensitivity of monitoring equipment for defects for the hydrogen situation is higher than in the case of natural gas: a defect that is not of importance in a pipeline used for “pure” natural gas, might be of importance if the pipeline is used for hydrogen/natural gas mixtures. Additionally, questions on the permeation of hydrogen/natural gas mixtures through the wall of polymer pipelines are also considered in the NATURALHY-project.

The results of the technical tasks will be used in the development of the Decision Support Tool which is the main technical deliverable of the project: this expert systems enables the user to determine the technical conditions under which hydrogen can be injected into a defined existing natural gas system, with acceptable safety standards, acceleration of the aging processes, drawbacks for the end users involved and costs related to measures to overcome any unacceptable consequences. The Tool to be developed, comprises, among others aspects, of a set of guidelines, tests procedures, criteria, models, material data and is dedicated 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 the end user infrastructure and appliances. Figure 2 gives an impression of a feasible outcome of the Tool applied to a specific limited natural gas grid.

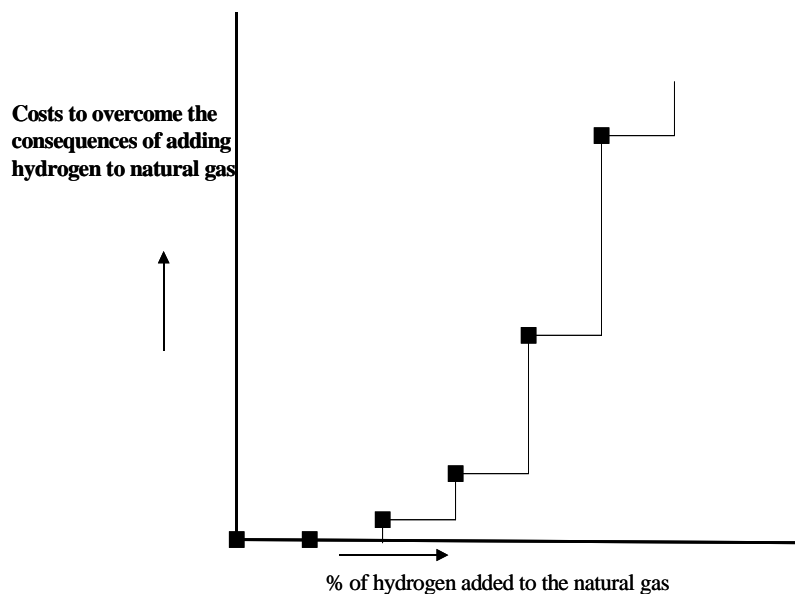


Figure 2: Costs as a function of the percentage of hydrogen added to natural gas



Socio-economic and life cycle assessment concerns 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.

No physical work is planned regarding hydrogen production: including hydrogen production would make the project too extensive for the Sixth Framework Programme. However, hydrogen production aspects are taken into account in the socio-economic and life cycle assessment. Hydrogen producers participate in the NATURALHY-project and several partners participate in projects dedicated to sustainable hydrogen production.

PROJECT ORGANISATION

A set of Work Packages (WPs), each on a well-defined issue or set of issues, are defined within the NATURALHY project to enable an efficient communication amongst the partners, and each WP has a specified leader. Although closely integrated, they have been defined in such way that they can mainly be executed independently from other WPs.

The following table summaries the distinct WPs in the NATURALHY-project as well as the leaders and organisations taking care of the technical coordination of these WPs.

Table 1: NATURALHY Work Packages

Number	Work Package	Work package leader (person/organisation)
WP1	Socio-economic and life cycle assessment	Prof. Nigel Mortimer / Warwick University
WP2	Safety	Prof. Geoff Hankinson / Loughborough University
WP3	Durability	Dr. Isabelle Alliat / Gaz de France
WP4	Integrity	Ir. Adriaan den Herder / Netherlands Organisation for Applied Scientific Research TNO)
WP5	End Use	Dr. Costa Komodromos / Warwick University
WP6	Decision Support Tool	Dr. Peter Bartlam / Instituto de Soldadura e Qualidade (ISQ)
WP7	Dissemination	Dr. George Vlondakis / EXERGIA, Energy and Environment Consultants S.a
WP8	Project management	Ir. Onno Florisson / N.V. Nederlandse Gasunie (Gasunie Research)



Getting the support of all stakeholders is crucial in the NATURALHY-project. Therefore, throughout the whole duration of the execution of the project, an extensive programme of engaging with the public, authorities and gas companies will be executed within the framework of the WP “Dissemination”. Regarding the communication with the public and decision makers about safety aspects, there will be an arrangement with the Network of Excellence HYSAFE (see the Section on “Co-operation”).

PARTICIPANTS

Table 2 shows the list of NATURALHY-partners.

Table 2: List of NATURALHY-partners

Partner Name	Partner 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
EUROGAS – Groupe Européen de Recherches Gazières	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	UNIV LEEDS	UK
Loughborough University	LOUGH	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	SH	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

PLANNING AND BUDGET

The actual execution of the NATURALHY-project started on 1st May 2004, and the duration of the project amounts to 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.

CO-OPERATION

At the request of the European Commission, the NATURALHY-consortium will cooperate with Integrated Project HYWAYS regarding the development of roadmaps and timelines to the hydrogen economy and with Network of Excellence HYSAFE regarding the communication with 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.

In order to establish a platform for dissemination, public awareness and understanding, a Strategic Advisory Committee has been defined that consists of leading global entities from



politics, decision makers, regulators and normalisation and authorities active in the fields of environment, safety, energy, standardisation and policy. The International Energy Agency, International Gas Union, UK Health and Safety Executive, ministries of economic and environmental affairs, European Natural Gas Vehicle Association, the Carbon Trust, Bellona, the coordinators of the Integrated Project HYWAYS and Network of Excellence HYSAFE will participate in this Committee which is chaired by the chairman of CEN. Representatives of the “EU-Platform for hydrogen and fuel cells” and a regulator will be invited onto the Committee as well.

ACKNOWLEDGEMENT

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