

# Large Scale Hydrogen Infrastructure and Mass Storage

IEA: Hydrogen Implementing Agreement (HIA)

Proposal for new Task

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## Introduction

Large scale future use of hydrogen as a carbon-free energy carrier requires production of hydrogen using multiple sources and a connected infrastructure network. Designing and installing this hydrogen infrastructure for future demand is of primary importance for the global use and acceptance of hydrogen. However, this infrastructure is also seen as one of the main bottlenecks of a hydrogen based energy system. This proposed Hydrogen Implementing Agreement Task is aimed at answering the complex questions that will arise from the implementation of hydrogen distribution networks and mass storage on a national and international scale.

Large scale hydrogen infrastructure and mass storage have become relevant topics due to the following developments:

- Hydrogen developments in the car industry have picked up a higher pace. The big car producers are introducing their new generation FC vehicles. Large scale use of hydrogen (for transportation) requires upstream hydrogen infrastructure supporting it.
- Hydrogen production methods can be discontinuous and usually not located where the hydrogen demand occurs. This is specifically relevant for the production of renewable hydrogen from wind or solar energy.
- Large scale use will require mass storage comparable to natural gas to balance supply and demand.
- Hydrogen will be produced from multiple energy sources making mass storage interesting with regard to security of supply of energy.

This proposed Task will combine existing knowledge with new insights and provide sound analysis using system modelling. Also the economics of a large scale infrastructure will be reviewed. This proposed Task will benefit from the knowledge generated by previous and ongoing Tasks for example Task 18 (Integrated Systems Evaluation).

### Leading up to this draft proposal

At the 55<sup>th</sup> Exco meeting in Petten Frank Denys (ExCo, The Netherlands) spoke to the HIA Secretariat about the Dutch interest to initiate a new task on Large Scale Hydrogen Infrastructure and Mass Storage. The HIA Secretariat (Mary-Rose de Valladeres) responded proactively and contacted Howard Stone from Arup Energy. Dr-Eng. Stone wrote an initial draft task which was presented by Frank Denys at the 56<sup>th</sup> ExCo meeting in Rapperswil. There was a general interest in this new task. It was decided to move forward, explore the possibilities and formulate a preliminary proposal.

This preliminary proposal will be sent to the HIA members so that each of them can explore possible national interest. In October 2008 a Task Definition workshop will be held in Amsterdam (The Netherlands). The results from the Task Definition workshop will be presented at the next ExCo meeting in Athens (November 2008).

# 1 Large Scale Hydrogen Infrastructure and Mass Storage

A bulk hydrogen delivery infrastructure has several dimensions dependant on the locality of production sites, transmission distance and scale of storage options. To connect hydrogen production sites with local users, pipelines will most likely be used. The technologies used to transport and store hydrogen are scale dependent and will be optimised according to their economics: mass production sites connected to a large grid of pipelines or small scale local production with a dedicated infrastructure connecting a few users. Discontinuities in demand and or production of hydrogen will require mass storage technologies also. The mass storage will interact with the hydrogen grid similar to the buffering capabilities in the current natural gas grid.

## 1.1 Objectives

1. To establish an international basis on the academic techniques and industrial practices required to implement a hydrogen pipeline distribution system and mass storage.
2. Provide an overview of existing and planned hydrogen infrastructure. Goals may include: benchmark, best practices, review of feasibility.
3. Explore and research options for mass storage of hydrogen.
4. Technical and economic comparison of different infrastructure options by modelling

## 1.2 Scope and Duration

It is anticipated that a 3 year project is required to complete the proposed work, but it may be extended. For a more detailed schedule see 1.5. The Task will be divided into a series of subtasks that will require a combination of academic and industrial competencies. The scope of the proposed Task will be further defined in the Definition Workshop in Amsterdam (12-13 February 2009).

As yet there are a series of hydrogen pipelines and mass storage devices in use on a day-to-day basis. Existing hydrogen production, storage and infrastructure is mostly used for hydrocarbon enrichment or aerospace applications. Several of these sites will be selected and studied in detail. Case notes will be published on each of the facilities highlighting current industrial techniques and best practice operational methods. New options in the field of mass storage will be explored. Future infrastructure and storage will be modelled to form an opinion on technically and economically preferred solutions, possible scenarios and options.

This Task will focus on large scale infrastructure for a large number of users. This Task will benefit from these existing experiences and the international knowledge base. In addition, there is also the potential of technology transfer between US Department of Energy funding into hydrogen pipelines, existing US/UK codes on underground gas storage and EU Framework 6 funding on underground carbon dioxide storage.

## 1.3 Synergy with Hydrogen Implementing Agreement Annexes and the IEA

IEA HIA tasks that relate to and stand to benefit from the proposed task include the following:

- Task 18 - Integrated Systems Evaluation (e.g. use of Hydrogems modeling toolbox)
- Task 19 - Safety
- Task 22 - Fundamental and Applied Hydrogen Storage Materials Development
- Task 24 - Wind Energy and Hydrogen Integration
- Task 23 - Small scale reformers for on-site Hydrogen supply
- Task 25 - High Temperature Hydrogen Production Process

This new task is very open to cooperate with the other running tasks, and will benefit for their advances. Other related efforts include the hydrogen scenarios of the IEA Prospects for Hydrogen and Fuel Cells report and the EU World Energy Technology Outlook - 2050. Together with the results of the HyWays project this work provides a basis for future hydrogen demand estimates and production mixes.

The IEA Green House Gas study on “Co-production of hydrogen and electricity by coal gasification with CO<sub>2</sub> capture” concludes that some further work on large scale underground storage of hydrogen is worthwhile and suggests that the Hydrogen Implementing Agreement to carry out such work. The study demonstrates that flexible co-production plants combined with underground buffer storage of hydrogen could be advantageous, as the gasification plant can continue to operate at continuous full load despite variations in hydrogen and electricity demands. These advantages are likely to be greater if large amounts of variable renewable electricity are introduced into the system in future, although this was not modeled in the study.

#### 1.4 Related efforts, organisations and agencies

Efforts whose scope and activities are related to the proposed task include among other things the following (European Union) projects:

- **HyWays.** HyWays has developed a validated and well-accepted roadmap for the introduction of hydrogen into the European energy system. HyWays systematically describes the future steps to be taken for large-scale introduction of hydrogen as an energy carrier in the transport sector, including the build up of hydrogen production and supply infrastructure. ([www.HyWays.de](http://www.HyWays.de))
- **NaturalHy.** NaturalHy tests the idea to use the existing natural gas pipeline infrastructure for transport and distribution of hydrogen in the initial stages of the introduction of hydrogen as energy carrier. Activities include identification and assessment of the current situation of standards and regulations regarding hydrogen/natural gas mixtures, and materials research based definition of the technical conditions under which hydrogen can be accommodated in the existing natural gas system with acceptable risks (e.g. leakage, degradation of pipeline materials). Also pure hydrogen tests are carried out to find out whether the existing natural gas infrastructure can be used for transport of pure hydrogen. ([www.naturalhy.net](http://www.naturalhy.net))
- **Roads2HyCOM.** The Roads2HyCOM project aims to support the Commission and European hydrogen and fuel cell stakeholders in planning future activities by assessing and monitoring current and future hydrogen and fuel cell technologies for stationary and mobile applications against current and future applications requirements, and the needs of communities which may adopt these technologies. Part of the project consisted of mapping and characterization of existing hydrogen infrastructures and hydrogen production sites in the EU. ([www.roads2hy.com](http://www.roads2hy.com))
- **USDOE** There is a research group within the DOE framework that is conducting pipeline materials research for the mass distribution of hydrogen. The DOE project manager overseeing this work is Dr. Monterey Gardiner. Dr. Tim Armstrong is an invited member of this Task.
- **Framework 6 / 7** Under EU funding there are existing projects that are investigating the use of underground storage of Carbon Dioxide, a large percentage of this work is directly related to the proposed task in terms of technical feasibility and social implications. Two contacts in this field are Dr Sam Holloway and Dr Dave Evans, both of whom are employed at The British Geological Survey. Dr Dave Evans is currently compiling a special publication on underground carbon dioxide storage. This special publication, due for publication in the coming months, will also contain an updated version of Stone et al., 2004.

## 1.5 Approach and Schedule

Projects will be defined through a series of subtasks that are focused on a combination of academic and industrial competencies. Each subtask will contribute to an understanding of the technologies and engineering capabilities that are needed to implement the distribution and storage components of a large scale hydrogen infrastructure. A preliminary task schedule appears below:

**Table 1 Proposed Schedule of Work for Task**

Subtask	Year 1	Year 2	Year 3
<b>1: Existing infrastructure</b>	Review of existing infrastructure and accompanying regulations, mapping tasks	Strategic visions for existing infrastructure, best practices, identify barriers and opportunities?	Final report and dissemination
<b>2: Pipelines</b>	Pipeline materials and industrial techniques, e.g. construction and maintenance	Advancement in pipeline technologies and materials selection	Final report and dissemination
<b>3: Mass storage</b>	Underground and above ground storage; identification and characterisation of options and existing locations for hydrogen, CO <sub>2</sub> , hydrocarbons storage and their technologies	Advancement in large scale storage technologies and site selection, new options, and sites.	Final report and dissemination
<b>4: System modelling</b>	System modelling of pipelines and mass storage device interaction	Integration of strategic advances in hydrogen demand and production using results of exploratory scenario studies and hydrogen production technology characteristics (e.g. other HIA task data)	Refining of year 2 model, e.g. to include new technologies from other HIA tasks & report findings
<b>5: Economic modelling</b>	Economic modelling of mass storage operations & industrial visits to facilities to gain understanding	Initial cost model of current infrastructure and current techniques	Advancement of year 2 model to include new research & report findings
<b>6: Coordination and Dissemination</b>	Annual meetings in different locations to encompass task members' in their home countries. Invitations to other relevant IEA HIA tasks in country of meeting (integrated meetings).  Communication actions: contact existing international projects and industrial partners; conferences; papers; government agencies		

Additionally there are relevant ideas that will have to be discussed in the upcoming Task Definition workshop in the Netherlands. These ideas are:

- Safety and Regulation concerning large scale infrastructure and mass storage.
- What are the first steps towards a large scale infrastructure?

- Possible synergies with other technologies / infrastructures?
- Modelling of a base case and identify region or country specific differences
- Specific country or regional infrastructural characteristics

## 1.6 Task Participation and Management

To date, The Netherlands, the U.S., Denmark, Australia and France have expressed serious interest in the proposed task. Germany, Japan, UK and Canada are interested. Iceland, Norway, Spain and Switzerland may be interested. The EC, Italy and Korea will further investigate interest.

The U.S. asked that the scope be expanded to include other delivery options. This will be discussed in the upcoming Task Definition meeting in Amsterdam, The Netherlands (October 2008)

The minimum level of commitment for an expert in this proposed task will be discussed. It is envisaged that an expert must join at least 2 subtasks, preferably a mapping/assessment and modelling task.

Mr. Frank Denys, The Netherlands representative, will act as Task Organiser together with Ms. Esther Keijser from SenterNovem. Dr. Marcel Weeda will act as a Task Organiser. Dr-Eng. Howard Stone will act as a Task Organizer. If the proposed task is approved, an Operating Agent will have to be found.

## 1.7 Expected Outcomes and Deliverables

Outcomes of this task will characterize the key elements and components required to implement a hydrogen distribution network from production sites to suburban areas. An international consensus is sought so that ‘best-practices’ from one country can be disseminated to other countries to assist in project implementation. It is anticipated that academia and commerce will work hand-in-hand to realize this task. Funding will be derived from international/national research bodies and through industrial partnerships with academia. It is expected that new techniques, industrial and academic, will result in peer reviewed publications in international journals and conference proceedings.

This project is based on the following roadmap:

- Regular meetings: twice a year in different locations;
- Written report: Twice a year (semi-annual and annual report);
- Final report: six months after the end of the project for each subtask;
- Regular (scientific) publications through combined subtasks;
- Creation of a website to upload presentations and disseminate information.

### Further information

H.B.J. Stone, I. Veldhuis and R.N. Richardson of the University of Southampton (UK), Underground storage in the UK, published at International Hydrogen Energy Conference, Istanbul, 2004

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*World Energy Technology Outlook - 2050, WETO-H<sub>2</sub>*, European Commission - DG Research, report EUR 22038, ISBN 92-79-01636-9, 2006