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## **European Hydrogen Infrastructure and Production**

Document Tracking ID 6968

Newest revision:

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This revision:

[http://www.ika.rwth-aachen.de/r2h/index.php?title=European\\_Hydrogen\\_Infrastructure\\_and\\_Production&oldid=6968](http://www.ika.rwth-aachen.de/r2h/index.php?title=European_Hydrogen_Infrastructure_and_Production&oldid=6968)

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Print date: Thu, 23 May 2013 13:22:23 +0000

### **About Roads2HyCom**

Roads2HyCom is a project supported by the European Commission's Framework Six program. Its purpose is to assess and monitor hydrogen and fuel cell technologies for stationary and mobile energy applications. This is done by considering what the technology is capable of, relative to current and future hydrogen infrastructures and energy resources, and the needs of communities that may be early adopters of the technology. By doing this, the project will support the Commission and stakeholders in planning future research activities. Project main website: <http://www.roads2hy.com>

### **HyLights, Roads2HyCom and the Hydrogen and Fuel Cells Technology Platform (HFP)**

The European Commission is supporting the Coordination Action "HyLights" and the Integrated Project "Roads2HyCom" in the field of Hydrogen and Fuel Cells. The two projects support the Commission in the monitoring and coordination of ongoing activities of the HFP, and provide input to the HFP for the planning and preparation of future research and demonstration activities within an integrated EU strategy.

The two projects are complementary and are working in close coordination. HyLights focuses on the preparation of the large scale demonstration for transport applications, while Roads2Hycom focuses on identifying opportunities for research activities relative to the needs of industrial stakeholders and Hydrogen Communities that could contribute to the early adoption of hydrogen as a universal energy vector.

Further information on HyLights is available on the project web-site at <http://www.hylights.org>.



This section describes Roads2HyCom deliverable 2.1 and 2.1a, labelled "**European Hydrogen Infrastructure Atlas**" and "**Industrial Excess Hydrogen Analysis**", *Executive Summary of Part I, II, III* (edited by Dr. Robert Steinberger-Wilckens, Sören Christian Trümper, **PLANET GbR**, Oldenburg, Germany). *Document Tracking No.: R2H2001PU. Date: 2007-03-07*

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## Introduction

To promote the widespread use of hydrogen and fuel cells it is necessary to know where hydrogen is being produced, in which quantities and how much of it is available. It is also important to know where any hydrogen and fuel cell applications are installed or planned to be installed and what technologies are demonstrated to monitor technology progress and analyse and plan future research agendas. Finally, in order to connect both the production with the demand side the link between them, i.e. the distribution infrastructure needs to be investigated.

All three different sorts of infrastructure were analysed in the report and, for clarity reasons, broken down into three consecutive parts:

- Part I: [Mapping of existing European Hydrogen Demonstration Sites](#) 
- Part II: [Industrial surplus hydrogen and markets and production](#) 
- Part III: [Industrial distribution infrastructure](#) 

The next sections give brief summaries of each report.

## Part I: Mapping of existing European Hydrogen Demonstration Sites

Demonstration projects can be seen as showcases for future commercial products, bridging the gap between near-market products and commercially viable systems. They facilitate the necessary learning process for both technical as well as socio-economic aspects of a technology. In addition, these demonstration projects can act as seeds for other future hydrogen projects or the anticipated large-scale demonstrations also known

as Lighthouse-Projects (LHP).

In this study data on hydrogen demonstration projects were collected from various sources and synchronised with the currently largest database for demonstration projects held by the Hydrogen and Fuel Cell Platform (HFP) Europe. More than 70 data sets could be added to both databases. Also, all data sets in both databases were supplied with a geographical reference by Roads2HyCom.

The geographic mapping of all identified projects revealed early clustering of demonstration projects with centres of aggregation in the German Rhein-Ruhr/Rhein-Main area and Denmark in connection with southern Sweden (see figure below).



### **Geographic distribution of identified hydrogen demonstration projects. Centres of aggregated activity are the German Rhein-Ruhr/Rhein-Main area and Denmark in connection with southern Sweden Clusters**

These were also the countries in which most of the demonstration projects are based or will be initiated so that it could be assumed that these are first signs and the success of local or regional dissemination efforts, but also regional expertise, co-operations or favourable rules and regulations. Stationary and transport applications dominated the different project types, highlighting a growing market maturity of applications in these areas as well as proving trust and confidence of industry in the prospects of these technologies. Also, industry clearly had a strong engagement in the project consortia. Although half of all collected demonstration projects were finished these could still serve as a track-record for future hydrogen communities, showing effort, political will as well as a learning process in the community.

For further analysis, a representative subset of the data was taken. These nine selected projects, included stationary and transport projects, were contacted and in-depths information were collected by means of a questionnaire, covering questions like investment costs, downtime, safety issues, CO2 emissions etc. Data collection showed unsatisfying communication with projects, underlining the need for a common and mandatory framework of data provision from projects. The results were aligned to a fixed set of metrics that was developed for the common analysis of infrastructure, technologies, and communities in Roads2HyCom.

All data were projected into a spiderweb diagram after being adjusted to a metric scale, which can be altered at any given time. This approach was chosen as it is numerically open and gives decision makers the chance to implement a "weighing factor", reflecting the objectives of their analysis. In regard to the in depth data



acquisition it was concluded that due the diverse data sets from a wide range of different project types no single performance figure can be calculated at this stage as it would only skew the overall scoring of each project. Instead, the proposed open approach with applicable "weighing factors" seemed to be the most suitable solution.

Still, from comparing the spider diagrams from all nine demonstration projects it could deduced, that half of the projects identified lack of codes and standards as an obstacle, most projects received sufficient local political support, national political commitment was mostly restricted to financial subsidies, and almost all projects had little or no GHG emissions from running the site.

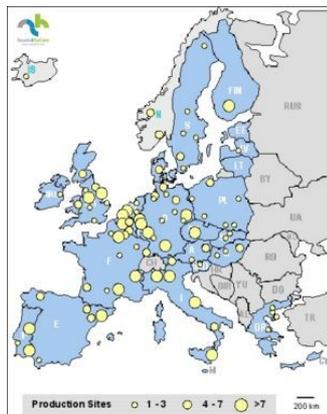
## Part II: Industrial surplus hydrogen and markets and production

Many industrial processes require hydrogen as an ingredient, or produce hydrogen as a by-product. Surplus hydrogen from these industrial processes could be used to fuel both transport and stationary applications during the transition phase towards a hydrogen economy. The main three players in the hydrogen market are merchant companies (which trade hydrogen), captive producers (which produce hydrogen for their direct customer or their own use), and by-product hydrogen producers (which provide hydrogen resulting from chemical processes).

Total hydrogen consumption in Western Europe is estimated to be about 61bn m<sup>3</sup> (2003), 80% of which was consumed by mainly two industrial sectors: the refinery (50%) and the ammonia industry (32%), which are both captive users. If one adds hydrogen consumption by methanol and metal industries, those four sectors cover 90% of the total consumption.

Total European production is estimated at about 90bn m<sup>3</sup>: 80bn m<sup>3</sup> for European Union members (including 22bn m<sup>3</sup> for Germany, 10bn m<sup>3</sup> for the Netherlands, and approximately 5-7bn m<sup>3</sup> for both the United Kingdom, France, Italy, Spain and Belgium), 2bn m<sup>3</sup> for EFTA countries, and 10bn m<sup>3</sup> for Candidate Countries (CC). Broken down to market sectors the captive industry produces around 64% of the total, followed by the by-products industry (27%) and merchant companies (9%).

The geographic distribution of all identified hydrogen production sites is shown on an aggregated level for further analysis of production sites in the context of future large-scale demonstration projects where the distance from production to use will be of importance. It can already be seen that there are clusters of production, mainly in the Benelux and Rhein-Main area as well as in the Midlands UK and North Italy (see [figure](#) below).



**Geographic distribution of identified industrial hydrogen production facilities. It can already be seen that there are clusters of production, mainly in the Benelux and Rhein-Main area as well as in the Midlands and North Italy**

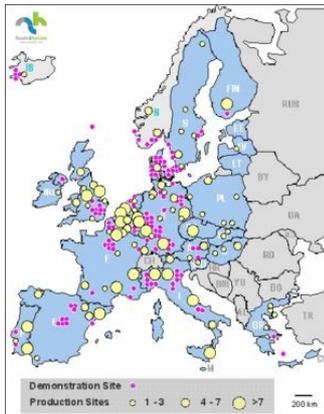
By-product hydrogen production, i.e. hydrogen produced inadvertently as a by-product of a chemical process, is estimated to be 23bn m<sup>3</sup> per year with Germany (6.8 bn m<sup>3</sup>) and the United Kingdom (3.6 bn m<sup>3</sup>) being the largest producers.

In the report, detailed figures for the hydrogen production and the by-product occurrence in different industries are shown. Analysing the different excess margin scenarios it appears that a potential of 2-10bn m<sup>3</sup> hydrogen might be available as "surplus hydrogen" in Europe, either in the form of excess capacity (0-5bn m<sup>3</sup>) or by-product hydrogen (2-5bn m<sup>3</sup>). This surplus volume is far from negligible: with 2-10bn m<sup>3</sup> hydrogen it is possible to supply about 1-6 million vehicles. That number, though, represents only 1.5-3% of all vehicles in the EU (estimated at 190m) and would cover a substantial Hydrogen Community or early adopter market, probably in locations closest to the surplus (it is, for example, much more than the total number of fossil-fuelled hybrid vehicles in the market today).

Numbers should be used with care, though, as the analysis is based purely on statistical assumptions and has not investigated actual capacity factors of plants. Consideration should also be given to the quality of the surplus hydrogen. Impurities in hydrogen can be an issue for use in PEFC, for example. Therefore gas-cleanup technologies might have to be considered when planning for projects using surplus hydrogen in order to meet the specifications laid down by fuel cell suppliers.

As each method of production presents specific issues in terms of quality it is not possible to give an overall figure of how much of the identified surplus hydrogen would need to be treated downstream and how, but it can certainly be said that purification will add extra cost that needs to be considered in any further analysis. Still, besides these extra costs, available hydrogen does exist and this surplus hydrogen can well be considered as a potential hydrogen source for the transition phase.

If both maps from Part I and Part II are put together, the geographic proximity between centres of demand and centres of availability becomes clearer (see [figure](#) below).



**Geographic distribution of identified hydrogen demonstration projects and industrial hydrogen production sites. Often, but not necessarily always, the location of a production site coincides with the location of a demonstration project. Centres of aggregated activity are the German Rhein-Ruhr/Rhein-Main area and Denmark in connection with southern Sweden Clusters**

It can be seen that often, but not necessarily always, the location of a production site coincides with the location of a demonstration project. Ideally, both sites should be located close to each other for a large-scale deployment project. Although local production from renewables in a closed loop would be desirable, a large-scale uptake of hydrogen will mostly require other, industrial sources, at least for the transition phase. Alternatively, if the hydrogen production is not directly in the demonstrating community, it can be trucked in, depending on the distance and the amount needed.

### Part III: Industrial distribution infrastructure

Nearly 1600km of hydrogen pipelines in Europe could be identified. These pipelines can be divided between 15 larger pipeline networks with single ownerships. These owners are Air Liquide, Linde (BOC), Air Products (Sapio) and some smaller network operators as well as two energy projects that intend to build a specialised pipeline within their project. The largest network of pipelines is operated by Air Liquide and runs across north-west France, Belgium and part of the Netherlands. Smaller industrial plants or fuelling stations that do not have the demand that would justify a pipeline or an on-site production buy their hydrogen in trailers or cylinders. In Europe the total volume of this industrial merchant hydrogen supplied by trailers or cylinders, is estimated to 425m m<sup>3</sup> (2006). If this road transport is used, liquefied hydrogen has the advantage of carrying much more energy per volume. However, the total hydrogen liquefaction capacity is still low with presently 20 t/day, but will soon slightly increase to 26 t/day due to the building of a new plant by Linde.

Both liquefied and compressed hydrogen is suitable for fuelling stations. There are 35 hydrogen fuelling stations currently operating in Europe of which most are located in Germany. There are, however, a large number of stations planned in Scandinavia in the course of building various interconnecting hydrogen highways in that area.



## Weblinks

- Download here all parts of the report in one file: [Roads2HyCom European Hydrogen Infrastructure Atlas \(zip, 5 MB\)](#) 
- Searchable Infrastructure Database: [Hydrogen and Fuel Cell Database](#) (Flash plugin required)



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