

Roads2HyCom

www.roads2hy.com

DELIVERABLE 2.1 AND 2.1a

**“European Hydrogen Infrastructure Atlas” and
“Industrial Excess Hydrogen Analysis”**

PART III: Industrial distribution infrastructure

Jérôme Perrin, AIR LIQUIDE, S.A., Paris, France

Dr. Robert Steinberger-Wilckens, Sören Christian Trümper (eds.)
PLANET GbR, Oldenburg, Germany

Document Number: R2H2007PU.1

Date: 3 July 2007

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 the projects and their partners is available on the project web-sites www.roads2hy.com and www.hylights.org

Blank Page



ABSTRACT

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 m³ (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 is, however, a large number of stations planned in Scandinavia in the course of building various interconnecting Hydrogen Hyways in that area.

Blank Page



EUROPEAN HYDROGEN INFRASTRUCTURE ATLAS

PART III: INDUSTRIAL DISTRIBUTION INFRASTRUCTURE

TABLE OF CONTENTS

1.	Introduction	7
2.	Pipeline distribution networks	9
2.1	Pipeline networks operated by Air Liquide	10
2.2	Pipeline networks operated by Linde (BOC)	13
2.3	Pipeline networks operated by Air Products (Sapio)	14
2.4	Other pipeline networks.....	15
2.5	Hydrogen Energy projects	16
3.	Gas filling centers, liquefaction, and truck delivery	17
3.1	Gas filling centers	17
3.2	Liquefaction units	17
3.3	Truck fleets.....	18
3.3.1	Compressed gas trailers.....	18
3.3.2	Liquid hydrogen trucks.....	19
4.	Fuelling stations.....	21
5.	Conclusion.....	23
6.	References.....	25
	Annex 1 : Hydrogen pipeline lengths by region	27
	Annex 2 : Hydrogen fuelling stations in Europe.....	31

Blank Page



1. Introduction

As part of a larger exercise to map existing and potential hydrogen infrastructure in Europe, the EU funded project Roads2HyCom has mapped the hydrogen distribution infrastructure. The distribution infrastructure ranges from pipelines for large scale industrial needs to local distribution of hydrogen via road transportation by truck and refuelling stations. This report summarises the findings from the Roads2HyCom investigation of the hydrogen distribution infrastructure in Europe. It complements the Roads2HyCom report on hydrogen demonstration projects and industrial hydrogen production sites (Roads2HyCom documents R2H2005PU and R2H2006PU).

The focus of this report lies on hydrogen distribution infrastructure from pipeline distribution for large industrial needs to local distribution via truck transport or refuelling stations, with or without on-site hydrogen production.

The main actors in hydrogen distribution are the merchant industrial gas companies, namely:

- Air Liquide (including Carbagas in Switzerland)
- Air Products (including the Sapio group in Italy)
- Linde (including AGA in Scandinavia and BOC in the UK)
- Messer (outside Germany and UK after acquisition by Air Liquide in 2004)
- Praxair
- Other smaller actors such as Sol, Westfalen AG, Infracore etc.

Blank Page



2. Pipeline distribution networks

Europe has the largest hydrogen pipeline length in the world with about 1600 km (as compared to the United States with about 800 km). The main countries operating hydrogen pipelines are the Benelux countries, Germany, and France. Smaller pipelines are also operated in the UK, Italy, and Sweden.

Table 1 shows these pipeline networks and their operators. For an overview of hydrogen pipeline lengths per region see Annex 1.

Table 1: European pipeline networks and their operators

Operator	Network name	Length [km]	Transit countries	Length [km]
Air Liquide	North Europe	949	Netherlands Belgium	187 613
	Dunkerque	14	France	303
	France East	37		
	France Center East	57		
	France South East	42		
	Le Havre	4		
	Ruhr	240	Germany	240
	Monthey	2	Switzerland	2
	Priolo	6	Italy	6
	<i>sub total</i>	1351	<i>sub total</i>	1351
Linde (BOC)	Leuna-Bitterfeld	135	Germany	135
	Teesside	35	United Kingdom	35
		<i>sub total</i>	170	<i>sub total</i>
Air Products (Sapio)	Rozenburg	50	Netherlands	50
	Teesside	5	United Kingdom	5
	Porto Marghera	2	Italy	2
		<i>sub total</i>	57	<i>sub total</i>
others	Stenungsund	18	Sweden	18
TOTAL		1596		1596



2.1 Pipeline networks operated by Air Liquide

Northern Europe : Netherlands, Belgium, North of France

Air Liquide's pipeline system for supplying hydrogen, oxygen, nitrogen and carbon monoxide in northern France, Belgium and the Netherlands has a total length of more than 2700 km (see figure 1). The hydrogen pipeline network alone has a total length of 964 km (as of July 2006), with 187 km in the Netherlands, 613 km in Belgium, and 164 km in France. Owned and operated by Air Liquide, it is the longest hydrogen pipeline network in the world. The diameter of most of the pipelines is primarily 100 millimeters; the working pressure is up to 100 bar. This network consists of two main parts interconnected close to Antwerpen (Belgium). The first part links the Air Liquide stations at Waziers and Isbergues (both France) with third-party stations near Zeebrugge and Antwerpen (both Belgium). After the interruption of the hydrogen production from the plant 'Grande Paroisse SA' in Waziers in 2001 this part of the pipeline is now supplied by Air Liquide SMR¹⁾ plants in Rozenburg and Bergen op Zoom (both Netherlands) and Antwerpen (Belgium), as well as from a by-product source from Dow in Terneuzen (Netherlands). The second part runs from close to Maubeuge (France) to Charleroi (Belgium), and from Feluy it passes close to Brussels and links to third-party stations in the north-east of Belgium towards Hasselt (all Belgium). The hydrogen sources located on this part are the Air Liquide TCR²⁾ plant in Feluy and a by-product source from a chlorine-alkaline electrolysis plant of Solvay at Jemeppe-sur-Sambre (both Belgium).

France : Dunkerque

A 14 km pipeline near Dunkerque connects a by-product source from an ethylene production plant (Copenor GIE) to the Air Liquide purification plant.



Figure 1: Hydrogen pipeline networks of Air Liquide in North-Europe (Benelux and France) and in the Ruhr area

¹⁾ SMR: Steam Methane Reforming
²⁾ TCR: Topsoe Convection Reformer



France : East

This network located in Moselle consists of one 37 km line from the Air Liquide hydrogen plant at Carling to the southeast. The hydrogen source is the ethylene cracker of Total Petrochemicals in Carling. Air Liquide is considering adding by-product hydrogen to the pipeline from the neighbouring styrene production plant of Total Petrochemicals.

France : Centre-East

This network runs 57 km to the south from the Air Liquide plant in Feyzin, Rhone, to Roussillon, Isère, linking five clients (among them Rhodia sites in Belle Etoile, St. Fons, Roussillon, and a glass factory). The hydrogen source is now the Air Liquide SMR plant in Saint Fons.

France : Southeast

This network runs 42 km from Lavera to Fos-sur-Mer in Bouches-du Rhone. Originally the hydrogen source were the Arkema chlorine-alkaline electrolysis plants in Fos and Lavera. Starting from 2006 this will be supplemented by a new SMR plant operated by Air Liquide.

France : Le Havre

A small section of 4.4 km connects the new Air Liquide SMR plant of Port-Jérôme and its main customer Exxon.

The total capacity of the above described northern European pipeline systems is estimated to be around 1200 million m³/year.

Germany : Ruhr area

At the end of 1998, Air Liquide acquired a pipeline and filling station in the Ruhr area of Germany that had been owned and operated by BOC since 1993 and by Hüls AG since 1938. The total length of the pipeline is 240 km (see figure 2). Fourteen production sites are connected to the pipeline, four of them are suppliers. The pipeline was initially established to deliver by-product hydrogen generated during the acetylene production to Hiberna, a company involved in coal hydration. This pipeline system has made by-product hydrogen much more marketable. The hydrogen producers currently connected to the Air Liquide pipeline, with their net supply, are Bayer AG (Krefeld, Leverkusen), Degussa AG (Luelsdorf, Marl), and Ruhrkohle Bergbau AG (Bottrop).

The total capacity of this Ruhr pipeline network is estimated to be 250 million m³/year.

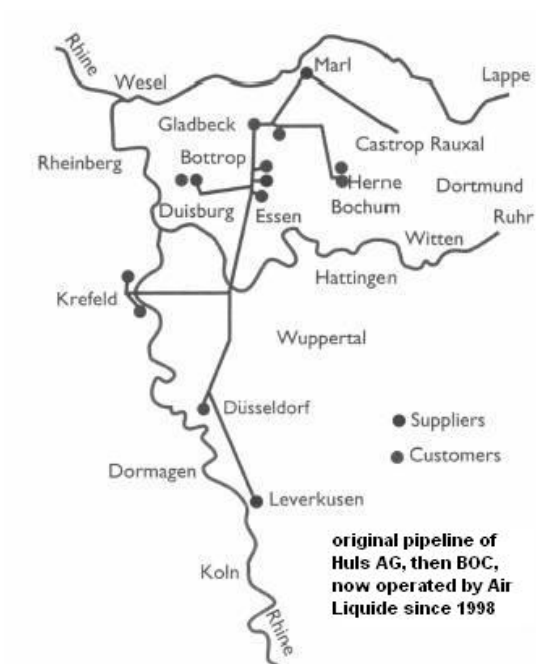


Figure 2: Hydrogen pipeline network of Air Liquide in the Ruhr area

Switzerland : Monthey

A 2 km pipeline links a hydrogen by-product source from a chlorine-alkaline electrolysis plant of Syngenta in Monthey, Valais, to the Air Liquide (Carbagas) filling station located in Massongex.

Italy : Priolo

A 6 km pipeline is planned to be built between the new Air Liquide SMR plant and the ERG refinery at the Priolo site in Sicily.



2.2 Pipeline networks operated by Linde (BOC)

Germany : Leuna-Bitterfeld

Linde Gas AG owns and operates a hydrogen pipeline system in the East German chemical industry region between Leuna, Buna and Bitterfeld with a total length of 135 km (see figure 3). This pipeline system links the Linde sources at Leuna to hydrogen consumers at the different locations such as the Total (formerly TotalFinaElf) refinery at Spergau and also incorporates a Linde filling station for trailers. The system is connected to the hydrogen pipeline of Dow/BSL between Buna and Böhlen, thus enabling product exchange and allowing further transport of hydrogen to a consumer at Zeitz.

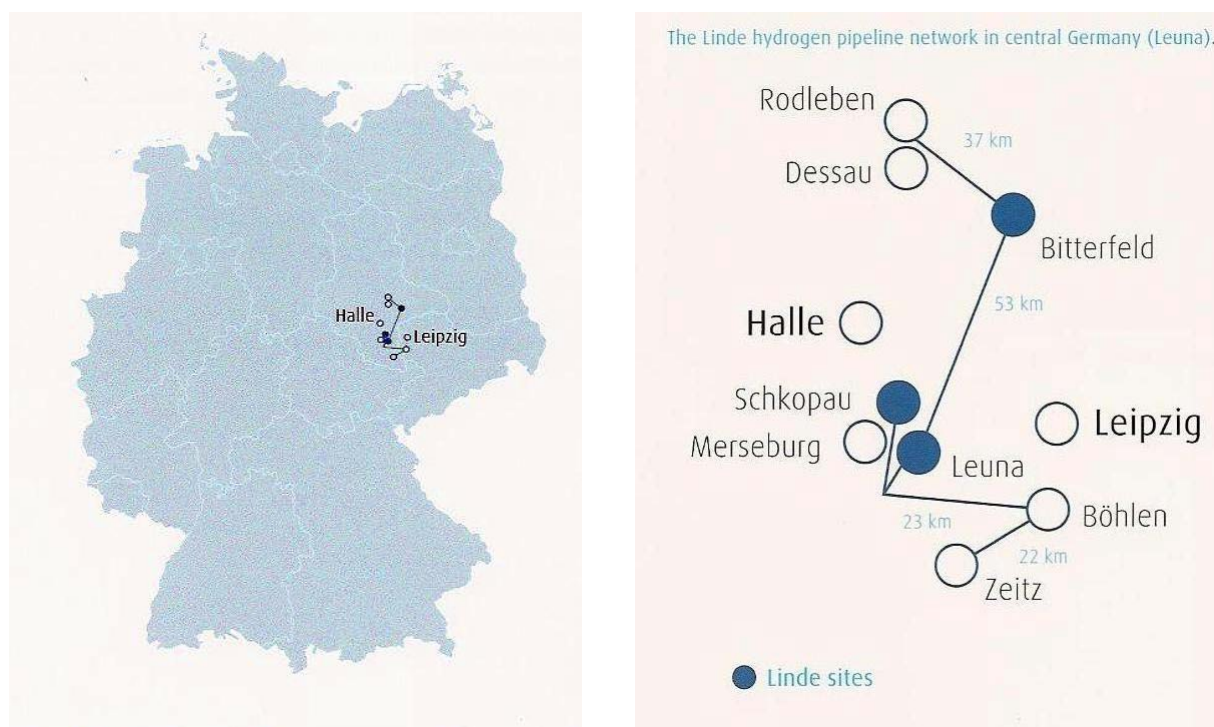


Figure 3: Hydrogen pipeline network of Linde in the Leuna-Bitterfeld area



United Kingdom :Teesside

BOC Gases Europe, belonging to the Linde Group since 2006, has built a hydrogen production plant linked to a pipeline with a total length of about 35 km at Teesside in the United Kingdom (see figure 4). The new plant which came on stream in 2002 is the largest outsourced hydrogen plant in the United Kingdom. Owned and operated by BOC Gases Europe, this pipeline supplies high-purity hydrogen by pipeline to the Huntsman production facilities on Teesside in both Wilton and North Tees. The pressure is up to 50 bar.

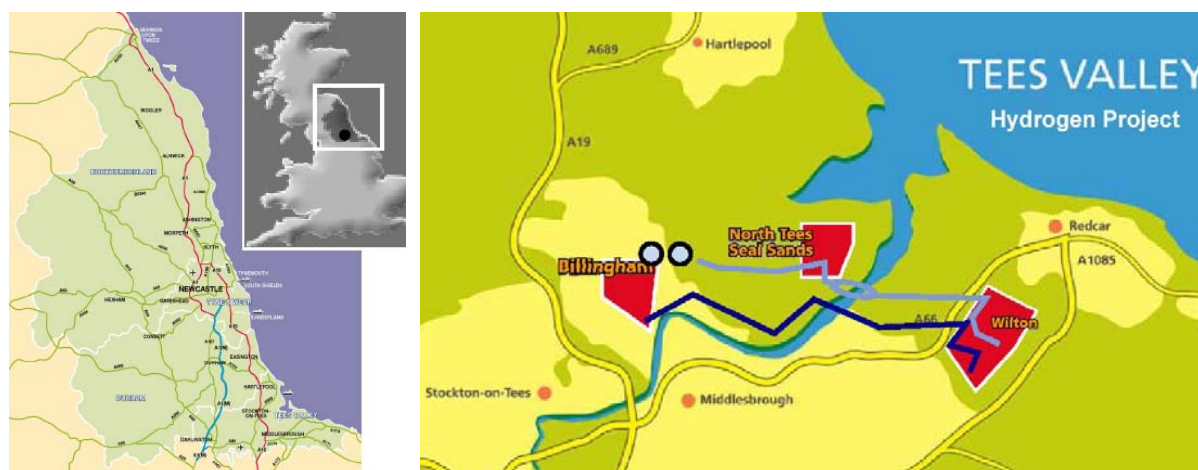


Figure 4: Hydrogen pipeline network (light blue) of BOC in at Teesside,UK

2.3 Pipeline networks operated by Air Products (Sapio)

Netherlands : Europoort – Rotterdam

Air Products operates a 50 km-long pipeline system for hydrogen (and carbon monoxide) in the Europoort area in the Netherlands (see figure 5). Air Product's liquid hydrogen plant at Rozenburg is also located in this area. In 1992, Air Products acquired Kemira's 400 ton ammonia plant and converted the unit to hydrogen production for the pipeline system in mid-1994. Its main client is ExxonMobil Chemical Holland in Rotterdam, using hydrogen to desulfurise fuels in its refinery. From Brielle to Pernis it runs parallel to the Dutch part of the Air Liquide's North Europe pipeline (see above).

United Kingdom : Teesside

Air Products operates a small pipeline of 5 km in the Teesside chemical site in the United Kingdom, close to where BOC has its pipeline (see above).

Italy : Porto Marghera

Sapio (Air Products group) operates a small hydrogen pipeline in the Porto Marghera chemical site near Venice.



Figure 5: Hydrogen pipeline network of Air Products in the Rotterdam area

2.4 Other pipeline networks

Sweden : Stenungsund

Six hydrogen pipelines, each one three kilometres long, mostly in the chemical complex of Stenungsund. The diameter of the pipelines is 50-250 mm and pressures are up to 28 bar. The typical flow rate is 2000 m³ per hour, and these are available more than 8000 hours per year.

Germany : Wilhelmshaven

Ineos operates a small hydrogen pipeline to connect their two plants in Wilhelmshaven. The pipeline has a length of about 12 km.



2.5 Hydrogen Energy projects

Within the European project “Zero Regio” Linde has proposed the installation of a 900 bar hydrogen pipeline (of small diameter) over a distance of 1.7 km in the Frankfurt/Rhein-Main area. Sapiro (Air Products group) also proposed to build a pipeline in the Arezzo-area.

Within the “Hydrogen Park” project in Porto Marghera (Venice) a new hydrogen pipeline is planned to be built underground through an urban area.



3. Gas filling centers, liquefaction, and truck delivery

3.1 Gas filling centers

Whereas large customers from refineries, chemical industries or steel and glass making, are preferably supplied by large on-site hydrogen production plants, or by hydrogen pipelines, smaller scale industrial gas applications (typically when the consumption remains smaller than 1000 m³ per hour) are supplied either by small on-site hydrogen production units, or by trailers or cylinders. In Europe the total volume of this industrial merchant hydrogen supplied by trailers or cylinders, is estimated to 425m³ (2006), whereas the total hydrogen merchant market including large industries is at least three times larger in volume. Nevertheless altogether this remains a small fraction of the total hydrogen production capacity estimated at about 90bn m³ (see also part II of this report).

The first step to address this market is to purify and package the gas in first-level gas stations from which trailers depart to serve customers or second-level cylinder filling centers. These gas stations may have their own on-site production, but more often they use either the excess capacity of a SMR source dedicated to a large customer or the by-product hydrogen from a chlorine-alkaline plant or a naphta cracker, sometimes via a pipeline.

3.2 Liquefaction units

There are only three hydrogen liquefaction plants in Europe: one operated by Air Liquide in Waziers (France), one by Air Products in Rozenburg (Netherlands), and one by Linde in Ingolstadt (Germany). The total hydrogen liquefaction capacity is presently 20 t/day (equivalent to 230 000 m³/day or 84m³/year) and should soon increase up to 26 t/day when Linde starts its second liquefier in Leuna (see also table 2).

Table 2: Overview capacities European liquefaction plants.

NUTS code	Site	Owner	Capacity [t/day]
FR301	Waziers	Air Liquide	10.5
NL335	Rozenburg	Air Products	5.4
DE211	Ingolstadt	Linde	4.4
DEE24	Leuna	Linde	5.7 (under construction)
Total capacity Europe (in 2007)			26.0



3.3 Truck fleets

3.3.1 Compressed gas trailers

European industrial gas companies (Air Liquide, Air Products, BOC, Linde, Praxair, Sapio, SOL etc.) all have truck fleets to transport compressed gaseous hydrogen (CGH₂). Steel tube-trailers or cylinder-trailers (see figure 6) at 200 bars or 300 bars can carry from 2000-6200 m³ of hydrogen. This corresponds to a theoretical hydrogen weight capacity between 180-540 kg whereas the empty truck weighs nearly 40 t. The best performance of 540 kg is reached when using bundles of light-weight type II composite cylinder bottles. Nevertheless the effective capacity of CGH₂ trucking is never 100% due to the imposed pressure equalisation with the customer tank.



Figure 6: Two types of compressed gas hydrogen trailers operated by Air Liquide in Europe: tube trailer (left side) carrying 2000-3000 m³ of hydrogen (depending on the numbers of tubes) and type II composite cylinder trailers (right side) carrying 6200 m³ of H₂ (equivalent to 540 kg). Picture courtesy of Air Liquide.

The total fleet of CGH₂ in Europe can be estimated from the fleet of Air Liquide which comprises more than 350 CGH₂ tube-trailers in operation across Europe. Taking into account the Air Liquide market share for industrial merchant hydrogen in Europe it is estimated that the total number of CGH₂ trailers in Europe is close to 1000.



3.3.2 Liquid hydrogen trucks

A super-insulated LH2 truck can transport over 6 times more than a CGH2 trailer. Linde has LH2 trucks with volumetric capacities of 15000, 41000, and 53000 litres. The weight of hydrogen transported in each of these containers is 1000, 2900, and 3750 kg respectively. Air Liquide's LH2 trucks have volumetric capacities between 40000-49000 litres, thus hydrogen weight capacities between 2850-3500 kg.

In order to estimate the total fleet of LH2 trucks in Europe there are two figures: Air Products reports 75 LH2 trucks in North America for a total liquefaction capacity of 136 short tons/day (equivalent to 123 t/day) whereas Air Liquide has 12 LH2 trucks in Europe for a liquefaction capacity of 10.5 t/day. The ratio of truck numbers to liquefaction capacity is only 0.61 trucks per t/day-capacity for Air Products in North America in contrast to a ration of 1.14 for Air Liquide. This can be explained with a 1.6 times larger volumetric capacity of trucks in North America (65000 litres) to those in Europe (40000 litres). Therefore, it can be estimated that the total number of LH2 trailers of Air Liquide, Linde and Air Products is approximately around 30 when the total liquefaction capacity will reach 26 t/day in Europe.

Blank Page



4. Fuelling stations

The most recent list of existing or planned hydrogen fuelling stations for vehicles (cars or buses) at the date of printing is shown in annex 8, a map of their distribution in Europe is shown in figure 7.

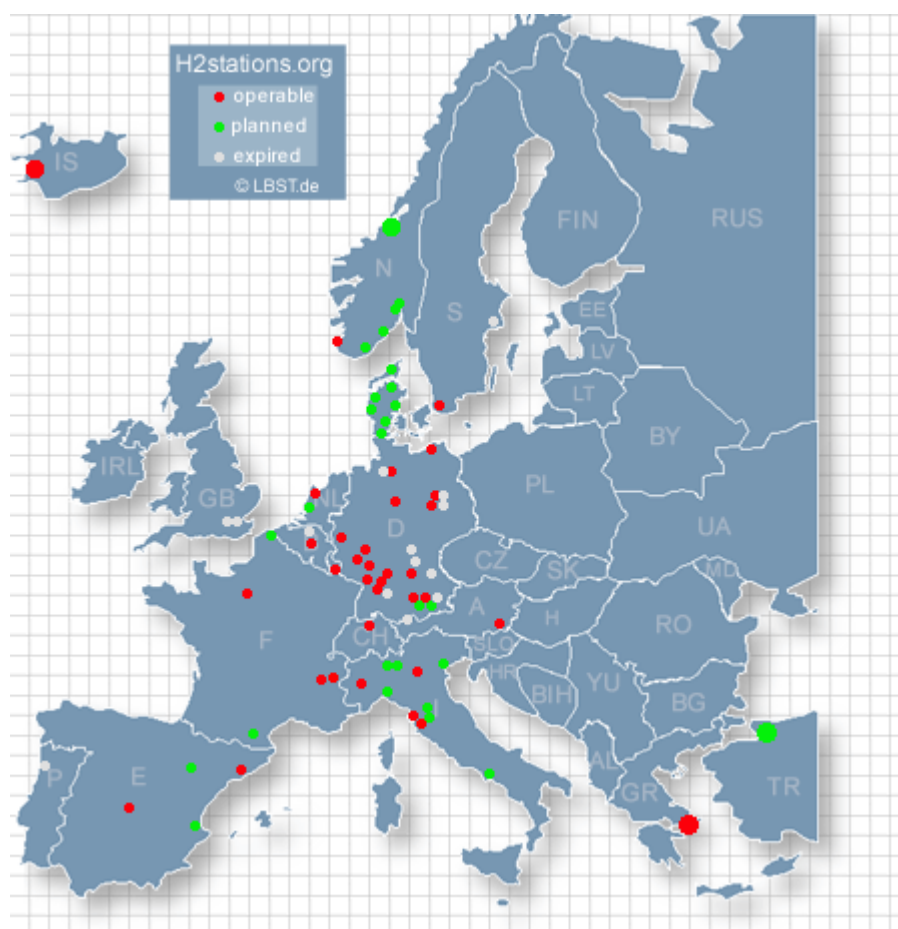


Figure 7: Overview European hydrogen fuelling stations, operable, expired or planned (LUDWIG-BÖLKOW-SYSTEMTECHNIK & BLANDOW 2007).



Although most of these stations deliver only compressed hydrogen gas (CGH₂) at 35 MPa, some of them are already upgraded to 70 MPa. Liquid hydrogen (LH₂) can also be trucked in from one of the three hydrogen liquefaction centres presently in operation in Europe. More than half of these stations have on-site hydrogen production, and more than one third are based on renewable energy sources (wind or photovoltaic solar energy together with an electrolyser, or reformation of biogas)

In addition, a number of projects trying to realise a hydrogen highway have been proposed such as the “hydrogen corridor” in Germany by Linde, and the “HyNor” project in Norway. More recently a Scandinavian Hydrogen Highway Partnership has been formed between Norway, Denmark and Sweden as illustrated in figure 8.

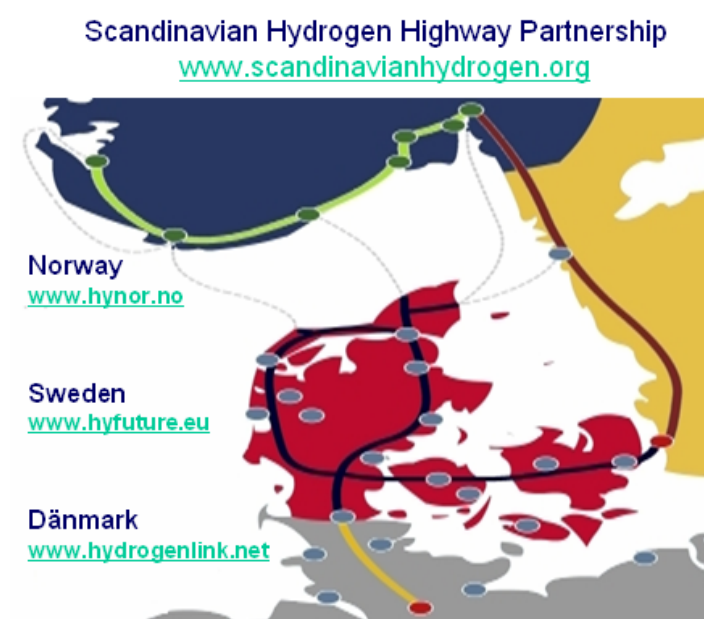


Figure 8: Outline of the planned pan-Scandinavian hydrogen highway, connecting the three countries with one highway on which a sufficient hydrogen fuelling infrastructure will be established (SCANDINAVIAN HYDROGEN HIGHWAY PARTNERSHIP 2006).



5. Conclusion

In this report the existing hydrogen distribution infrastructure in Europe has been mapped by Roads2HyCom. Nearly 1600km of hydrogen pipelines in Europe could be identified. These pipelines can be divided between 15 larger pipeline networks with single ownerships. The largest network of pipelines is operated by Air Liquide and runs across north-west France, Belgium and part of the Netherlands.

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.

There are 35 hydrogen refuelling stations currently operating in Europe of which most are located in Germany. There is, however, a large number of stations planned in Scandinavia in the course of building various interconnecting Hydrogen Hyways in that area.

Blank Page



6. References

FUEL CELLS 2000: *Worldwide Hydrogen Fueling Stations* [cited 2006-10-01]. Available from World Wide Web: www.fuelcells.org/info/charts/h2fuelingstations.pdf

LUDWIG-BÖLKOW-SYSTEMTECHNIK & BLANDOW, Volker: *Hydrogen Filling Stations Worldwide* [cited 2007-05-02]. Available from World Wide Web: <http://www.h2stations.org/>

SCANDINAVIAN HYDROGEN HIGHWAY PARTNERSHIP, [cited 2006-10-06]. Available from World Wide Web: <http://www.scandinavianhydrogen.org>

Blank Page



Annex 1 : Hydrogen pipeline lengths by region

NUTS 3	Country (= NUTS level 0)	Region (= NUTS level 1)	Region (= NUTS level 2)	Region (= NUTS level 3)	Owner	Pipeline length [km] ¹⁾
NL335	Netherlands - Nederland	West-Nederland	Zuid-Holland	Groot-Rijnmond	Air Liquide	92
NL411	Netherlands - Nederland	Zuid-Nederland	Noord-Brabant	West-Noord- Brabant	Air Liquide	50
NL342	Netherlands - Nederland	West-Nederland	Zeeland	Overig Zeeland	Air Liquide	45
sub-total						187
BE211	Belgium - Belgique - België	Vlaams Gewest	Antwerpen	Antwerpen	Air Liquide	72
BE213	Belgium - Belgique - België	Vlaams Gewest	Antwerpen	Turnhout	Air Liquide	44
BE221	Belgium - Belgique - België	Vlaams Gewest	Limburg	Hasselt	Air Liquide	11
BE212	Belgium - Belgique - België	Vlaams Gewest	Antwerpen	Mechelen	Air Liquide	9
BE241	Belgium - Belgique - België	Vlaams Gewest	Vlaams-Brabant	Halle-Vilvoorde	Air Liquide	48
BE236	Belgium - Belgique - België	Vlaams Gewest	Oost-Vlaanderen	Sint-Niklaas	Air Liquide	52
BE234	Belgium - Belgique - België	Vlaams Gewest	Oost-Vlaanderen	Gent	Air Liquide	65
BE257	Belgium - Belgique - België	Vlaams Gewest	West-Vlaanderen	Tielt	Air Liquide	20
BE256	Belgium - Belgique - België	Vlaams Gewest	West-Vlaanderen	Roeselare	Air Liquide	41
BE251	Belgium - Belgique - België	Vlaams Gewest	West-Vlaanderen	Brugge	Air Liquide	46
BE253	Belgium - Belgique - België	Vlaams Gewest	West-Vlaanderen	Ieper	Air Liquide	34
BE352	Belgium - Belgique - België	Wallonie	Namur	Namur	Air Liquide	18



NUTS 3	Country (= NUTS level 0)	Region (= NUTS level 1)	Region (= NUTS level 2)	Region (= NUTS level 3)	Owner	Pipeline length [km] ¹⁾
BE322	Belgium - Belgique - België	Wallonie	Hainaut	Charleroi	Air Liquide	46
BE325	Belgium - Belgique - België	Wallonie	Hainaut	Soignies	Air Liquide	56
BE323	Belgium - Belgique - België	Wallonie	Hainaut	Mons	Air Liquide	42
BE310	Belgium - Belgique - België	Wallonie	Brabant-Wallon	Nivelles	Air Liquide	9
sub-total						613
FR301	France	Nord-Pas de Calais	Nord-Pas de Calais	Nord	Air Liquide	105
FR302	France	Nord-Pas de Calais	Nord-Pas de Calais	Pas de Calais	Air Liquide	58
FR232	France	Bassin Parisien	Haute- Normandie	Seine Maritime	Air Liquide	4
FR413	France	Est	Lorraine	Moselle	Air Liquide	37
FR716	France	Centre-Est	Rhône-Alpes	Rhône	Air Liquide	20
FR714	France	Centre-Est	Rhône-Alpes	Isère	Air Liquide	37
FR824	France	Méditerranée	Provence-Alpes- Côte d'Azur	Bouches du Rhône	Air Liquide	42
sub-total						303
DEA24	Germany - Deutschland	Nordrhein- Westfalen	Köln	Leverkusen, Kreisfreie Stadt	Air Liquide	8
DEA1C	Germany - Deutschland	Nordrhein- Westfalen	Düsseldorf	Mettmann	Air Liquide	23
DEA11	Germany - Deutschland	Nordrhein- Westfalen	Düsseldorf	Düsseldorf, Kreisfreie Stadt	Air Liquide	25
DEA12	Germany - Deutschland	Nordrhein- Westfalen	Düsseldorf	Duisburg, Kreisfreie Stadt	Air Liquide	12
DEA14	Germany - Deutschland	Nordrhein- Westfalen	Düsseldorf	Krefeld, Kreisfreie Stadt	Air Liquide	16
DEA13	Germany - Deutschland	Nordrhein- Westfalen	Düsseldorf	Essen, Kreisfreie Stadt	Air Liquide	33
DEA31	Germany - Deutschland	Nordrhein- Westfalen	Münster	Boitrop, Kreisfreie Stadt	Air Liquide	10
DEA36	Germany - Deutschland	Nordrhein- Westfalen	Münster	Recklinghausen	Air Liquide	50
DEA32	Germany - Deutschland	Nordrhein- Westfalen	Münster	Gelsenkirchen, Kreisfreie Stadt	Air Liquide	40



NUTS 3	Country (= NUTS level 0)	Region (= NUTS level 1)	Region (= NUTS level 2)	Region (= NUTS level 3)	Owner	Pipeline length [km] ¹⁾
DEA55	Germany - Deutschland	Nordrhein- Westfalen	Arnsberg	Herne, Kreisfreie Stadt	Air Liquide	8
DEA52	Germany - Deutschland	Nordrhein- Westfalen	Arnsberg	Dortmund, Kreisfreie Stadt	Air Liquide	15
sub-total						240
ITG19	Italy - Italia	Isole	Sicilia	Siracusa	Air Liquide	6
CH012	Switzerland - Schweiz - Suisse - Svizzera	Schweiz	Région Lémanique	Valais	Air Liquide (Carbagas)	2
sub-total						8
Total Air Liquide						1351
DEE22	Germany - Deutschland	Sachsen- Anhalt	Halle	Burgenlandkreis	Linde	9
DED34	Germany - Deutschland	Sachsen	Leipzig	Leipziger Land	Linde	25
DEE24	Germany - Deutschland	Sachsen- Anhalt	Halle	Merseburg- Querfurt	Linde	23
DEE25	Germany - Deutschland	Sachsen- Anhalt	Halle	Saalkreis	Linde	17
DEE14	Germany - Deutschland	Sachsen- Anhalt	Dessau	Bitterfeld	Linde	44
DEE11	Germany - Deutschland	Sachsen- Anhalt	Dessau	Dessau, Kreisfreie Stadt	Linde	14
DEE12	Germany - Deutschland	Sachsen- Anhalt	Dessau	Anhalt-Zerbst	Linde	3
sub-total						135
UKC11	United Kingdom	North East	Tees Valley and Durham	Hartlepool and Stockton-on- Tees	Linde (BOC)	17
UKC12	United Kingdom	North East	Tees Valley and Durham	South Teesside	Linde (BOC)	18
sub-total						35
Total Linde (BOC)						170
NL335	Netherlands - Nederland	West-Nederland	Zuid-Holland	Groot-Rijnmond	Air Products	50
UKC12	United Kingdom	North East	Tees Valley and Durham	South Teesside	Air Products	5
ITD35	Italy - Italia	Nord-Est	Veneto	Venezia	Sapio	2
Total Air Products						57
SE0A2	Sweden - Sverige	Västsverige	Västra Götalands län	Stenungsund	n/a	18



NUTS 3	Country (= NUTS level 0)	Region (= NUTS level 1)	Region (= NUTS level 2)	Region (= NUTS level 3)	Owner	Pipeline length [km] ¹⁾
Total others						18
Grand Total Europe						1596

¹⁾ although sub-totals and totals for each pipeline length are deemed correct, the allocation to a region might bear an uncertainty of $\pm 10\%$



Annex 2 : Hydrogen fuelling stations in Europe

NUTS 3	Country (= NUTS level 0)	Region (= NUTS level 1)	Region (= NUTS level 2)	Region (= NUTS level 3)	Location	Project / organisations involved	H ₂ production or supply technology	Starting date
AT221	Austria - Österreich	Süd-Österreich	Steiermark	Graz	Graz	HyCentA / OMV, Linde, Magna-Steyr ...	CGH ₂ (40MPa) and LH ₂ from LH ₂ truck delivery	2005
BE242	Belgium - Belgique - Belgie	Vlaams-Gewest	Vlaams-Brabant	Leuven	Leuven	Chart Industries Inc. (Nexgen), Citensy	LNG, CNG, and Hydrogen	under construction
DK001	Denmark - Danmark	Danmark	Danmark	København og Frederiksberg kommuner	Copenhagen	Total, BVG	LH ₂ (trucked from Linde) + CGH ₂ (25 MPa) from on-site PEM electrolysis (Proton)	2003
DK00F	Denmark - Danmark	Danmark	Danmark	Nordjyllands amt	Aalborg	Hydrogen Link project	CGH ₂ from bio-fuel reforming	planned
DK00F	Denmark - Danmark	Danmark	Danmark	Nordjyllands amt	Hobro	Hydrogen Link project	CGH ₂ from on-site electrolysis, SMR, industrial H ₂	planned
DK00E	Denmark - Danmark	Danmark	Danmark	Viborg amt	Sydthy	Hydrogen Link project	CGH ₂ from on-site electrolysis using wind energy	planned
DK00D	Denmark - Danmark	Danmark	Danmark	Århus amt	Århus	Hydrogen Link project	CGH ₂ from on-site electrolysis, on-site methanol reforming	planned
DK00B	Denmark - Danmark	Danmark	Danmark	Vejle amt	Fredericia	Hydrogen Link project	CGH ₂ from on-site electrolysis, on-site methanol reforming	planned
DK009	Denmark - Danmark	Danmark	Danmark	Sønderjyllands amt	Padborg	Hydrogen Link project	CGH ₂ from on-site electrolysis, SMR	planned



NUTS 3	Country (= NUTS level 0)	Region (= NUTS level 1)	Region (= NUTS level 2)	Region (= NUTS level 3)	Location	Project / organisations involved	H ₂ production or supply technology	Starting date
DK00C	Denmark - Danmark	Danmark	Danmark	Ringkøbing amt	Ringkøbing	Hydrogen Link project	CGH ₂ from on-site electrolysis using wind energy	planned
DK00C	Denmark - Danmark	Danmark	Danmark	Ringkøbing amt	Holstebro	Hydrogen Link project	CGH ₂ from on-site biogas reforming	planned
DE600	Deutschland - Germany	Hamburg	Hamburg	Hamburg	Hamburg	CUTE project / Vattenfall, BP, Norsk Hydro	CGH ₂ (35MPa) from on-site electrolysis using green electricity from Vattenfall	2003
DE80D	Deutschland - Germany	Mecklenburg- Vorpommern	Mecklenburg- Vorpommern	Nord- vorpommern	Barth	Wasserstoff-Initiative- Vorpommern (WIV), Proton Energy Systems, Wolters- Ostseebus	CGH ₂ (21MPa) from on site electrolysis using photovoltaic solar energy	2002
DE914	Deutschland - Germany	Niedersachsen	Braunschweig	Gifhorn	Isenbüttel	Volkswagen, Solvis, Proton Energy Systems	LH ₂ (trucked from Linde), CGH ₂ (35MPa) from on-site electrolysis using photovoltaic solar energy	2000 (LH ₂) 2005 (CGH ₂)
DE300	Deutschland - Germany	Berlin	Berlin	Berlin	Berlin- Usedomer strasse	Hydrogen Competence Center / Total, BVG, Linde, MAN	LH ₂ (trucked from Linde), and CGH ₂ (25MPa) from on- site electrolysis (Proton)	2002
DE300	Deutschland - Germany	Berlin	Berlin	Berlin	Berlin- Messedamm	Clean Energy Partnership / Aral, BMW, BP, DaimlerChrysler, Ford, GHW, Linde, MAN, Opel, Norsk Hydro, Vattenfall	LH ₂ (trucked from Linde), and CGH ₂ (35MPa) from on- site electrolysis (Hydro)	2004
DE300	Deutschland - Germany	Berlin	Berlin	Berlin	Berlin-Spandau	Clean Energy Partnership / Total, Linde, BVG, TUB	LH ₂ (trucked from Linde), and CGH ₂ (35MPa) from steam reforming of LPG	2006



NUTS 3	Country (= NUTS level 0)	Region (= NUTS level 1)	Region (= NUTS level 2)	Region (= NUTS level 3)	Location	Project / organisations involved	H ₂ production or supply technology	Starting date
DED21	Deutschland - Germany	Sachsen	Dresden	Dresden, Kreisfreie Stadt	Dresden	FhG for Transportation and Infrastructure Systems	CGH ₂ from on-site PEM electrolysis, mobile unit	2006
DE21B	Deutschland - Germany	Bayern	Oberbayern	Freising	München, Franz Josef Strauss Flughafen	H2argemuc / Munich Airport, Aral, BP, E.ON, Bayerngas, Linde, BMW ...	LH ₂ (trucked from Linde) and CGH ₂ (35MPa) from on-site SMR	1999
DE212	Deutschland - Germany	Bayern	Oberbayern	München, Kreisfreie Stadt	München	BMW, Linde	LH ₂ (trucked from Linde)	1989
DE21H	Deutschland - Germany	Bayern	Oberbayern	München, Landkreis	Brunnhthal	ET (Energie Technologie)	LH ₂ (trucked from Linde) and CGH ₂ (up to 100 MPa)	1998
DE21H	Deutschland - Germany	Bayern	Oberbayern	München, Landkreis	Lohhof	LH2C / Linde hydrogen center	LH ₂ and CGH ₂ (up to 45 MPa)	2006
DE212	Deutschland - Germany	Bayern	Oberbayern	München, Kreisfreie Stadt	München	BMW (FIZ), Total	LH ₂	2007
DE111	Deutschland - Germany	Baden- Württemberg	Stuttgart	Stuttgart, Stadtkreis	Stuttgart	CUTE project / Stuttgarter Strassenbahn, SSB, Neckerwerke Stuttgart, Switch, BP	CGH ₂ (35 MPa) trucked in from SMR industrial H ₂	2003
DE111	Deutschland - Germany	Baden- Württemberg	Stuttgart	Stuttgart, Stadtkreis	Untertürkheim	Daimler Chrysler	CGH ₂	2002?
DE113	Deutschland - Germany	Baden- Württemberg	Stuttgart	Esslingen	Kirchheim unter Teck - Nabern	Daimler Chrysler	LH ₂ (trucked from Linde) and CGH ₂ (35 MPa)	1998
DE112	Deutschland - Germany	Baden- Württemberg	Stuttgart	Böblingen	Sindelfingen	Daimler Chrysler	LH ₂ (trucked from Linde) and CGH ₂ (35 and 70 MPa)	2002
DE124	Deutschland - Germany	Baden- Württemberg	Karlsruhe	Rastatt	Rastatt	Daimler Chrysler	CGH ₂	in operation
DE118	Deutschland - Germany	Baden- Württemberg	Stuttgart	Heilbronn, Landkreis	Neckarsulm	Audi	CGH ₂	in operation



NUTS 3	Country (= NUTS level 0)	Region (= NUTS level 1)	Region (= NUTS level 2)	Region (= NUTS level 3)	Location	Project / organisations involved	H ₂ production or supply technology	Starting date
DE714	Deutschland - Germany	Hessen	Darmstadt	Wiesbaden, Kreisfreie Stadt	Mainz-Kastel	Opel, Linde	LH ₂ (trucked from Linde)	2000
DE71C	Deutschland - Germany	Hessen	Darmstadt	Offenbach, Landkreis	Dudenhofen	Opel, Linde	CGH ₂ (up to 70 MPa) + LH ₂ (trucked from Linde)	2003
DE712	Deutschland - Germany	Hessen	Darmstadt	Frankfurt am Main, Kreisfreie Stadt	Frankfurt	Zero Regio project / Opel, DC, Agip, CR Fiat, City Mantova, Eni Tecnologie, Infraser, v, Hoechst, Linde, Regione Lombardia, Sapio, TÜV Hessen ...	CGH ₂ (70 MPa) from H ₂ produced as by-product of Hoechst Industry Park chemical plant, connected by a 2 km long high pressure (90 MPa) pipeline	2007
DEA21	Deutschland - Germany	Nordrhein- Westfalen	Köln	Aachen, Kreisfreie Stadt	Aachen	Ford	CGH ₂ (35 MPa)	2004
DEA11	Deutschland - Germany	Nordrhein- Westfalen	Düsseldorf	Düsseldorf, Kreisfreie Stadt	Düsseldorf	Linde	LH ₂ and CGH ₂ (up to 35 MPa) mobile station	2006
FR242	France	Bassin Parisien	Centre	Eure et Loir	La Ferté Vidame	Peugeot-Citroen PSA (test centre)	CGH ₂ (35 MPa and 70 MPa) from Air Liquide	2006
FR714	France	Centre-Est	Rhône-Alpes	Isère	Sassenage	Air Liquide	CGH ₂ (35 MPa) fixed	2002
FR714	France	Centre-Est	Rhône-Alpes	Isère	Sassenage	Air Liquide	CGH ₂ (up to 70 MPa) mobile	2006
FR301	France	Nord-Pas de Calais	Nord-Pas de Calais	Nord	Dunkerque	ALTHYTUDE project / Gaz de France, Irisbus, Hydrogenics, H2 Développement	Hythane (CNG+ up to 20% CGH ₂) at 20 MPa with H ₂ from on-site electrolysis (Hydrogenics)	2006
FR623	France	Sud-Ouest	Midi-Pyrénées	Haute Garonne	Toulouse	ALTHYTUDE project / Gaz de France, Irisbus, Air Products	Hythane (CNG+ up to 20% CGH ₂) at 20 MPa with H ₂ from on-site SMR	2006
GR300	Greece - Ellada	Attiki	Attiki	Attiki	Keratea	RES2H2 project / CRES wind park	CGH ₂ (20 MPa) from on-site electrolysis using wind energy	2005



NUTS 3	Country (= NUTS level 0)	Region (= NUTS level 1)	Region (= NUTS level 2)	Region (= NUTS level 3)	Location	Project / organisations involved	H ₂ production or supply technology	Starting date
IS000	Iceland - Island	Ísland	Ísland	Ísland	Grjóthals, Reykjavik	ECTOS project / Shell Hydrogen	CGH ₂ (44 MPa) from on-site electrolysis under pressure using hydro- and geothermal electricity	2003
ITC4B	Italy - Italia	Nord-Oveste	Lombardia	Mantova	Mantova	Zero Regio project / Opel, DC, Agip, CR Fiat, City Mantova, Eni Tecnologie, Infraser, v, Hoechst, Linde, Regione Lombardia, Sapio, TÜV Hessen ...	CGH ₂ (70 MPa) from on site SMR	2007
ITC45	Italy - Italia	Nord-Oveste	Lombardia	Milano	Arese	Lombardy Region, Centro Ricerche Fiat, Politecnico di Milano	CGH ₂ and LH ₂ with CH ₄ , GPL, Mix; H ₂ from SMR and gasifier	planned
ITC45	Italy - Italia	Nord-Oveste	Lombardia	Milano	Biccoca	AEM SpA, BMW, ENEA, Zincar Srl	CGH ₂ from on-site SMR	planned
ITC33	Italy - Italia	Nord-Oveste	Liguria	Genova	Genova	n/a	n/a	planned
ITC11	Italy - Italia	Nord-Oveste	Piemonte	Torino	Torino	City of Turin, Turinese Transport Group, Irisbus, Sapio, Ansaldo Ricerche, CVA, ENEA	CGH ₂ (35 MPa)	2005
ITD35	Italy - Italia	Nord-Est	Veneto	Venezia	Marghera	Hydrogen Park / EVC Italia, SAE Impianti, Sapio, ENEL ...	CGH ₂ and H ₂ -Methane mixtures; H ₂ from chlorine process and used for heat production; hydrogen pipeline in urban area	planned
ITE16	Italy - Italia	Centro	Toscana	Livorno	Livorno	Tuscany government, ENI, Agip	Multi-fuel station; CGH ₂ from on-site electrolysis using photovoltaic and wind energies	2006
ITE17	Italy - Italia	Centro	Toscana	Pisa	Pontedera	Fiat, ILT (PIEL)	CGH ₂ from on-site electrolysis	2003



NUTS 3	Country (= NUTS level 0)	Region (= NUTS level 1)	Region (= NUTS level 2)	Region (= NUTS level 3)	Location	Project / organisations involved	H ₂ production or supply technology	Starting date
ITE14	Italy - Italia	Centro	Toscana	Firenze	Firenze	SOL Group, Comune di Firenze, Nuvera Fuel Cells, Comune di Bologna, ENEA ...	CGH ₂ from SMR or on-site electrolysis	planned
ITE19	Italy - Italia	Centro	Toscana	Firenze	Siena	n/a	n/a	planned
ITF33	Italy - Italia	Sud	CaMPania	Napoli	Napoli	n/a	n/a	planned
LU000	Luxembourg	Luxembourg	Luxembourg	Luxembourg	Luxembourg	CUTE project / Air Liquide, Ville de Luxembourg, FLEAA, Shell Hydrogen ...	CGH ₂ (35 MPa) from tube trailer	2003
NL326	Netherlands - Nederland	West-Nederland	Noord-Holland	Groot-Amsterdam	Amsterdam	CUTE project/ Shell Hydrogen, DaimlerChrysler, GVB, Hydrogenics ...	CGH ₂ (35 MPa) from on-site electrolysis using rewable energy	2003
NL335	Netherlands	West-Nederland	Zuid-Holland	Groot-Rijnmond	Rotterdam	Shell Hydrogen	combined hydrogen & gasoline station; H ₂ supply presumably for local pipeline	planned for 2009
NO011	Norway - Norge	Norge	Oslo og Akershus	Oslo	Oslo	HyNor project / Norsk Hydro, Oslo Commune, Norgesbuss ...	CGH ₂ from electrolysis using hydroelectric power plant	2006-2009
NO032	Norway - Norge	Norge	Sør-Østlandet	Buskerud	Drammen	HyNor project / Vardar, Drammen Commune	CGH ₂ from CO ₂ neutral H ₂ production by reforming methane rich wastegas with CO ₂ capture	2006-2009
NO034	Norway - Norge	Norge	Sør-Østlandet	Telemark	Nottoden	HyNor project / Norsk Hydro, Organic Power	CGH ₂ (up to 70MPa) from on-site electrolysis using electricity from waste incineration	2007



NUTS 3	Country (= NUTS level 0)	Region (= NUTS level 1)	Region (= NUTS level 2)	Region (= NUTS level 3)	Location	Project / organisations involved	H ₂ production or supply technology	Starting date
NO034	Norway - Norge	Norge	Sør-Østlandet	Telemark	Porsgrunn	HyNor project / Heroya industrial park, Norsk Hydro	CGH ₂ from by-product chlorine-alkaline production	2006
NO041	Norway - Norge	Norge	Agder og Rogaland	Vest-agder	Grimstad	HyNor project	CGH ₂ from on-site electrolysis using photovoltaic solar energy	2006-2009
NO042	Norway - Norge	Norge	Agder og Rogaland	Aust-agder	Lyndgal	HyNor project	Trucked hydrogen	2006-2009
NO043	Norway - Norge	Norge	Agder og Rogaland	Rogaland	Stavenger	HyNor project / Statoil, Stavenger commune ...	CNG and trucked CGH ₂ (70MPa)	2006
NO061	Norway - Norge	Norge	Sør-Trøndelag	Trøndelag	Trondheim	HyTrec / Statoil, Stadtkraft, DNV	CGH ₂ from electrolysis using wind power emulator and on site SMR with CO ₂ capture	2007
PT114	Portugal	Continente	Norte	Grande Porto	Porto	CUTE project / STCP, BP, DaimlerChrysler, Hydrogenics	CGH ₂ (35 MPa) from on-site SMR	2001
PT171	Portugal	Continente	Lisboa	Grande Lisboa	Lisbon	Berlin, Copenhagen, Lisbon fuel cell bus Program	Linde supplied LH ₂ to a mobile station	1996
ES300	Spain - España	Comunidad de Madrid	Comunidad de Madrid	Madrid	Madrid	CUTE project and CITYCELL project / Air Liquide, Gaz Natural, Repsol YPF, EMT Madrid	CGH ₂ (35 MPa) from on-site SMR	2003
ES511	Spain - España	Este	Cataluña	Barcelona	Barcelona	CUTE project and CITYCELL project / TMB Barcelona, BP, Hydrogenics	CGH ₂ (35 MPa) from on-site electrolysis using photovoltaic energy	2003



NUTS 3	Country (= NUTS level 0)	Region (= NUTS level 1)	Region (= NUTS level 2)	Region (= NUTS level 3)	Location	Project / organisations involved	H ₂ production or supply technology	Starting date
ES523	Spain - España	Este	Comunidad Valenciana	Valencia	Valencia	Shell Hydrogen, Ford, Carburros Metálicos (Air Products), NTDA Energia, Enercon, Generalitat Valenciana, Iberdrola	CGH ₂ from on-site electrolysis using wind energy	2006
SE044	Sweden - Sverige	Sverige	Sydsverige	Skåne län	Malmö	Sydskraft, Hydrogenics	CGH ₂ (35 MPa) from on-site electrolysis, CNG, Hythane at 20% & 70% H ₂ in NG, Gasoline and Diesel	2003
SE010	Sweden - Sverige	Sverige	Sverige	Stockholm	Stockholms län	CUTE project / Busslink, Fortum AB, Hydrogenics ...	CGH ₂ (35MPa) from on-site electrolysis using hydroelectricity	2003
CH033	Switzerland - Schweiz - Suisse - Svizzera	Schweiz	Nordwestschweiz	Aargau	Lenzburg	Esoro, SL Gas (Messer)	CGH ₂ (30 MPa) from tube trailer or on-site production	n/a
UKH33	United Kingdom	East of England	Essex	Essex CC	Hornchurch	CUTE project / London Buses, Daimler Chrysler, BOC	CGH ₂ vaporized and compressed from LH ₂ trucked in, underground LH ₂ storage	2005
TR421	Turkey	Dogu Marmara	Kocaeli	Kocaeli	Gebze	H2 Energy Park / Turkish SPO, TUBITAK MRC Energy Institute, Universities, Turk DEMIRDOKUM, FORD OTOSAN, TOFAS, Ozmak	CGH ₂ from fuel reforming and from on-site electrolysis using renewable energy	2006

Sources: LUDWIG-BÖLKOW-SYSTEMTECHNIK & BLANDOW 2007 (*stations no more in operation have been omitted*)
'FUEL CELLS 2000' 2006 (*potential sites not yet planned have been omitted*)