European Integrated Hydrogen Project [www.eihp.org]

EIHP

Proceedings

of the Mid-Term Assessment Workshop of the

European Integrated Hydrogen Project - Phase II [EIHP2]

Proceedings
Volume 2
Breakout Session
Refuelling Station

held at the European Commission's

CCAB - Centre Albert Borchette

Brussels, 02 October 2002

WP2 Refuelling Station - Breakout Group - Topics & Contr.

Moderators: Henrik Andersen, Christian Machens

- **14:10: “Challenges in development of an infrastructure in Europe - Experience from CUTE ” (M. Jones, BP)**
- **14:30: “Development of a Code for H2 Vehicle Refuelling Stations” (J. Barron, Shell)**
- **14:50: “Hydrogen Filling Station Based on Water-Electrolysis” (Ch. Machens, Vandenborre Technologies)**
- **15:10: “Hydrogen Filling Station Based on NG Reforming” (H. Andersen, Norsk Hydro)**
- **15:30: “Liquid Hydrogen Filling Station” (L. Allidiers, Air Liquide)**
- **15:50: “Gaseous Hydrogen Filling Station” (P. Bout, APCI)**
- **16:10: General discussion and formulation of conclusions/findings**

WP2 Refuelling Station - Breakout Group - Summary 1

Session notes and remarks by Dr. Jeff Seisler, ENGVA

A variety of fuelling options for hydrogen were presented and discussed.

These included:

- Hydrogen fuelling on existing petrol stations
- Hydrogen station based upon water electrolysis
- Hydrogen filling station based on natural gas reforming
- Liquid hydrogen filling station
- Gaseous hydrogen filling station

WP2 Refuelling Station - Breakout Group - Summary 2

There were several issues that are similar for each of the options on fuelling stations:

- First cost of the station. Electrolysis would add about kEuro.400-500 for a station that would have a compressor installed (such as might be for CNG). Current natural gas reformation technology also would add about kEuro. 400-500 to a normal compressor station (based on CNG). One element cost reduction relates to economies of scale; another will relate to fuelling station design strategies. Both of these will be important among the options that were discussed.
- Building codes and fire codes are of concern, for physical distances that are required between equipment, habitation areas, compressors, storage, etc. These affect the cost of fuelling stations, the design, and the areas (downtown; rural) that stations can be installed.

WP2 Refuelling Station - Breakout Group - Summary 3

There were several issues that are similar for each of the options on fuelling stations (cont.'d):

- Size of 'footprint'. Many of the fuelling station systems are large (i.e. package compressor system with electrolysis ~ 15 metres long). If the equipment is too big, it will not fit into areas in more congested urban areas.
- Transport of the fuel is an important issue. Cryogenic fuels (LNG, LH_2) carried by truck increase in cost as the distance travelled increases. Truck transport of gaseous fuel is challenging because the lack of energy density decreases the fuel capacity of a truck or train. The economics and physical aspects of such transport are important.

WP2 Refuelling Station - Breakout Group - Summary 5

Remarks:

One thing that was not mentioned that I think is going to be important is for hydrogen vehicles (unlike NGVs): H_2 vehicles will be dedicated (H_2-only) vehicles. The penetration rate of fuelling stations is going to have to be much more significant and widespread and quicker to satisfy the fuel needs of growing numbers of drivers. With CNG, we can 'suffer' through having less concentration of stations because many of the vehicles are bi-fuel and can use petrol as well. Thus the rapid need for high volumes of stations is diminished, thus elongating the time, and thus the economics/costs of building the fuelling infrastructure. In turn this situation affects the overall strategy as to which customers are approached: fleets only; commuters; or some combination. This would make for an interesting study for both natural gas and hydrogen, both gaseous and cryogenic.

As I said in my closing statement, the future is a big place. It's going to take a long time to get there and the trip is going to be expensive.

Mid-Term Assessment Workshop

Brussels
02 October 2002

Breakout Group Sessions
WP2 Presentation by:
James Barron

Hydrogen Vehicle Refuelling Stations

Development of a Code for Vehicle Refuelling Stations

WP2 Group Objective:

- Develop code for CGH_2 refuelling stations as first priority:
  Supply sources of H_2 Hydrogen:
  - On-site generation eg electrolyser, reformer
  - 'Trucked-in' CGH_2 or LH_2; pipeline

- Develop code for LH_2 refuelling stations as second priority

- Codes to be recommended to become ISO Standards

Scope of Code: CGH2 Vehicle Refuelling Stations

Main Plant Components:

- Compression system
- Buffer storage system
- Dispenser to hose refuelling nozzle

Contents of Code:

- Design (including installation on existing service stations)
- Hazardous areas and zones, isolation distances
- Construction
- Operation and Maintenance

Reference Documents considered in preparation of Draft

- EIGA Document 15/96: Gaseous Hydrogen Installations
- NFPA 50A: Standard for Gaseous Hydrogen systems at Consumer Sites
- German TRG 406 (Draft): CGH2 Refuelling Stations
- ISO 15916: Basic considerations for the safety of hydrogen systems

Progress plan for development of CGH2 Code

- Draft prepared & circulated to WP2 Group (August 2002)
- WP2 Group meeting held 18 & 19 Sept 2002 in Amsterdam to discuss Draft
- Review of Hazardous areas, zones & isolation distances also referred to WP5 Group for comment on selection & determination
- WP2 Group meeting 2 Oct 2002 in Brussels to discuss follow-up action items arising from meeting on 18 & 19 Sept 2002
- Target to complete Drafts within EIHP2 Project duration

VANDENBORRE
HYDROGEN SYSTEMS

EIHP2 Mid-Term Assessment workshop
Brussels, 02nd Oct. 2002

„Hydrogen filling stations based on water electrolysis“

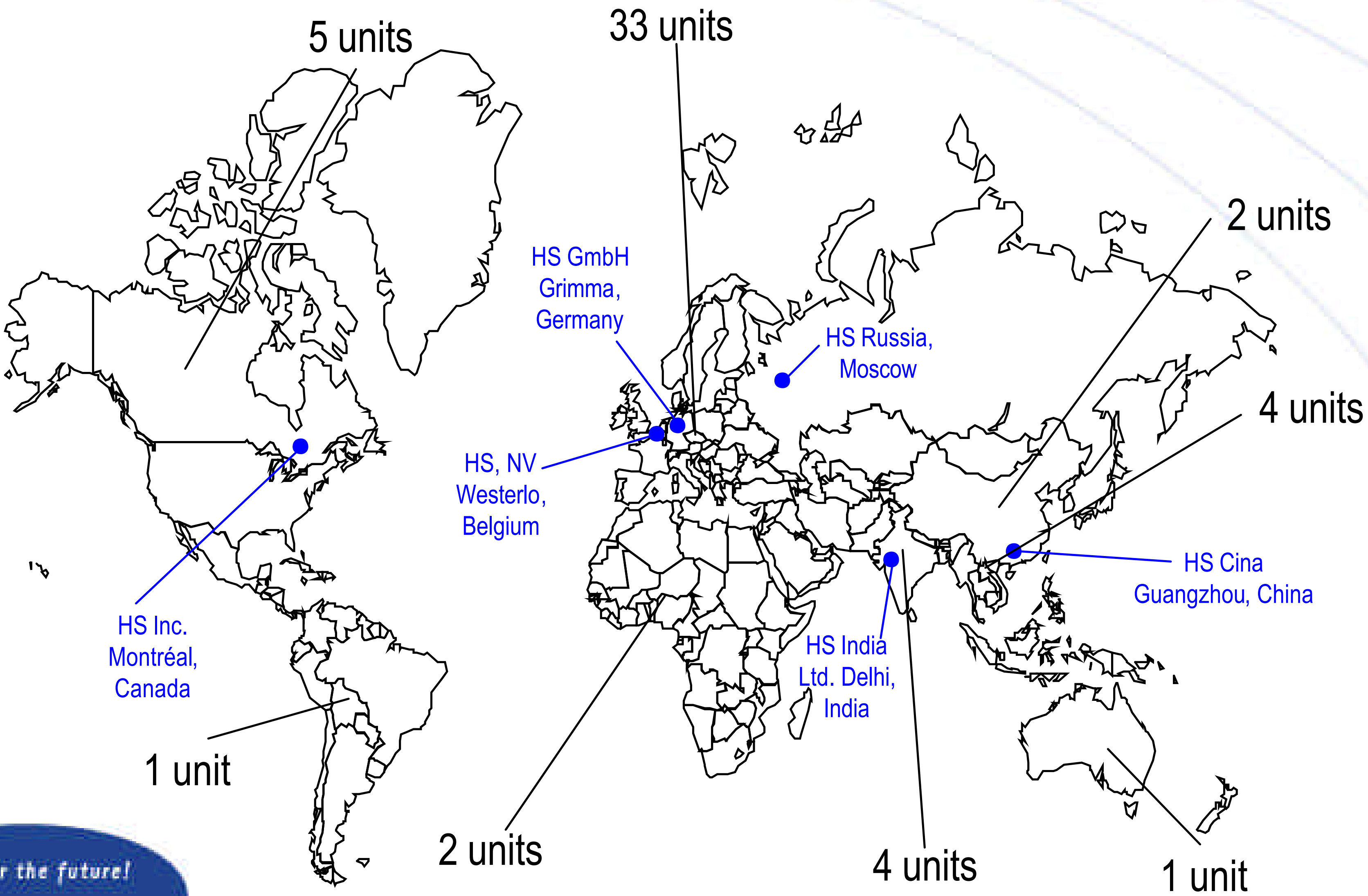
by

Christian Machens

Energy for the future!

VANDENBORRE HYDROGEN SYSTEMS

Worldwide locations and units in the field



Energy for the future!

What is a filling station ?

- Location where vehicles (FCV / ICEV) can be fuelled with Hydrogen (in this case CGH_2 > 200 bar)

- Standardised refuelling procedure

- Standardised safety aspects (Equipment, safety-distances, standards)

- Standardised Product Quality (also P, %, T, RH, ...)

- Standardised metering system

- Standardised maintenance

Overview on standards

	CNG	LNG	CH2	LH2
Gas supply	ISO 15403	NF EN 1160 PREN 1532 PREN 13645 EN 1473	ISO 14687 ISO WG 7 ISO WD 15916	ISO 14687 ISO WG 7 ISO WD 15916 ISO WG 2 ISO/WD 13986
Refuelling Station	PREN 13638 EN 13423	NFPA 59 A NFPA 497	ISO WG 4	WG 3 ISO WG 15594
Dispenser metering	Under construction by OIML			
Vehicle installation	Regulation 110 ISO 15501	NFPA 57 SAE 2323 SAE J2343		
Vehicle cylinder	ISO 11439	EN 1251 EN 1252 EN 12213 EN 12300 PREN 12456	ISO WG 6 ISO 15869	ISO WG 1 ISO 13984 ISO 13985
Vehicle refuelling coupling	ISO FDIS 14469	No standard available	ISO WG 5 ISO/AWI 17268	
Vehicle Components	ISO 15500	NF EN 12065 UNE EN 12066 UNE EN 12308 NF EN 12567 EN 1626 EN 1797 EN 12434		

Source: Ballast Nedam

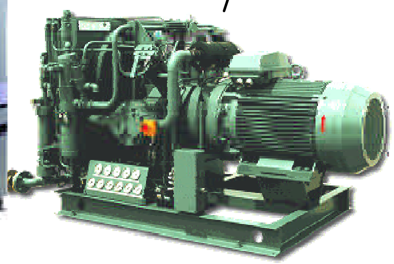
VANDENBORRE HYDROGEN SYSTEMS

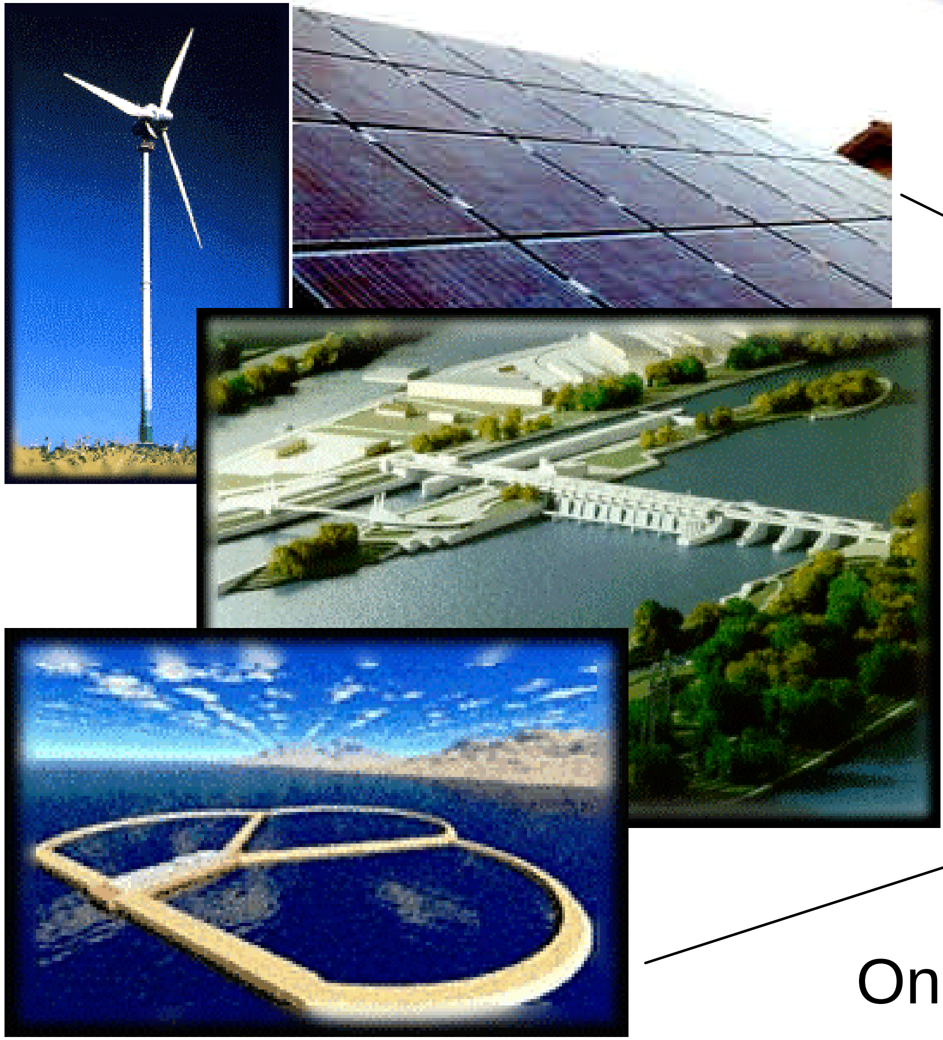
Filling station for Compressed Gaseous Hydrogen (CGH_2) produced on-site by water-electrolysis:

(CUTE standards)

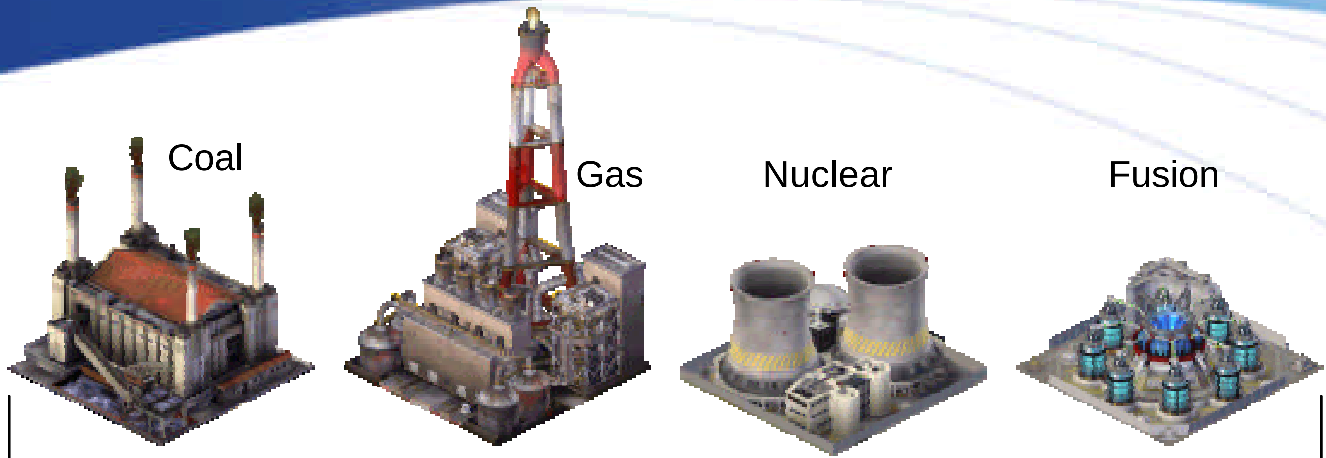
Electrolyser -> Compressor -> Storage ->Dispenser

Electrolyser	Compressor	Storage	Dispenser
(25 bar)	(345 bar)	(300 bar)	(> 200 bar)
ISO 197	ISO 197	ISO 197	ISO 197





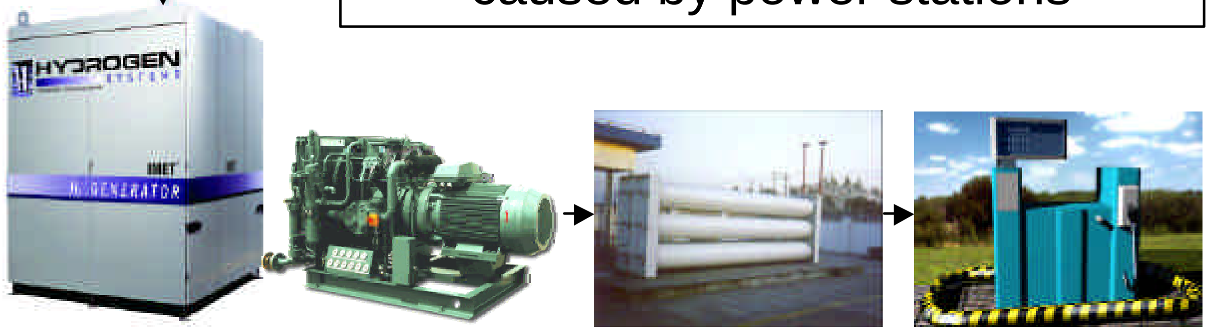
Only water – electrolysis can produce H_2 without pollution !



Peakshaving surplus power use

Only water-electrolysis can make use of surplus electric power caused by power stations

FCV / ICEV



To be achieved:

- Development of specific standards for on-site production
- More demonstration projects (e.g. CUTE)
- Information to the public
- Legislation to ensure support of H_2 – vehicles
- Acknowledgement of H_2 as a fuel

European Integrated Hydrogen Project - Phase II

Mid-Term Assessment Workshop

Brussels
02 October 2002

Breakout Group Sessions
WP2 Presentation by:
Henrik Andersen – Norsk Hydro

Natural Gas Reforming

NG Reforming – Basic Requirement

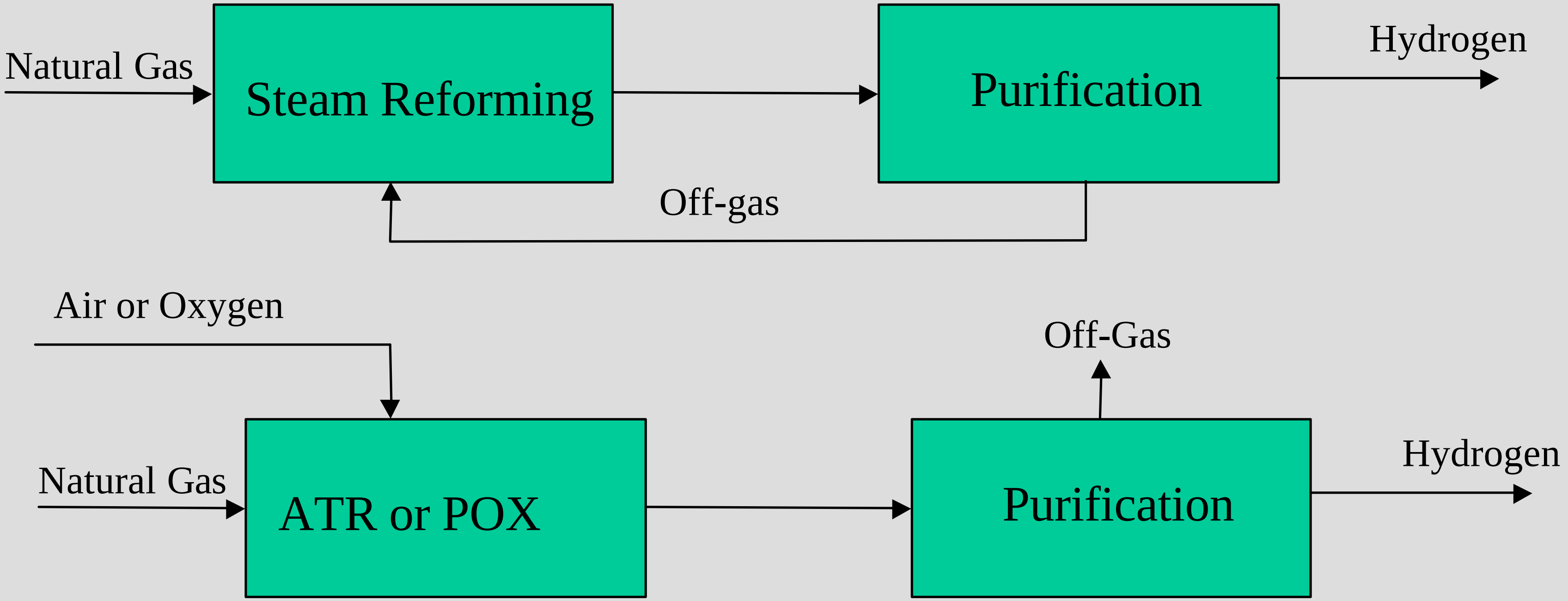
- Quality
  - H2 quality
  - Appereance
- Safety
  - Build-in safety features
- Environment
  - Emissions
- Cost
  - Efficiency
  - Compactness

NG Reforming – Efficiency

Reforming : $CH_4 + 2H_2O = 4H_2 + CO_2$;	0.4 Nm3 NG/Nm3 H2
Electrolysis : $H_2O = H_2 + 1/2O_2$;	4.0 kwh/Nm3 H2

• NG reforming :	75-80% (HHV)
• Water-Electrolysis :	80-85% (HHV)
•Power production from natural gas :	~ 50% (HHV)
•Total chain-efficiency:	40-45% (HHV)

NG Reforming – Technology diversity



NG Reforming – Public Acceptance

- From Industry to the Public

NG Reforming – Hydrogen Quality

- Preferred purification technology is PSA (Pressure Swing Adsorption)
  - Efficiency, cost and size is a function of H2 quality

Hard Targets:
- CO below 2 ppm
- CH4 below 1 ppm
- Inerts below 0.5%

NG Reforming – Emissions

Emissions	Steam Reforming	ATR
To Air	NOx Steam CO2	Offgas: CO2
To earth	Process water Spend catalyst	Process water Spend Catalyst

NG Reforming – Safety Issues identified during RRR

- Undesired catalytic side reactions
  - Cock-formation
  - Methanisation
- High Temperatures
  - Steam reforming operates at 800-900 deg.C
- Combustion and reaction integrated
  - PSA offgas is used as fuel
  - Sensitive to changes in fuel Wobbe number
- High degree of heat integration
- Sensitive to natural gas quality
  - Sulphur, higher hydrocarbons, CO_2 etc
    - Sulphur deactivates catalyst

Mid-Term Assessment Workshop

Brussels
02 October 2002

Presentation by
Laurent ALLIDIERES
Air Liquide
Division Techniques Avancées

LH_2 Refueling Stations

AIR LIQUIDE
100 years. A pioneering inspiration

Benefits & drivers for hydrogen fuel

- Environmental benefits: cleaner fuels with less emissions (NOx, particulates, CO_2…)
  - Local impact: air quality
  - Global impact: limitation of greenhouse gas effect

- Diversified energy sources
  - Security of supply
  - Remote energy supply
- Higher efficiency to improve natural resources utilization

Potential higher efficiency « well to wheel » of fuel cells:

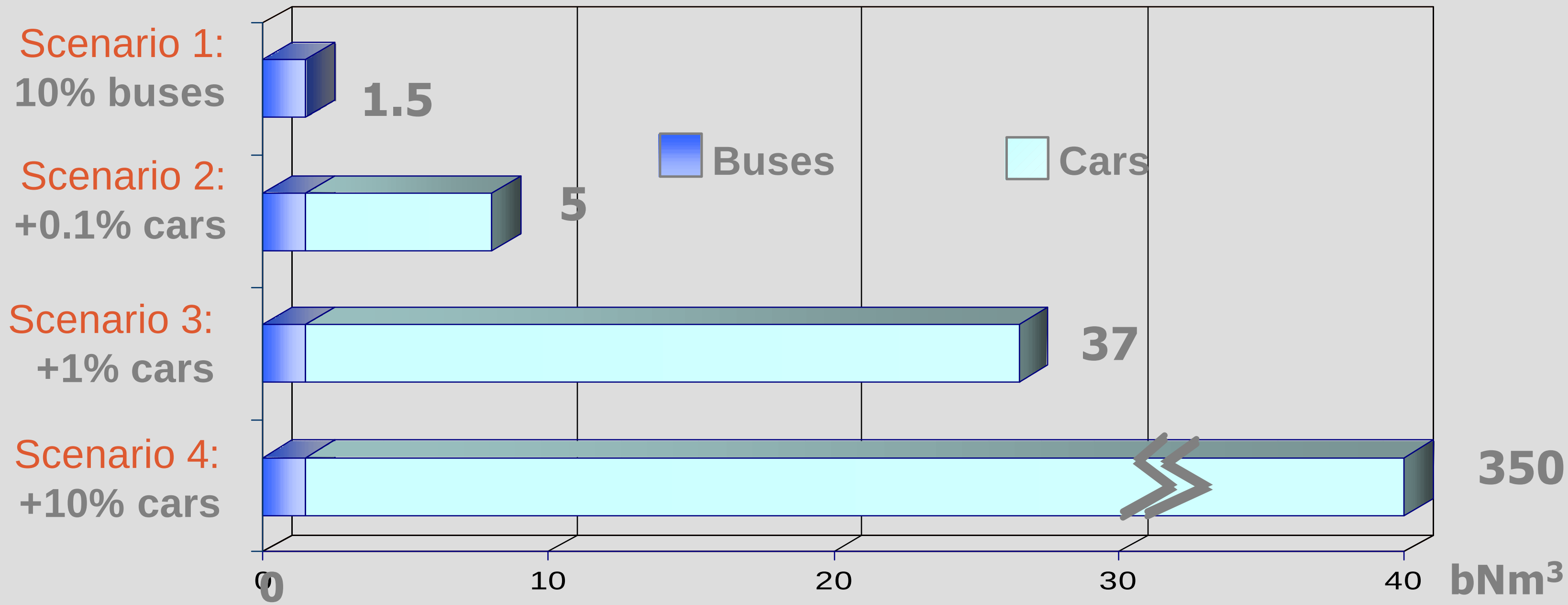
	Well to tank	Tank to wheel	Total
ICE	88%	16%	14%
FC	58%	48%	28%

ICE: Internal Combustion Engine = car **FC**: Fuel Cell

Toyota Source

Hydrogen for transportation: potential market

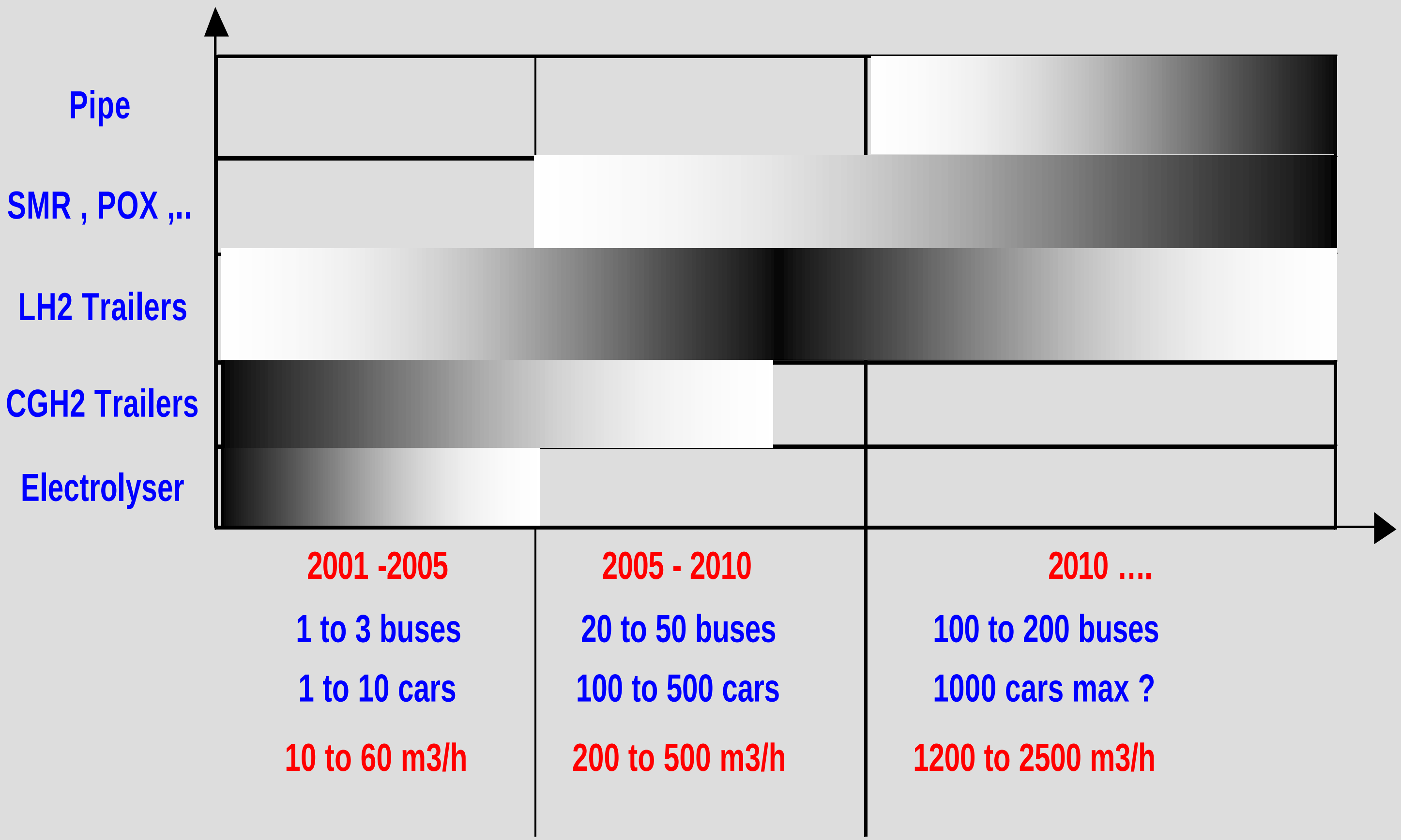
Hydrogen consumption scenarios for transportation (2010's)



WW energy requirement for transportation : 1600 millions TOE

WW H2 production : 540 bNm3 = 140 millions TOE

Supply chain scenario (1)



Three phase growth model

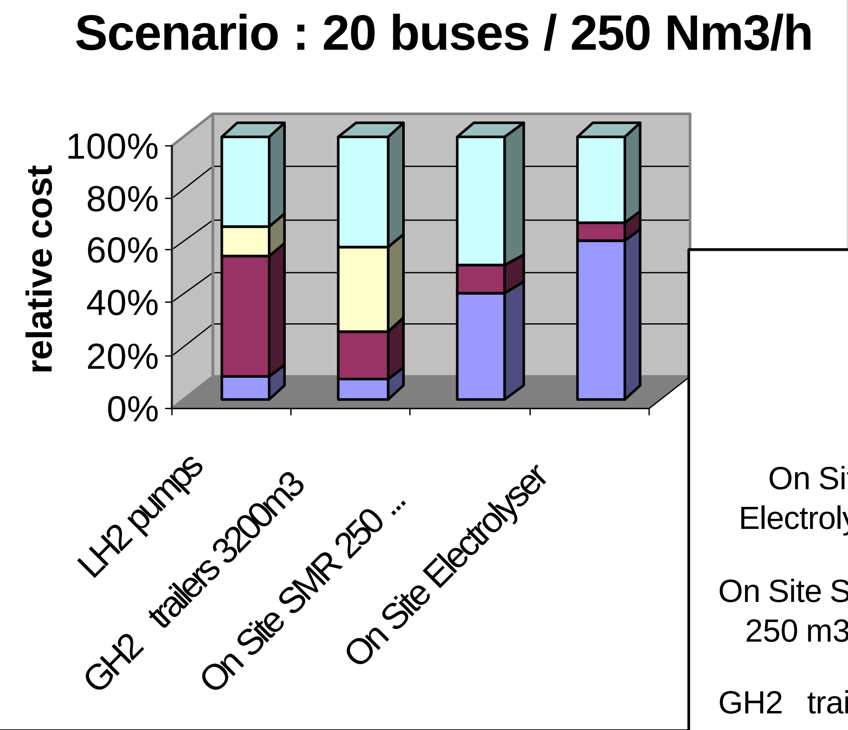
Today	Today + 5 to 10 years	Today + 10 to 15 years
Hydrogen in industrial process	**Hydrogen in industrial process** + **as a fuel for captive fleets**	**Hydrogen in industrial process** + **as a fuel for captive fleets** + **for cars**

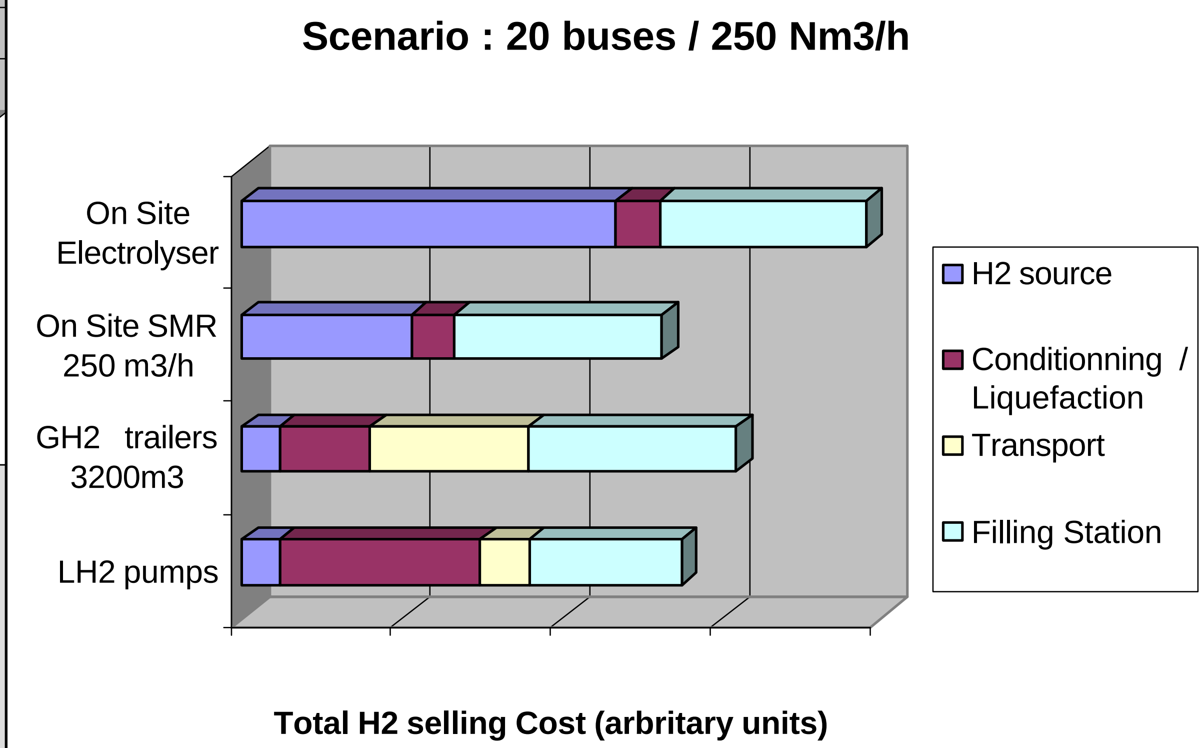
Technology → (Today to Today + 5 to 10 years)

Outsourcing → (Today to Today + 5 to 10 years)

Large scale pilots → (Today + 5 to 10 years to Today + 10 to 15 years)

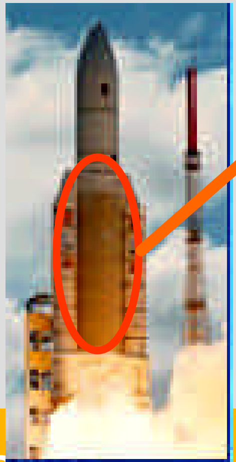
Supply chain scenario (2)



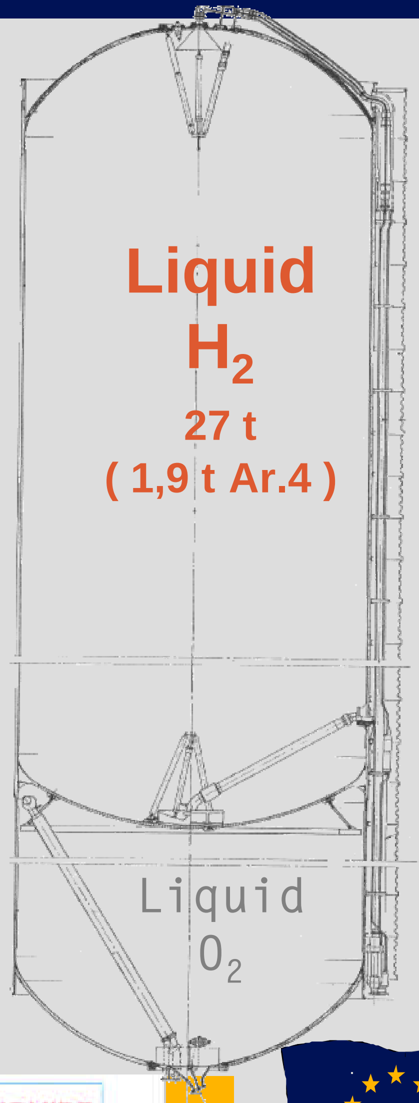


Hydrogen as a fuel for the space industry

Ariane 5 ↓→



- Energy / weight ratio liquid hydrogen
- H2 reaction with oxygen to provide propulsion



AIR LIQUIDE

Various scenarios

GH_2 source :
pipeline or large SMR > 30 000 m³/h

Liquefaction 10 t/d

Transport ST LH_2

Refueling Station
- LH2 tank
- LH2 pump
- Dispenser

Filling center 200 b

Transport TT GH_2 200 b

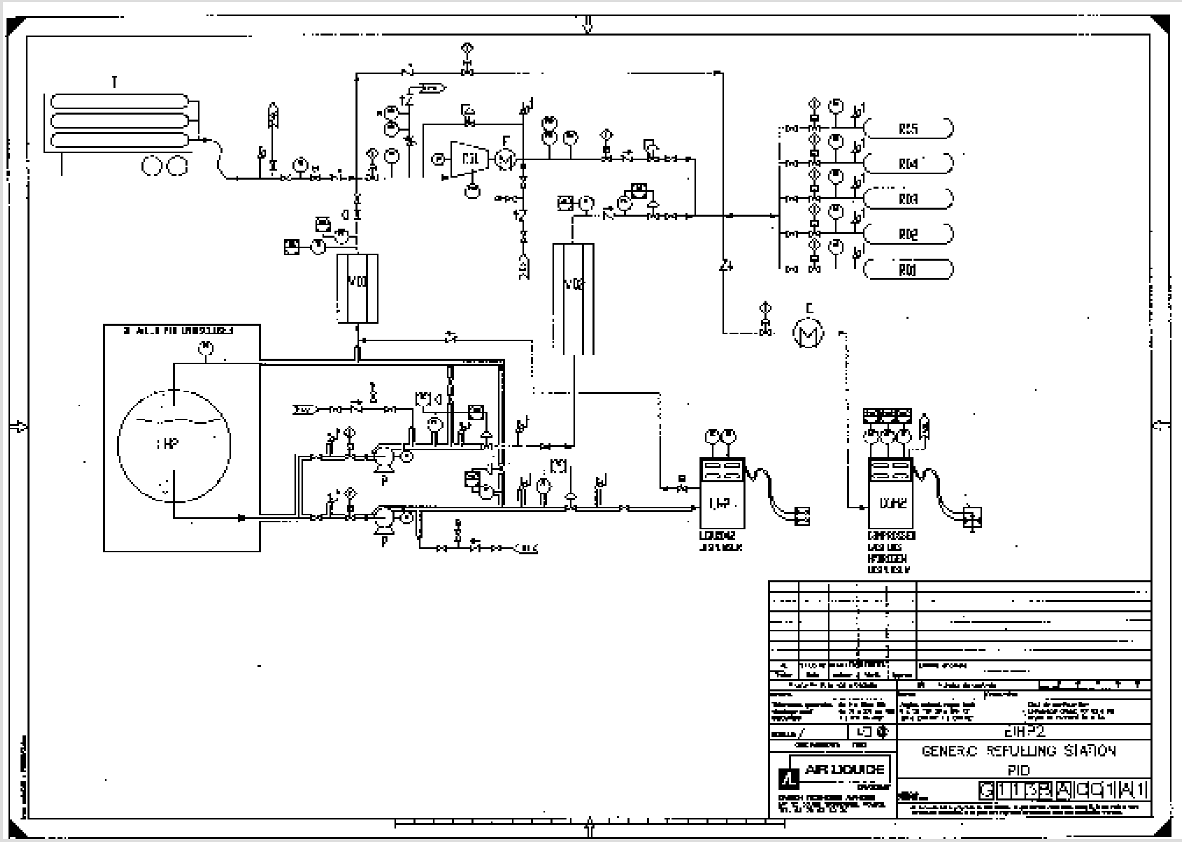
On site SMR or Electrolysis 250 m³/h

Refueling station
- CGH2 storage
- Compressor
- Buffer
- Dispenser

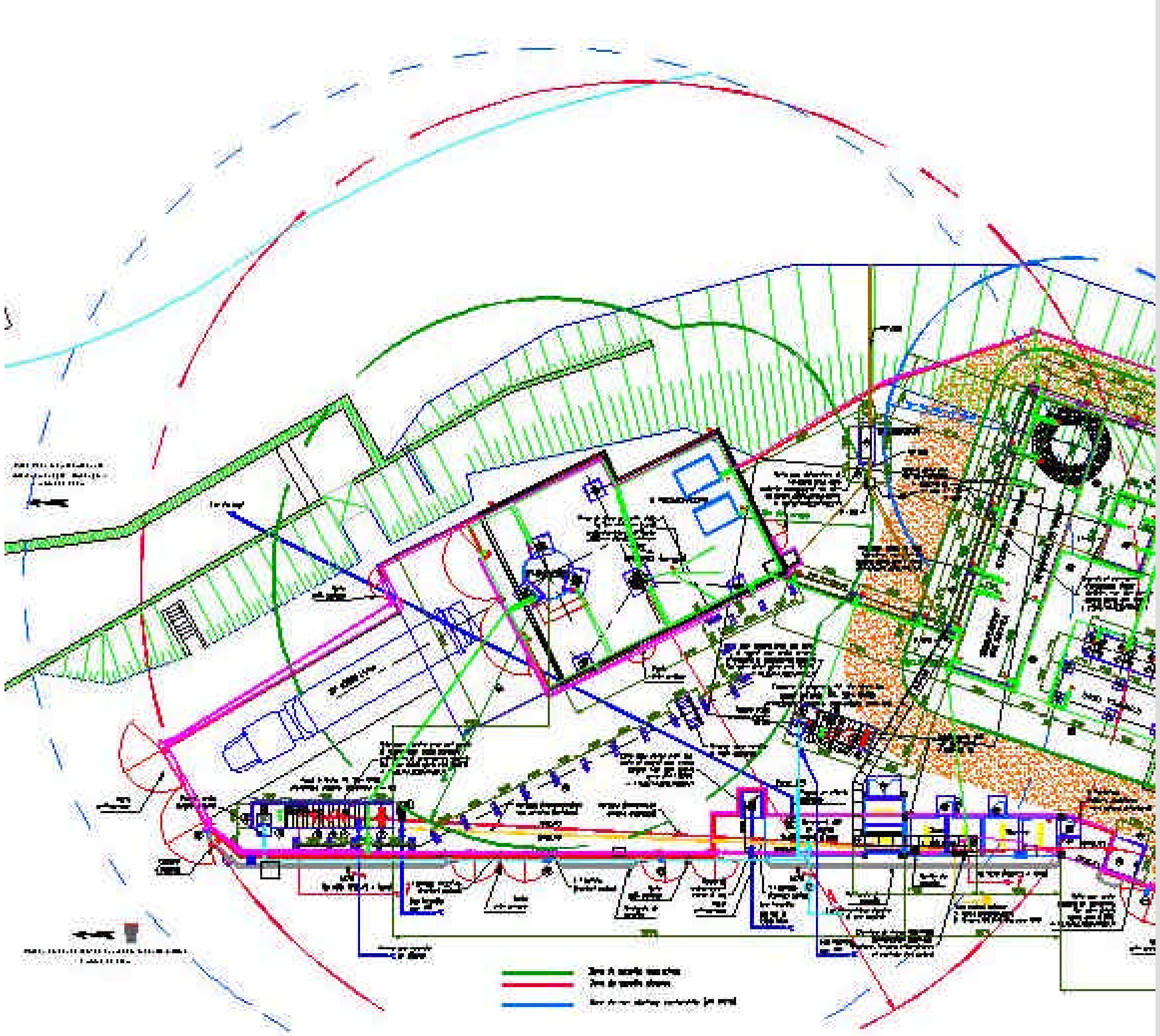
Vaporization

The liquid Hydrogen fuel station concept

- LH_2 has a legitimacy in the H_2 well to wheel supply chain scenarios
- A significant advantage is the possibility of having on the same LH_2 supply mode distribution for simultaneous gaseous and liquid dispensers
- This possibility is already illustrated in projects in Munich / Berlin (End 2002) / London (2003) and others.



Current situation in France for industrial LH2



- Current safety distances for LH_2 "stations" in France
  - 8m : No man's land
  - --- 15m : heat resistant material. Enclosure limit
  - --- 30m : "Dangerous area"
  - --- 35m : No Hydrocarbon storage
  - 70m : No public building
  - ...

Point of view of French authorities

- « Do not confuse norm and local regulation »
- « We will review EU proposals »
- OK to reconsider safety distances evaluations and new product / technology developments
- Open to underground LH_2 (cryogenic) storages
  - Not recommended in EN13458 and ISO TC220 : No actual study has ben done.
  - « Natural » protection against vandalism and potential terrorist attacks
  - Potential opportunity for safety distances reduction

How to go one step further in EIHP

- Review safety studies based on a VALIDATED simulation code
  - Diphasic phase,
  - Condensation and solidification of air,
  - Diffusion of H_2 in air / soil
  - BLEVE
- Dispenser / user interface review must be done
- Continue work on LCGH2 draft for regulation
- One clear challenge
  - Industrial Hydrogen ⇒ Hydrogen in everyday's life
- LH2 underground storages
  - Safety studies and tests are necessary
  - Will be done but not within EIHP 2 scope => Middle term development

Projects Feedback

- Air Liquide activities in
  - Europe
    - CUTE and SASSENAGE PILOT PLANT
    - PP available for public relation end of this year
  - US
    - Under development
  - Japan
    - NEDO / Tokyo Area
  - Others
    - Cluster activities
- Feedback in Y2003
  - ...

↑ *H2 Testing zone in Air Liquide DTA*

Conclusion

← CGH_2 dispenser

↓ CGH_2 refuelling station

Technology is more mature than regulation…

Mid-Term Assessment Workshop

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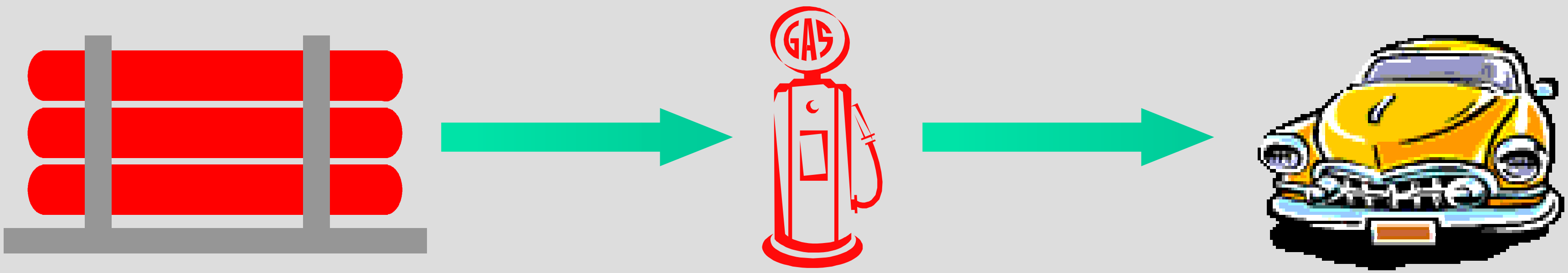
Presentation by
Peter Bout

Gaseous Hydrogen Filling Station



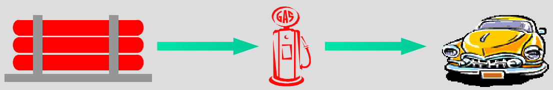
Production, Compression & HP Storage

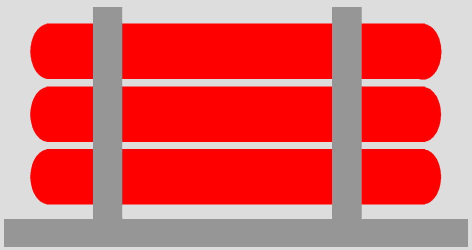
Dispenser

Vehicle Fuelling

WP 2.2	**Station components to be harmonised**	(draft under discussion)
WP 2.4	**Introduction of new layouts & technologies**	(to be started)

Gaseous Hydrogen Filling Station





Production, Compression & HP Storage

CGH from ~ Electrolysis

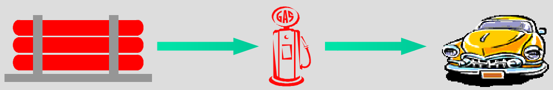
~ Reformer

~ Solar

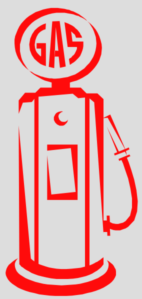
~ etc.

In general, known applications to be made suitable for this application.

WP 5
Risk assessment
(preliminary discussions)



Dispenser



Issues to be resolved

- **Design considerations**
  - ~ **Earthing**
  - ~ **Leak prevention/detection**
  - ~ **Dispenser/vehicle communications** (temperature control)

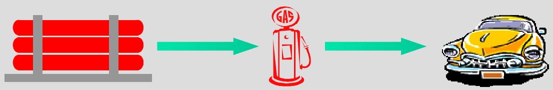
b) **Flowmeter**
  - ~ **Accuracy** (wide & rapidly changing pressure range)
  - ~ **Suitable for hydrogen**

c) **User interface/operation**

WP 2.2
Station components to be harmonised
(draft under discussion)

WP 3.3
Approval of CGH connector

WP 3.4
Interface with ISO TC197



Vehicle Fuelling

Issues to be resolved

- **Tank approval**
  - ~ **Safety tests & design standards**

b) Dispensing standards for

- ~ **Safety distances & training**
- ~ **Fail safe connection** (mechanical & communications)
- ~ **Fill strategies** (repeatable fills regardless of vender outlet)

c) Acceptance by the public

WP 2.2
Station components to be harmonised
(draft under discussion)

WP 3.2
CGH refuelling procedures

WP 4.5
Approval of components & vehicles