NoE "HySafe“ Recent Results of Internal Research Projects

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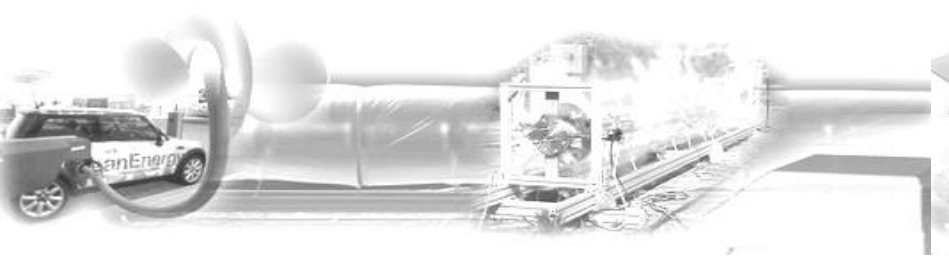
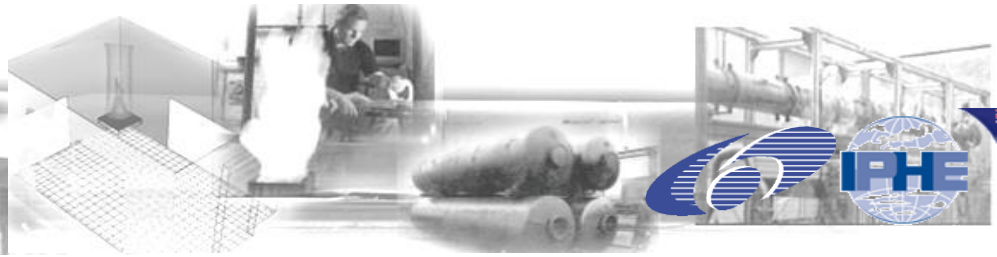
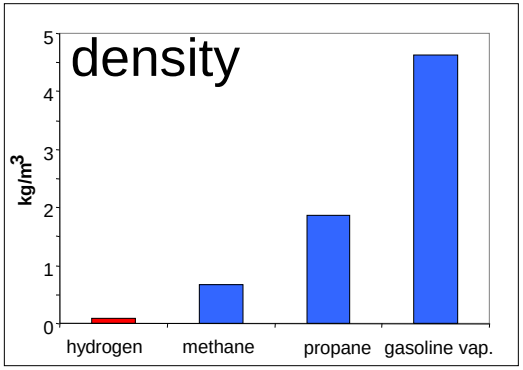
23 Oktober 2008, Standards and Safety Workshop, H2 Expo, Hamburg, Germany

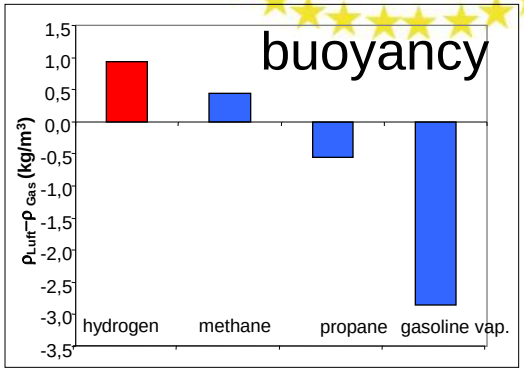


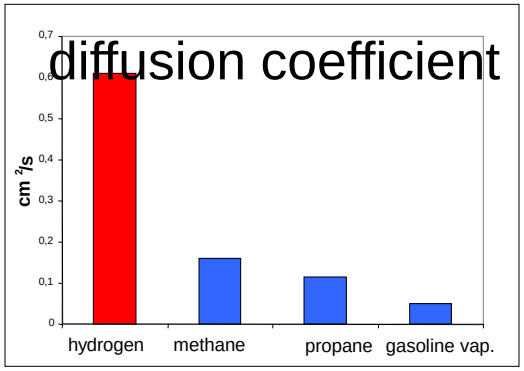


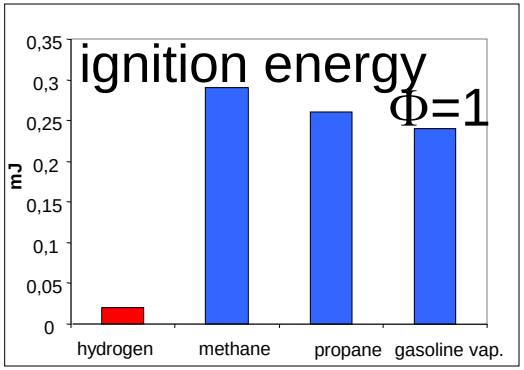
Motivation

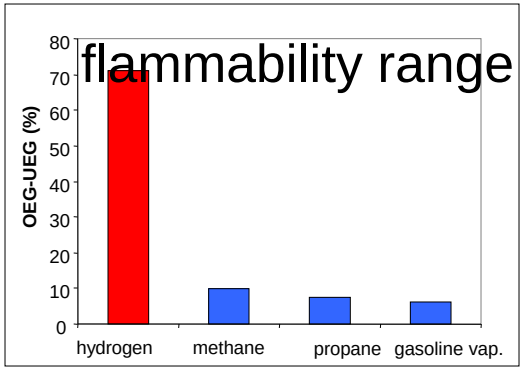
Safety relevant properties of - hydrogen
- methane
- propane
- gasoline vapour

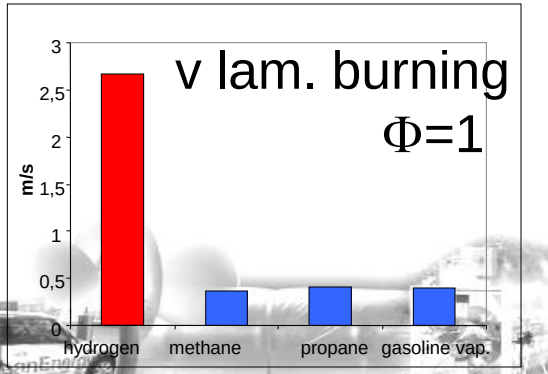


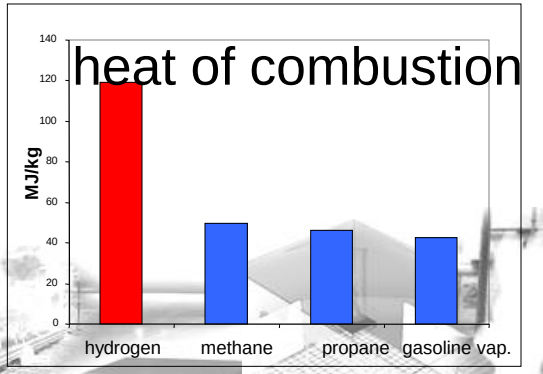


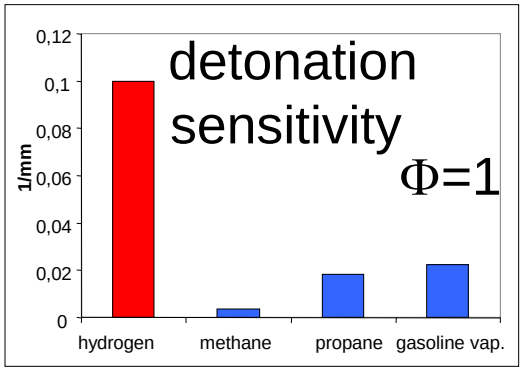












NoE Objectives

NoE HySafe Objectives

- strengthen and focus, **integrate** fragmented **research** on hydrogen safety
  → competitive scientific and industrial community
- Promoting **public awareness and trust** in hydrogen technologies
- development of an excellent **safety culture**

General Goal

Contribute to a **safe transition** to a **sustainable development**
in Europe by facilitating the **safe introduction of hydrogen** technologies / applications

Some HySafe details

Consortium

- 24 partners from 12 European countries
  incl. Russia (Kurchatov Institute) and one Canadian partner (University of Calgary)
- 13 public research organisations, 7 industrial partners, 5 universities
- ~150 scientists involved

Budget

Total > 13 M€ with a EC grant of max. 7 M€

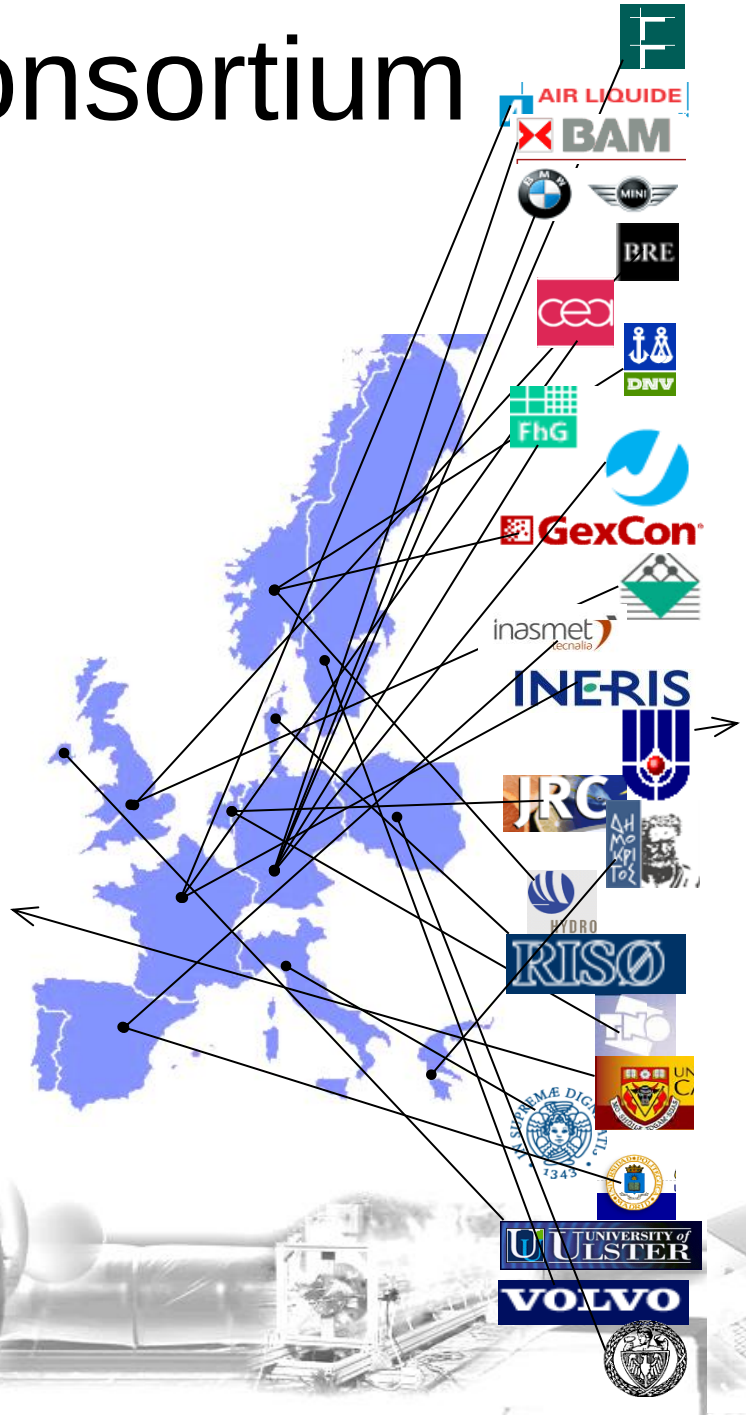
Time schedule

network/project start: 03/2004

subsidised max. duration: 5 years

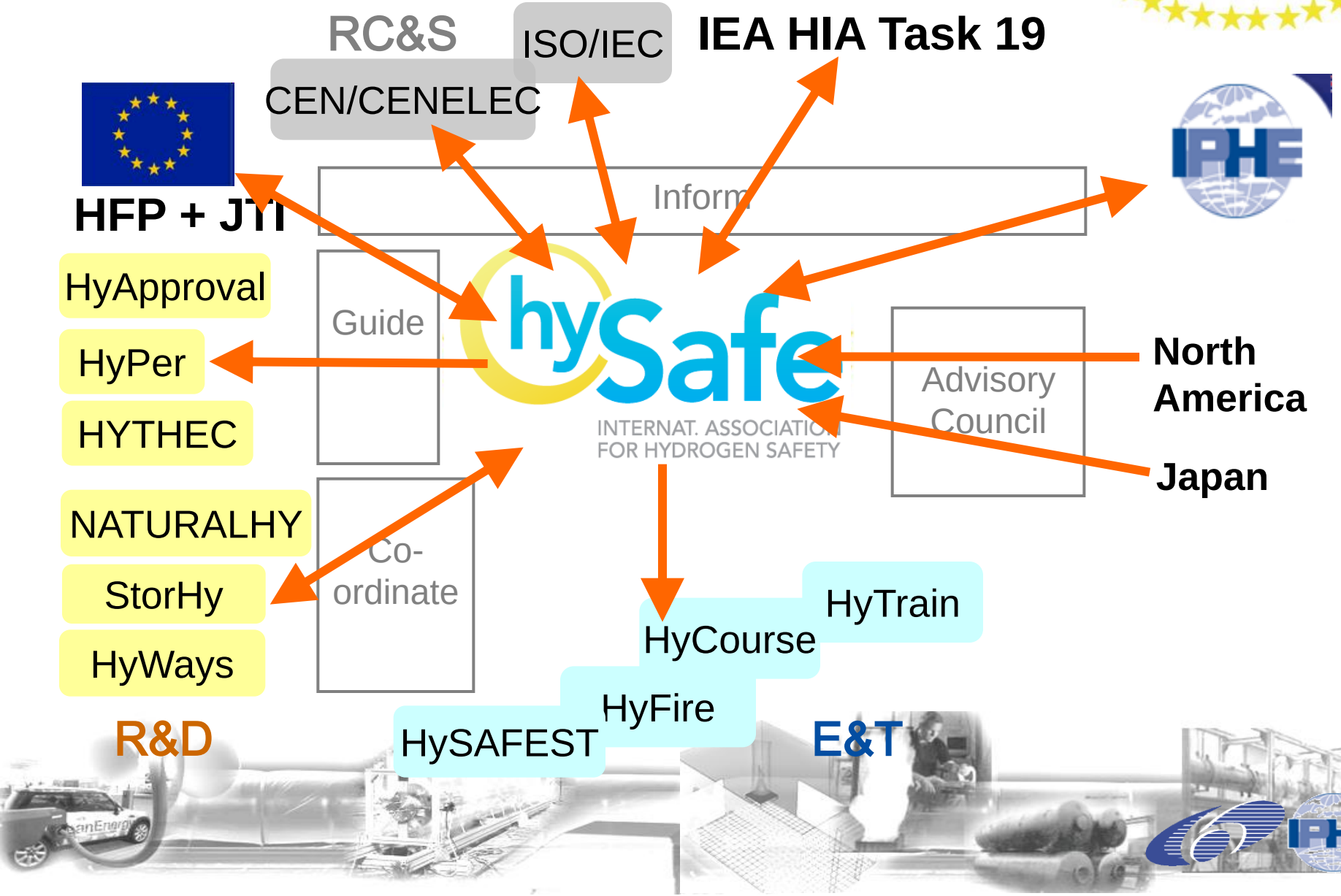
→ 02/2009 activities transferred to the International Association “HySafe”

Consortium

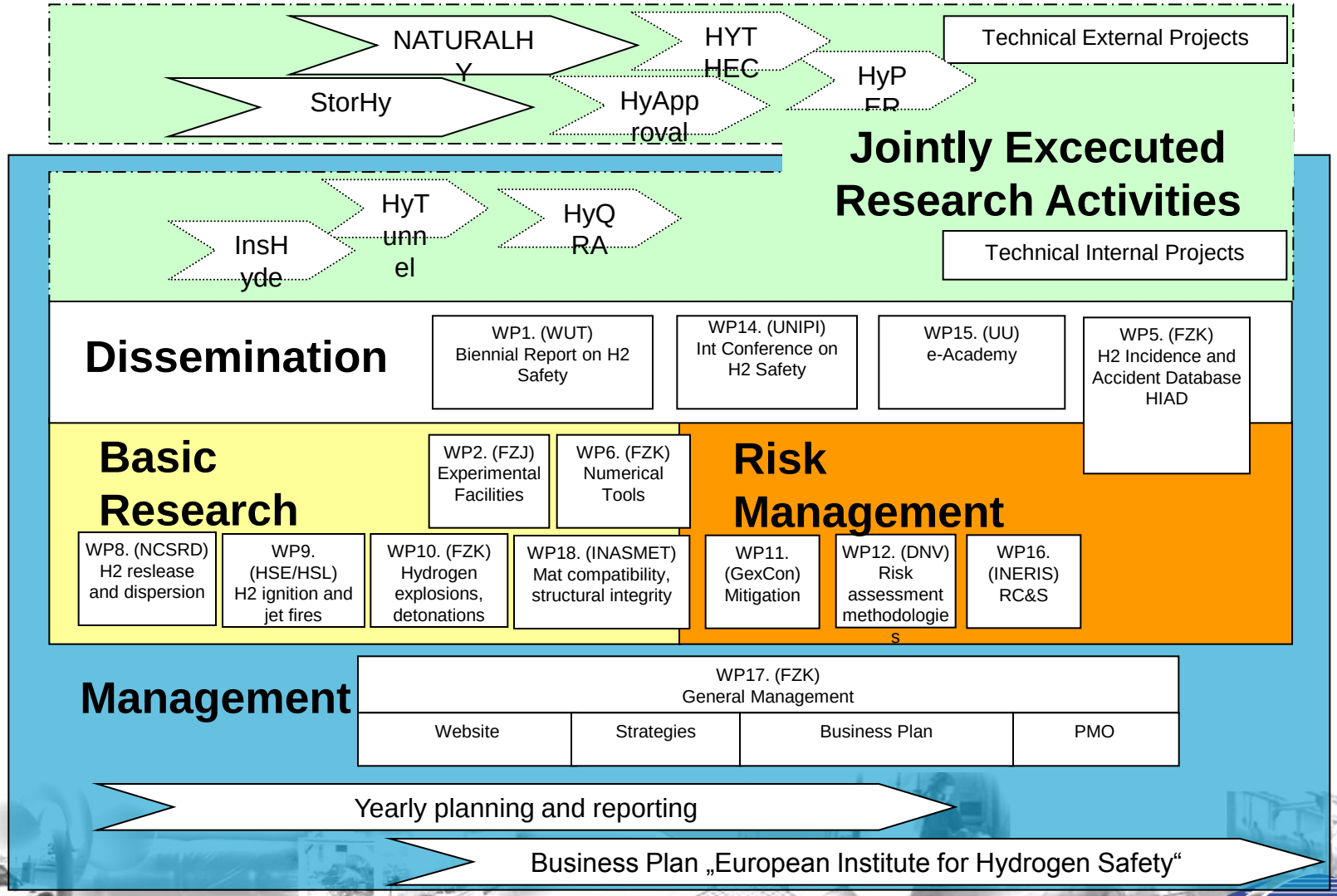


Forschungszentrum Karlsruhe GmbH	DE
L'Air Liquide	**FR**
Federal Inst for Materials Research and Testing	**DE**
BMW Forschung und Technik GmbH	**DE**
Building Research Establishment Ltd	**UK**
Commissariat à l'Energie Atomique	**FR**
Det Norske Veritas AS	**NO**
Fraunhofer-Gesellschaft ICT	**DE**
Forschungszentrum Jülich GmbH	**DE**
GexCon AS	**NO**
The UKs Health and Safety Laboratory	**UK**
Foundation INASMET	**ES**
Inst Nat de l'Environm industriel et des RISques	**FR**
European Commission - JRC - Inst for Energy	**NL**
National Center for Scientific Research Demokritos	**EL**
Norsk Hydro ASA	**NO**
Risø National Laboratory	**DK**
TNO	**NL**
University of Calgary	**CA**
University of Pisa	**IT**
Universidad Politécnica de Madrid	**ES**
University of Ulster	**UK**
VOLVO Technology Corporation	**SE**
Warsaw University of Technology	**PL**
Russian Research Centre Kurchatov Institute	**RUS**

External Networking



Clusters and Packages

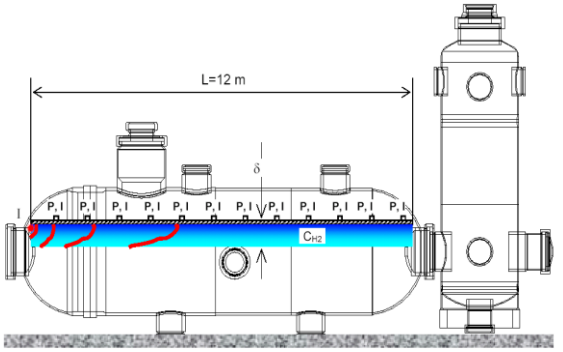


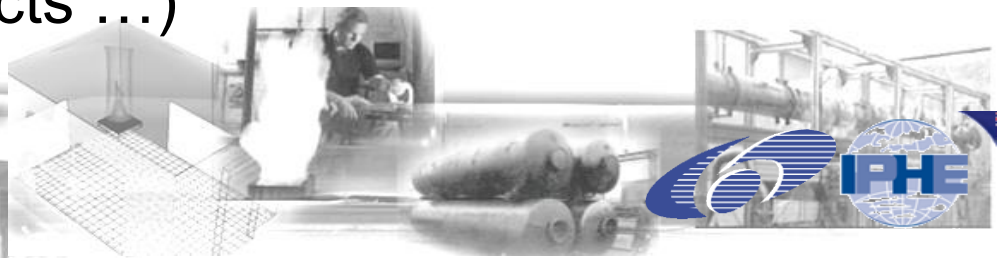
Research Headlines

- **(Partially) Confined Releases**
- **Mitigation**

determined by
- initial PIRT study
- expert questionnaire
- state-of-the-art survey

communicate the network's working topics,
orientate the work on intermediate time scale (proposals for experiments, benchmarking, Internal Projects …)





Internal Project “InsHyde”

- Investigation of realistic non-catastrophic releases in (partially) confined areas
- Determination of permeation and release limits
- Systematic assessment of mitigation (including detection) measures (sensors + venting + recombiner...)
- Simulations and experiments for critical releases
- Deriving „Recommendations“, → standards, ...
- Proposing a dedicated EC project “HyGarage” (lead NCSRD)

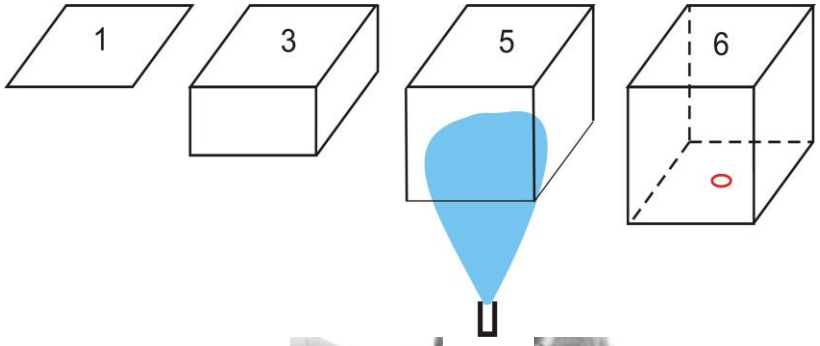
Garage facility at partner CEA

“InsHyde” Max. Inventory

- Released mass of Hydrogen: - 1-10 g (Standard variation)
- Release time: - 0.1-100 s (Jet → Plume)
- Ignition time: - to be chosen in a way, that presumably
- Ignition location: maximum H_2- combustion occurs
- Ignition energy: - weak, strong
- Complexity of geometry

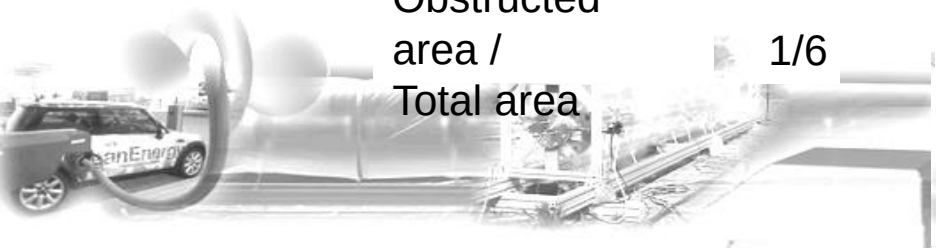
  a) Obstacles: - different number of wire netting layers → turbulence and flame convolution

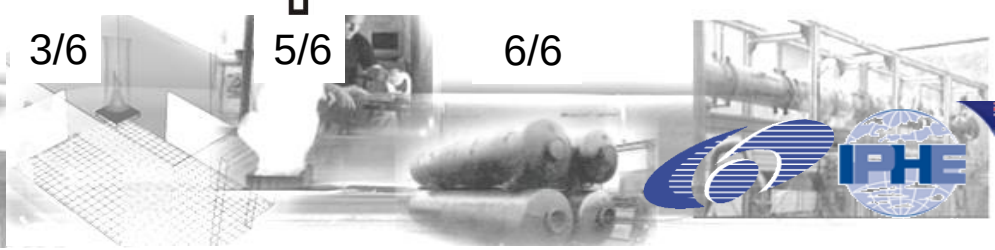
  b) Enclosure: - different number of restrictive plates (i.e. aluminum)



Obstructed area / Total area

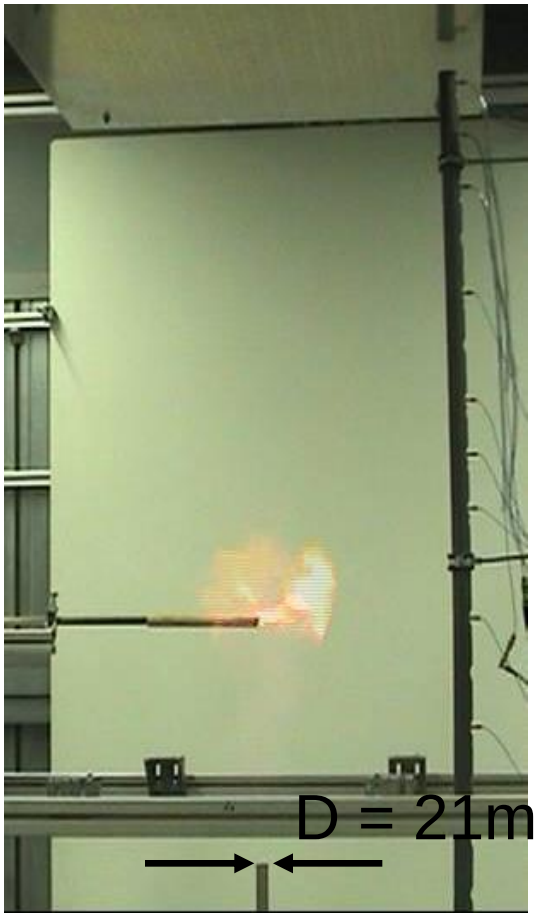
1/6 3/6 5/6 6/6





“InsHyde” – Integral tests

Inventory 10 g



$\dot{m}$ = 0.15 g/s,
h_{ign} = 0.45 m

$\dot{m}$ = 3.0 g/s,
h_{ign} = 0.8 m

$\dot{m}$ = 6.0 g/s,
h_{ign} = 0.8 m

"InsHyde" – Permeation

Survey on Existing Allowable Rates

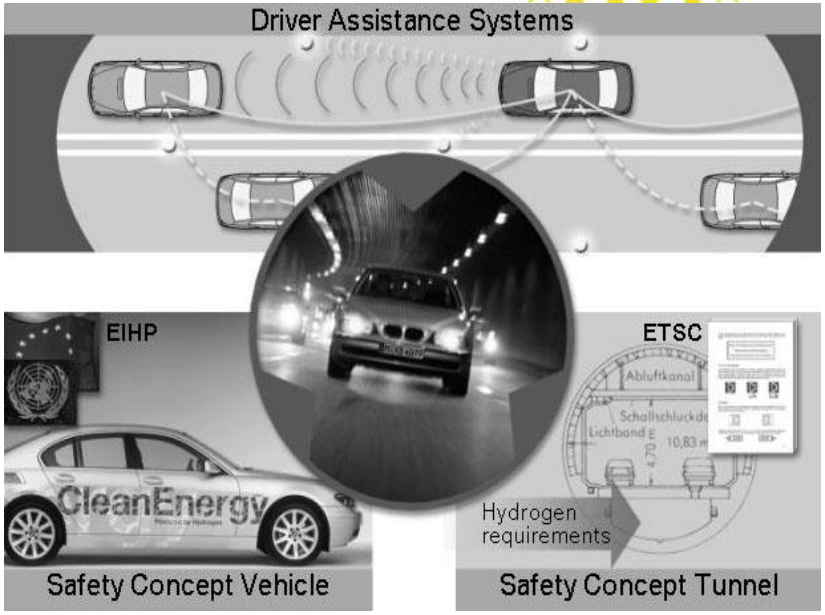
- Draft UN ECE regulation (EIHP draft & possibly the basis of the EU Regulation) and superseded versions of draft ISO/DIS15869:
  - For Type 4 containers, the steady state permeation rate < 1.0NmL/hr/L internal vol.
  - The test is conducted at ambient temperature and nominal working pressure.
- ISO/DIS 15869.2 & .3:
  - For Type 4 containers, the steady state permeation rate < 2.0NmL/hr/L water capacity at 35 MPa, and 2.8NmL/hr/L water capacity at 70 MPa.
  - The test is conducted at ambient temperature and nominal working pressure.
- SAE J2579, Jan. 2008:
  - The steady state hydrogen discharge rate due to leakage and permeation from the hydrogen storage system shall not > 75NmL/min at 85^0C and nominal working pressure for a standard passenger vehicle.
  - The rate may be increased in proportion to the enclosure volume for large vehicles.

Internal Project “HyTunnel”

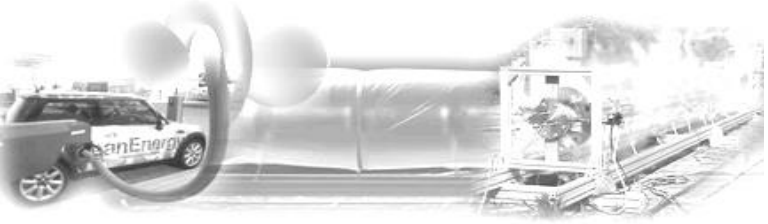
- Selection of broadly accepted szenarios.
- Review of available relevant numerical and experimental simulations
- Qualitative assessment on standard mitigation measures effectiveness (benchmark)

i. Experimental part (depending on financing)

ii. Extension of the EC Tunnel „directives“



→ Improved Tunnel Safety with H_2 as the fuel of the future



COMMISSION OF THE EUROPEAN COMMUNITIES

Brussels, 30.12.2002
COM(2002) 769 final

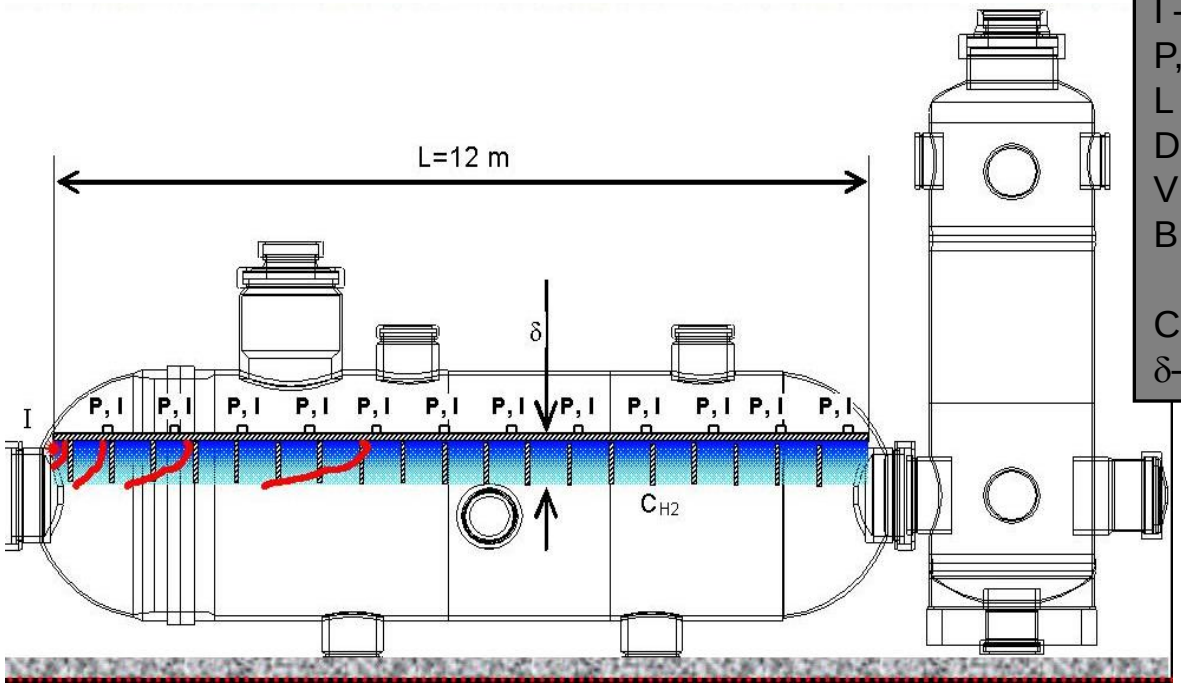
2002/0309 (COD)

Proposal for a

DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

on minimum safety requirements for tunnels in the Trans-European Road Network

“HyTunnel” - Experimental Layout



I – ignition point;
P, I – pressure and light gauges.
L = 12 m – A1 length;
D = 3.5 m – A1 diameter;
V = 100 m^3 (+30 m^3)– total volume;
BR = 0.6 (0.3) by obstacle laden grid

C_{H2} –hydrogen concentration;
δ– layer thickness

- Objective: Critical conditions for FA and DDT in semi-confined gas mixture layer
- Expected data: Dependence of critical σ* and λ* on gas layer thickness δ

“HyTunnel” – Main Experiments

Large scale facility (5.7 x 1.6 x 0.6 m)

- effective venting ratio α = 0.46 (layer thickness δ = 0.15 m)

Diagonal view

Film opening

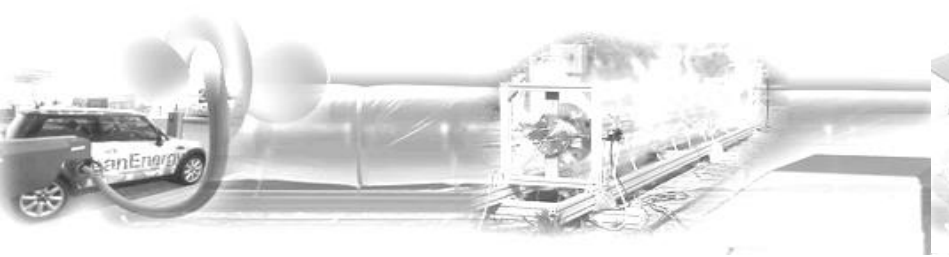
“HyTunnel” – FA/DDT
some results

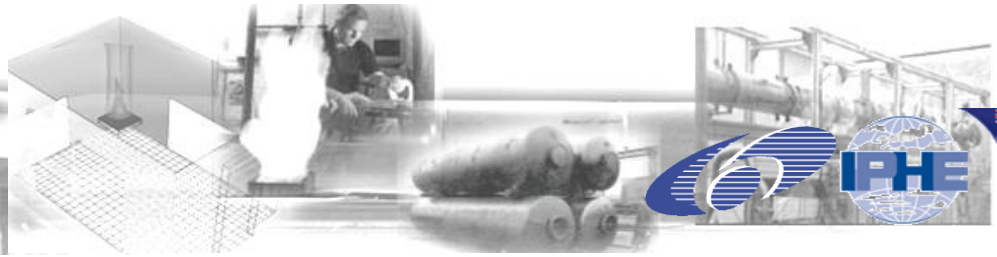
- Large scale test completed
- Effective flame acceleration (FA) depends on mixture reactivity and gas layer thickness.
  Flame accelerates to sonic velocity:

  for **15% H_2** **d ≥ 0.6 m**

  for **20% H_2** **d ≥ 0.3 m**
- **Detonation** in semi-confined geometry at **25% H_2** can occur if gas layer **d ≥ 0.3 m**
- Critical layer thickness for **detonation propagation**:

  15 > d/l > 7.5





WP18.3 Sub-task “HyFrac”

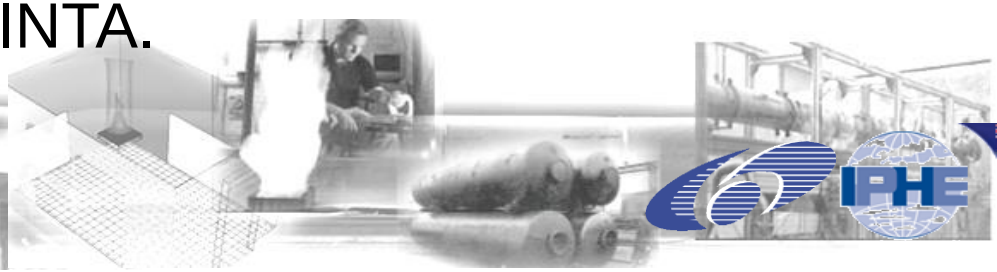
Objectives

Experience from space research/rocket engineering indicates that hydrogen 5.0 with less than 5ppm O_2 contamination
(HPH2, as required for PEM FC) can induce accelerated material damage processes.

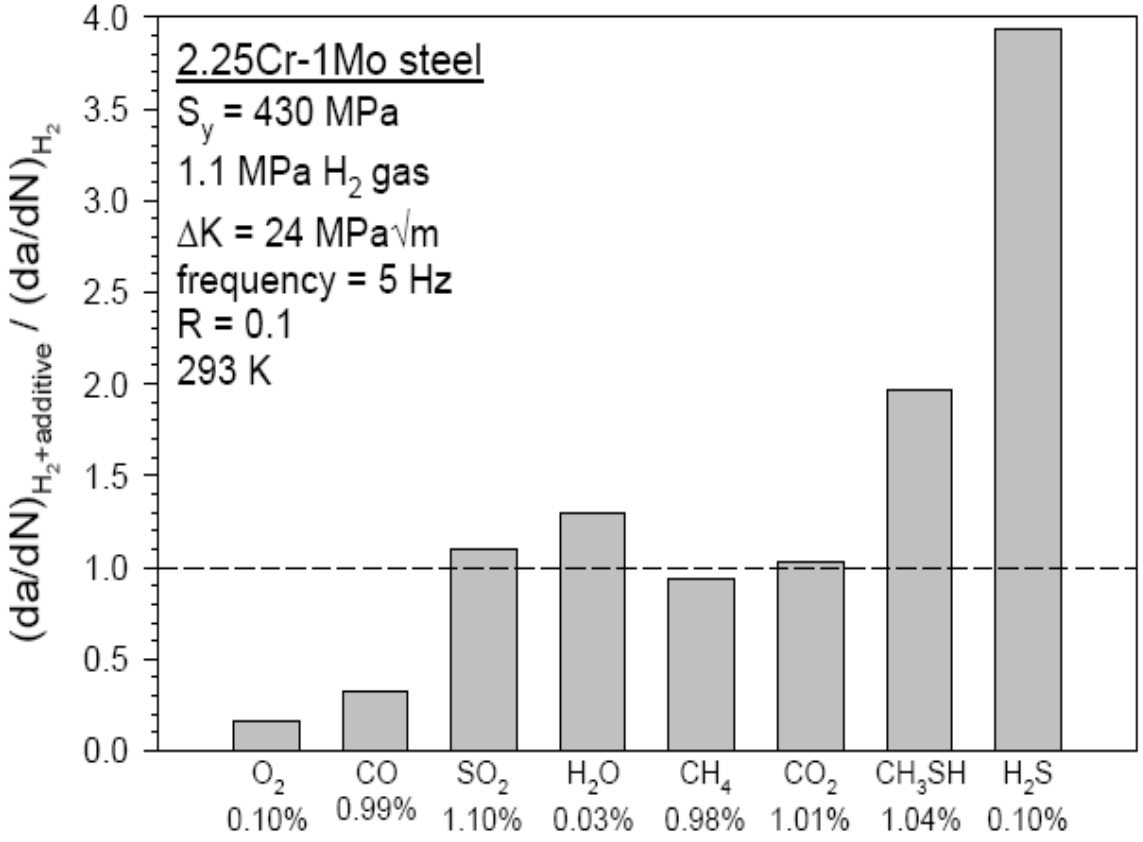
Objectives:

- Investigation of the effect of HPH2 induced cracking
- Recommendations for the safety aspects of the use of HPH2 in fuel cell cars

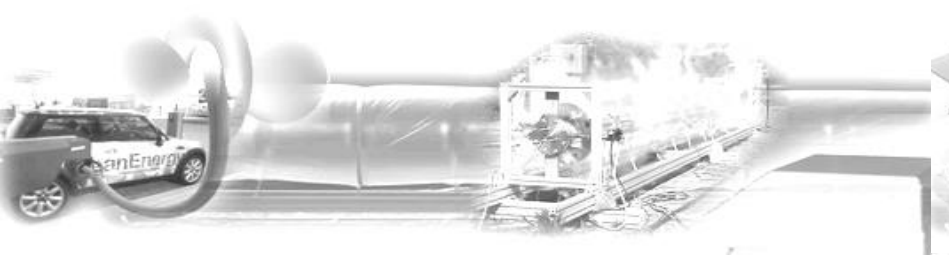
Lead: **AL** Partners: BAM, DNV, HSE/HSL, INASMET, Risø and Active Supporters: ET, INTA.

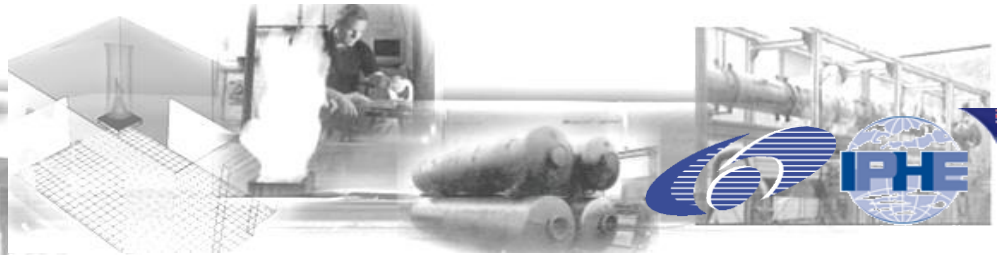


Impurity effects on fatigue crack growth



Comparison between pure gas and H_2 with additives [4]





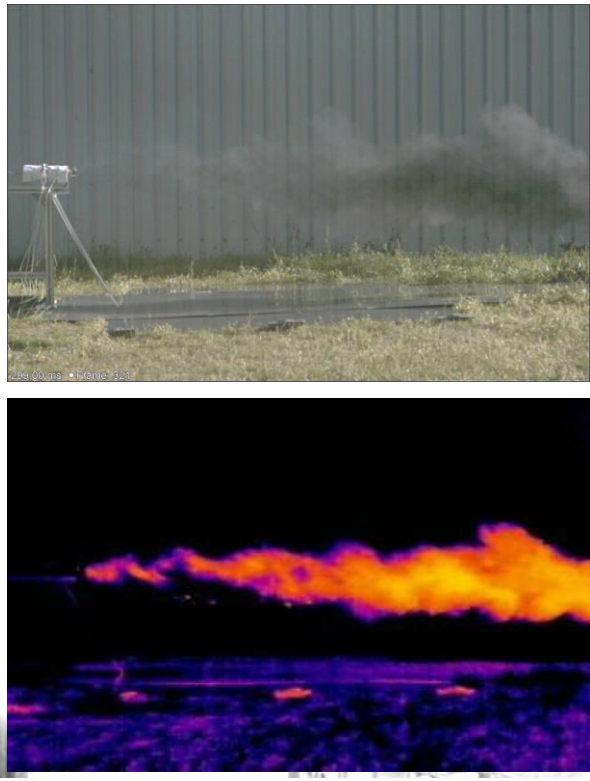
WP18.4 “HyNano” – Objectives

Fundamental understanding the safety issues regarding nano-scaled solid-state hydrogen storage materials/systems through:

(i) development of standard testing techniques to quantitatively evaluate both materials and systems,

(ii) understand the fundamental science of environmental reactivity of hydrides and

(iii) develop methods and systems to mitigate the risks to acceptable levels.



nano-structured alanate blown out of a heat exchanger tube at 10 bar and 120 °C (frames of a high speed video (left) and of a infrared video (right) at the same instant)

Progress status WP18.4

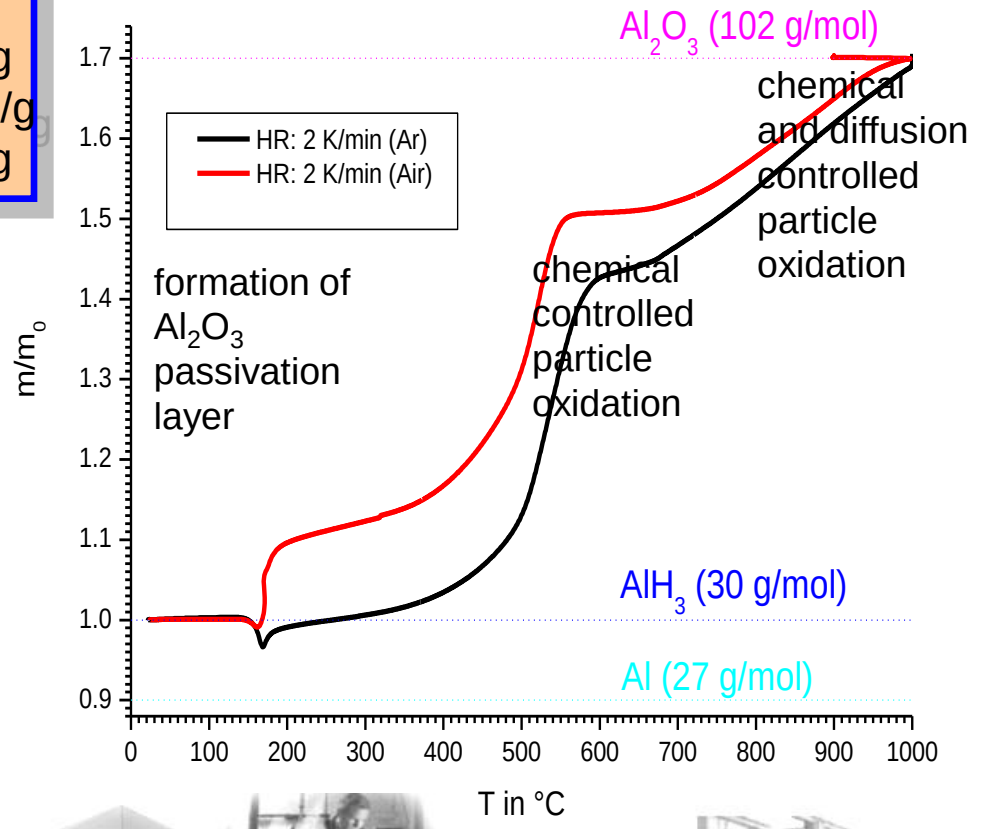
Methods of investigation: decomposition – oxidation

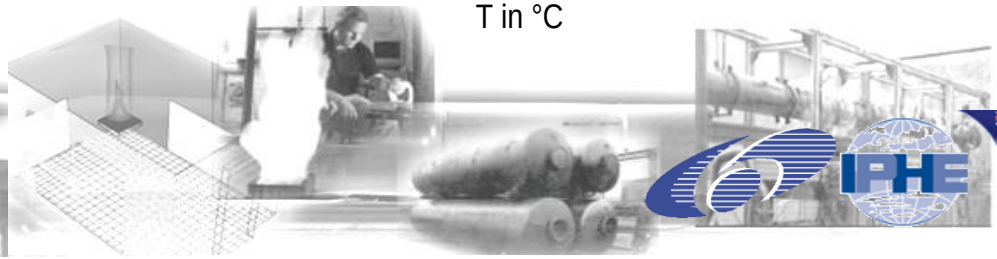
AlH_3 from pyrolysis furnace	2.59 m^2/g
AlH_3 in TGA*	15 to 20 m^2/g
AlH_3 (original crystals)	0.69 m^2/g
ALEX (nano-Al)	12.28 m^2/g
5 µm Aluminum (ALCAN)	1,36 m^2/g

Methods of Thermal Analysis:
DSC, TG, X-Ray

Specific Surface by BET-Analysen and TGA analysis

*estimated from mass increase by oxidation
with a passivation layer of 3 nm

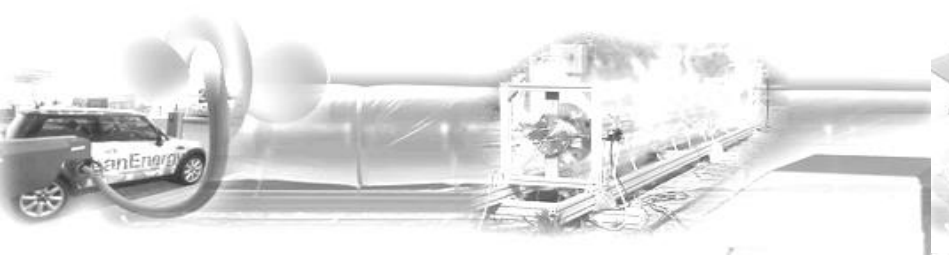


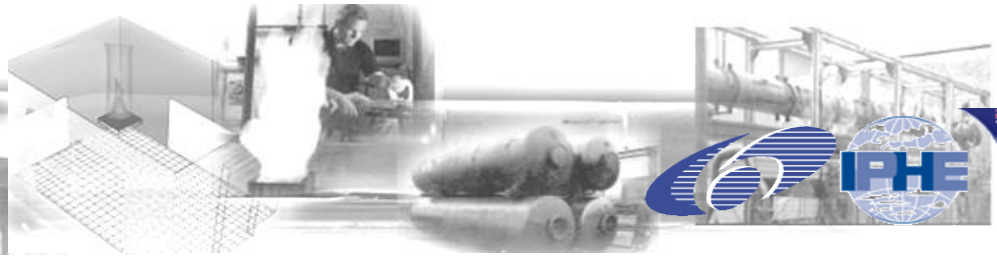


Internal Project HyQRA

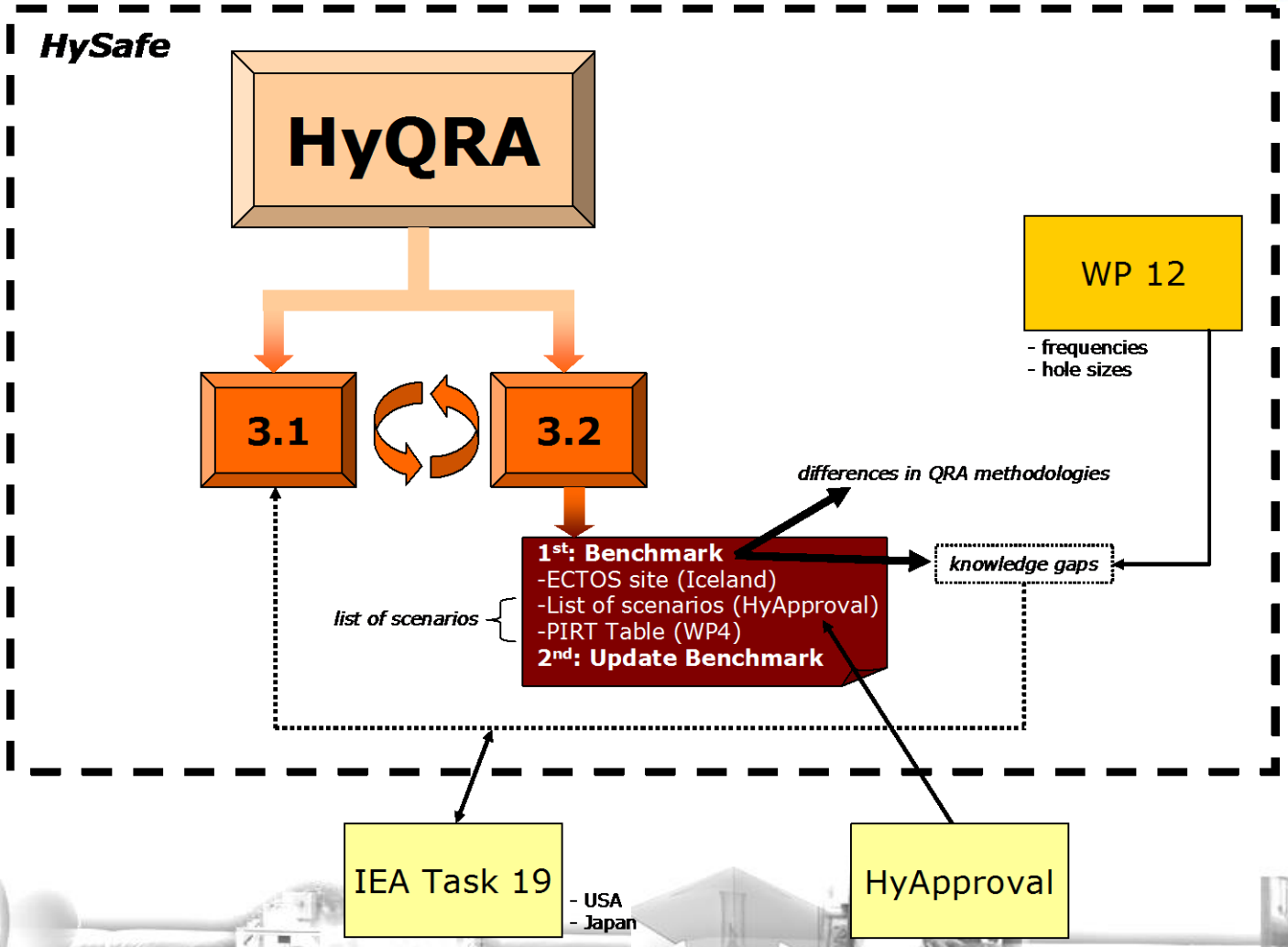
Benchmark exercise, expected outcomes

- Identification of differences in QRA methodologies and expressions of risk concepts
- Identification of knowledge gaps on data used in various QRA steps, specifically for hydrogen
- For this purpose, a not too detailed reference installation would provide sufficient insight in the various concepts, but with flexibility to demonstrate risk approaches both for on-site as well as for off-site risks.
- We defined the ‘Benchmark Base Case’ hydrogen refuelling station: BBC.



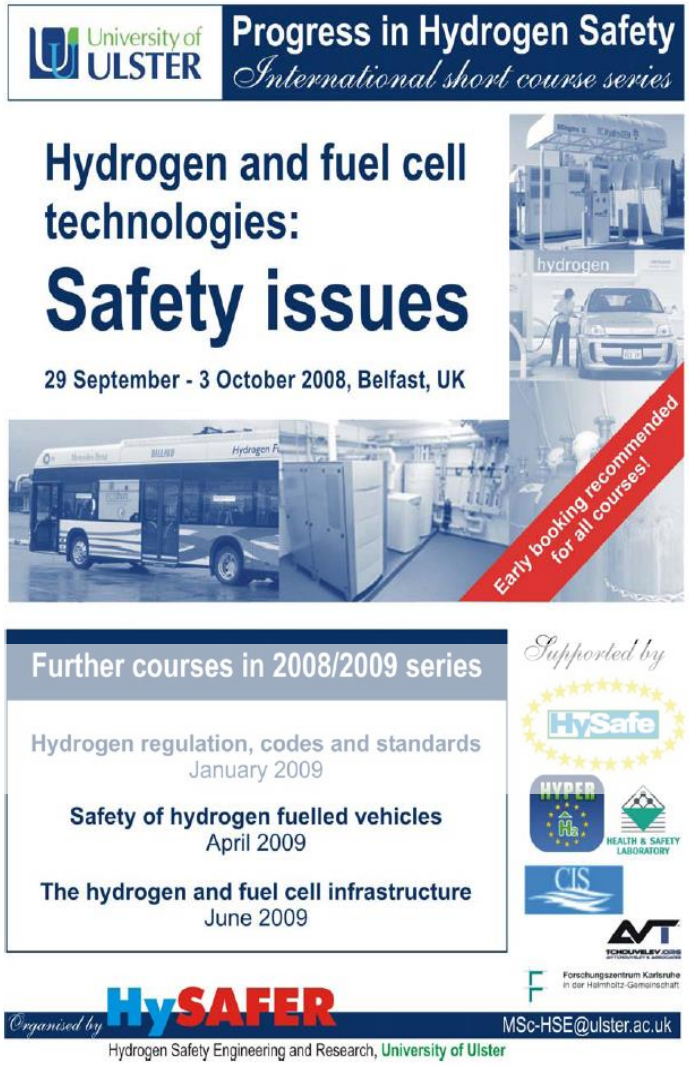


HyQRA Project Structure



Surrounding geometry
of the Benchmark Base Case - HRS

Education and Training Offers



for details see www.hysafe.net/PGC

Invitation to the 3rd Int. Conf. on Hydrogen Safety

September 16-18th, 2009

Ajaccio, Corse, France

HySafe

IPHE
International Partnership for the Hydrogen Economy

HYDROGEN IMPLEMENTING AGREEMENT

HyFLEET:CUTE

HELP
Hydrogen Executive Leadership Panel

NATURALHY

STORHY

Italian National Firecorps

AUTO21
Safety and Infrastructure Study of Hydrogen Fuelled Vehicles

H2
Codes and Systems for Hydrogen Safety

Hydrogen Safety, Codes and Standard Program

Canadian Hydrogen Safety Program

CCS Global
SINCE 1977

ISO

HySafe
ICHS

Contact: ICHS@hysafe.org

INTERNATIONAL CONFERENCE ON HYDROGEN SAFETY

All Information → www.hysafe.net

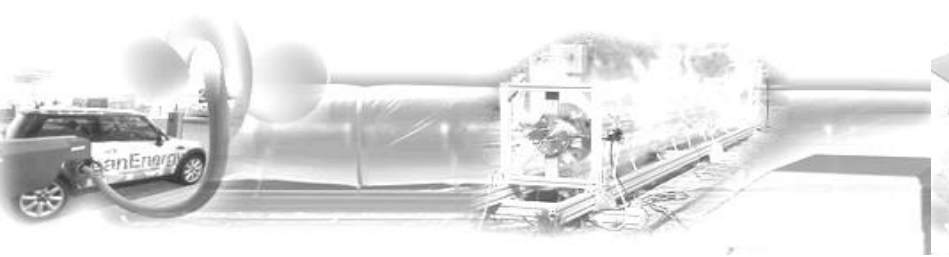
Support

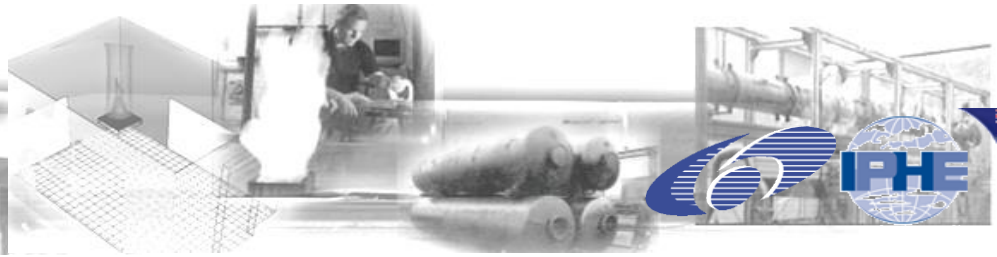
NoE HySafe is co-funded by the European Commission within the 6th Framework Programme (2002-2006); Contract n°: SES6-CT-2004-502630.

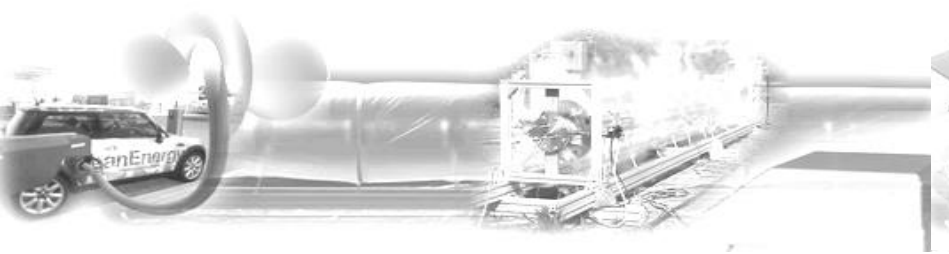
The network is contributing to the implementation of the Key Action "Integrating and strengthening the ERA" within the Energy, Environment and Sustainable Development.

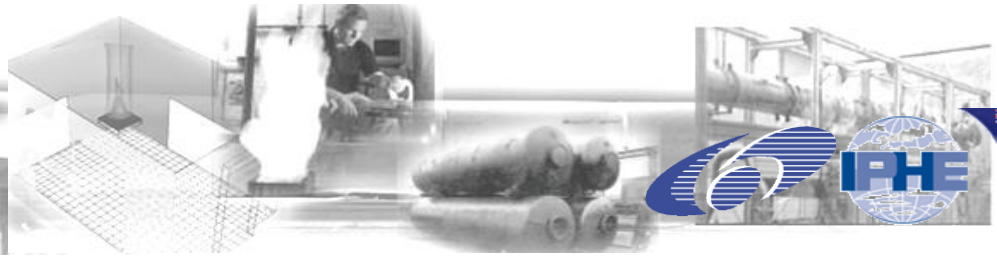
Thanks to all HySafe colleagues…

… and thank you for your attention.









Post Graduate Certificate

for details see www.hysafe.net/eAcademy

External Networking