L’utilizzo sicuro dell’idrogeno:
la ricerca e la regolamentazione tecnica
Istituto Superiore Antincendi, 10 dicembre 2021

Impiego dell’idrogeno in ambito industriale: studio, sperimentazione e problematiche di sicurezza

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Sicurezza VS Rischio

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Safety is freedom from unacceptable risk (ISO/IEC Guide 51:1999)

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- Risk is the <u>technical (quantitative) measure of safety</u>
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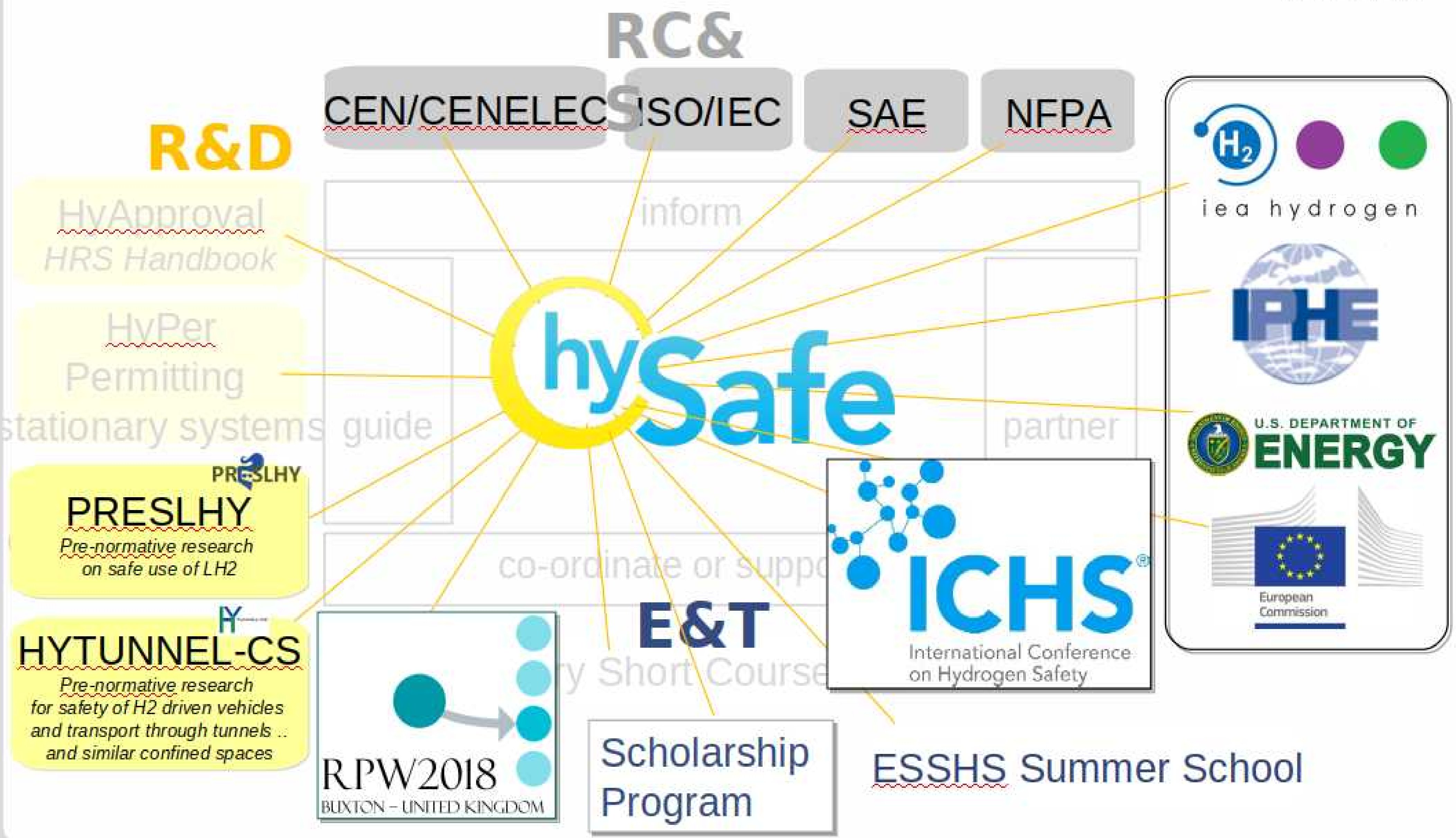
hySafe
INTERNATIONAL ASSOCIATION FOR HYDROGEN SAFETY

IA HySafe Members

48 members from industry, research organisations and universities representing 17 countries worldwide.

International Focal Point for H2 Safety



RC&S
HFS – ISO 19880-1

Gaseous hydrogen
— Fuelling stations —
General Part 1:
requirements

Liaison fra IAHySafe e ISOTC197
“Hydrogen technologies”

DRAFT INTERNATIONAL STANDARD
ISO/DIS 19880-1

ISO/TC **197** Secretariat: **SCC**

Voting begins on:
2018-02-19

Voting terminates on:
2018-05-14

Gaseous hydrogen — Fuelling stations —

Part 1:
General requirements

Carburant d'hydrogène gazeux — Stations-service —

Partie 1: Exigences générales

ICS: 43.060.40; 71.100.20

Reference number
ISO/DIS 19880-1:2018(E)

R&D Breve lista dei progetti di ricerche

- HySafe
- HyTunnel
- HyLow
- HyMethShip
- HyBalance
- HyCare
- HyGrid
- HyCool
- HyResponder
- HyPer
- HyApproval
- ……..

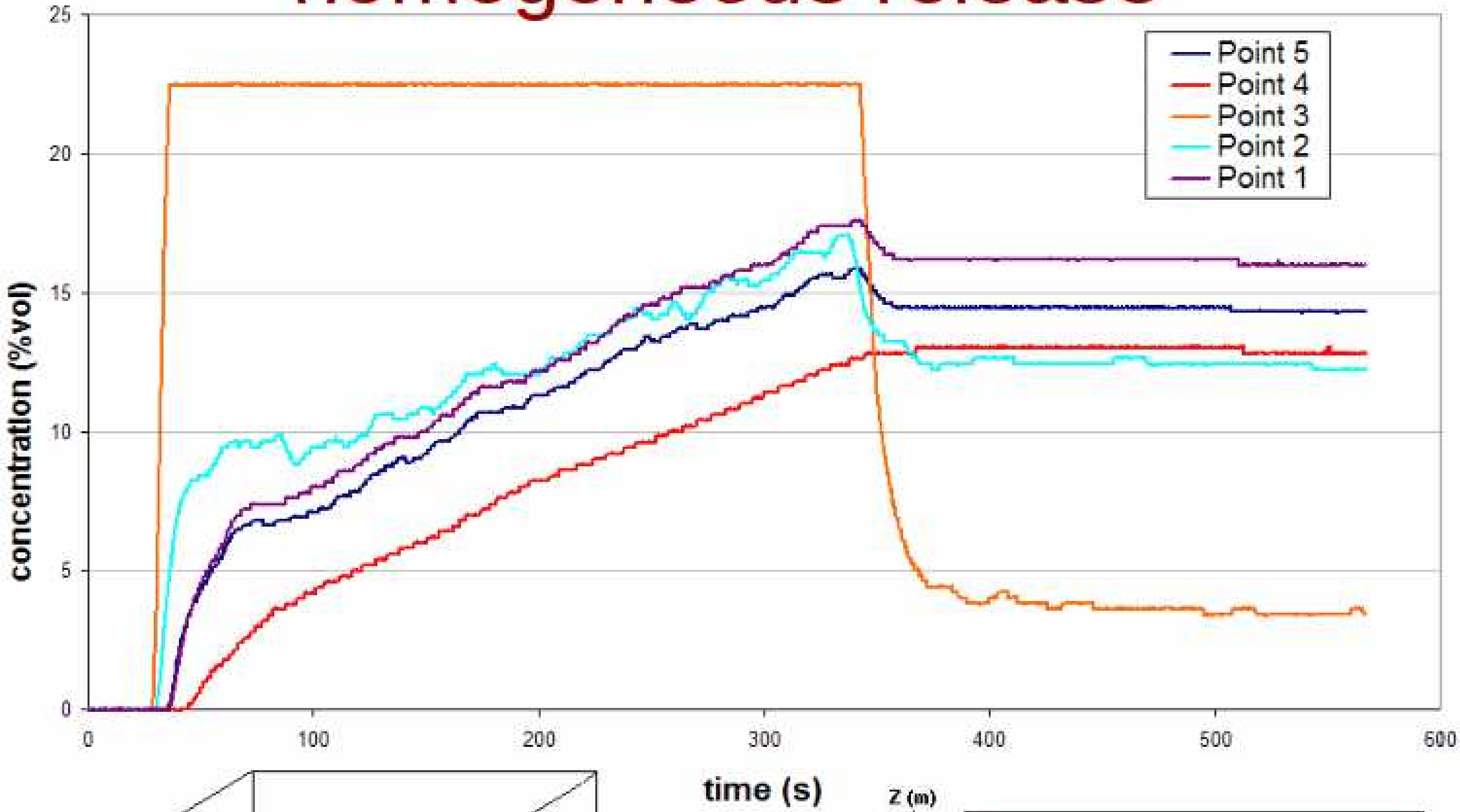
- StoHy
- NaturalHy
- IdealHy
- CertifHy
- PreslHy
- ……..

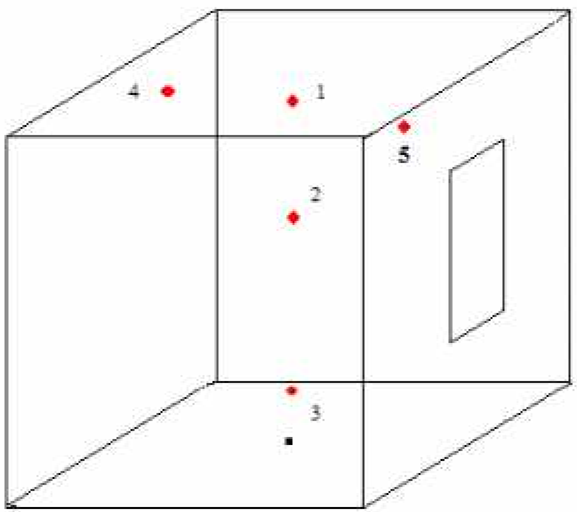
CVE (Chamber View Explosion) experimental apparatus

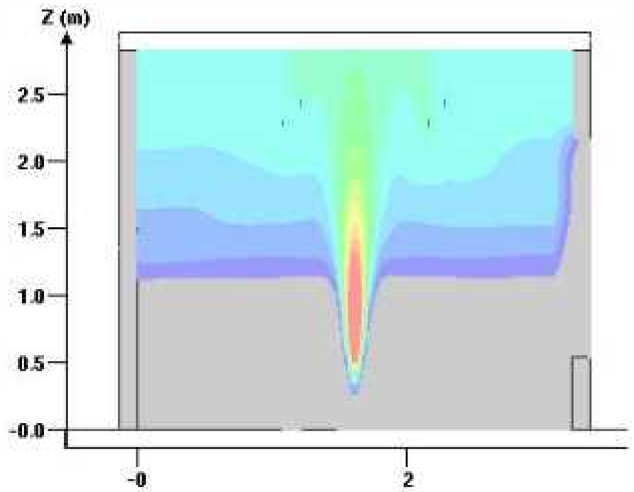
Glass side view

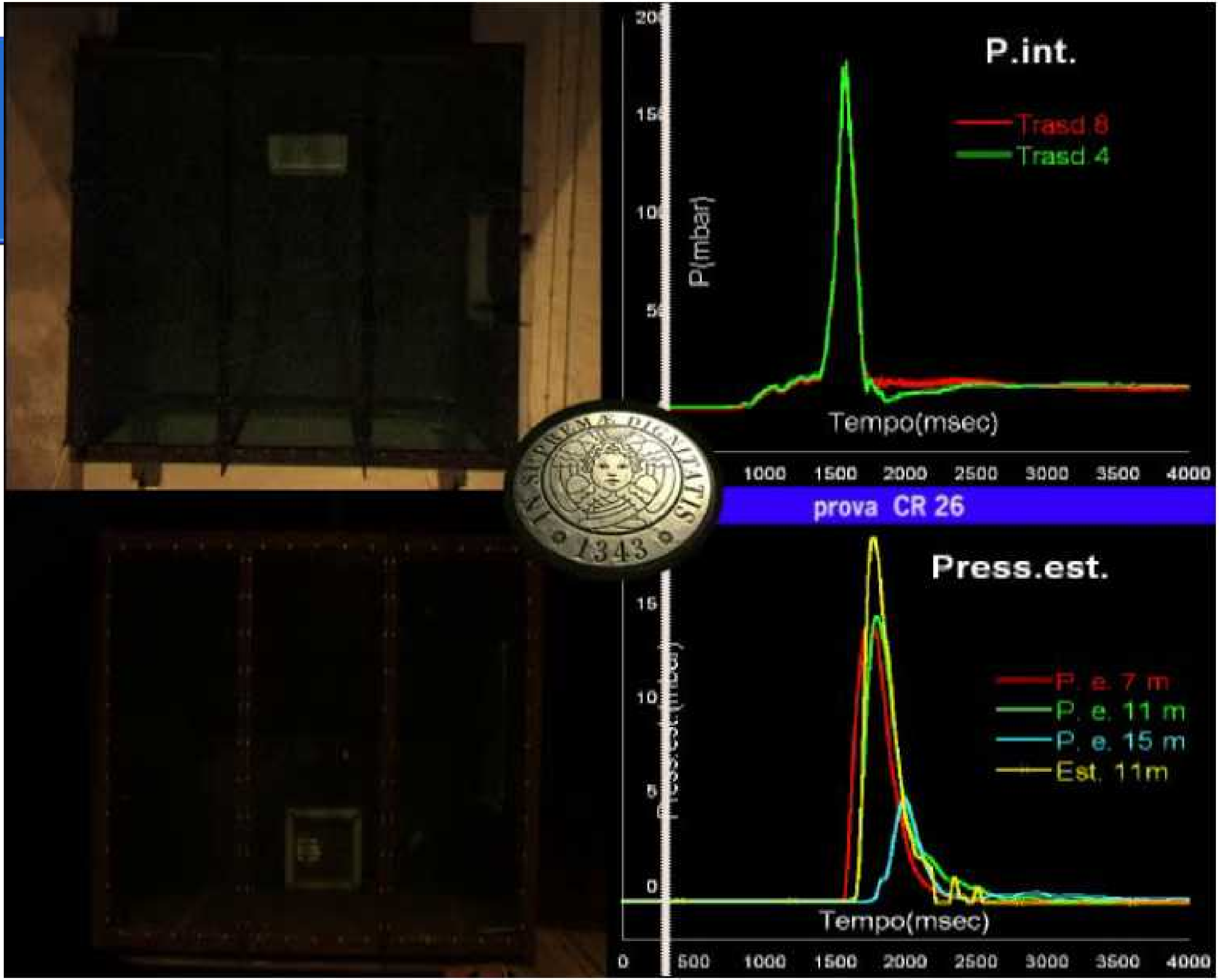
Test side view

Concentration trend during non-homogeneous release








P.int.
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P. e. 15 m
Est. 11m
Tempo(msec)
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1343

ICHS®

International Conference on Hydrogen Safety

"Safe Hydrogen for Net Zero"

SEPTEMBER 21-24, 2021

ONLINE CONFERENCE
Supported by The
Scottish Government

PROGRAMME

www.ichs2021.com

HySafe International Association for Hydrogen Safety — The Scottish Government

ORGANISED BY

HySafe International Association for Hydrogen Safety
The Scottish Government

WITH ENDORSEMENT OF

IPHE – International Partnership for Hydrogen and Fuel Cells in the Economy
Vigili del Fuoco Corpo Nazionale – Ministry of the Interiors The National Fire Corps ITALY
European Commission
Hydrogen Council
U.S. Department of Energy – Office of Energy Efficiency & Renewable Energy
Department for Business, Energy & Industrial Strategy

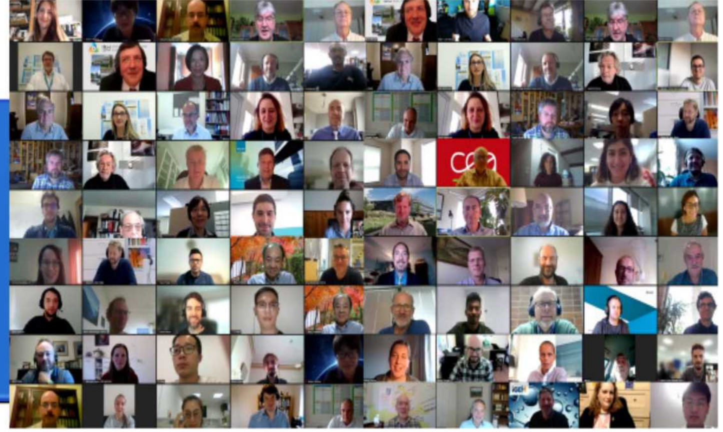
IN COLLABORATION WITH

ISO – ISO/TC 197 Hydrogen Technologies
Scottish Hydrogen & Fuel Cell Association
IGEM
HSE

Prossima Conferenza ICHS2023 Québec City (Canada) Settembre 2023

Amburgo (DE) 2017

Adelaide (SA) 2019



Edinburgh (SCO) 2021

ICHS STORY

San Sebastian (SP) 2007

Pisa (IT) 2005

Pisa (IT) 2005

Brussels (BE) 2013

Ajaccio (FR) 2009

San Francisco (USA) 2011

Yokohama (JP) 2015

Continuous Development of the State-of-the-Art

HySafe
INTERNATIONAL ASSOCIATION FOR HYDROGEN SAFETY

Process with 2 years periodicity:

Year 1: Orientation by incremental update of gaps and priorities via Research Priorities Workshop

Year 2: Communication of progress via International Conference on Hydrogen Safety …

and

Update of the BRHS being the state-of-the-art report

To be published as Hydrogen Safety Handbook (Elsevier)

Research Priorities Workshop RPW

ICHS® International Conference on Hydrogen Safety

BRHS

time

Research Priorities Workshop (RPW) Story

- **<u>RPW 2018 – Buxton, UK - HSE</u>**
- RPW 2016 – Petten, NL -European Commission Joint Research Centre (Pettn)
- RPW 2014 – Washington DC, USA - USA Department of Energy (Washington DC),
- RPW 2012 – Berlin, DE - Berlin Germany hosted by Bam 2012
- RPW 2010 – Petten, NL - The first workshop was organized by JRC in October 2009 . Workshop focused on the CFD modeling and development.

Link to IaHySafe https://hysafe.info/
Link to RPW https://hysafe.info/activities/research-priorities-workshops/

Research Priorities Workshop (RPW)

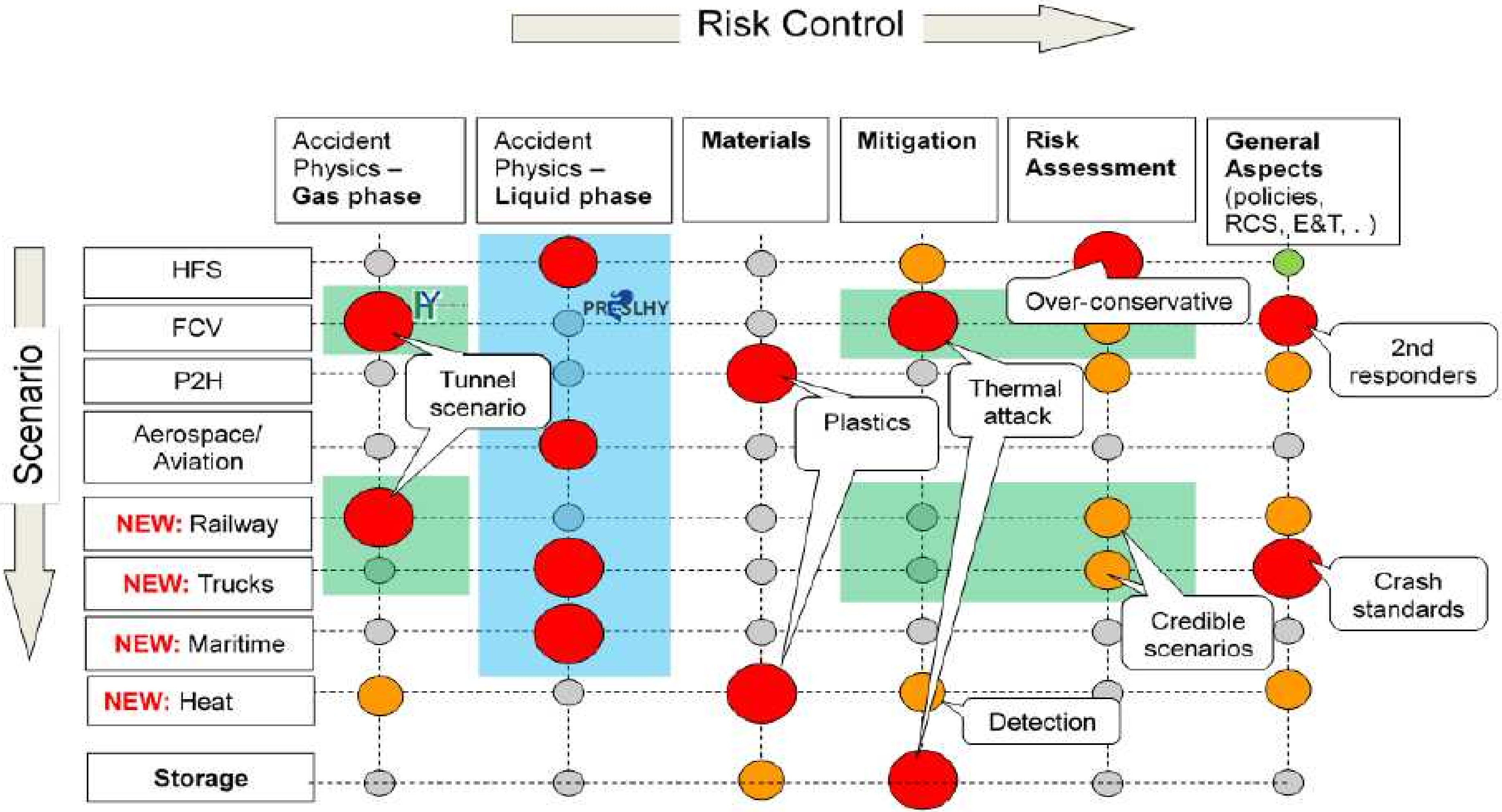


Figure 11.1 Matrix summarising findings and highlighting Tier 1 and Tier 2 priorities.

HFS initial Topics

Application - refuelling stations

Q	TOT	%	RANK
1	62	13.78	4
2	97	21.56	1
3	61	13.56	5
4	44	9.78	6
5	38	8.44	7
6	78	17.33	2
7	70	15.56	3

- 1. Adverse effects on material and systems in 'below-design', idling conditions (corrosion, T cycles, etc.)
- 2. Reduction of the over conservative expensive design raising safety and efficiency concerns (e.g. alarm limits, electrical grounding of busses and cooling requirements)
- 3. Material and processing (welding) issues for high pressure components
- 4. Compressor: ventilation requirements for compressor containers
- 5. Compressor: effect of compressor vibrations on material
- 6. Cascade effects: effect of various accidental releases in case of scale-up, complex real geometry (large bus fleets, trains, etc.)
- 7. Vent stack design, accounting also for cold releases from LH2 transfer and cryostat purging

HFS Priority

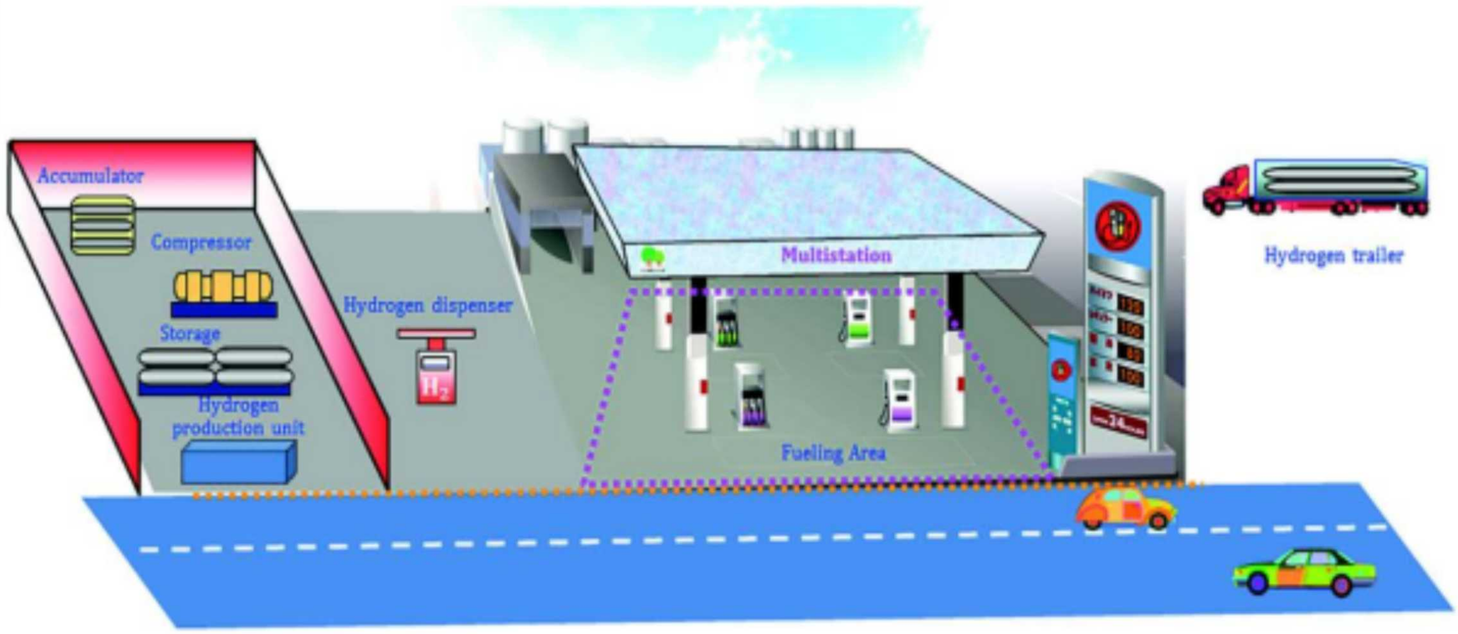


Figure 2 — Image of an example hydrogen fueling station

- 1 st priority: Reduce over conservative and expensive design, raising safety and efficiency concerns – still a priority despite some progress on this topic;
- 2nd priority: cascading effects including effects of various accidental releases of large inventories in complex real geometries, including co-location with conventional fuels;
- 3rd priority: material and processing (welding) issues for high pressure components. For public supply infrastructure, i.e. HFS scale up and efficiency requirements implies increasing usage of LH2.

Fuel Cell Electric Vehicles (FCEV)

1. Complex accident situation in tunnels

2. Understanding vehicle fires and the response of storage components to thermal excursion

3. Hydrogen venting via TPRD in garages

Land transport (brings together FCEVs, Rail & Heavy-Duty Trucks)

- 1 st priority: Credible Accident Scenarios with high pressure hydrogen/LH2 s torage and interaction with infrastructure (i.e. in tunnels and other enclosed spaces) are identified as key for all land vehicle applications;

- 2 nd priority: Fire attack and implications of increasing on board inventories are generic issues, focused particularly for the rail and trucks, and clearly needs attention, noting suggested on-board storage inventories of 50-100 kg for trucks, 200-500 kg for rail;

- 3 rd priority: Part of same generic picture is operation of TPRDs across these applications and for rail, hydrogen risks in the presence of high voltage systems is a concern.

Maritime

- 1 st priority: Credible Accident Scenarios with high pressure hydrogen/LH2 storage and interaction with infrastructure (i.e. in tunnels and other enclosed spaces) are identified as key for all land vehicle applications;

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Aerospace/ Aviation

- 1 st priority: Multi-phase physical processes in heat transfer, mixing with air, and initial thermodynamic status of LH2;
- 2 nd priority: Behaviour of liquid hydrogen and liquid oxygen mixtures;
- 3rd priority: Determining the probability of detonation with inhomogeneous gaseous clouds.

Power to Hydrogen and Heat

- Priority 1: Behaviour of H2 in H2/NG on plastics pipes, valves, fittings **in house gas installations**, storage cylinders - effect on component, linked to the control of leaks in buildings and buried pipework;
- Priority 2: Review of testing procedures such as embrittlement & fatigue life test for H2/NG,
- Priority 3: Certification of mitigating safety measures (TPRD Explosion Protection Systems, etc.) for H2/NG

STORAGE

- 1 st priority: tank fire resistance (previously identified as a priority in 2016),
- 2 nd priority: non-destructive testing techniques for manufacturing,
- 3 rd priority: understanding the effects of tank overheating on the structural performance and lifetime of the tank – highlighted as key by session chair to underpin refuelling protocols.

Accident Physics
Gaseous Hydrogen

- 1 st priority: Premixed combustion associated with large scale problemswith obstacles, flame acceleration and particularly DDT;

- 2 nd priority: Hydrogen venting:

- 3 rd priority: Ignition statistical approaches and spontaneous ignition.

These priorities are key to growing application inventories and preventing and understanding the consequences of accidental releases in these new and developing scenarios.

Accident Physics
Liquid Hydrogen

- 1 st priority: Multi-phase accumulations with explosion potential;
- 2 nd priority: Combustion properties of cold gas clouds, especially in congested areas;
- 3 rd priority: Knowledge and experience related to releases of large quantities. As reference to the main text of this document illustrate, this is an area with a number of outstanding issues.

These efforts are essential, as LH_2 as a technology is key to a number of applications, as noted with the strong overlap in priorities with aerospace and maritime, and others that will need larger hydrogen inventories.

Materials – 1: Testing aspects related to the characterization of materials

- 1 st priority: International consensus on metrics for qualification of metals for specific applications
- 2 nd priority: Definition of test protocols, selection criteria and relevant standards for polymer materials
- 3 rd priority: Activities on seals, gaskets, hoses, valves and joints.

They should receive similar attention to the tank material and their behaviour tested under different and realistic conditions.

Materials – 2: Performance assessment of materials

- 1 st priority: Database providing fatigue data for the most probable materials to be used for hydrogen pressure vessels
- 2 nd priority: Better understanding on Fatigue Crack Initiation and Propagation. In particular focusing on small cracks and better understanding of the effect of hydrogen pressure on the threshold of the stress intensity factor range. Special attention to lowt emperature / high-pressure conditions. From a general point of view a better understanding of materials behaviour under mechanical stresses is needed
- 3 rd priority: Definition of appropriate models for lifetime predictions for polymers. In particular, correlation between the behaviour of polymers under low hydrogen pressures and high hydrogen pressures and effects of temperature peaks (or valleys) and temperature excursions in tanks containing polymers. Correlations between permeation and pressure/temperature conditions, especially with the aim of achieving preiction capabilities.

Integrated Tools for Risk Assessment

- 1 st priority: Data/probabilities for hydrogen system component failure
- 2 nd priority: Develop models for accounting for mitigation.
- 3 rd priority: Develop a realistic model for high-pressure hydrogen releases inside ventilated enclosures.

General Aspects of Safety

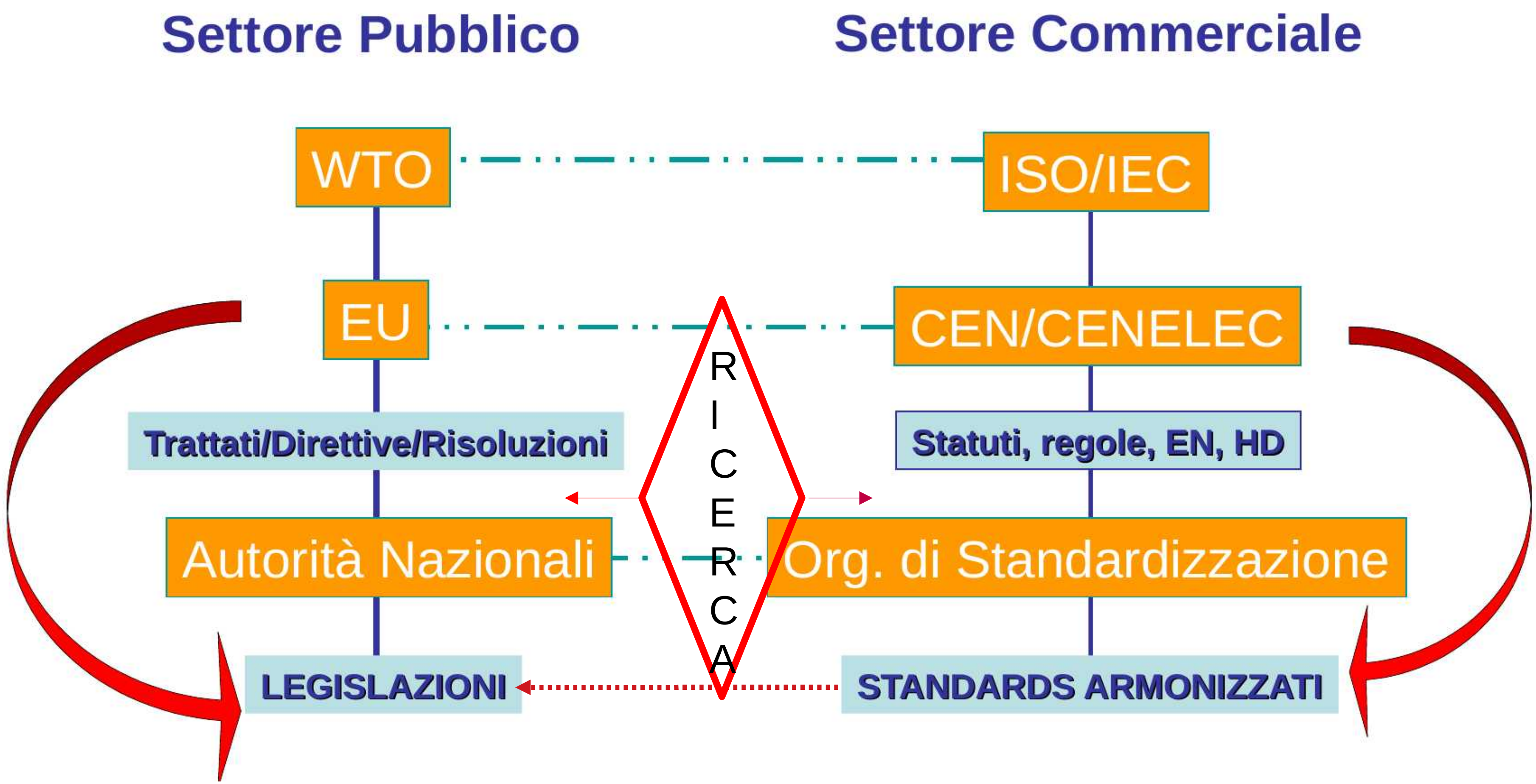
- 1 st priority: Training for First Responder trainers and Hazmat Offices

- 2 nd priority: Safe design concepts for tunnels, car park and complex buildings to prevent and mitigate hydrogen accidents;

- 3 rd priority: Best practice for decisions and actions following detection of hydrogen in tunnels and complex buildings.

Rapporto fra la Ricerca e la Regolamentazione Tecnica

REGULATIONS e STANDARDS in CAMPO INTERNAZIONALE



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Sicurezza VS Rischio

> Definition: **NORMATIVO GIURISPRUDENZIALE**

Non esiste una definizione specifica- E' un concetto primitivo o costrutto sociale
La Costituzione Italiana usa il termine Sicurezza (Art.41 – L'iniziativa economica privata è libera. Non può svolgersi… in modo da recare danno alla Sicurezza...) ma mai il termine Rischio. Non contiene termini quali Accettabilità o Tollerabilità

> This effectively means that:

- Il Rischio può essere usato come uno dei possibili utili indicatori della sicurezza ma non vi è esplicita relazione tra Sicurezza e Rischio.
- La Sicurezza è sempre invocata ma mai quantificata e trattata, al massimo, trattata come grandezza Ordinale e mai Cardinale.

La valutazione del livello di sicurezza è sempre postumo ad un fatto avvenuto.

- La giurisprudenza e gli eventuali processi stabiliscono, caso per caso, se il grado di sicurezza era consono in relazione ai dettati legislativi, alle procedure legali adottate, alle decisioni si processi e sentenze di vario ordine e grado, ai principi di precauzione. etc..

-Tale processo non tiene conto, se non in maniera teorica, della dimensione probabilistica. Il concetto probabilistico è tenue nella cultura giuridica la quale <u>tratta sempre di problemi accaduti e mai di problemi che potrebbero accadere</u>

Processo autorizzativo

- Presuppone un dialogo fra il mondo della ricerca e della tecnologia e gli Enti dilagati alla normazione (es. Ministeri)
- E’ difficile convincere solo sulla base delle conoscenze tecniche anche se sono le più aggiornate possibili
- Per parlarsi bisogna conoscere le 2 lingue (tecnica e normativa): cioè è una problematica di Ingegneria Legale
- Normalmente le competenze tecniche degli enti di normazione sono alte. Il contrario spesso non è vero