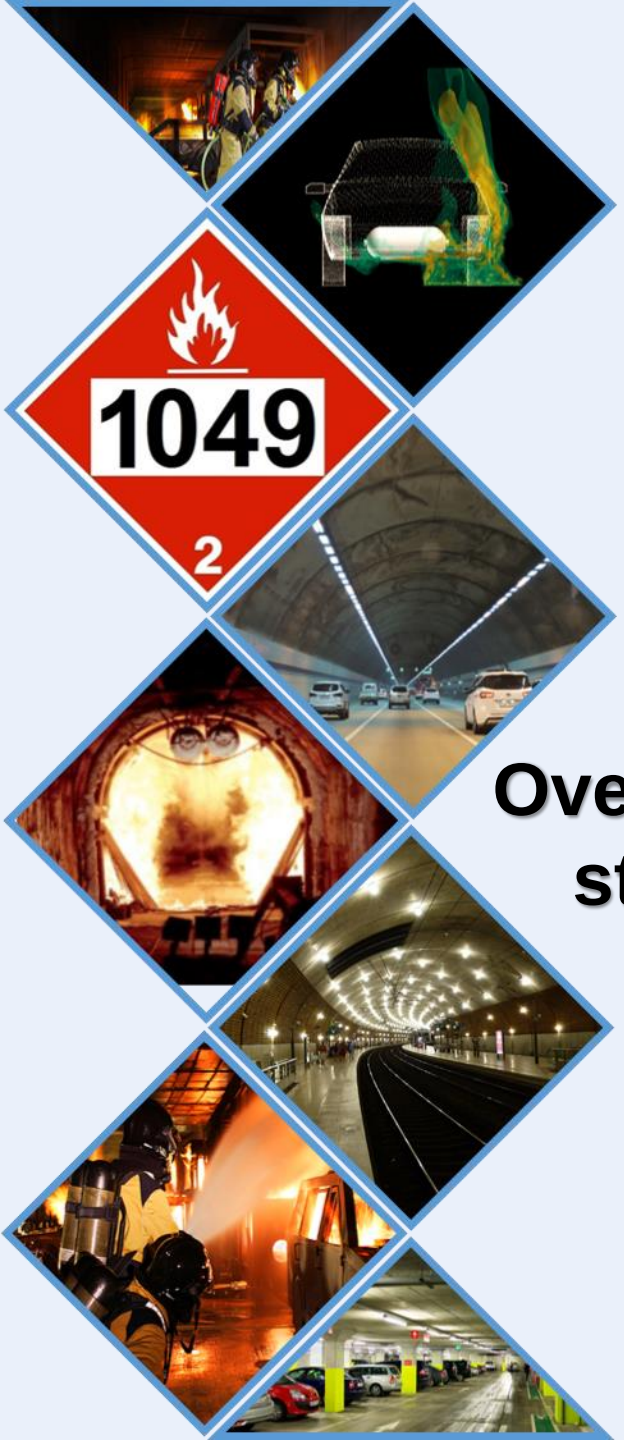


HyTunnel-CS dissemination conference
14-15 July 2022, Brussels, Belgium

Overview of HyTunnel-CS project and structure of recommendations to stakeholders

D. Makarov, D. Cirrone, V. Molkov
(Ulster University)

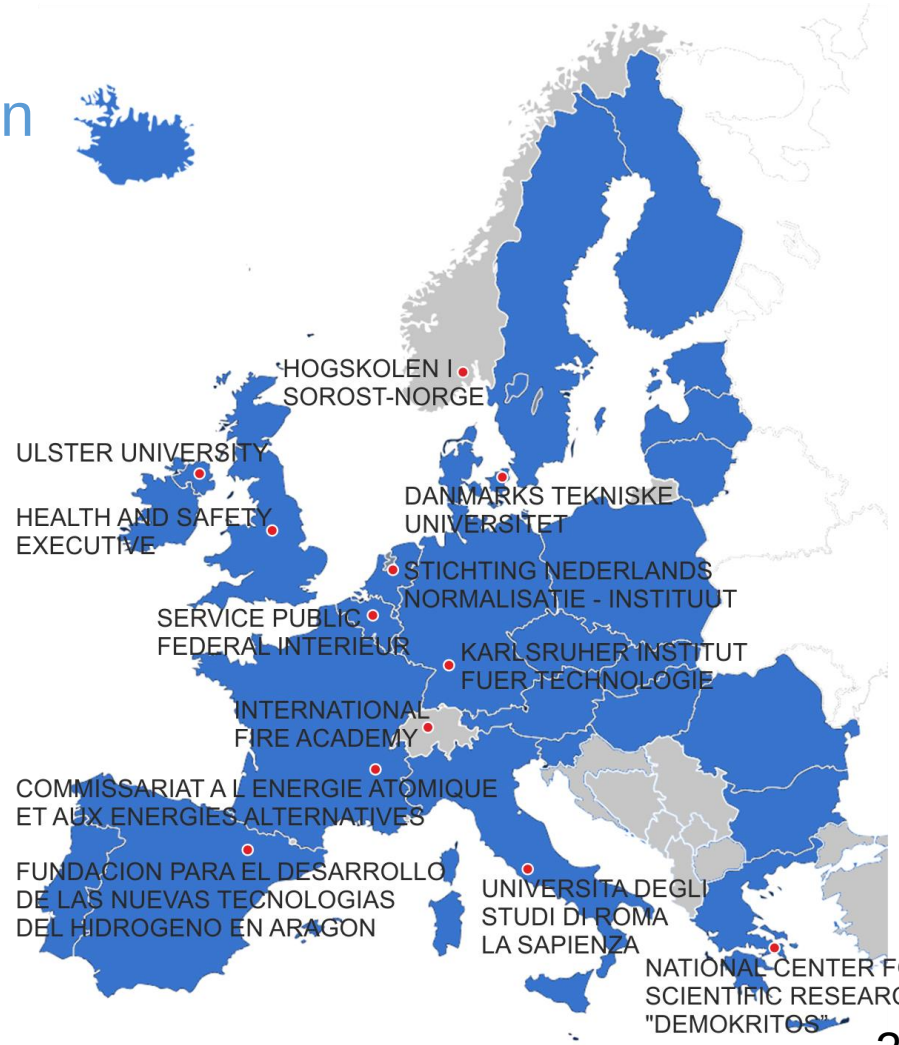
Clean Hydrogen Partnership

Co-funded by the European Union

HyTunnel-CS project overview

https://hytunnel.net/

- Project title: Pre-normative research for safety of hydrogen driven vehicles and transport through tunnels and similar confined spaces
- Project dates: 01/03/19 - 31/07/22
- Total project budget: €2.5M
- 13 partners from 11 countries

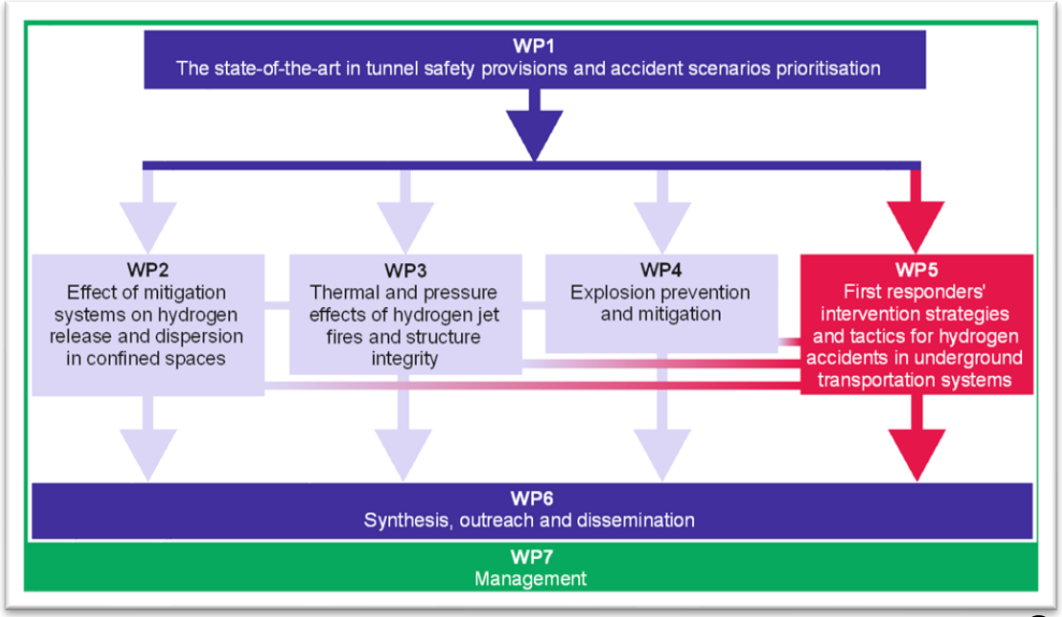


HyTunnel-CS partners	
UU - University of Ulster, UK (coordinator)	IFA - International Fire Academy, Switzerland
KIT - Karlsruher Institut fuer Technologie, Germany	URS - Universita Degli Studi Di Roma La Sapienza, Italy
NCSRD - National Center for Scientific Research "Demokritos", Greece	NEN - Stichting Nederlands Normalisatie – Instituut, Netherlands
USN - Hogskolen I Sorost-Norge, Norway	SPFI - Service Public Federal Interieur, Belgium
HSE - Health and Safety Executive, UK	CEA - Commissariat A L Energie Atomique Et Aux Energies Alternatives, France
DTU - Danmarks Tekniske Universitet, Denmark	PS - Pro-Science - Gesellschaft Fur Wissenschaftliche Und Technische Dienstleistungen Mbh, Germany
FHa - Fundacion Para El Desarrollo De Las Nuevas Tecnologias Del Hidrogeno En Aragon, Spain	

Project summary (1/2)

Ambition, research approach, aim

- **Ambition:** Allow hydrogen-powered vehicles and hydrogen delivery transport enter underground traffic infrastructure.
- **Aim:** Conduct internationally leading PNR to close knowledge gaps and technological bottlenecks in the provision of safety and acceptable level of risk in the use of hydrogen and fuel cell cars as well as hydrogen delivery transport in underground transportation systems.
- **Research approach:** Consider hydrogen vehicle and underground traffic structure as a single system with integrated safety approach using complementarities and synergies of theoretical, numerical and experimental studies.



Project summary (2/2)

Main objectives

- Generate **unique experimental data** regarding the interaction of hydrogen with safety equipment and systems of underground infrastructure using the best European hydrogen safety research facilities including real tunnels.
- Create deeper knowledge of the relevant physics to underpin advanced hydrogen safety engineering and **develop innovative prevention and mitigation strategies**.
- Develop further existing and **new contemporary CFD and FE models**, **engineering correlations**, **hazard and risk assessment tools**; validate them against experimental data.
- Prepare **harmonised recommendations for intervention strategies and tactics for first responders** providing conditions for their life safety and property protection.
- Develop **recommendations for inherently safer use of hydrogen vehicles in underground transportation systems**.
- Produce commonly agreed, scientifically based **recommendations for the update of relevant RCS**.

Expected impact of HyTunnel-CS project

- **Stakeholders, including OEMs:**
  Deliverable D6.9 "Recommendations for inherently safer use of hydrogen vehicles in underground transportation systems", including new engineering tools for e-Laboratory of Hydrogen Safety
- **First responders:**
  Deliverable D5.4 "Harmonised recommendations for intervention strategies and tactics for first responders providing conditions for their life safety and property protection"
- **Industry:**
  Deliverable D6.10 "Recommendations for the update of relevant RCS", including through partner NEN (secretariate of CEN/CENELEC/JTC6)
- **Research, including academia:**
  Closed knowledge gaps, addressed technological bottlenecks, shared beyond the state-of-the-art in hydrogen safety

D6.9 “Recommendations for safer use of H_2 vehicles in underground … systems”

Summary

- One of the main outcomes of HyTunnel-CS project
- The synthesis of the HyTunnel-CS outputs on understanding, prevention and mitigation strategies, and engineering solutions
- Defines the requirements for safety design and inherently safer use of hydrogen systems in tunnels and other enclosed spaces
- Gives guidance on the evaluation of appropriateness and effectiveness of conventional and innovative safety measures, in the event of incidents involving hydrogen-powered vehicles
- Defines the applicability range of recommended hazard and risk assessment models, tools and methodologies

D6.9 “Recommendations for safer use … ”

Incident scenarios with H_2 transport in underground infrastructure

1. Unignited hydrogen release and dispersion in a confined space with mechanical ventilation.
2. Unignited hydrogen release in confined spaces with limited ventilation.
3. Unignited hydrogen release in a tunnel with natural/mechanical ventilation.
4. Hydrogen jet fire in confined spaces with limited ventilation.
5. Hydrogen jet fire and vehicle fire in a mechanically ventilated confined space (maintenance shop/underground parking).
6. Hydrogen jet fire impingement on a tunnel.
7. Hydrogen jet fire and vehicle fire in a tunnel.
8. Fire spread in underground parking.
9. Hydrogen storage vessel rupture in a tunnel.
10. Hydrogen storage vessel blowdown with delayed ignition in a tunnel.

Onboard hydrogen storage quantities: 5 to 400 kg

D6.9 “Recommendations for safer use … ”

Structure

1. Introduction
   - Safety objectives
   - Incident scenarios with H_2 transport in underground infrastructure
2. Principles of hydrogen safety design
3. Dealing with unignited hydrogen releases and jet fires
4. Hydrogen explosions prevention and mitigation
   - Prevention and mitigation of hydrogen deflagrations, DDT and detonations
   - Hydrogen tank rupture in a fire: consequences and prevention
5. Impact of hydrogen vehicle incidents on structures
6. Quantitative risk assessment methodology

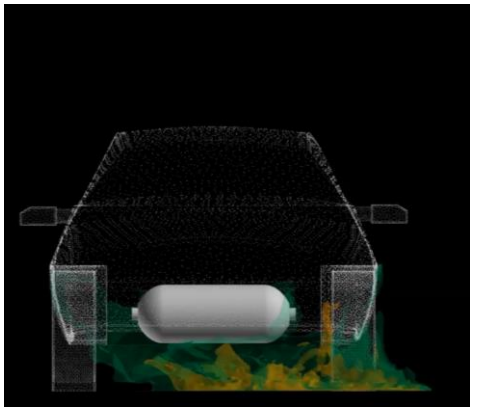
- Appendix 1. Harm criteria
- Appendix 2. Information on existing RCS
- Appendix 3. Hydrogen safety engineering models and tools

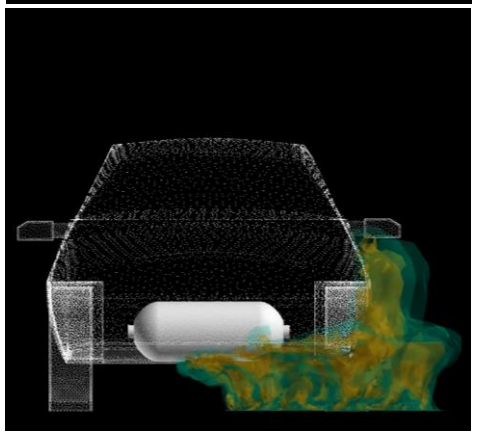
Innovative safety strategies

Ignited and unignited releases

Tackling hazards of hydrogen vehicles protected by TPRD:

- Design release system to **exclude** formation of flammable cloud that can deflagrate and transit to detonation (DDT) in an underground structure.
- We can **reduce hazard distances** for hydrogen releases (the similarity law) and jet fires (the dimensionless flame correlation) at atmospheric and **cryogenic temperature** by proper TPRD design.
- We can design **TPRD parameters** to exclude flammable cloud and hot products at T>300^{o}C under the ceiling **to allow underground parking**.
- We can define **TPRD diameter** to exclude the pressure peaking phenomenon **to park in garages** and place tanks **in storage enclosures** onboard of trains, ships, planes.
- We can **design** any **tank-TPRD system to exclude tank rupture in fire of any intensity** (beyond reduced by GTR#13 localised fire intensity of **HRR/A=0.35 MW/m^2**) and different TPRD response time.





D6.9 “Recommendations for safer use … ”

Safety objectives

- Analysis of effectiveness and applicability of conventional safety provisions for transport in tunnels and confined spaces.
- Wide range of hazards and incident prevention and mitigation techniques
- Design of fuel cell electrical vehicle (FCEV) is of paramount importance to allow the inherently safer use of hydrogen vehicles in existing tunnels and underground parking
- Design of FCEV should account for recommendations made in D6.9 document

Dissemination channels

https://hytunnel.net/

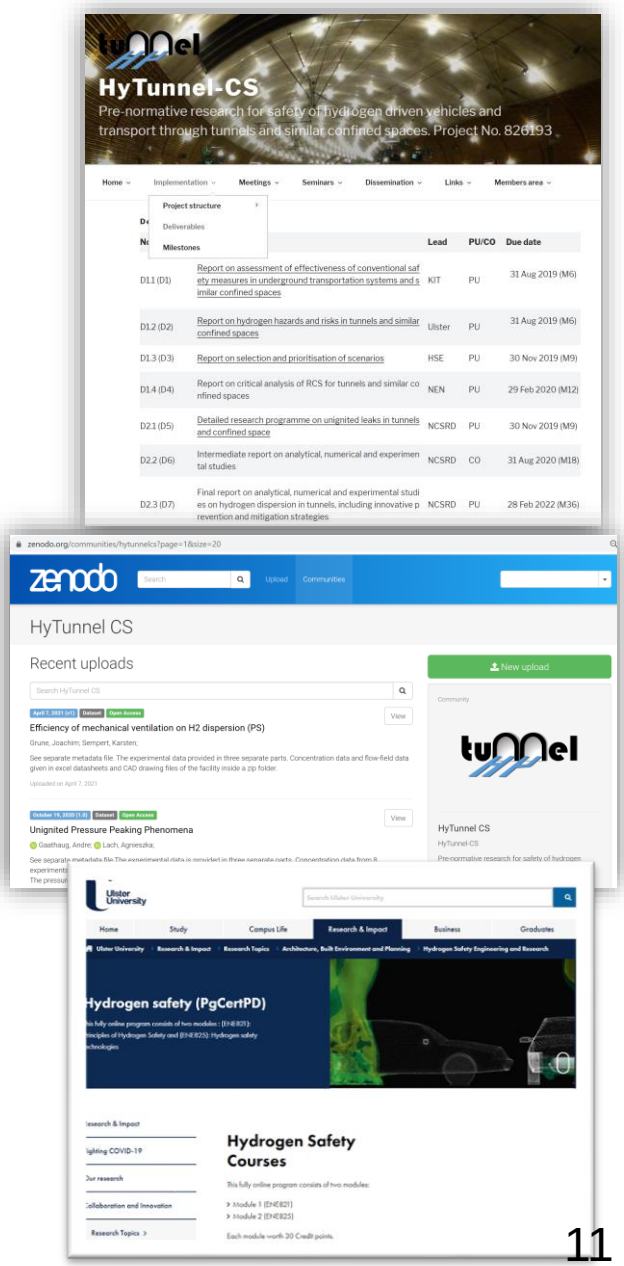
- All public deliverables
- Key project outputs **D5.4**, **D6.9**, **D6.10**
- Dissemination conference registration
- Reference to project publications
- Links to open data repositories

Open access to primary experimental data

- https://zenodo.org/communities/hytunnelcs
- https://usn.figshare.com/articles/dataset/...

Education

- Hydrogen Safety PGCertPD (Ulster University) https://www.ulster.ac.uk/research/topic/built-environment/hydrogen-safety-engineering/study



Acknowledgements

This project has received
funding from the Fuel Cells
and Hydrogen 2 Joint Undertaking
(now Clean Hydrogen Partnership)
under Grant Agreement No 826193.
This Joint Undertaking receives support
from the European Union's Horizon 2020 Research
and Innovation program, Hydrogen Europe and Hydrogen
Europe Research.