



ELVHYS - Enhancing safety of liquid and vaporised hydrogen transfer technologies in public areas for mobile applications

3rd Stakeholders' Workshop – NCSR «Demokritos», Athens (Greece)

Federico Ustolin (NTNU) et al

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Instructions for participants

- Microphone and video camera options will be deactivated by the hosts at the start of the workshop, however, please ensure at any time that your microphone and video camera are off.
- Presentations will allow 5 minutes for questions. Please ask your questions to presenters by using the Q&A option.
- Presentations will be made openly available on ELVHYS website after the workshop.



Programme	
Time (CEST)	Presentation title
09:00-09:05	Welcome (F. Ustolin, NTNU; A. Venetsanos, NCSRD)
09:05-09:30	ELVHYS project overview, including bunkering activities (F. Ustolin, NTNU)
09:30-09:55	Procedures for LH ₂ transfer from trailer to a stationary storage tank (D. Houssin, Air Liquide)
09:55-10:20	Development of LH ₂ fuelling procedures and risk assessment within ISO/TC197/WG35 (B. Ravinel, Daimler Truck AG)
10:20-10:40	Coffee break
10:40-11:05	Modelling of a LH ₂ loading cycle from onshore storage to a seaborne tanker (A. Reyes Lúa, SINTEF)
11:05-11:30	Thermodynamic modelling of LH ₂ -bunkering (K. Vågsæther, USN)
11:30-12:00	Round table discussion (F. Ustolin, NTNU; All)
12:00-13:00	Lunch break
13:00-13:25	DISCHA tool for discharge and tank to tank transfer simulations (A. Venetsanos, NCSRD)
13:25-13:50	CFD model of refuelling through the entire equipment of a HRS (H. Ebne-Abbasi, UU)
13:50-14:15	LES model of pressure recovery phenomena in a large-scale LH ₂ storage at HRS (D. Cirrone, UU)
14:15-14:35	Coffee break
14:35-15:00	A condensation model based on Greens Function solution of heat transfer equation at GH ₂ -LH ₂ interface (Z. Xu, KIT)
15:00-15:25	Refuelling and discharge of cryo-compressed hydrogen storage systems for heavy duty trucks (S. Aceves, NTI Mexico)
15:25-15:50	Final round table discussion (F. Ustolin, NTNU; All)
15:50-16:00	Closure of the workshop (F. Ustolin, NTNU; A. Venetsanos, NCSRD)

Progress / Closed gaps

Fundamental/Modelling “Release”:

- ✓ Discharge coefficients for cryo- and cryocompressed releases
- ✓ Rainout phenomena better understood
- ✓ Fundamental data for mixing of large scale releases

Fundamental/Modelling “Ignition”:

- ✓ MIE and hot surface T determined for cryogenic conditions
- ✓ Empirical tests for RPT without fast reaction
- ✓ Electrostatics of cryogenic releases
- ✓ Worst case effects for small cryogenic inventories determined via variation of ignition time and position

Fundamental/Modelling “Combustion”:

- ✓ Flame length correlations validated
- ✓ σ , σ_{crit} and run-up distance for DDT determined at cryogenic conditions
- ✓ ...

 PRESLHY

SH2IFT Project Findings

SH₂IFT

Fundamental/Modelling “BLEVE”:

- ✓ Experiments performed and BLEVE observed at BAM

(see van Wingerden, Kees, et al. *Chemical Engineering Transactions*, 2022, 90. Jg., S. 547-552)



Fundamental/Modelling “RPT”:

- ✓ RPT observed in BAM tests spilling LH₂ on water

(see van Wingerden, Kees, et al. "Experimental Investigation into the Consequences of Release of Liquefied Hydrogen onto and under Water." (2022))



ELVHYS



Enhancing safety of liquid and vaporised hydrogen transfer technologies in public areas for mobile applications

Funding: 2.0 M€

Duration: 2023-2026

Coordinator: NTNU

Partners:



Website

Objective: provide indications on inherently safer and efficient cryogenic hydrogen technologies and protocols in mobile applications by proposing innovative safety strategies including selection of effective safety barriers and hazard zoning strategies, which are the results of a detailed risk analysis.

NTNU role: coordinator, consequence analysis, risk analysis



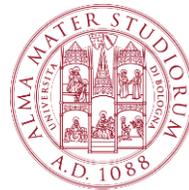
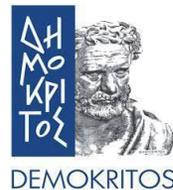
ELVHYS

Expected outcomes & objectives

1. Detailed **risk analysis** for LH2 transferring operations for mobile applications (ships, trucks, stationary tanks) fillings
2. **Generic hazard distances** for LH2 transferring operations in the different applications, also addressing **SimOps**
3. **Guidelines for design** of LH2 transferring facilities
4. **Consensual loading procedures** for LH2 transferring operations
5. Provide inputs for developing **Standards, Technical Specifications, or Technical Reports** at the international level

ELVHYS – Consortium

 **NTNU** (Coordinator)



ELVHYS – Stakeholder Advisory Board

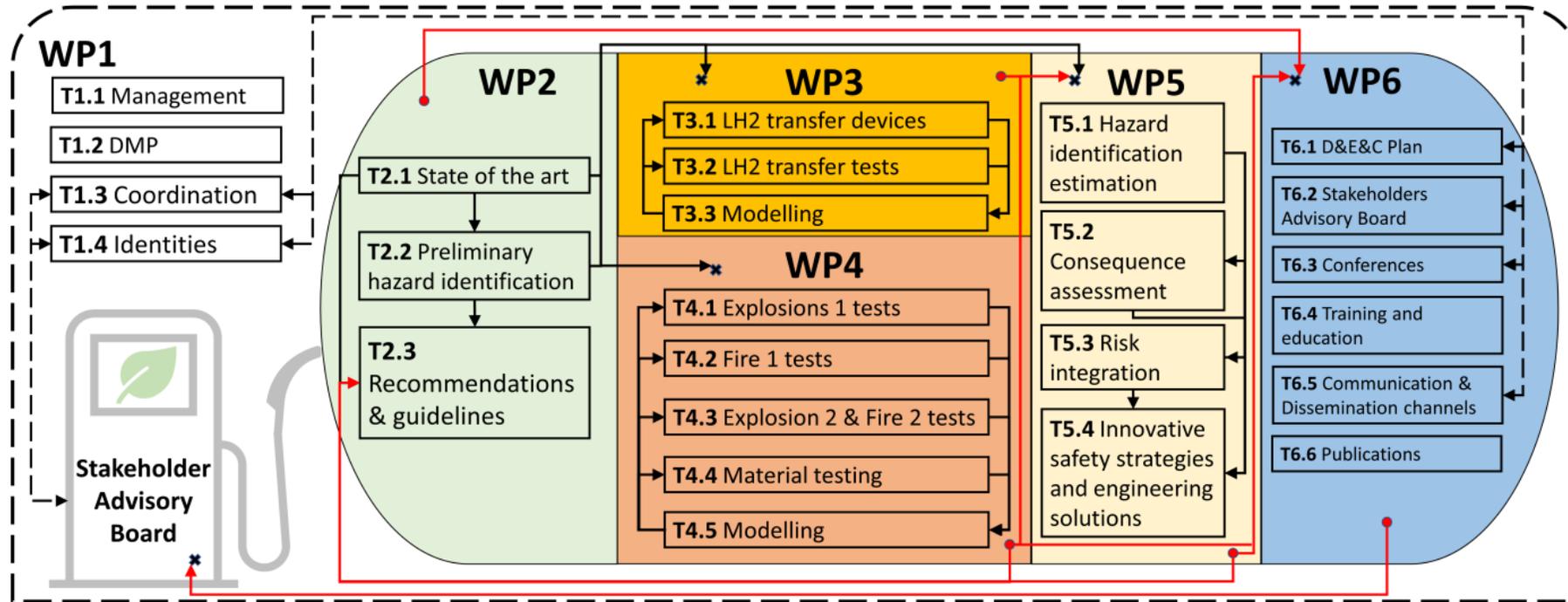
- At the moment **30 organizations** are included in the SAB
- The organizations are based in **8 European** (Belgium, France, Germany, Italy, Norway, Sweden, The Netherlands, UK) and **4 non-European countries** (Canada, China, Japan, USA)
- Type of organizations: industries and companies (8), research centres (6), universities (5), national public institutes (3), association (HySafe), intergovernmental org. (IEA), industry org. (Hydrogen Council), rail operator (SNCF)

ELVHYS – Collaboration with other projects

Collaborations with other projects related to LH2 and cryogenic hydrogen transfer and storage were established:

1. **e-SHyIPS** (Horizon Europe, coordinator: Politecnico of Milano, Italy)
2. **ESKHYMO** (France, 2022-2026, coordinator: CEA, France)
3. **LH2 Pioneer** (NFR, coordinator: SINTEF Energy)
4. **MF Hydra** (LH2 ferry, Norway, Norled)
5. **sHYpS** (EU, coordinator (Horizon Europe, 2022-26, coordinator: NavalProgetti S.r.l., Italy)
6. **STACY** (EIG Concert Japan, 2022-2026, coordinator: Julich, Germany)
7. **NICOLHy** (Horizon Europe, 2024-26, coordinator: BAM, Germany)
8. **HEAVEN** (Horizon Europe, 2023-26, coordinator: Rolls-Royce, Germany)
9. **DelHyVEHR** (Horizon Europe, coordinator: Engie, France)

ELVHYS – Work Plan



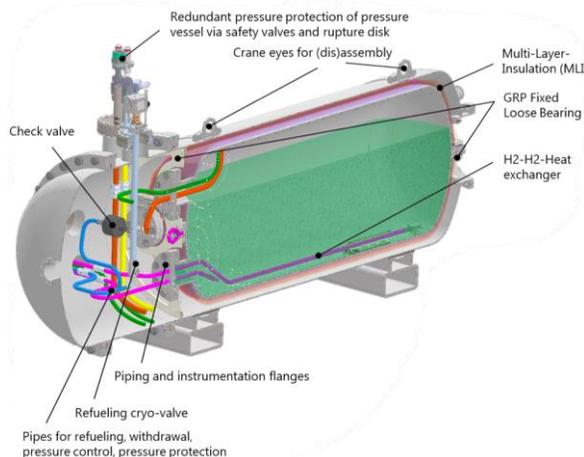
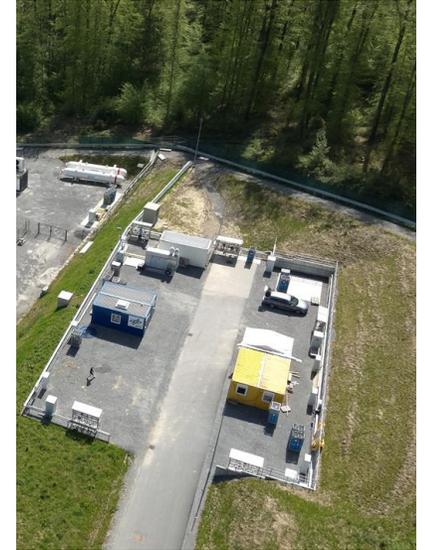
- WP1 - Project Management & Coordination
- WP2 - From industrial background and strategy to findings application
- WP3 - Cryogenic hydrogen transfer facilities performance
- WP4 - Fires & explosions from cryogenic hydrogen transfer facilities
- WP5 - Risk Analysis for selected cryogenic hydrogen transferring operations
- WP6 - Dissemination, exploitation and communication

ELVHYS – Fuelling/bunkering procedures

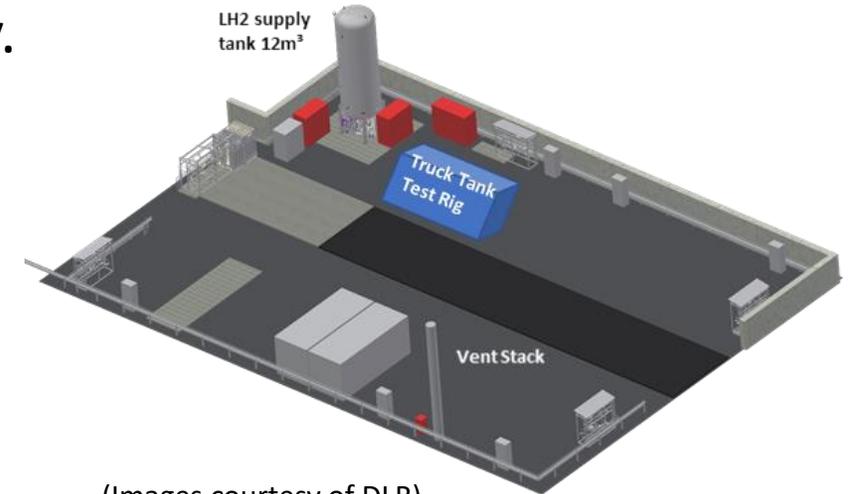
WP3 - Cryogenic hydrogen transfer facilities performance

Experimental work

- Tests will be carried out at DLR Lampoldshausen facility in Germany in Q2 2025.
- KIT and Air Liquide partners are supporting DLR in this activity.
- DLR built a dedicated facility which is almost ready.



(Images courtesy of KIT)



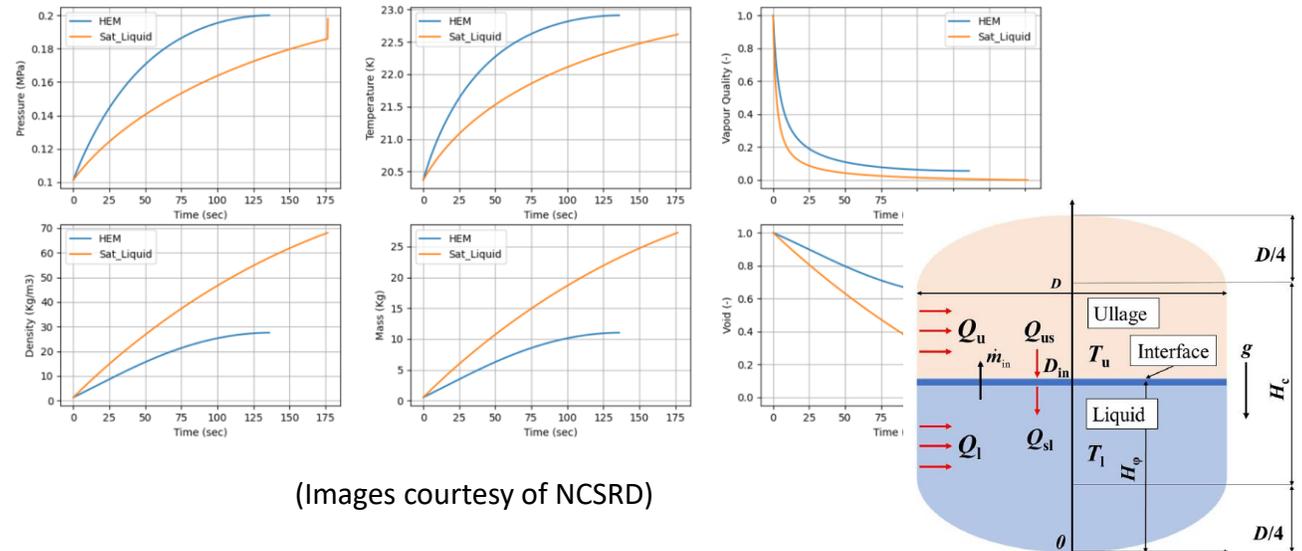
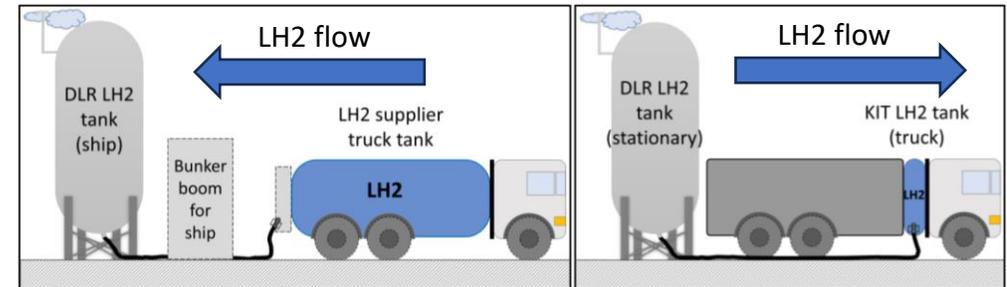
(Images courtesy of DLR)

ELVHYS – Fuelling/bunkering procedures

WP3 - Cryogenic hydrogen transfer facilities performance

Modelling activities

- NCSR “Demokritos” partner is leading this activity.
- The goal is to further develop their DISCHA engineering tool which was previously created to simulate LH2 releases.
- A dedicated presentation will follow in this workshop.



(Images courtesy of NCSR)

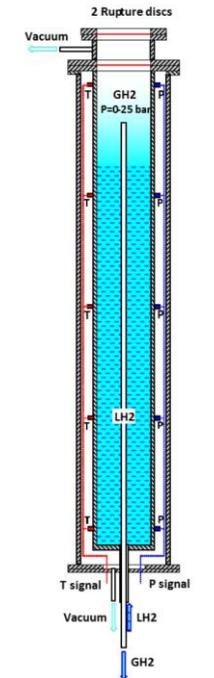
(Wang H.R. et al., 2022)

ELVHYS – Fuelling/bunkering procedures

WP4 - Fires and explosions from cryogenic hydrogen transfer facilities

Experimental work

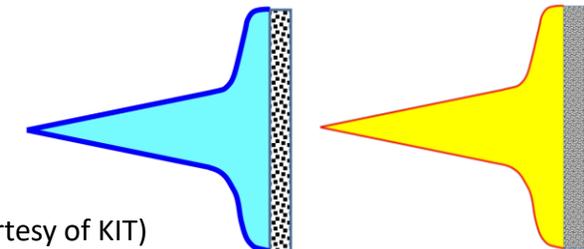
- HSE will perform tests in Q3 2024 on:
 1. Oxygen enrichment and condensed phase explosions
 2. Leakage into cold room/tank connection space considering barriers and obstacles
- KIT will perform tests in Q3 & Q4 2024 on:
 3. BLEVE tests with a shock tube
 4. Fire tests of short LH2 transfer line elements
 5. Material testing against unignited and ignited LH2 jets



HSE test (Hooker et al., 2012)



DNV test (Aaneby et al., 2021)



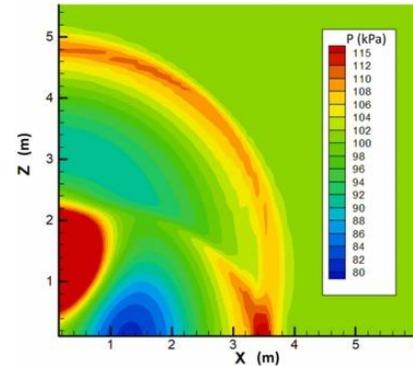
(Images courtesy of KIT)

ELVHYS – Fuelling/bunkering procedures

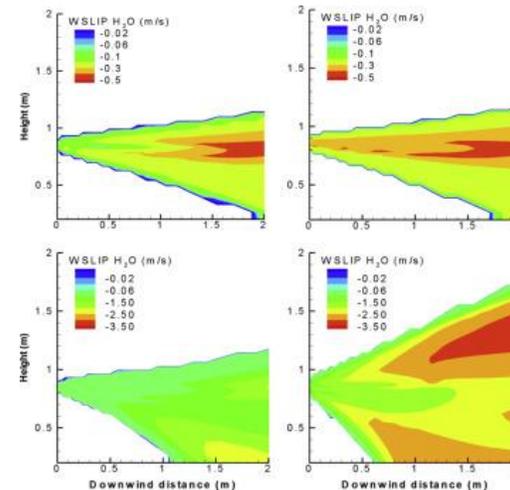
WP4 - Fires and explosions from cryogenic hydrogen transfer facilities

Modelling activities

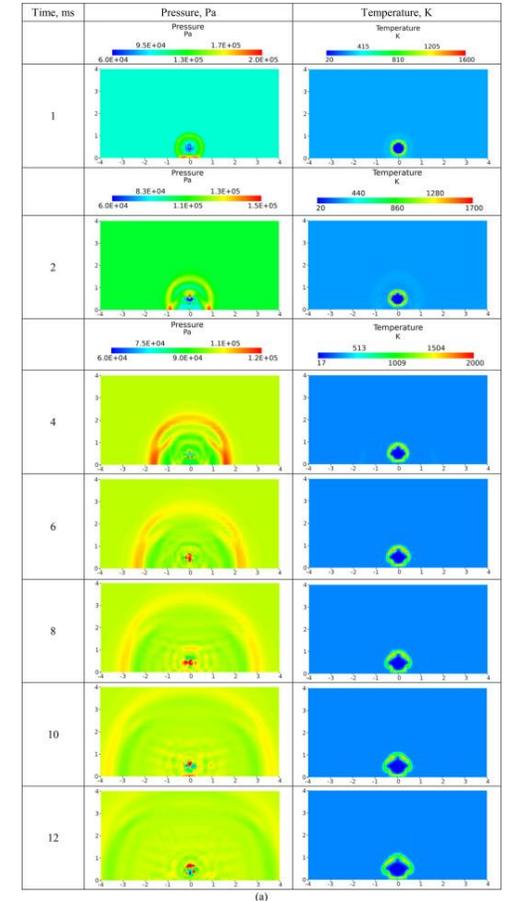
- NCSRD partner is leading.
- Partners involved in modelling of WP4 physical phenomena: HSE, KIT, NTNU, UNIBO, UU.
- Physical phenomena that will be modelled are:
 1. BLEVE
 2. Unignited and ignited LH2 releases
 3. Fire resistance of LH2 components
 4. Jet fires
 5. PPP



(Ustolin et al., 2021)



(Giannisi and Venetsanos, 2018)

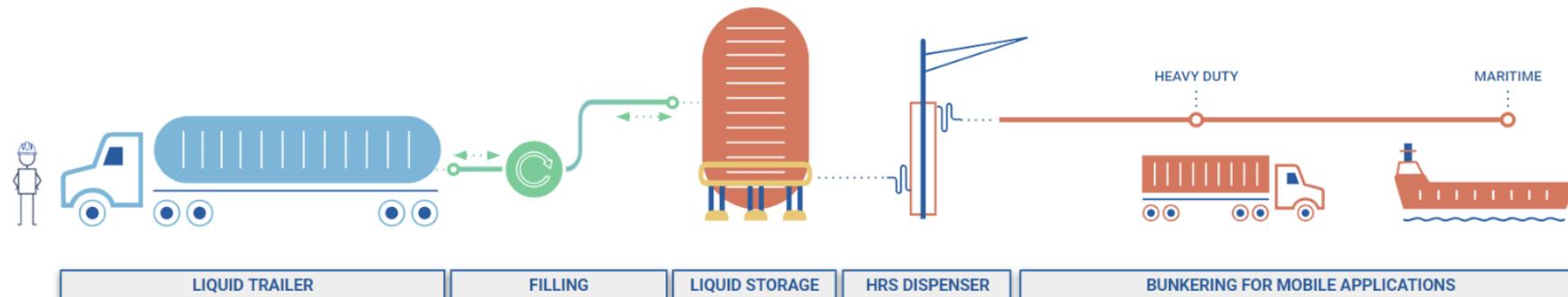


(Cirrone et al., 2023)

ELVHYS – Fuelling/bunkering procedures

WP5 - Risk Analysis for selected cryogenic hydrogen transferring operations

- NCSR D partner is leading this activity supported by AL, DLR, KIT, NTNU, UNIBO, UU. The tasks of this risk analysis are:
 - **Task 5.1** – Hazard identification and damage state estimation
 - **Task 5.2** – Consequence assessment
 - **Task 5.3** – Frequency assessment and risk integration
 - **Task 5.4** – Innovative safety strategies and engineering solutions



(Image courtesy of Air Liquide)



Thank you for your attention



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UK Research
and Innovation

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