



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

2<sup>nd</sup> Stakeholders' Workshop – HSE, Buxton (UK)

Federico Ustolin (NTNU) et al

29.11.2023



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| Programme   |   |
|-------------|---|
| Time (GMT)  | Presentation title  |
| 09:00-09:05 | Welcome (F. Ustolin, NTNU; W. Rattigan, HSE)  |
| 09:05-09:30 | ELVHYS project overview (F. Ustolin, NTNU)  |
| 09:30-09:55 | HSE experimental work on large-scale LH2 releases as part of the PRESLHY project (S. Coldrick, Health & Safety Executive) |
| 09:55-10:20 | The consequences of releasing liquid hydrogen on and into water (K. van Wingerden, Vysus Group)                           |
| 10:20-10:40 | Coffee break  |
| 10:40-11:05 | NPRA: LH2 releases at large scale associated with Norwegian Ferry application (D. Allason, DNV)                           |
| 11:05-11:30 | Pro-Science/KIT experimental work on cryogenic H2 releases as part of the PRESLHY project (A. Friedrichs, KIT)            |
| 11:30-12:00 | Intermediate round table discussion (F. Ustolin, NTNU; All)   |
| 12:00-13:00 | Lunch break   |
| 13:00-13:25 | The consequences of exposing cryogenic storage vessels containing liquid hydrogen to a fire load (M. Kluge, BAM)          |
| 13:25-13:50 | HEAVEN project: overview of the first piloted Flight of LH2 Powered Electric Aircraft (S. Jallais, Air Liquide)           |
| 13:50-14:20 | Coffee break  |
| 14:20-14:45 | LH2 release experiments to support large scale Shell projects (S. Betteridge, Shell)                                      |
| 14:45-15:10 | Experimental research on cryogenic hydrogen behaviour at Sandia National Laboratories (E. Hecht, Sandia)                  |
| 15:10-15:40 | Final round table discussion (F. Ustolin, NTNU; All)  |
| 15:40-15:50 | Closure of the workshop (F. Ustolin, NTNU; W. Rattigan, HSE)  |

# 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
- ✓  $\sigma$ ,  $\sigma_{crit}$  and run-up distance for DDT determined at cryogenic conditions
- ✓ ...

 PRESLHY

# SH2IFT Project Findings

# SH<sub>2</sub>IFT

## 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 LH<sub>2</sub> 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



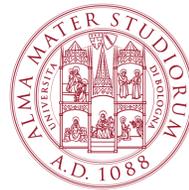
# ELVHYS

## 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 **29 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)

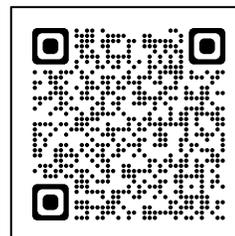
# ELVHYS – Stakeholder Advisory Board

| No | Organization  | Type                           | Country     |
|----|---|--------------------------------|-------------|
| 1  | Airbus  | Industry                       | France      |
| 2  | CEA (ESKHYMO project)   | Research Centre                | France      |
| 3  | Daimler Truck AG  | Industry                       | Germany     |
| 4  | DNV   | Certification body             | Norway/UK   |
| 5  | Technical University of Denmark DTU   | University                     | Denmark     |
| 6  | Energy Observer   | Company                        | France      |
| 7  | Fellow, Royal Society for the Encouragement of Arts, Manufactures and Commerce (FRSA) | Global network of changemakers | USA         |
| 8  | Forschungszentrum Jülich (STACY project)  | Research Centre                | Germany     |
| 9  | Hydrogen Council  | Industry organization          | ---         |
| 10 | HYEX  | Company                        | Norway      |
| 11 | Hyundai Motor Company   | Industry                       | South Korea |
| 12 | HySafe - International Association for Hydrogen Safety                                | Association                    | Belgium     |
| 13 | IEA - International Energy Agency   | Intergovernmental org.         | ---         |
| 14 | ISPRA - Italian National Institute for Environmental Protection and Research          | Public body                    | Italy       |
| 15 | Kawasaki Heavy Industries   | Industry                       | Japan       |

# ELVHYS – Stakeholder Advisory Board

| No | Organization  | Type            | Country         |
|----|---|-----------------|-----------------|
| 16 | NavalProgetti srl (sHYpS project)   | Company         | Italy           |
| 17 | Norled (MF Hydra – LH2 ferry project)   | Company         | Norway          |
| 18 | Politecnico di Milano (e-SHyIPS project)  | University      | Italy           |
| 19 | PPG   | Company         | UK              |
| 20 | RISE  | Research Centre | Sweden          |
| 21 | RIVM - the Netherlands National Institute for Public Health and the Environment | Public body     | The Netherlands |
| 22 | Shandong University (SDU)   | University      | China           |
| 23 | SINTEF Energy (LH2 Pioneer project)   | Research Centre | Norway          |
| 24 | SINTEF industry   | Research Centre | Norway          |
| 25 | SNCF - DIRECTION TECHNOLOGIES, INNOVATION ET PROJETS GROUPE (rail operator)     | Operator        | France          |
| 26 | University of Bergen  | University      | Norway          |
| 27 | University of Salerno   | University      | Italy           |
| 28 | University of South-East Norway USN   | University      | Norway          |
| 29 | University of Trieste   | University      | Italy           |

The SAB list can be found on the project website (scan QR code)

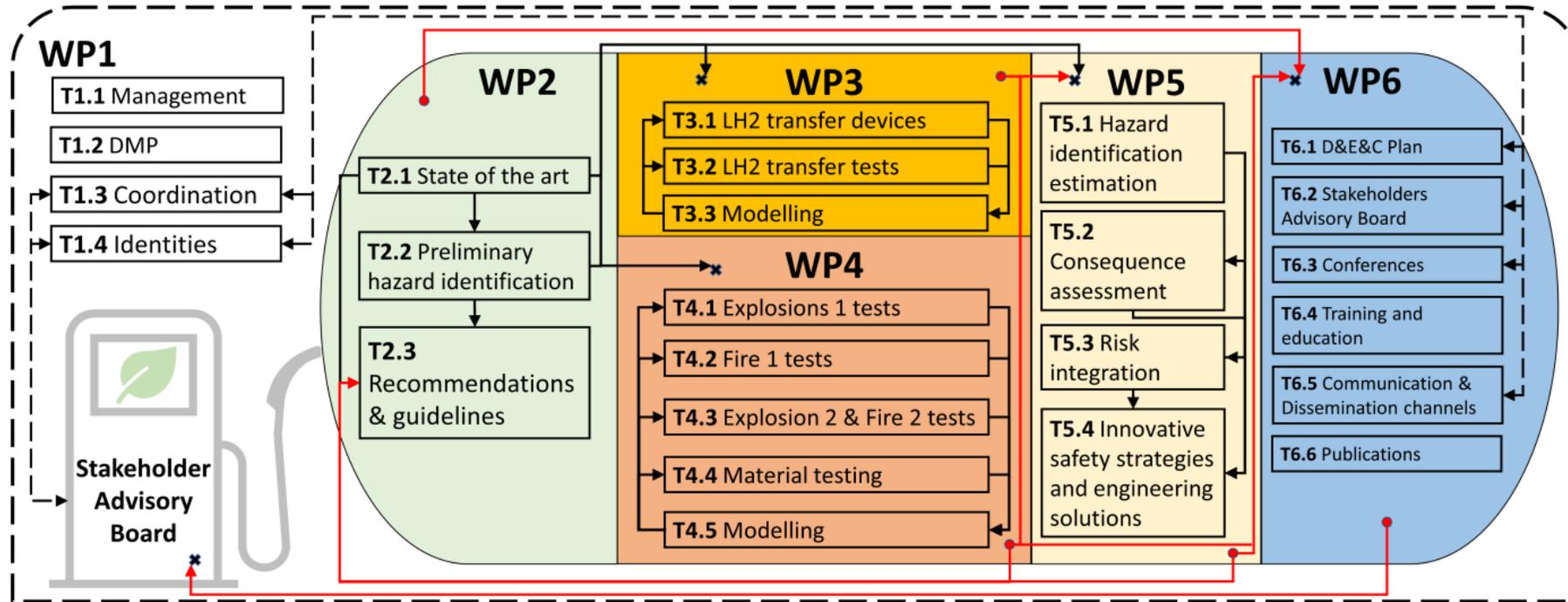


# ELVHYS – Collaboration with other projects

Intention to establish collaborations with other projects related to LH2 and cryogenic hydrogen transfer and storage

1. **e-SHyIPS** - Define the new guidelines for an effective introduction of hydrogen in maritime passenger transport sector (Horizon Europe, coordinator: Brendan Patrick Sullivan, Politecnico of Milano, Italy)
2. **ESKHYMO** - Enhance Safety Knowledge for Hydrogen Measurements/Modelling in cryogenic phase (France, 2022-2026, coordinator: Etienne Havret, CEA, France)
3. **LH2 Pioneer** - Ultra-insulated seaborne containment system for global LH2 ship transport (NFR, coordinator: David Berstad, SINTEF Energy)
4. **MF Hydra** (LH2 ferry, Norway, Norled)
5. **sHYpS** - Sustainable Hydrogen Powered Shipping (EU, coordinator (Horizon Europe, 2022-26, coordinator: Pierluigi Busetto, NAVAL PROGETTI, Italy)
6. **STACY** - Towards Safe Storage and Transportation of Cryogenic Hydrogen (EIG Concert Japan, 2022-2026, coordinator: Ernst-Arndt Reinecke, Julich, Germany)

# ELVHYS – Work Plan

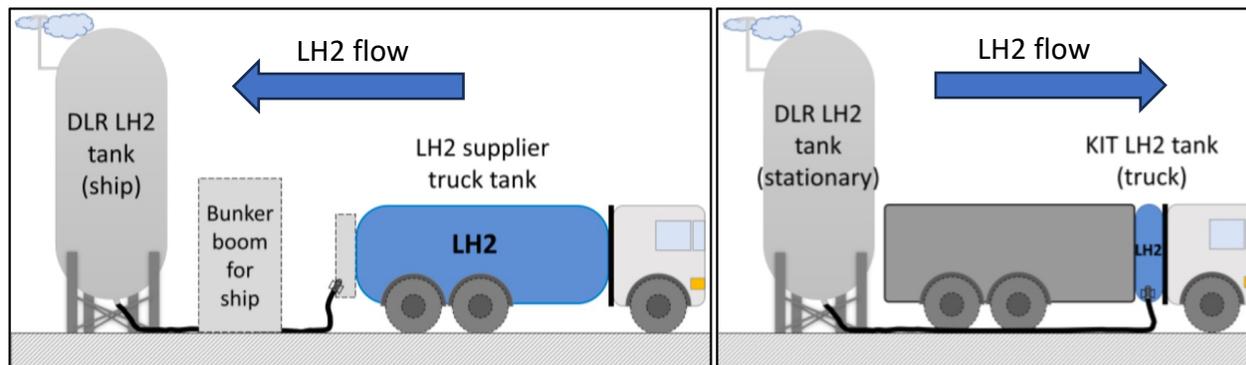


- WP1 - Project Management & Coordination
- WP2 - From industrial background and strategy to findings application
- WP3 - Cryogenic hydrogen transfer facilities performance
- WP4 - Fires & explosions from cryogenic hydrogen transfer facilities
- WP5 - Risk Analysis for selected cryogenic hydrogen transferring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

# ELVHYS – Tasks

## WP3 - Cryogenic hydrogen transfer facilities performance

- **Task 3.1** - LH2 transfer devices definition
- **Task 3.2** - LH2 transfer tests: bunkering, fuelling, refuelling, defueling
- **Task 3.3** - Support by theoretical and numerical studies for experimental setup, and numerical experiments to formulate cryogenic hydrogen transfer protocols



**Tests will be carried out by DLR in Germany in 2024**

# ELVHYS – Tasks

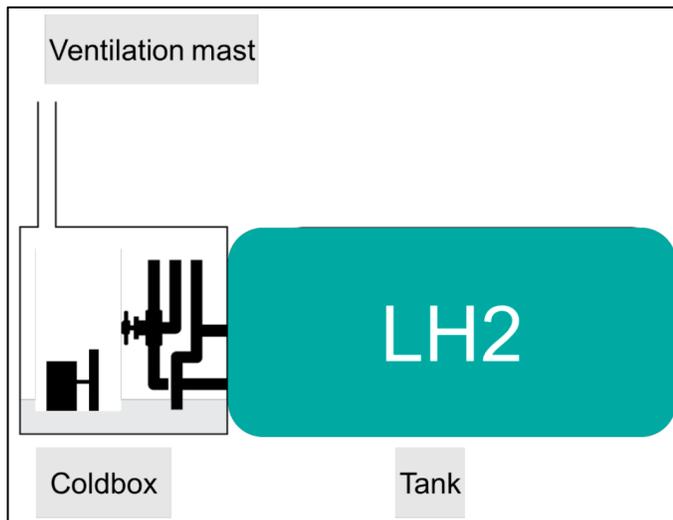
## WP4 - Fires and explosions from cryogenic hydrogen transfer facilities

- **Task 4.1** – Oxygen enrichment and condensed phase explosions
- **Task 4.2** – Leakage into cold room/tank connection space considering barriers and obstacles



HSE test (Hooker et al., 2012)

**Tests will be carried out by HSE in UK in 2024**



DNV test (Aaneby et al., 2021)

# ELVHYS – Tasks

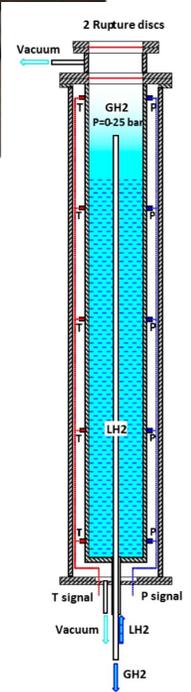
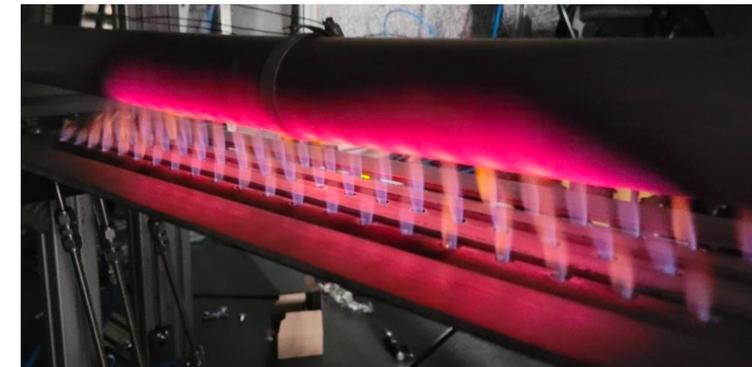
## WP4 - Fires and explosions from cryogenic hydrogen transfer facilities

- **Task 4.3** – Performance of LH2 components and explosion consequences
- **Task 4.4** – Material testing against unignited and ignited jets (MLI, glass spheres, perlite layers and fire protecting wall) according to ISO 20088
- **Task 4.5** – Modelling in support of and utilising WP4 experimental activities

**Tests will be carried out by KIT in Germany in 2024**



SH2IFT test (Ødegård et al., 2022)



# ELVHYS – Tasks

## WP5 - Risk Analysis for selected cryogenic hydrogen transferring operations

- **Task 5.1** – Hazard identification and damage state estimation
  - Sub-Task: 5.1.1 Hazard identification
  - Sub-Task: 5.1.2 Damage state of the installation resulting in the release of hydrogen
- **Task 5.2** – Consequence assessment
  - Sub-Task: 5.2.1 Modelling of accidental phenomena
  - Sub-Task 5.2.2: Vulnerability assessment
- **Task 5.3** – Frequency assessment and risk integration
  - Sub-Task: 5.3.1 Frequency of incident occurrence
  - Sub-Task: 5.3.2 Risk integration
- **Task 5.4** – Innovative safety strategies and engineering solutions
  - Sub-Task: 5.4.1 Safety barriers
  - Sub-Task: 5.4.2 Safety zoning strategies

# ELVHYS – News

Some selected news from the last newsletter published on the project website

- ELVHYS project shortlisted for the Best Success Story Award 2023 by the Clean Hydrogen Partnership!
- ELVHYS first research outcomes were presented at International Conference of Hydrogen Safety (ICHHS) 2023

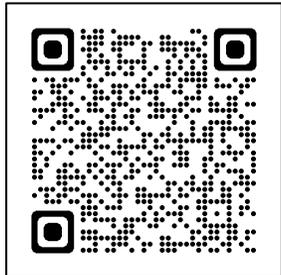


**Faster hydrogen refuelling  
of heavy-duty transport**





# Thank you for your attention



[federico.ustolin@ntnu.no](mailto:federico.ustolin@ntnu.no)



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