WP6 – Implementation: Exploitation and Dissemination

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Pre-normative REsearch for Safe use of Liquid HYdrogen

Content

I. Overview of WP6
II. Handbook of hydrogen safety: chapter on LH2 safety
III. Guidelines for a safe design and operation of LH2 infrastructure
IV. Recommendations for RCS
V. Engineering tools and correlations
VI. White Paper
VII. Dissemination Conference
VIII. Dissemination of the results

WP6 structure

- Task 6.1 Handbook of Hydrogen Safety: chapter on LH2 safety (**HySafe**; All; M1-34)
- Task 6.2 Guidelines for a safer design and operation of LH2 infrastructure (**AL**; All; M7-36)
- Task 6.3 Recommendations for RCS (**AL**; All; M19-36)
- Task 6.4 Engineering correlations and tools (**UU**; All; M7-36)
- Task 6.5 White paper on the use of LH2 (**KIT**; All; M18-36)
- Task 6.6 Dissemination conference (**UU**; All; M6-36)

Deliverables and Milestones

WP6 Implementation: Exploitation and Dissemination.

D/MS	Title	Task	Lead	Due
D6.6	Plan for the dissemination, communication and exploitation	6.6	UU	M6
MS25	ToC of Handbook of Hydrogen Safety: chapter on LH2 safety	6.1	UU	M12
MS26	ToC of Guidelines for safe design and operation of LH2 infrastructure	6.2	UU	M14
MS27	ToC of White paper	6.5	UU	M18
D6.7	Plan for the dissemination, communication and exploitation-1st update	6.6	UU	M18
MS28	Brochure and preliminary programme of the dissemination conference	6.6	UU	M22
MS29	Detailed description of novel engineering tools for LH2 Version 1	6.4	UU	M24
MS30	Discussion draft of recommendations for RCS	6.3	UU	M28
D6.1	Handbook of Hydrogen Safety: chapter on LH2 safety	6.1	HySafe	M34
D6.2	Guidelines for safe design and operation of LH2 infrastructures	6.2	AL	M35
D6.3	Recommendations for RCS	6.3	AL	M35
D6.4	White Paper	6.5	KIT	M35
D6.5	Detailed description of novel engineering tools for LH2 safety	6.4	UU	M35
D6.8	Plan for the dissemination, communication and exploitation-2nd update	6.6	UU	M36
D6.9	Report on the communication activities carried out to the general public	6.6	UU	M36

Chapter on LH2 in Handbook…

Task: 6.1 (M1-34) Lead: HySafe Partners: All

Gathering of information on up-to-date knowledge, gaps and progress on LH2 and cryo-compressed H2 in a publishable report:

- Internal collaboration: PRESLHY partners. Alignment to the review of the state-of-the-art, strategies produced in WP2 and new knowledge generated in WP3-5.
- External collaboration: HySafe experts.

MS25 ToC of Handbook of Hydrogen Safety: chapter on LH2 safety, M12 (UU)

D6.1 Handbook of Hydrogen Safety: chapter on LH2 safety, M34 (HySafe)

Chapter on LH2 in Handbook…

Task: 6.1 (M1-34) Lead: HySafe Partners: All

Key points:

- Preparation of ToC: inclusion of the possible experts compiling each section
- Proposal to include a first version of the chapter in the handbook to be published in 1 year
- Update and expansion of the LH2 chapter in M34
- Plan and timing to contact the external experts collaborating to the draft of the handbook
- Distribution of the chapter on LH2 safety
  - PRESLHY and HySafe websites
  - Handbook publication

Guidelines for a safe design…

Task: 6.2 (M7-36) Lead: AL Partners: All

- Facilitation of inherently safer design and operation of LH2 systems and infrastructure in Europe.
- Focus on areas where LH2 specific standards are not available or suitable for use in public areas.
- Inclusion of innovative safety strategies and engineering solutions and tools developed in WP3-5.

MS26 ToC of Guidelines for safe design and operation of LH2 infrastructure, **M14** (UU)

D6.2 Guidelines for safe design and operation of LH2 infrastructures, M35 (AL)

Recommendations for RCS

Task: 6.3 (M19-36) Lead: AL Partners: All

Implementation of the project outputs in relevant RCS. The program will include:

- Identification of existing RCS in WP2.
- Formulation of guidelines developed in Task 6.2 according to the standard developing organisations (SDO).
- Presentation and submission of the recommendations to SDOs, such as CEN/CLC Technical Committee 6, ISO Technical Committee 197, etc…

Presentation at ISO/TC 197 meeting, **M12**

MS30 Discussion draft of recommendations for RCS, M28 (UU)

D6.3 Recommendations for RCS, M35 (AL)

Recommendations for RCS

Preparation of a reference case

- Real refuelling station.
- Ideal characteristics and layout:
  - LH2 storage tank
  - H2 dispensers at different pressure: 70 MPa and 30 MPa
  - Multi-fuel station (gasoline, diesel, hydrogen)
- Total – Linde station in Munich or station in Berlin.
- Comparison NFPA 2 and EIGA LH2 hazard distances.

Problems:

- Accessibility to data on design and layout of the stations.

Engineering correlations and tools

Task 6.4 (M7-36) Lead: UU Partners: All

Task description

Task 6.4 (M7-36) Lead: UU Partners: All

Correlations developed in WP3-5 will be brought into a unified format suitable for implementation into integrated platforms for hazards and risk assessment.

- **UU:** Development of detailed unified template for description of correlations and tools developed in WP3-5.
- **ALL:** Detailed description of correlations and tools developed in WP3-5 according to the unified template (on quarterly basis as a tool is available).
- **ALL:** Inclusion of developed tools into safety engineering design, education and training platforms.

MS29 Detailed description of novel engineering tools for LH2, Version 1, M24 (UU)

D6.5 Detailed description of novel engineering tools for LH2 safety, M35 (UU)

Unified template

The unified template should include:

- Short user's manual: description of scenario, required input data and results.
- Scientific summary of the model, including assumptions it is based on.
- Indication of the limits within which the model has been validated.
- Useful experimental data when relevant.
- Detailed algorithm description for implementation in a software.
  - If the algorithm requires input parameters by the user, e.g. an initial guess or time step, the user should be properly advised on a value to choose and its effect on accuracy and time of calculation.
- Reference to publication.

Draft of ToC

✓ Conduction and conclusion of PIRT exercise

✓ Definition of refined work programme

ALL: Definition of a more detailed list of the correlations and tools that we intend to develop throughout the project (suggestion by M12)

WP3 - Release and Mixing (1/2)

Experiments:

- Small scale multiphase release (KIT)
- LH2 pool (KIT)
- Rainout (HSL)

Modelling:

- Numerical studies on small scale multiphase releases (Exp3.1, KIT); spill and spread of LH2 and subsequent dispersion of hydrogen for experiments on LH2 pool (Exp3.4, KIT) and rainout (Exp3.5, HSL) (UWAR)
- Multiphase high pressure release and experiments on mid-scale multi-phase release which are currently in reserve (E3.2-E3.3, HSL) (UWAR)
- Contribution to development of simple tools based upon correlations (INERIS)

WP3 - Release and Mixing (2/2)

- Analysis of the applicability of notional nozzle theory and volumetric release source concept for prediction of concentration decay in cryogenic under-expanded jets (UU)
- Perform simulations of experiments on multi-phase releases with inclusion of conjugate heat transfer to develop a CFD model and use it as a contemporary engineering tool for evaluation of mass flow rate from LH2 tank (UU)
- Adaptation of current pool model (gasflow code) to LH2 pool (KIT)
- Multicomponent boiling pool model (NCSRD)
- Explicit modelling of phase change rates to be compared with existing Raoult methodology for estimation of phase distribution of two phase multicomponent mixtures (NCSRD)

WP4 – Ignition

Experiments:

- General ignition parameters (INERIS)
- Electrostatic ignition in cold jet (KIT)
- Electrostatic ignition in cold plume (HSL)
- Ignition of a spill of LH2 (KIT)
- Ignition of H2/condensed O2 phase (HSL)

Modelling:

- Spark ignition of cryogenic hydrogen-air mixtures with air accounting for chemical kinetics (UU)
- *Diffusion ignition simulations for cryogenic releases (UU, experiments in reserve)*
- Studies to understand phenomena associated with cryogenic mixtures of H2/O2 and their formation/ignition (UU)

WP5 – Combustion (1/2)

Experiments:

- Cryogenic hydrogen jet fire experiments with detailed temperature and heat flux measurements (KIT)
- Flame propagation regimes at cryogenic temperatures (KIT)
- Flame propagation over a spill of LH2 (KIT)
- *BLEVE (KIT)*
- LH2 Combustion with congestion/confinement variation (HSL)

WP5 – Combustion (2/2)

Modelling:

- Development and validation of models for simulation of radiation from cryogenic jet fires and assessment of thermal hazards aside cryogenic jets (UU)
- Development of UDF for evaluation of thermal dose (UU)
- *Simulations of pressure-peaking phenomenon for cryogenic release indoors (if experiment available) (UU)*
- *Simulations on BLEVE (if experiments available) (UU)*
- Simulations of jet fires under different weather conditions to be tested by KIT (E5.1), incorporating radiation modelling (UWAR)
- LH2 and/or cryo-compressed tank rupture in a fire: fireball and blast wave dynamics (E5.3) and pre-mixed phenomena with cryogenic hydrogen (E5.5), which are currently on reserve (UWAR)

White paper

Task: 6.5 (M18-36) Lead: KIT Partners: All

The White Paper will include:

- Discussion on general economics and safety of LH2.
- Comparison of hazards and risks of LH2 systems against gaseous H2 systems.
- Contribution of external experts.

MS27 ToC of White paper, M18 (UU)

D6.4 White Paper, M35 (KIT)

Dissemination conference

Task: 6.6 (M6-36) Lead: UU Partners: All

Organisation of dissemination conference at the end of the project to present the detailed project outcomes to the H2 safety community (M36):

- Venue: FCH JU facilities in Brussels
- Duration: 1 or 2 days
- Budget: €10,000 (HySafe budget)

MS28 Brochure and preliminary programme of the dissemination conference M22 (UU)

Dissemination of the results (1/2)

D6.6 Plan for the dissemination, communication and exploitation M6 (UU)

D6.7 Plan for the dissemination, communication and exploitation-1st update M18 (UU)

D6.8 Plan for the dissemination, communication and exploitation-2nd update M36 (UU)

D6.9 Report on the communication activities carried out to the general public M36 (HySafe)

Dissemination of project findings through the following channels:

- Project website
- Flyer
- Newsletter
- Workshops
- Promotion of conference presentations and special sessions at conferences
- International meetings and events
- Journal publications

Dissemination of the results (2/2)

Unless the JU requests or agrees otherwise or unless it is impossible, any dissemination of results (in any form, including electronic) must:

(a) display the JU logo;

(b) display the EU emblem and

(c) include the following text:

“This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under the European Union’s Horizon 2020 research and innovation programme under grant agreement No 779613”.

Grant Agreement:
Page 47, Article 29, Dissemination of the results
Page 55, Article 38, Promoting the action

Brochure contents

- Motivation
- Objectives
- Research roadmap, i.e. WP structure and summarised list of the investigated phenomena for each research pillar:
  - Release and mixing
  - Ignition
  - Combustion
- Key research outputs
- Consortium
- General information

Brochure draft (1/2)

Consortium

PRESLHY network is an international and interdisciplinary group of experts from academic, research and industrial institutions:

Karlsruhe Institute of Technology, Germany (co-ordinator)

Air Liquide, France

Health & Safety Laboratory, UK

International Association for Hydrogen Safety, Belgium

INERIS, France

National Center for Scientific Research "Demokritos", Greece

Pro-Science GmbH, Germany

University of Ulster, UK

The University of Warwick, UK

Information

PRESLHY project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement No 779613.

To find more information about our research activities, please visit:

www.preslhy.eu

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2018-2020
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PRESLHY

Pre-normative Research for Safe Use of Liquid Hydrogen

FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

Brochure draft (2/2)

Motivation

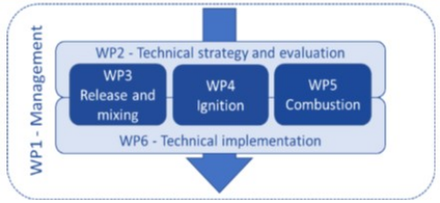
Liquid hydrogen (LH_2) provides larger densities and gains in efficiency over gaseous transport and storage. The hazards and risks associated with LH_2 are different from the relatively well-known compressed gaseous hydrogen. PRESLHY project addresses the pre-normative research for a safer use of cryogenic and liquid hydrogen as energy carrier.

Objectives

The project initiates from identification of the safety critical areas where knowledge gaps are present and specific standards are needed (WP2). The mission of the research work is to close these gaps pursuing the following objectives:

- Carry out an experimental campaign to comprehend LH_2 relevant phenomena;
- Develop and validate new appropriate models and engineering correlations;
- Underpin the design of efficient prevention and mitigation concepts;
- Emend over-conservative requirements;
- Provide reliable and consistent hazard zones rules for LH2 based technologies;
- Achieve a cost-efficient and inherently safer design;
- Build internationally harmonized standards and regulations.

Research roadmap



Release and mixing

- Two-phase flow and dispersion;
- Impinging and/or wall attached jets;
- LH_2 pool formation and evolution;
- Wind effect on large-scale LH_2 releases;
- Release and dispersion in confined and obstructed spaces.

Ignition

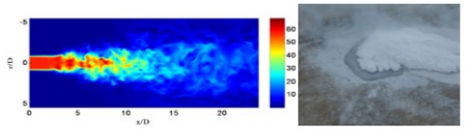
- Electrostatic charge in cold jet/plume;
- LFL, HFL and MIE for low cryogenic H_2;
- H_2/condensed O_2 phase mixtures;
- LH_2 pools ignition.

Combustion

- Cryogenic and LH_2 jet fires;
- LH_2 pool fires;
- Flame propagation and DDT;
- BLEVE
- Combustion in congested/confined areas

The research pillars are analysed through:

- Analytical and theoretical studies;
- Numerical modelling;
- Experimental campaign.



Research outputs

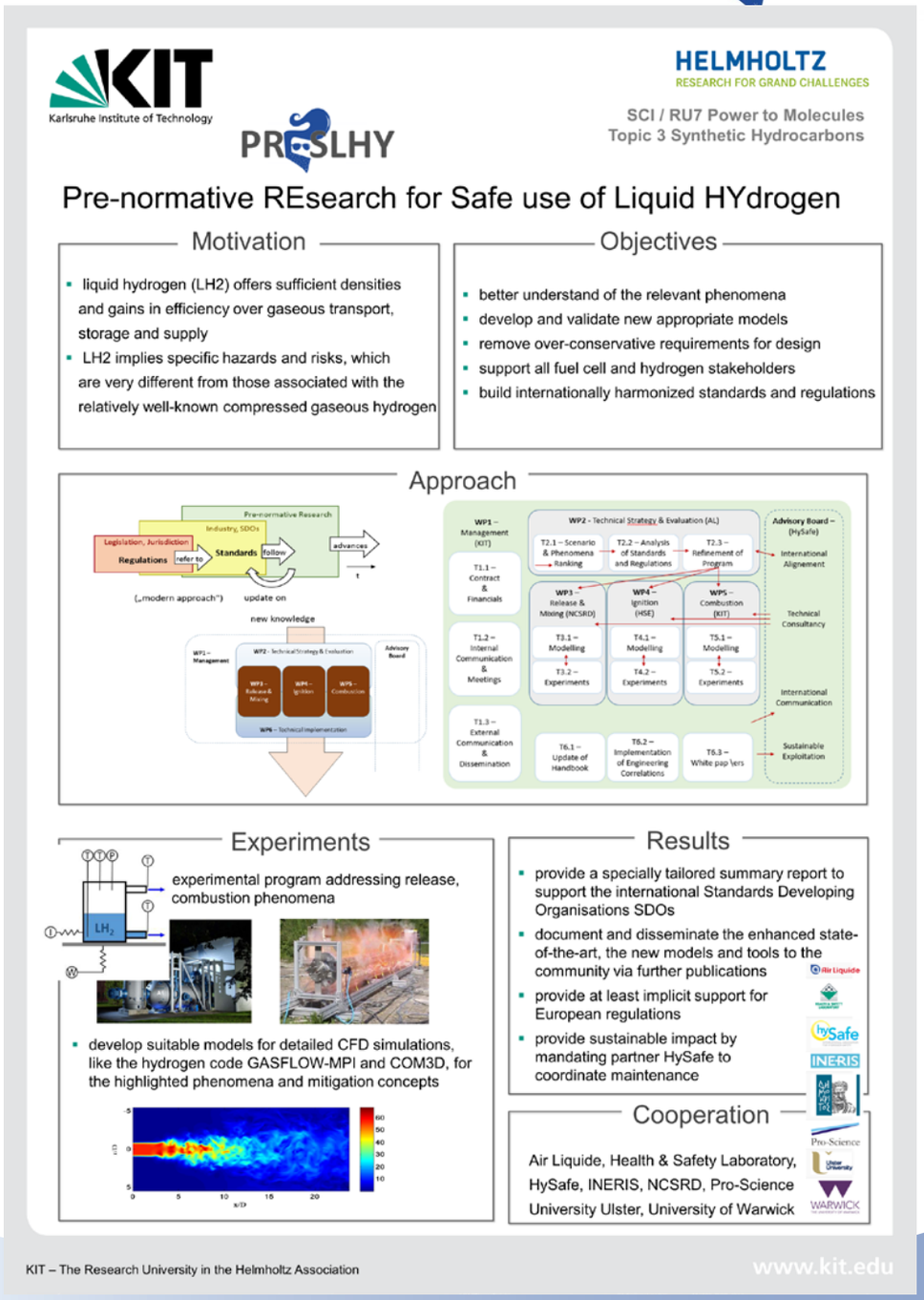
The pre-normative research outcomes and advancement of knowledge beyond the state-of-the-art are implemented and exploited through the following strategic actions:

- Access to experimental data through RADAR online database and scientific publications;
- Chapter on LH_2 safety for the Handbook of Hydrogen Safety;
- Guidelines for a safer design and operation of LH_2 infrastructure;
- Recommendations for Regulations, Codes and Standards (RCS);
- Engineering correlations and tools;
- White Paper on the use of LH_2;
- Dissemination Conference.

Poster

Poster realised for KIT internal review programme.

This version could be modified to be PRESLHY official poster following the structure of the brochure and its contents once they are defined.



Newsletter Plan (1/2)

Proposal: 5 newsletters between January 2019 and December 2020

N.	Month	Date	Content or Events we can report on
1	13	January 2019	General update on project progress Experimental campaign description into detail. First results and conclusions of sets of experiments: • Release and mixing: Small scale multi-phase discharge (KIT, M8*) • Ignition: General ignition (INERIS, M8*) • Combustion: Jet Fires (KIT, M12*) and Flame Acceleration & DDT (KIT, M11*) Workshops (RPW, projects workshops, installation visits etc…) and meetings update
2	19	July 2019	Experimental campaign update • Release and mixing: Pool (KIT, M16*) • Ignition: Ignition above pool (KIT, M19*) Conclusions of theory and analysis for all phenomena (M18) Update on dissemination and exploitation activities (UU, M18) Progress of computational studies Workshops and meetings update

* Month the experiment series are expected to be completed, deliverable with results summary are expected 3 months later

Newsletter Plan (2/2)

N.	Month	Date	Content
3	25	January 2020	Experimental campaign update • Ignition: Ignition of cold plume (HSL, M21*) • Combustion: Flame dynamics above Pool (KIT, M12*) ICHS 2019 (M21) Workshops and meetings update 1st announcement on dissemination conference
4	30	June 2020	Experimental campaign update • Ignition: Electrostatic charge (KIT, M27*) and condensed phase (HSL, M28*) Workshops and meetings update Advertisement of dissemination conference
5	36	December 2020	Summary of experimental campaign results and conclusions, including • Combustion: Flame in obstructed cloud (HSL, M31*) Summary of computational investigations Update and advertisement of all the project products (WP6) Workshops and meetings update

* Month the experiment series are expected to be completed, deliverable with results summary are expected 3 or 2 months later

Scientific publications

Scientific conference contributions and papers for peer-reviewed journals resulting from the project will report the acknowledgement as stated in the Grant Agreement:

"This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement No 779613". (Page 47, Grant Agreement, Article 29 Dissemination of the results)

- Venetsanos A., Homogeneous Non-Equilibrium two-phase choked flow modelling, International Journal of Hydrogen Energy, accepted in October 2018
- Cirrone D., Makarov D., Molkov V., Thermal radiation from cryogenic hydrogen jet fires, International Journal of Hydrogen Energy, In Press, available online
- Cirrone D., Makarov D., Molkov V., Near field thermal dose of cryogenic hydrogen jet fires, submitted to ISFEH conference April 2019

Gantt chart

WP6 Implementation: Exploitation and Dissemination. Leader: UU (6). KIT(3) AL (4) HSL (0.5) HYSAFE (2) INERIS (0.5) NCSRD (1) PS (0.5) UWAR (0.5)

Deliverables (D) and Milestones (MS)		Resp	2018												2019												2020											
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
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