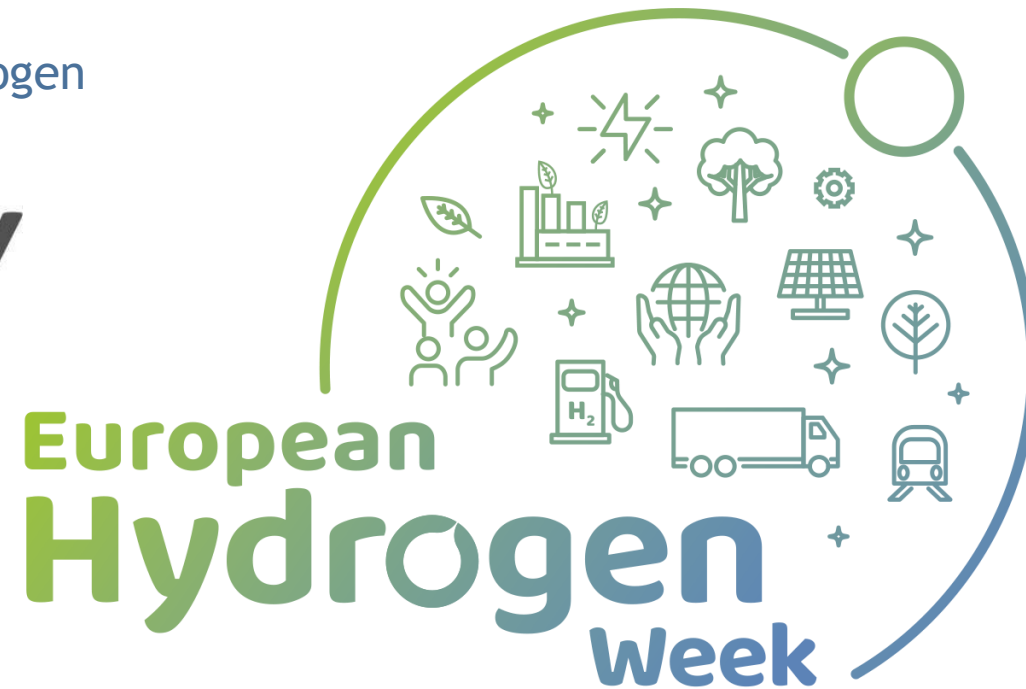


PRESLHY

Pre-normative Research

for Safe Use of Liquid Hydrogen



Thomas Jordan

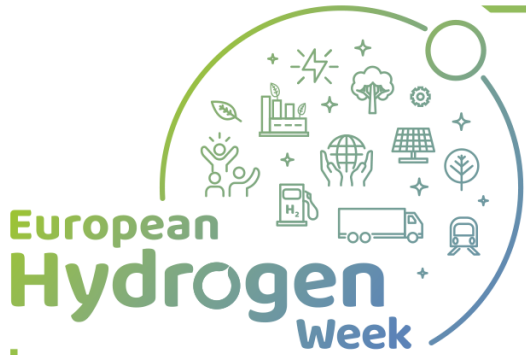
Karlsruhe Institute of Technology

[www.preslhy.eu](http://www.preslhy.eu)

[thomas.jordan@kit.edu](mailto:thomas.jordan@kit.edu)

#PRD2020  
#CleanHydrogen





# PRESLHY Project Overview

**Call year:**  
**2017**

**Call topic:**  
FCH-04-4-2017:  
PNR for a safe  
use of liquid  
hydrogen

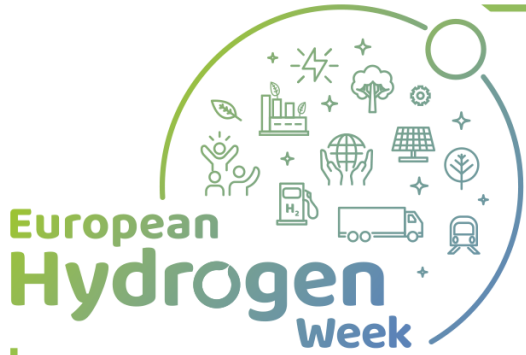
**Project dates:**  
01/2018- 05/2021

**Total project budget:**  
1 905 862,50 €



**% stage of implementation**  
01/11/2020: 80%

**FCH JU max. contribution:** 1 724 277 €  
**Other financial contribution:** - €



# PRESLHY Partners



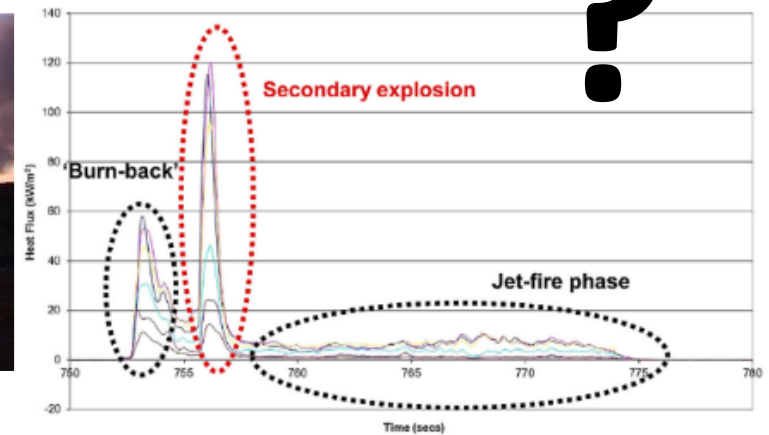
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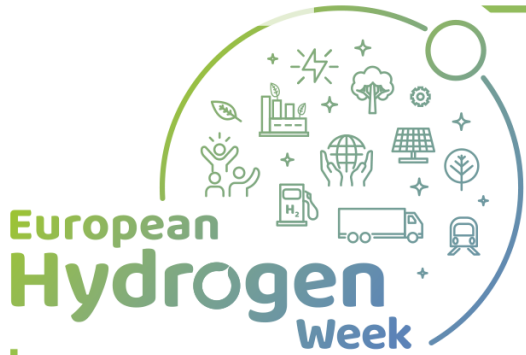


# PRESLHY Motivation



- Scale-up of existing and new applications increase H2 demand.
- Liquid hydrogen (LH2) provides **larger densities** and gains in **efficiency** and **potentially reduces risks** compared to compressed gaseous transport and storage
- Many **knowledge gaps** wrt accidental behavior of LH2 and **inconsistent** and **potentially over-conservative RCS** (e.g. NFPA 2 and EIGA)





# PRESLHY Main Objectives

- Report **initial state-of-the-art and knowledge gaps** with priorities with respect to the intended use of liquid or cryogenic hydrogen technologies
- Execute adjusted **experimental program** addressing release, ignition and combustion phenomena with highest priorities

## → Close knowledge gaps

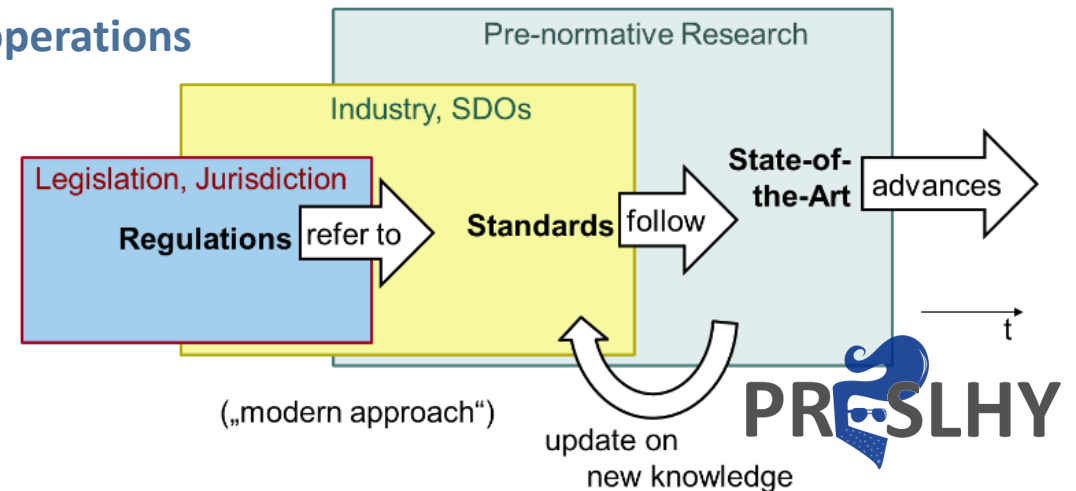
- Develop **suitable models and engineering correlations** and integrate them in a suitable open risk assessment toolkit

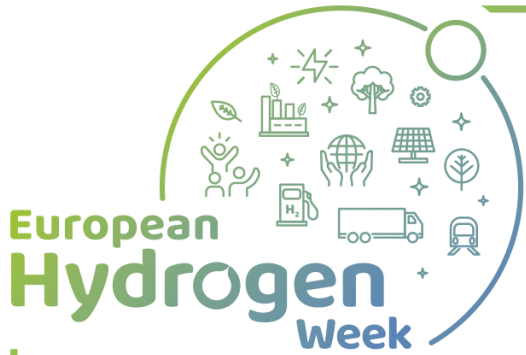
## → Provide enhanced recommendations for safe design and operations of liquid or cryogenic hydrogen technologies

- Support international SDOs in updating of existing standards or developing of new international

## → Support development of performance based, risk informed, internationally harmonised standards

- Document and publish detailed, aggregated and interpreted data in a FAIR way and
- disseminate the **enhanced state-of-the-art**





# PRESLHY Networking



EHSP  
RCS SCG

JRC (HIAD)

ISO TC 197  
CEN/CENELEC TC6

IEA  
Hydrogen  
Task Force

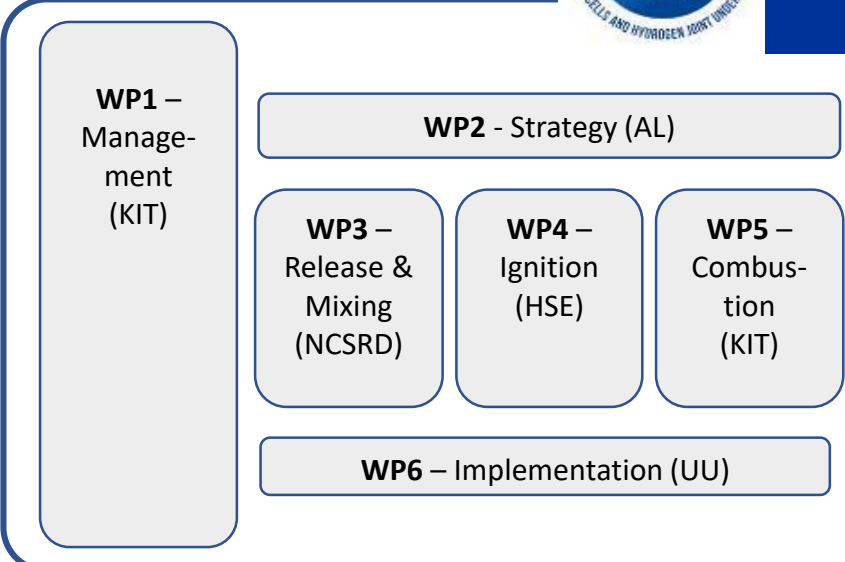
US DOE

ISO/PWI 24077: „Safe Use of LH2 in Non-Industrial Settings“ established on 6.12.2018

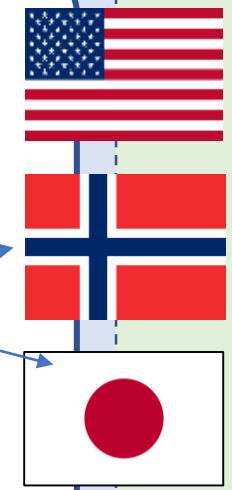
Presentation at CEN/CENELEC on 28.01.2020

Presentation at IEA Safety Task on 19.10.2018

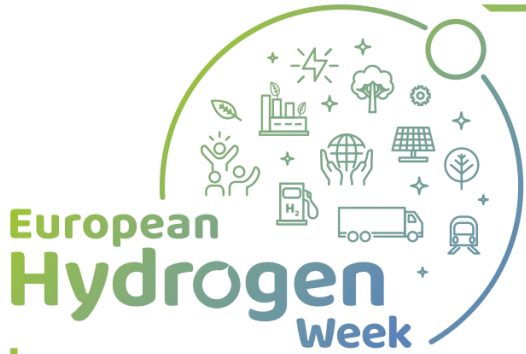
Common Workshops on 06.03.2019 and Spring 2021



Advisory Board



GexCon, IFE, Equinor + Shell  
KHI, Toyota



# Project Progress/Actions - Aspects



## Achievement to-date

INCONSISTENT,  
RCS WITH A  
FRAGMENTED  
INCOMPLETE  
SCIENTIFIC BASIS



25%

50%

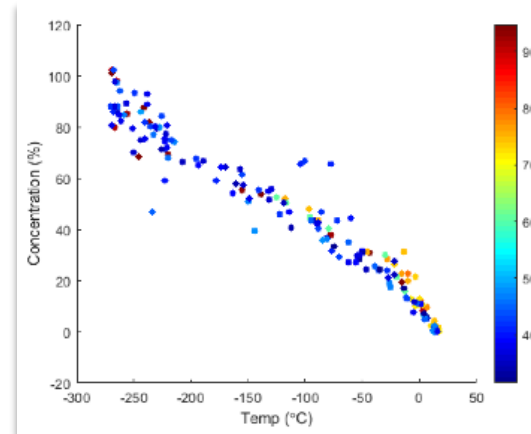
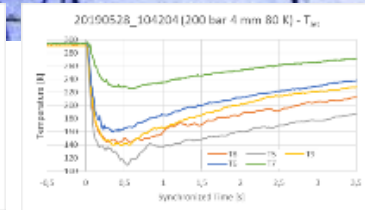
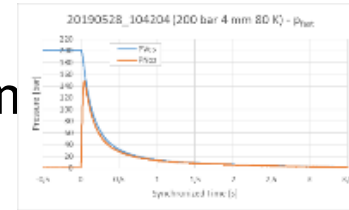
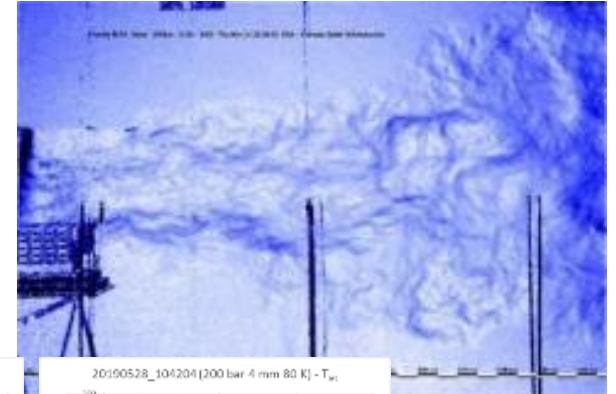
75%

RISK INFORMED,  
HARMONISED  
INTERNATIONAL  
STANDARD FOR  
SAFE USE OF LH2  
IN NON-  
INDUSTRIAL  
SETTINGS

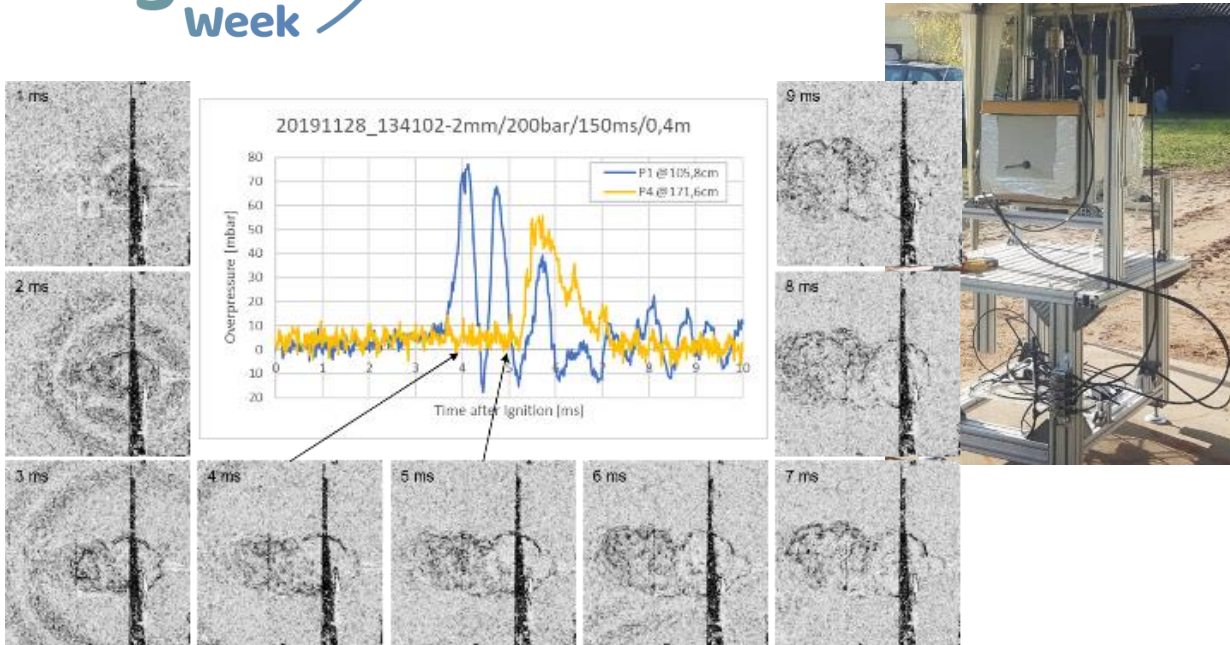
- Initial state of the art and RCS and priorities documented
- Experimental program on highly ranked priorities completed
- Knowledge gaps closed with respect to release/mixing, ignition and combustion
- ISO and CEN informed and ISO TC 197 PWI 24077 initiated
- Guidelines to be injected in standardization process under development
- Proposal for NWI

# Closed Knowledge Gaps - Release

- 1 D model for multi-phase release including non-equilibrium processes
- Discharge coefficients for circular nozzles  $D=0.5-4$  mm  
5 - 200 bar; 20 - 300K (KIT/PS E3.1 DISCHA tests)  
see <https://doi.org/10.5445/IR/1000096833>
- No rainout for large scale above ground horizontal releases (HSE E3.5: rainout tests)
- Correlation of T and concentration of mixtures of H<sub>2</sub> with cryogenic origin and air



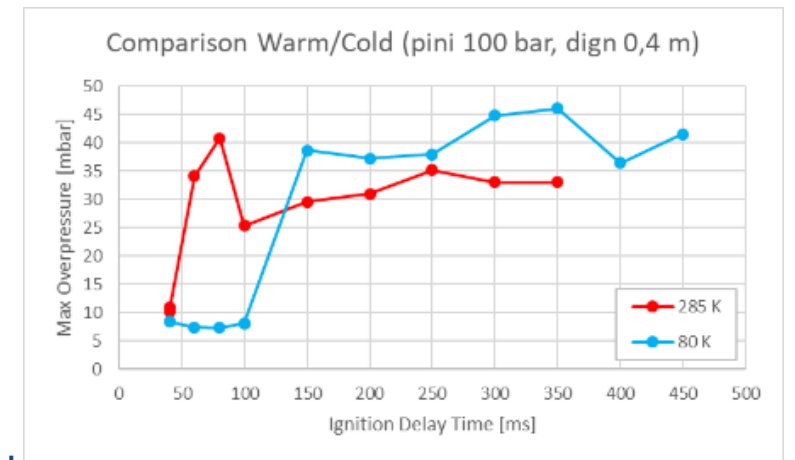
# Closed Knowledge Gaps - Transient Combustion Effects



> 100 Ignited jet tests combined with discharge experiments E5.1  
 $T = 80\text{K} \dots 300\text{K}$   
 $p = 5 \dots 200\text{bar}$   
 $D_{\text{nozzle}} = 0.5 \dots 4\text{mm}$

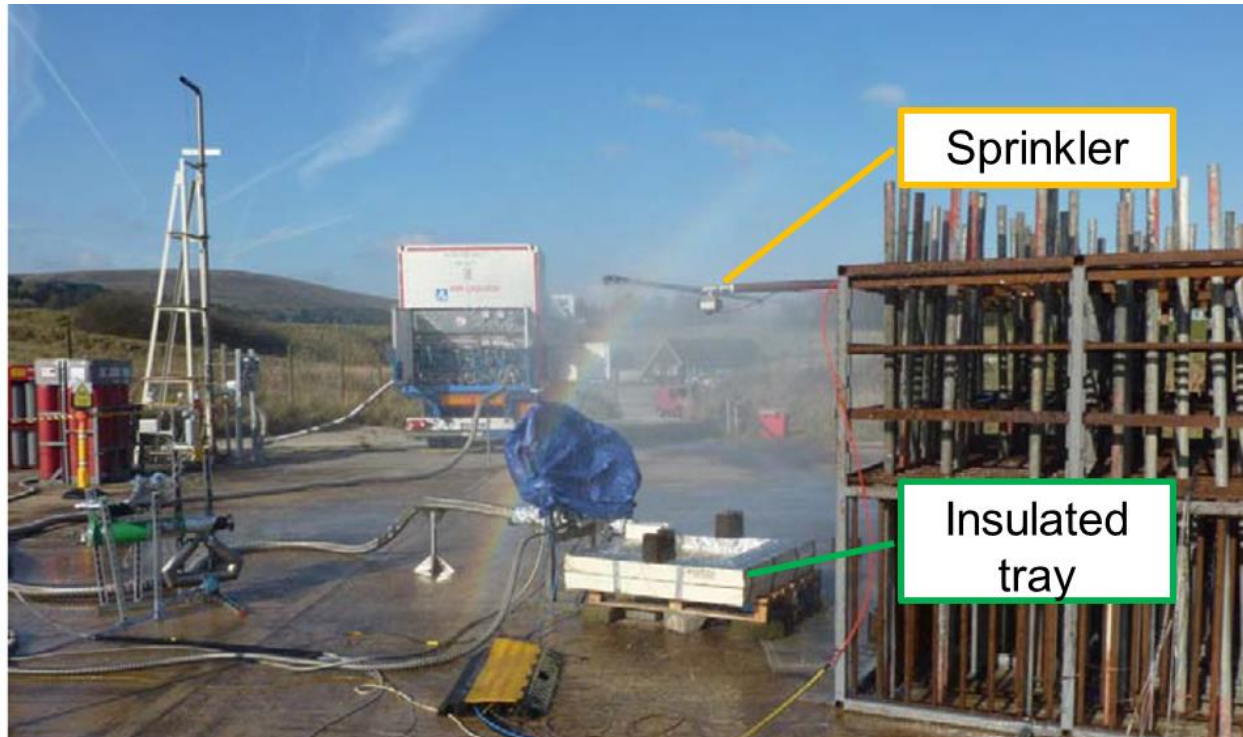
Iterative procedure for identifying most critical ignition time and location

- Better understanding of transient jets and combustion processes
- Inventory based map of worst effects (pressure & thermal)
- to be extrapolated to large inventories for RCS



# Closed Knowledge Gaps - Multi-phase accumulations with explosion potential

- Repeated spills in gravel bed might generate highly reactive condensed phase mixtures - not on other substrates (E4.4 Ignition above pool)



- Water sprays on LH2 and LH2 spills on small water pools non critical (E4.4 and E4.X)

# Closed Knowledge Gaps - Combustion in confined/congested domains

- Stronger pressure loads for cold tests in comparison with warm tests with the same volume, hydrogen concentration and blockage ratio

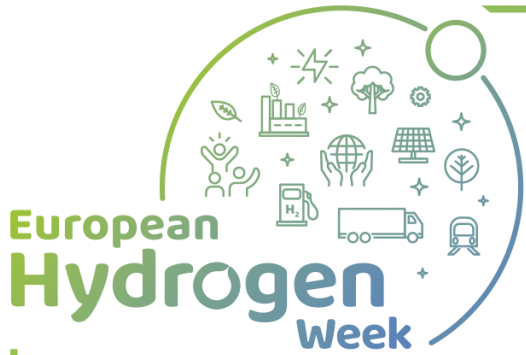


E5.3 Semi-confined channel at KIT/PS



E5.5 Test set-up at HSE, Buxton

- Increase in critical and effective expansion ratios determine flame acceleration in cryogenic mixtures
- Reduced run-up distance for detonation transition DDT in cryogenic mixtures (← density effects)
- Influence of blockage ratio on DDT less pronounced
- Effects in free unconfined domains to be investigated



# PRESLHY Exploitation Plan and Expected Impact

## Exploitation

- Closure of knowledge gaps
- Enhancing the state-of-the-art
- Developing models for risk assessment
- Deriving recommendations for users and SDOs
- Initiating review or development of standards

## Impact

- Enabling the safe and economic introduction of LH2/cryogenic hydrogen technologies with a flexible, but robust framework consisting of
- improved knowledge basis and
  - consistent recommendations and
  - performance-based, harmonized specific standards to be referred by regulation

# Outreach

Eu  
H



[www.preslhy.eu](http://www.preslhy.eu)



## PRESLHY Exploitation & Dissemination Activities

Management  
(WP1)

Implementation  
(WP6)

Task 1.3  
Website

Data  
Manage  
ment

Engineering  
tools

Handbook

Guidelines

RCS Recom-  
mendations

White  
Paper

Task 6.6  
Dissemina-  
tion  
Conference

**PRESLHY**

PRENORMATIVE RESEARCH FOR  
SAFE USE OF LIQUID HYDROGEN

Research and Innovation Action supported by the FCH JU,  
Grant Agreement No 779613, 2018-2020, [www.preslhy.eu](http://www.preslhy.eu)

223  
1966



## First announcement Dissemination conference of PRESLHY project 5-6 May 2021, Athens, Greece

We are pleased to invite you to the conference concluding PRESLHY project on pre-normative use of liquid hydrogen. Speakers from PRESLHY consortium will present the standing research performed on the major phenomena associated to the release of liquid and cryo-compressed hydrogen, the ignition of cryogenic hydrogen-air mixtures, and the combustion of hydrogen. The conference will address the potential impact of the project on the international community working on hydrogen and fuel cell technologies. Invited international speakers will enrich the conference program, providing a glimpse of the state of the art and worldwide research on the safety of liquid hydrogen.

### Date and venue

The conference will be held on the 5-6 May 2021 in Athens, Greece. Future announcements will include further updates and details on the conference venue, taking into account the developments of Covid-19 pandemic and possibility of a virtual event.

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**PRESLHY**  
PRENORMATIVE RESEARCH FOR  
SAFE USE OF LIQUID HYDROGEN  
2018-2020  
[www.preslhy.eu](http://www.preslhy.eu)

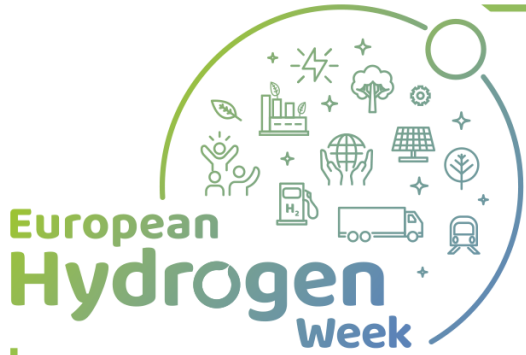


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#CleanHydrogen



FUEL CELLS AND HYDROGEN  
JOINT UNDERTAKING

PRE-NORMATIVE RESEARCH FOR  
SAFE USE OF LIQUID HYDROGEN



# Acknowledgement

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



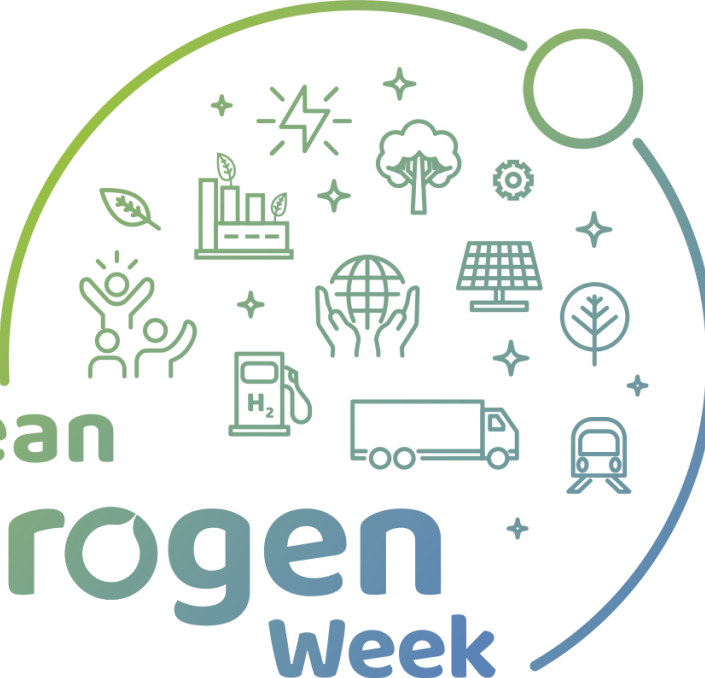
European  
Commission

Horizon 2020  
European Union funding  
for Research & Innovation

... and many thanks to all contributors  
(e.g. Equinor, SHELL, ...)

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#CleanHydrogen





# European Hydrogen Week

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