



# Launch of the STACY Project – Towards Safe Storage and Transportation of Cryogenic Hydrogen

Ernie Reinecke, Ahmed Bentaib, Nabiha Chaumeix,  
Hirohisa Tanaka, Yves Ballossier, Shannon Krenz

International Conference on Hydrogen Safety, Québec City, Canada, September 19-21, 2023



# European Interest Group (EIG) CONCERT-Japan



## European Interest Group (EIG) CONCERT-Japan

- 13 science, technology and innovation (STI) funding agencies from 11 European countries and Japan
- supporting Japanese-European research collaboration in a variety of fields
- supporting sustainable and multilateral research cooperation, especially promoting the transnational mobility between European and Japanese researchers

**➔ Research-Network between Europe and Japan**



# European Interest Group (EIG) CONCERT-Japan

## Call 2021: „Sustainable Hydrogen Technology as Affordable and Clean Energy”

- Ammonia hydrogen combustion in micro gas turbines (ADONIS)
- Structure-based metabolic engineering of algal H<sub>2</sub> production (H2M)
- **Towards Safe Storage and Transportation of Cryogenic Hydrogen (STACY)**
- Japanese-European Research Collaboration of New Affordable and Durable Electrocatalysts for Fuel Cells (NADC-FC)
- **Sustainability development and cost-reduction of hybrid renewable energies powered Hydrogen stations by risk-based multidisciplinary approaches (SUSHy)**
- Enhancement of Hydrogen Storage Properties of AlTiVCr Light Weight High Entropy Alloys (HEA) by Ti<sub>3</sub>C<sub>2</sub> MXene and Severe Plastic Deformation (EHSAL)



# STACY – Towards Safe Storage and Transportation of Cryogenic Hydrogen

## Background

- World-wide efforts to decarbonize the energy sector with increasing fraction of renewable energies
- Energy storage technologies required to store excess energy generated from fluctuating sources
- Large-scale storage and transportation of liquefied (cryogenic) hydrogen (LH<sub>2</sub>) expected to play a fundamental role in a potential future hydrogen economy



➔ **Safe implementation of LH<sub>2</sub> storage and transportation technologies mandatory with regard to economic benefit and public acceptance**

# LH2-related safety issues

## HySafe Research Priority Workshop, Québec City, October 2022

- High ranked hazards, relevant for maritime transportation:
  - **Confined and unconfined explosions**
  - Cryogenic spills on steel
  - **Accumulation of flammable gas mixtures**
  - Dense gas dispersion from LH2 releases
  - ...





# STACY – Main Objectives

**Contribute to the safety assessment of LH2 storage and transportation on long-distance carriers**

- (1) determine **fundamental safety-related combustion parameters** not yet available in the open literature,
- (2) study **mitigation by means of catalytic recombiners** to prevent the formation of flammable gas mixtures in case of leakages,
- (3) simulate potential **hydrogen release scenarios** and **efficiency of mitigation measures**.





# STACY – Main Objectives

**Contribute to the safety assessment of LH2 storage and transportation on long-distance carriers**

- (1) determine **hydrogen release** & **hydrogen combustion** parameters, **hydrogen storage** and **hydrogen liquefaction** conditions, **hydrogen** and **hydrogen** **mixtures**
- (2) study **hydrogen** and **hydrogen** **mixtures** to provide **hydrogen** and **hydrogen** **mixtures** in case of **hydrogen** and **hydrogen** **mixtures**
- (3) simulate potential **hydrogen release scenarios** and **efficiency of mitigation measures**.

**Focus on Networking and Collaboration between European and Japanese Institutions**



# STACY – Research Team

**Expertise in the fields of combustion, recombination, catalysis, hydrogen safety assessment**

- **CNRS-ICARE:** Flame and explosion dynamics, explosion safety, involved in industrial projects and research programs
- **IRSN:** Hydrogen safety assessment in nuclear power plants, involved in development of safety assessment methodologies and risk prevention procedures
- **KGU:** Catalyst development, involvement in “intelligent catalyst” development at Daihatsu Motor Co., Ltd.
- **FZJ:** Hydrogen recombiners, involvement in industrial recombiner development and recombiner qualification





# STACY – Specific Objectives (1)

## (1) Fundamental safety-related combustion properties of H<sub>2</sub>

- Background: Knowledge gaps for low temperatures identified in the PRESLHY project
- Experiments at combustion laboratory at CNRS/ICARE
  - the flammability domain
  - the flame speed
  - the expansion ratio

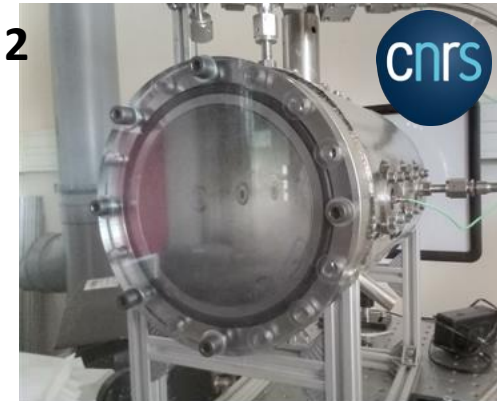
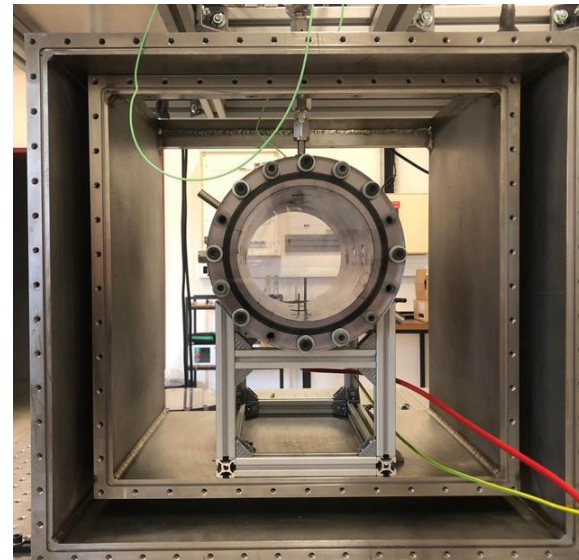
➔ **Criteria for e.g. flammability, laminar flame speed and flame acceleration under low temperatures**



# STACY – Specific Objectives (1)

## (1) Fundamental safety-related combustion properties of H<sub>2</sub>

- Double-walled box for vacuum insulation
- Circulation of refrigerant fluid within double layer of cylindrical bomb
  - -20 °C with commercial cryostat
  - -180 °C with in-house cryostat



➔ **Criteria for e.g. flammability, laminar flame speed and flame acceleration under low temperatures**

# STACY – Specific Objectives (2)

## (2) Mitigation by means of catalytic recombiners

- Develop and qualify a specific catalyst to operate under the typical conditions of a LH2 carrier
- Catalyst development, manufacturing, and lab-scale testing at KGU (Japan)
- Recombiner qualification at FZJ (Germany)

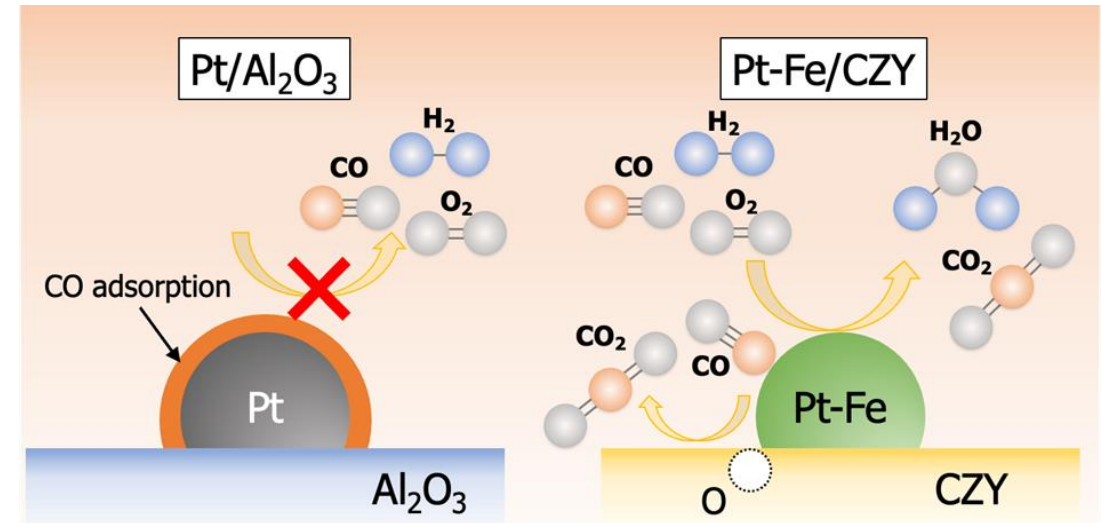
➔ Numerical model to describe recombiner operation



# STACY – Specific Objectives (2)

## (2) Mitigation by means of catalytic recombiners

Issues	Solution
1) Cryogenics	Nano-particulation, Intelligent Catalyst
2) Ignition	Multi-stage design
3) High Flow	Nano-particulation
4) Poisoning	Utilizing technology accumulation through materials research Water / CO / Oxygen



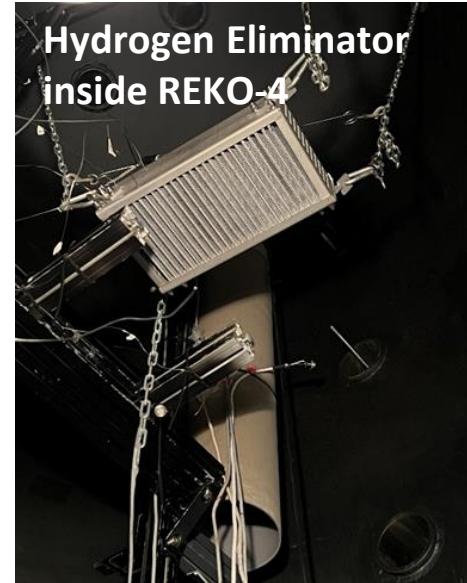
➔ Numerical model to describe recombiner operation

# STACY – Specific Objectives (2)

## (2) Mitigation by means of catalytic recombiners



- Determination of operational characteristics at temperatures down to  $-80\text{ }^{\circ}\text{C}$

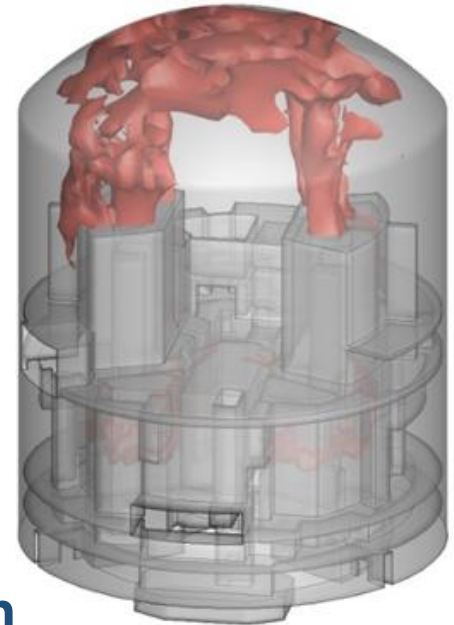


➔ Numerical model to describe recombiner operation

# STACY – Specific Objectives (3)

## (3) Simulation of potential hydrogen release scenarios and efficiency of mitigation measures

- Further develop numerical methods to describe hydrogen release and mixing under specific conditions of LH2 transportation
  - Application of well-proved codes
    - to study potential accident scenarios, and
    - to provide information on potential boundary conditions and locations for additional mitigation measures
- ➔ **Information on hazardous areas and the efficiency of mitigation measures (active and passive venting, catalytic recombiners)**



# STACY – Industrial Advisory Board

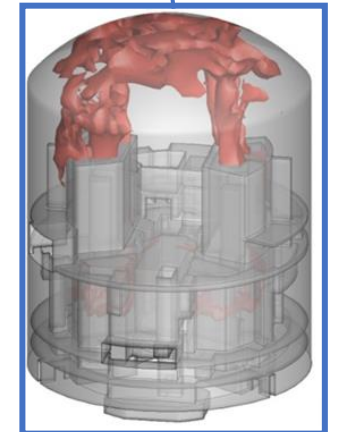
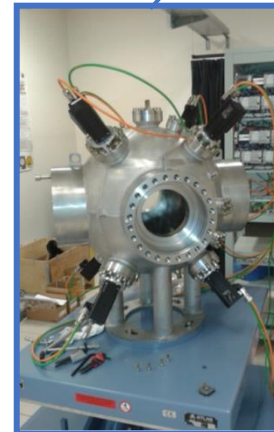
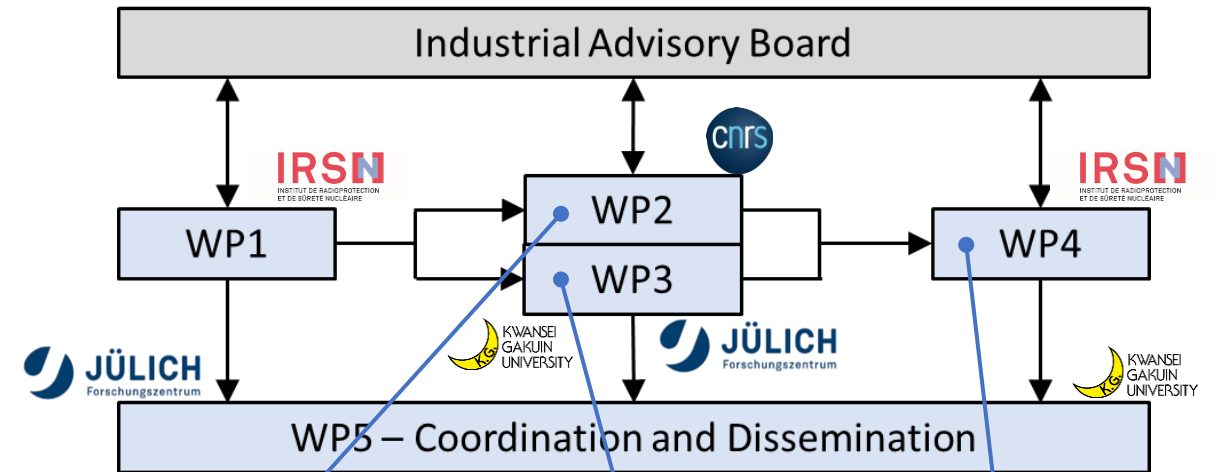
## Ensuring the relevance of the scientific research

- Kawasaki HI                      LH2 carriers
- Daihatsu Motor Co.              LH2 storage, car catalyst
- JAEA                                  Hydrogen safety in nuclear power plants
- Air Liquide                          Production, storage, and distribution of GH2/LH2
- CCD                                  Prototyping catalytic systems
- EnerSys-Hawker                      Catalytic recombiners

# STACY – Work Packages

**Duration: March 2022 – July 2025**

- WP 1: Critical review and scenario identification
- WP 2: Combustion fundamentals
- WP 3: Catalytic recombination
- WP 4: Safety methodology assessment
- WP 5: Coordination and Dissemination





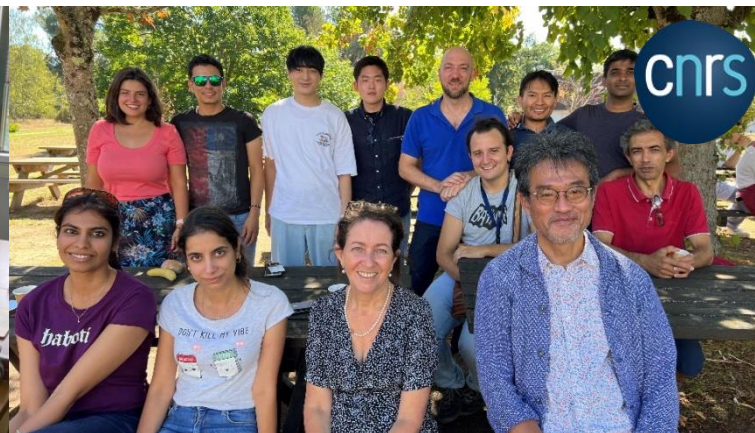
# Intensifying International Collaboration

## September 5-13, 2022

- Collaborative performance of experiments @FZJ
- Visit of CNRS/Orléans and IRSN/Paris

## September 7-13, 2023

- Collaborative performance of experiments @FZJ



# 1<sup>st</sup> STACY Workshop

**December 15/16, 2022,  
Kobe International Conference Center, Japan**

- Organized by Tanaka Laboratory,  
Endorsed by Kwansei Gakuin University
- Symposium
  - Lectures by STACY PIs and IAB
- LH2 excursion through the courtesy of  
Kawasaki Heavy Industries
  - Hydrogen co-generation system
  - LH2 receiving terminal
- Young Generation Workshop
- Technical Tour to SPring-8 synchrotron  
radiation facility



# 2<sup>nd</sup> STACY Workshop

**September 4/5, 2023, CNRS, Orléans, France**

- Organized by ICARE
- Symposium
  - Lectures by STACY PIs, IAB and related projects
    - KHI, AirLiquide, Cataler Corp.
    - Didier Bouix, EOCONCEPT
    - French national project AIDHy
    - SUSHy, ELVHYS, ESKHYMO



- Young Generation Workshop
  - CORIA (Rouen University)
  - Pprime (Poitiers University)
- Lab Tour
  - Combustion research
  - Atmosphere research
  - Space propulsion



# International Dissemination

## International Workshops and Seminars

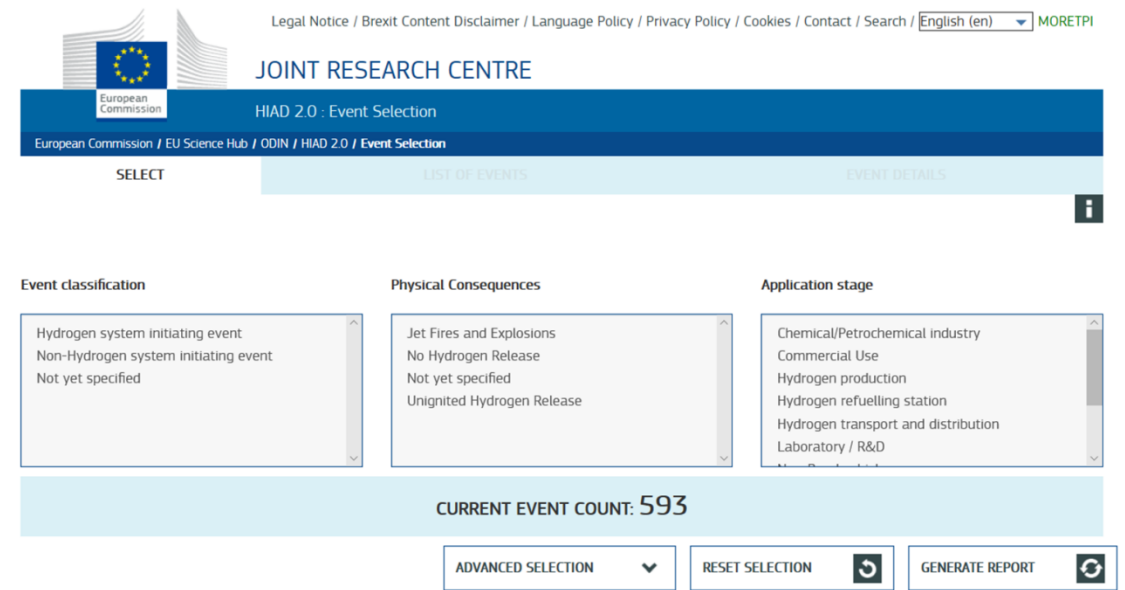
- HySafe Research Priorities Workshop  
November 21-23, 2022, Quebec, Canada
- CNL Hydrogen Safety Workshop  
November 24-25, 2022, Ottawa, Canada
- Int. Workshop on Hydrogen Safety for NPPs  
January 19-20, 2023, Fontenay-aux-Roses, France
- 1<sup>st</sup> SUSHy Joint Workshop  
March 9-10, 2023, Bergen, Norway (online)
- ESKHYMO: LH2 - Technical Workshop  
March 29-30, 2023, Paris, France
- ELVHYS 1<sup>st</sup> Stakeholder's Workshop  
June 21, 2023, Paris, France (online)



# International Knowledge Management

## Collaboration on Accident Databases

- Effort to stimulate collaboration between the European Hydrogen Safety Panel and Japanese experts
- Effort to exchange information, e.g. through databases on hydrogen incidents and accidents



The screenshot shows the 'HIAD 2.0 : Event Selection' web interface. At the top, there is a navigation bar with the European Commission logo and the text 'JOINT RESEARCH CENTRE'. Below this is a breadcrumb trail: 'European Commission / EU Science Hub / ODIN / HIAD 2.0 / Event Selection'. The main content area features three dropdown menus for selection: 'Event classification' (with options: Hydrogen system initiating event, Non-Hydrogen system initiating event, Not yet specified), 'Physical Consequences' (with options: Jet Fires and Explosions, No Hydrogen Release, Not yet specified, Unignited Hydrogen Release), and 'Application stage' (with options: Chemical/Petrochemical industry, Commercial Use, Hydrogen production, Hydrogen refuelling station, Hydrogen transport and distribution, Laboratory / R&D). Below the dropdowns, a light blue bar displays 'CURRENT EVENT COUNT: 593'. At the bottom, there are three buttons: 'ADVANCED SELECTION' with a dropdown arrow, 'RESET SELECTION' with a circular arrow icon, and 'GENERATE REPORT' with a circular arrow icon.

**HIAD 2.0 – Hydrogen Incident and Accident Database**

# International Knowledge Management

## Potential Japanese Databases

- The High Pressure Gas Safety Institute of Japan (KHK)

➔ On-line meeting with KHK on June 16, 2023

➔ Invitation of JRC/HIAD to Japanese Hydrogen Safety Workshop on September 25, 2023

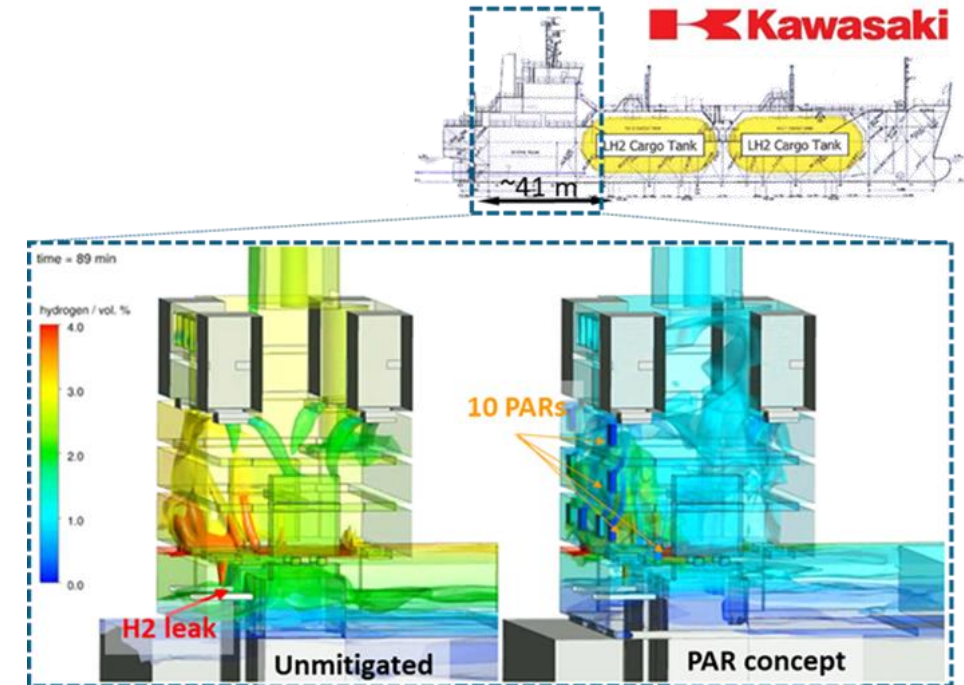


The screenshot shows the '事故事例データベース' (Accident Case Database) on the KHK website. It displays a specific case with the following details:

Case Details	
Scenario	
Case Name	Fire of gas leaked from a flange of piping at a vacuum gas oil hydro-desulfurization unit
Pictograph	H <sub>2</sub>
Date	September 27, 1989
Place	Takaishi, Osaka, Japan
Location	Refinery
Overview	At a vacuum distillate hydro-desulfurization unit in operation, hydrogen and vacuum gas oil blew out from an outlet piping flange of a new reactor. A fire occurred. As tightening management of hot bolting at start-up three months before was inadequate, the flange opened and the gas leaked.
Incident	In a refinery, a fire occurred during usual operation at a new reactor of a vacuum distillate hydro-desulfurization unit. Internal gas (hydrogen, hydrocarbon, etc.) blew from a flange of upper piping in the reactor. It ignited and flames 0.5-2 meters high spurted. Insufficient hot-bolting three months before at the beginning of operation was the cause. Refer to Fig2.
Processing	Manufacture
Individual Process	Reaction
Chemical Reaction	Other (hydro-desulfurization)
Substance	Hydrogen, Fig2

# Conclusions

- Contribution to LH2-related safety technologies, numerical models and methodologies for risk assessment
- Stimulate networking activities to promote hydrogen safety between European and Japanese institutions
- Exchange of hydrogen safety-relevant information through databases



*Kelm et al., Simulation of H<sub>2</sub> mixing and PAR operation during accidental release in an LH<sub>2</sub> carrier engine room, ICHS, 2021*



- The authors thank the European Interest Group CONCERT-Japan for their support of the project in the framework of the 8th Joint Call "Sustainable Hydrogen Technology as affordable and clean energy".
- The German sub-project of the joint project STACY is funded by the German Federal Ministry of Education and Research under grant number 01DR22007.
- The French sub-project acknowledges the financial support of the French government within the program "EIG CONCERT-JAPAN" – STACY Grant agreement n° ANR-22-HTCE-0003-02.
- The joint project STACY is supported by Strategic International Collaborative Research Program of Japan Science and Technology Agency (JST SICORP), Grant Number JPMJSC21C3, Japan.

GEFÖRDERT VOM



Bundesministerium  
für Bildung  
und Forschung







# Thank you for your kind attention !

<https://stacy-project.eu>  
[e.reinecke@fz-juelich.de](mailto:e.reinecke@fz-juelich.de)

GEFÖRDERT VOM



Bundesministerium  
für Bildung  
und Forschung

