ELVHYS

PRESLHY

PRESLY contributions to ELVHYS

T. Jordan, M. Kuznetsov KIT, Germany

ELVHYS WS5, 5 June 2025, KIT, Germany

Pre-normative REsearch for Safe use of Liquid HYdrogen

KIT Karlsruher Institut für Technologie

Air Liquide

HSE Health & Safety Executive

hySafe INTERNATIONAL ASSOCIATION FOR HYDROGEN SAFETY

INERIS

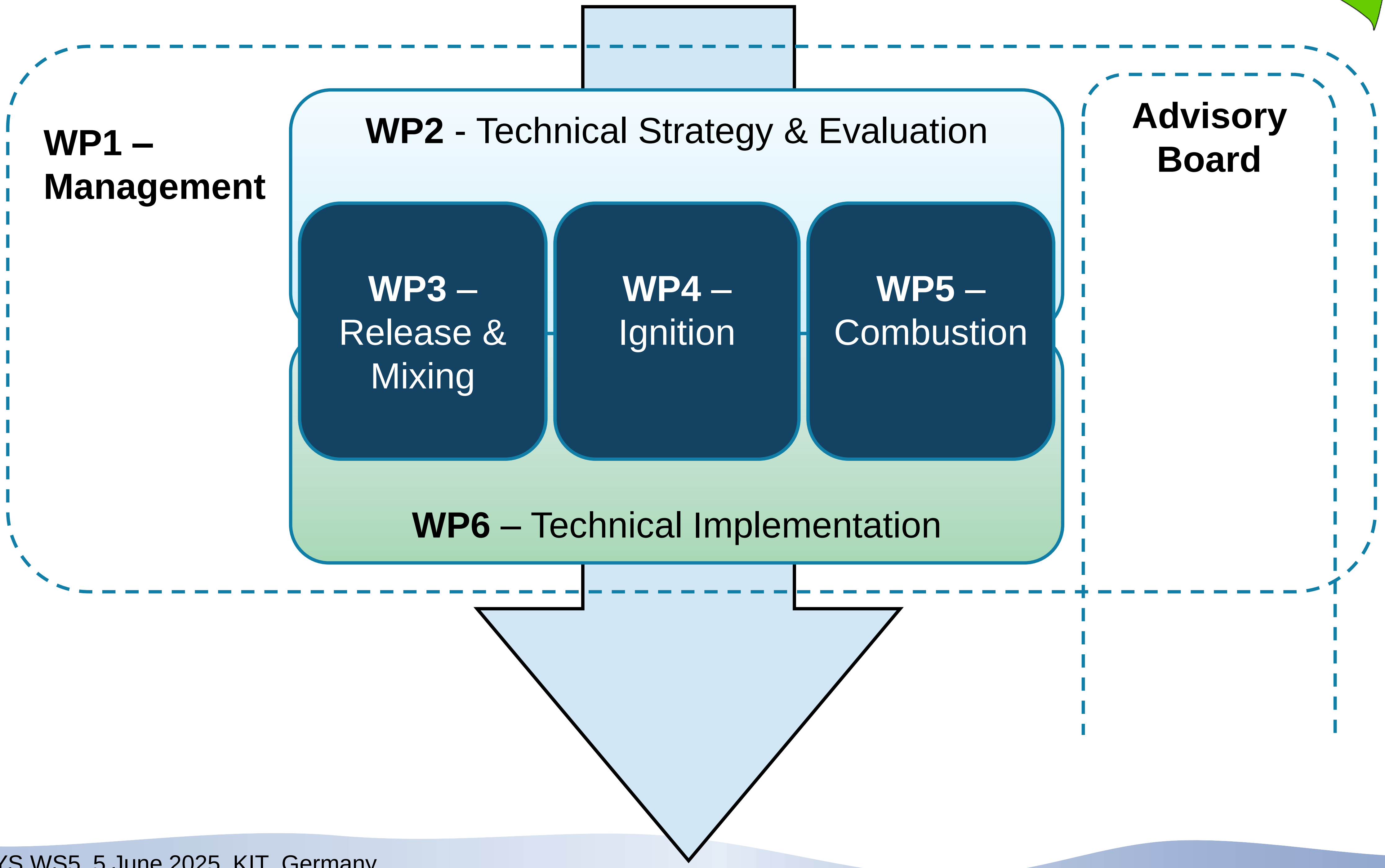
ΔΗΜΟΚΡΙΤΟΣ

Pro-Science

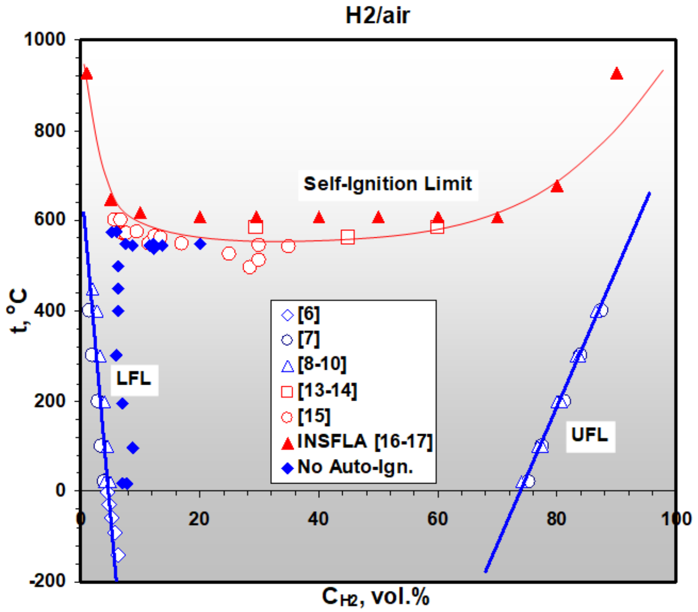
Ulster University

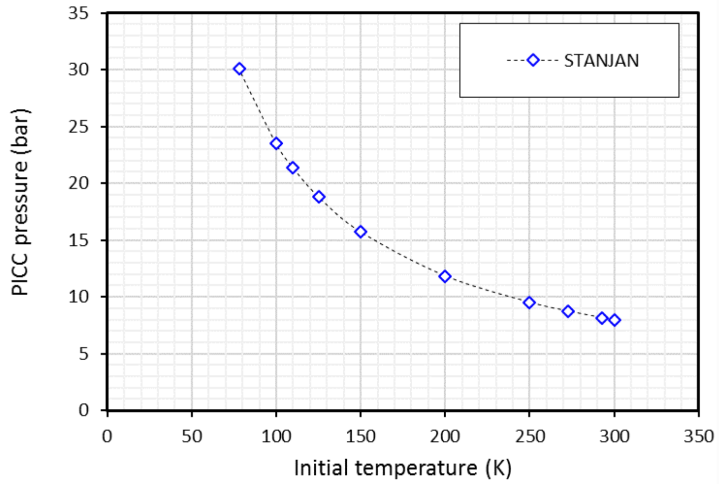
WARWICK THE UNIVERSITY OF WARWICK

General Approach

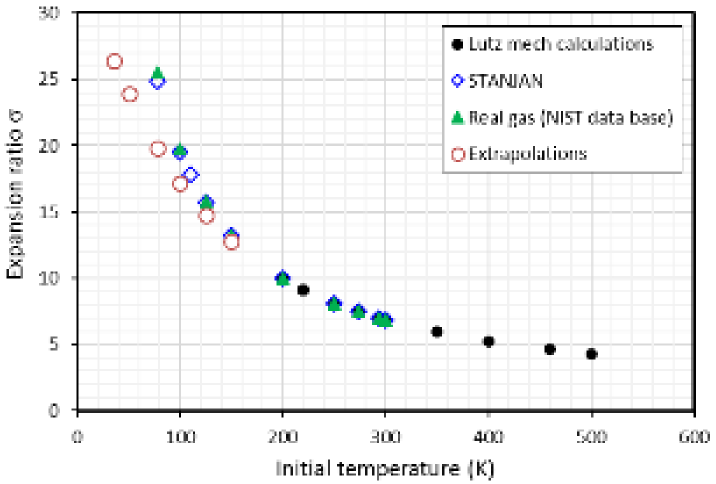


SOAR combustion properties

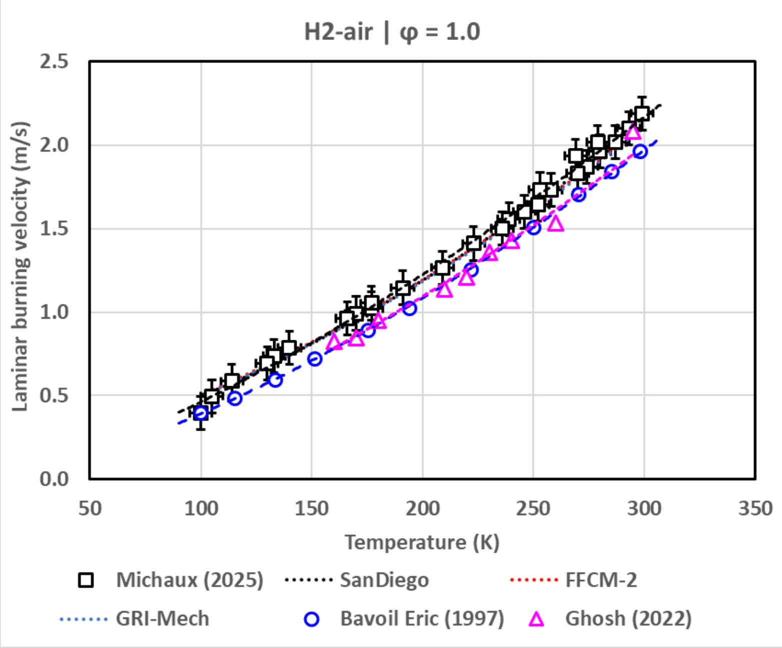




$$P_{icc}(T) = P_{icc}(T_0) \cdot \left(\frac{T_0}{T} \right)$$

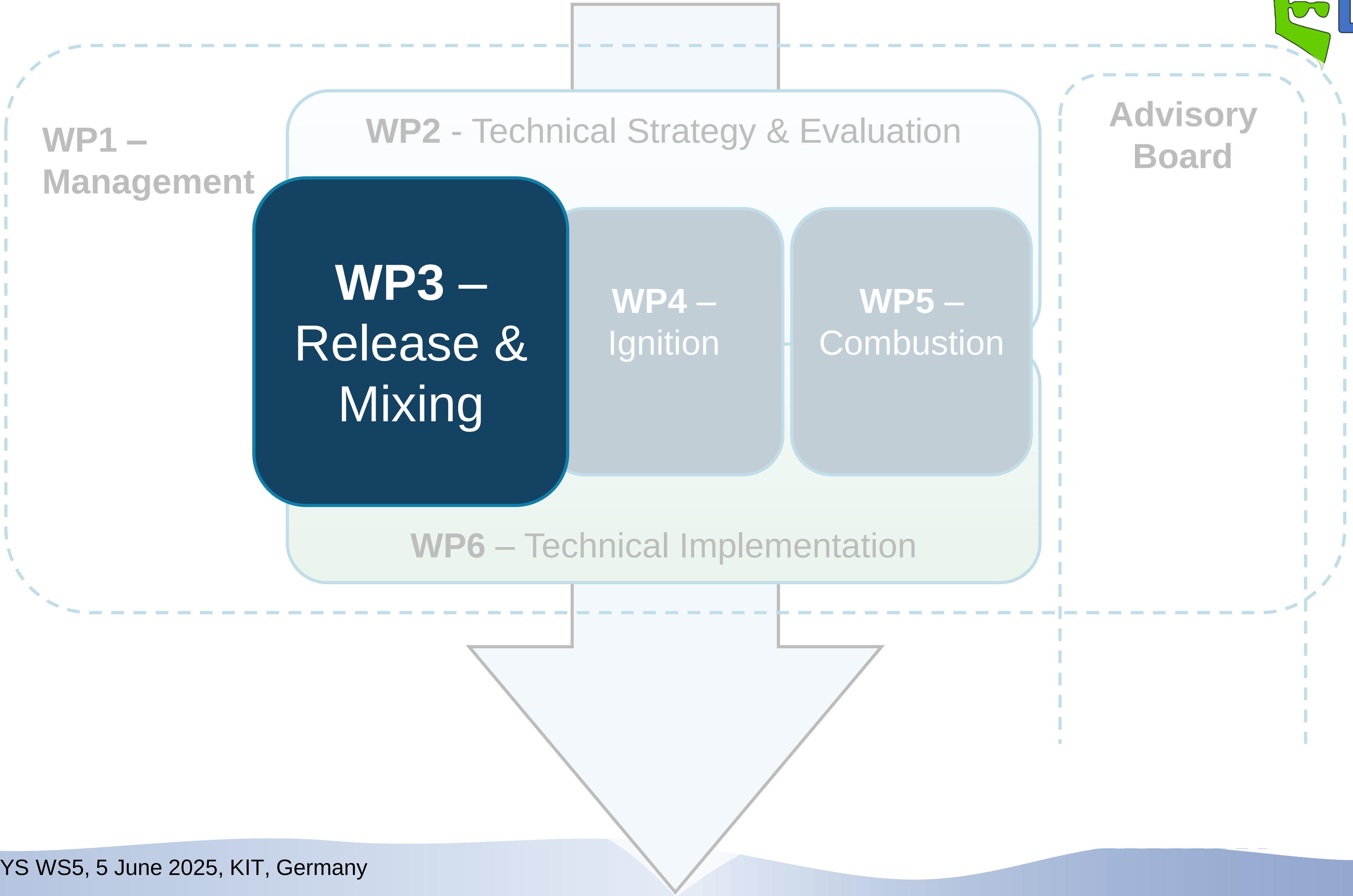


$$\sigma(T) = \sigma(T_0) \cdot \left(\frac{T_0}{T} \right)$$



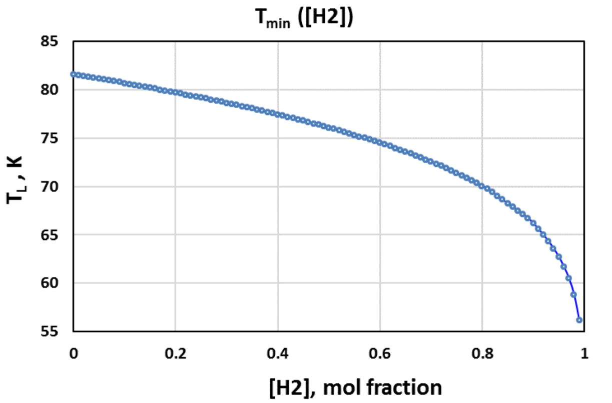
- Flammability limits linearly decrease with temperature decrease
- Adiabatic combustion pressure increases with temperature decrease because of higher density
- Expansion ratio increases inversely proportional to the temperature
- Laminar flame velocity decreases four times with temperature decrease from 300K to 100K
- The visible flame velocity decreases at cryogenic temperatures not so much

$$U_f = \sigma \cdot S_L$$

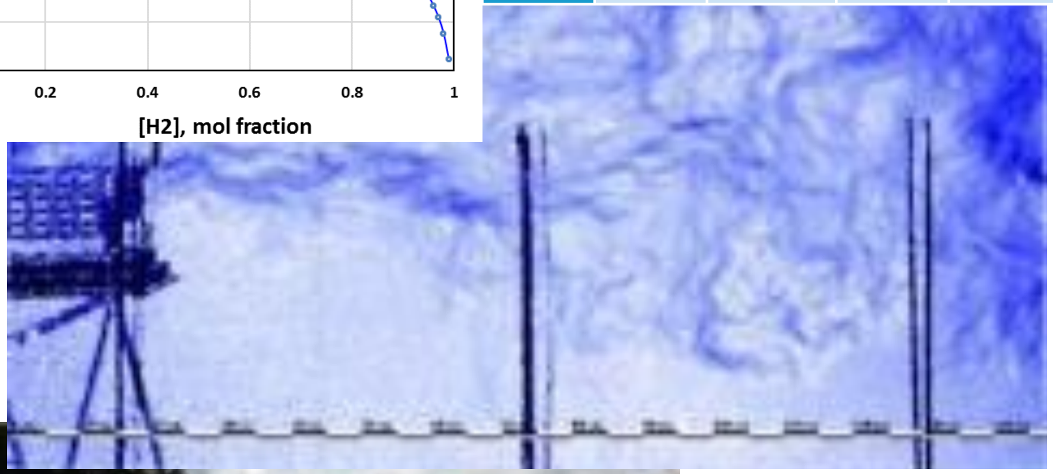

WP1 – Management
WP2 - Technical Strategy & Evaluation
Advisory Board
WP3 – Release & Mixing
WP4 – Ignition
WP5 – Combustion
WP6 – Technical Implementation

Closed Knowledge Gaps - Release

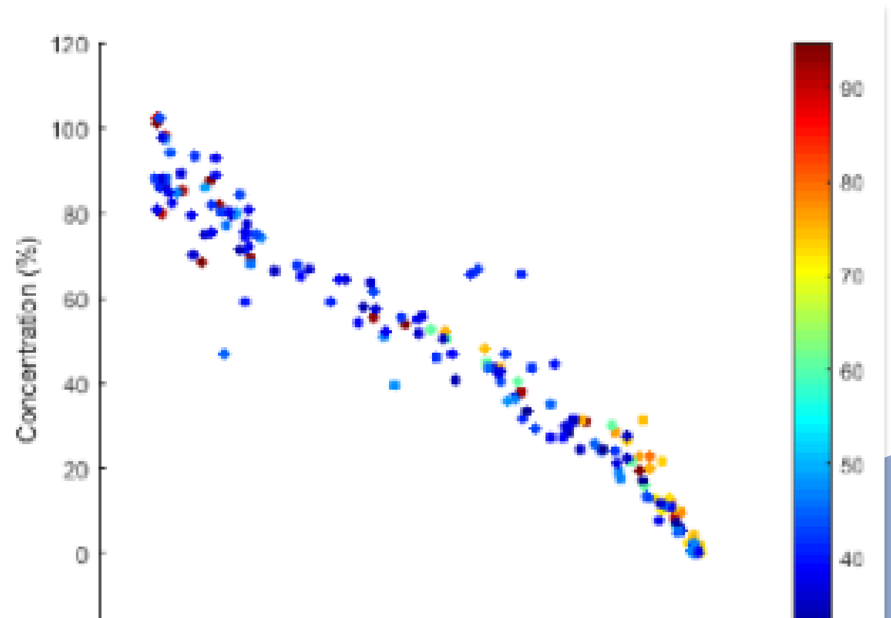
- Discharge coefficients for circular nozzles D=0.5-4 mm 5 - 200 bar; 20 – 300K
- Mixing behavior and multi-phase effects with ambient air
- Gaseous flammable mixtures with ambient air exist only above 70K
- No rainout for large scale above ground horizontal releases
- Correlation of T and concentration of cryogenic H2 and air mixtures
- Assessment of effect of heat transfer through a pipe wall during cryogenic hydrogen release



T, K	P, bar	%O2 max	%H2	Note
71	1	5.25	75	UFL
79	1	14.7	30	St
81	1	20.2	4	LFL



HSE E3.5: rainout tests

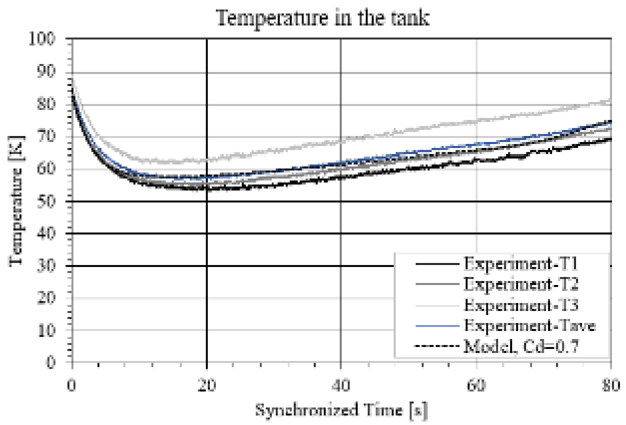


Correlations/Tools for Releases

The non-adiabatic blowdown model for a cryogenic hydrogen storage tank (UU)

Aim: accurately predict the temperature and pressure dynamics in cryogenic hydrogen storages during blowdown, the parameters at the nozzle and release rate by taking into account:

- Non-ideal behaviour of hydrogen gas;
- Heat transfer through a tank wall;
- Heat transfer through the discharge pipe wall.



P_{in}=200 bar, T_{in}=80K, d=1 mm

Steady state single / two-phase choked / expanded flow through a discharge line with variable cross section with account of friction and extra resistances (NCSRD)

Aim: predict the choked mass flow rate and distribution of all relevant physical quantities along the discharge line by taking into account:

- Discharge line friction and extra resistances;
- Transition to two-phase state.

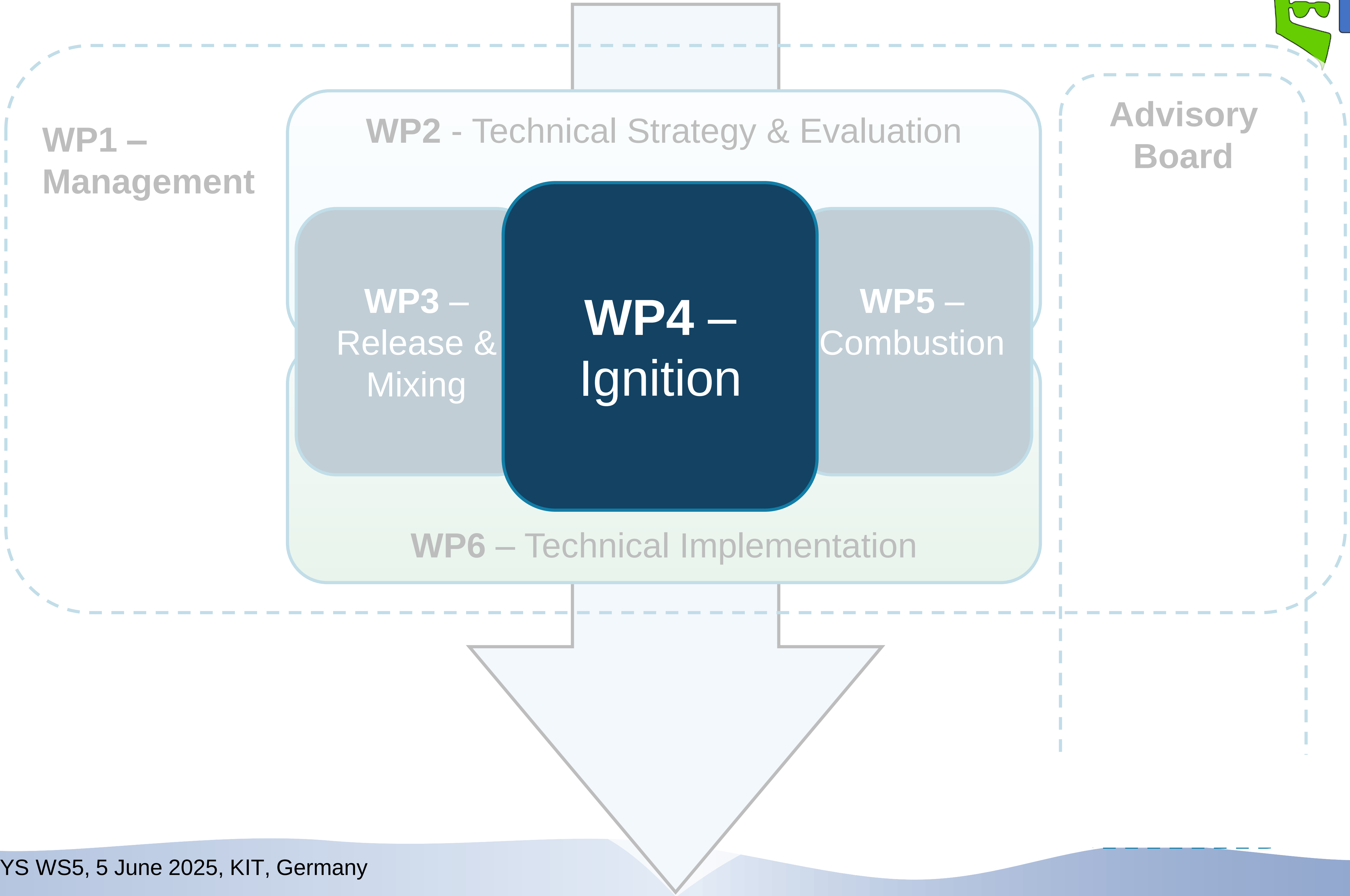
Correlations/Tools for LH2 pools

Extent of cryogenic pools – HyPond (INERIS)

Aim: estimate the maximum extent of a liquid pool likely to spread on the ground following a low pressure spillage of liquid hydrogen. The model addresses continuous spillages, which can be caused by a hose rupturing or disconnection, etc.

$$r_{pond} = \sqrt{\frac{Q_m \cdot L_{vap} \cdot \sqrt{\pi \cdot a_{diff}}}{k \cdot \pi \cdot (T_{ground} - T_{eb})}} \cdot t^{1/4}$$

- Q_m: LH_2 mass flowrate;
- Q_{cond}: thermal exchange between the pool and the ground;
- L_{vap}: heat of vaporization of LH_2;
- k: thermal conductivity of the ground;
- a_{diff}: thermal diffusivity of the ground;
- t: time elapsed since the start of the release;
- A_{pond} is linked to the characteristic radius r_{pond} of the pond as $A_{pond} = \pi \cdot r_{pond}^2$.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Closed Knowledge Gaps - Ignition

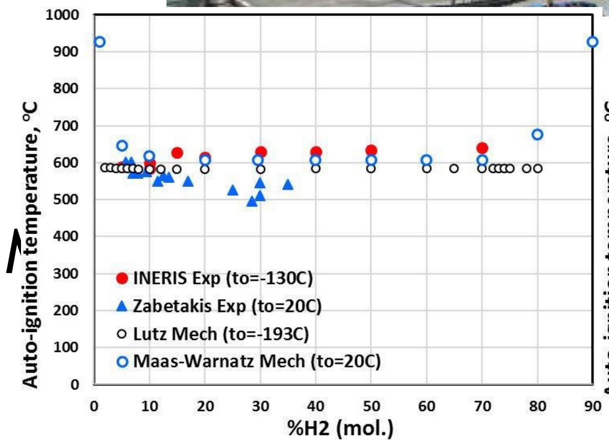
- Ignition temperature by **hot surface** independent on mixture temperature
  Small influence of stoichiometry and flow velocity.

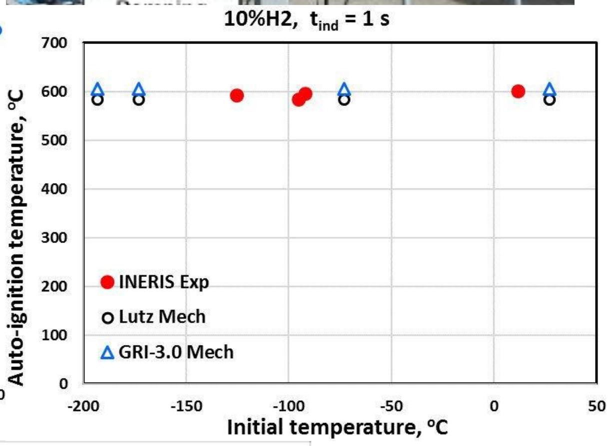
- **Minimum Ignition Energy MIE** by spark ignition showed slight increase for hydrogen-air mixtures at 173.
  Analytical and numerical models/simulations to predict
  by spark ignition for hydrogen-air mixtures.

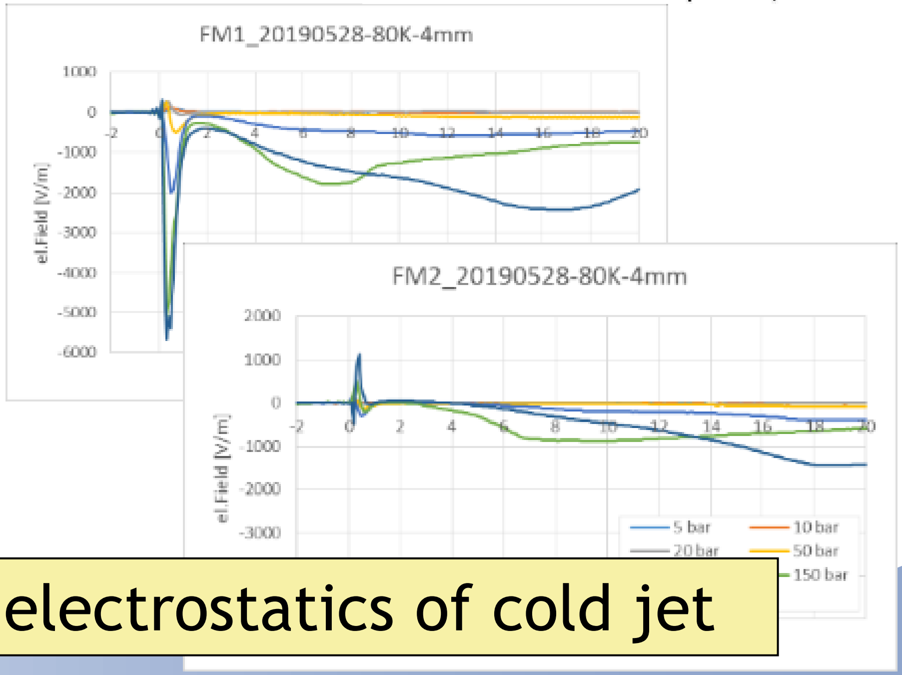
- **Electrostatic** field measurements with field mills in DISCHA experiments (>100) showed strong electrostatic fields (~6000 V/m) for 80 K releases (~100 larger than at ambient T).
  Electrostatic fields increase with increasing release pressure.
  Simple model derived.

- **No spontaneous ignition** was observed in any experiment.

INERIS E4.1 general ignition tests





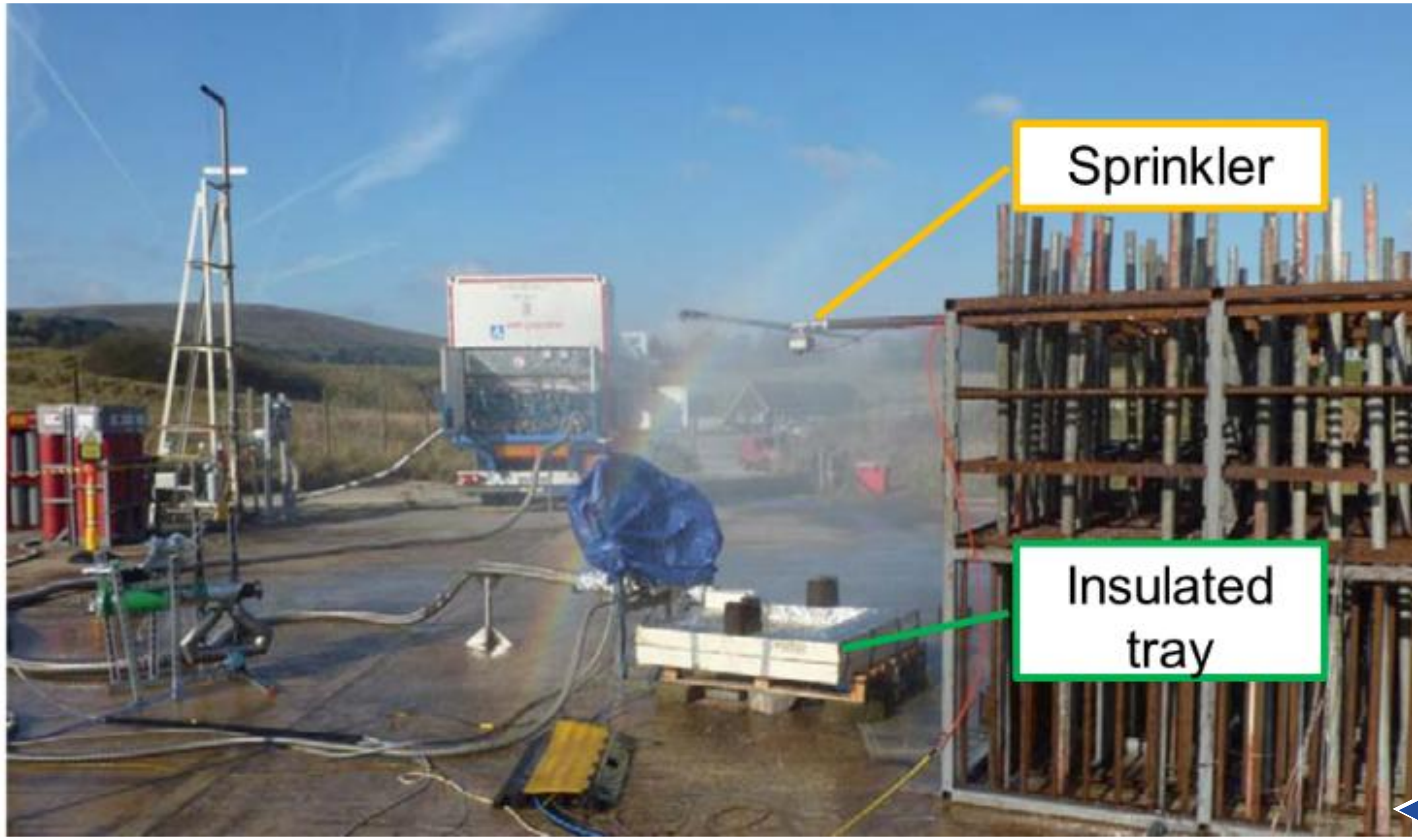


KIT/PS E4.3 electrostatics of cold jet

Multi-phase accumulations with explosion potential

Repeated spills on gravel bed might generate highly reactive condensed phase mixtures
Not on other substrates

KIT/PS E4.4 ignition above pool



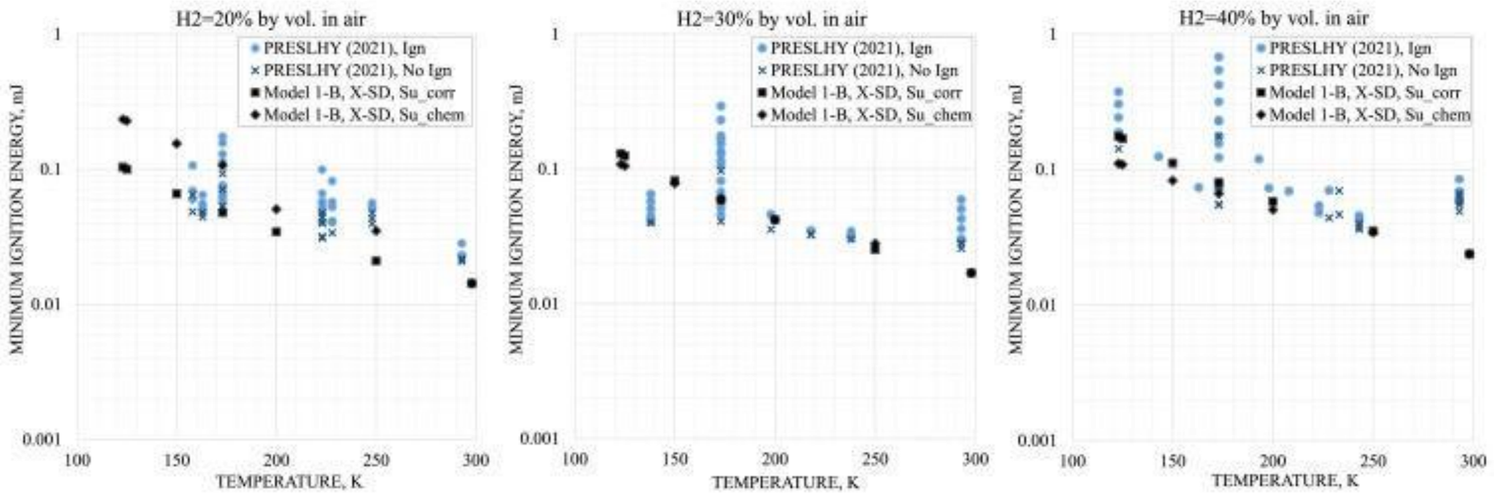
No critical effects observed for water sprays on LH2 and LH2 spills on small water pools

Correlations/Tools for Ignition

Ignition Energy for hydrogen-air mixtures (UU)

Aim: determine the Minimum Ignition Energy (MIE) by spark ignition in hydrogen-air mixtures with arbitrary concentration and initial temperature. Novelties:

- Use of the laminar flame thickness to determine the critical flame kernel instead of experimental data not available for low T
- Account of flame stretch and preferential diffusion

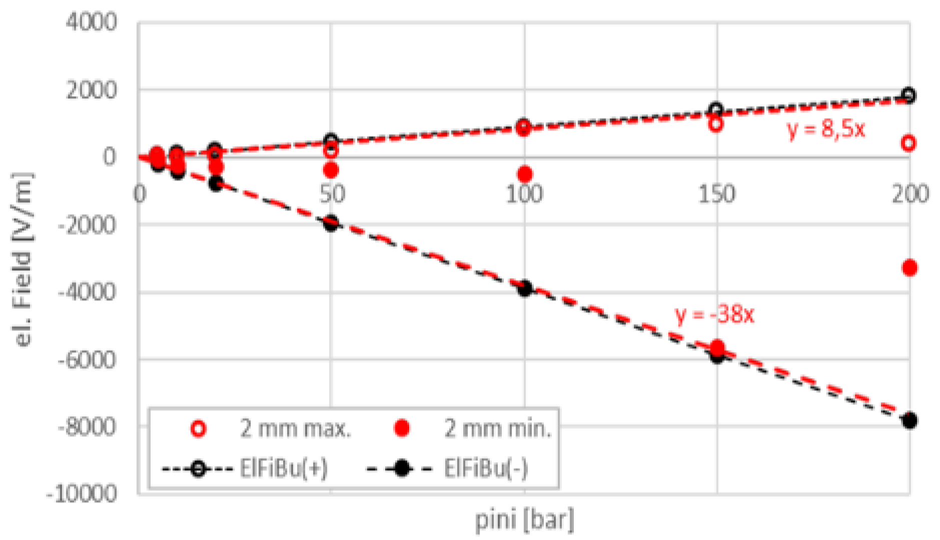


Electrostatic field built-up generated during H2 releases (PS)

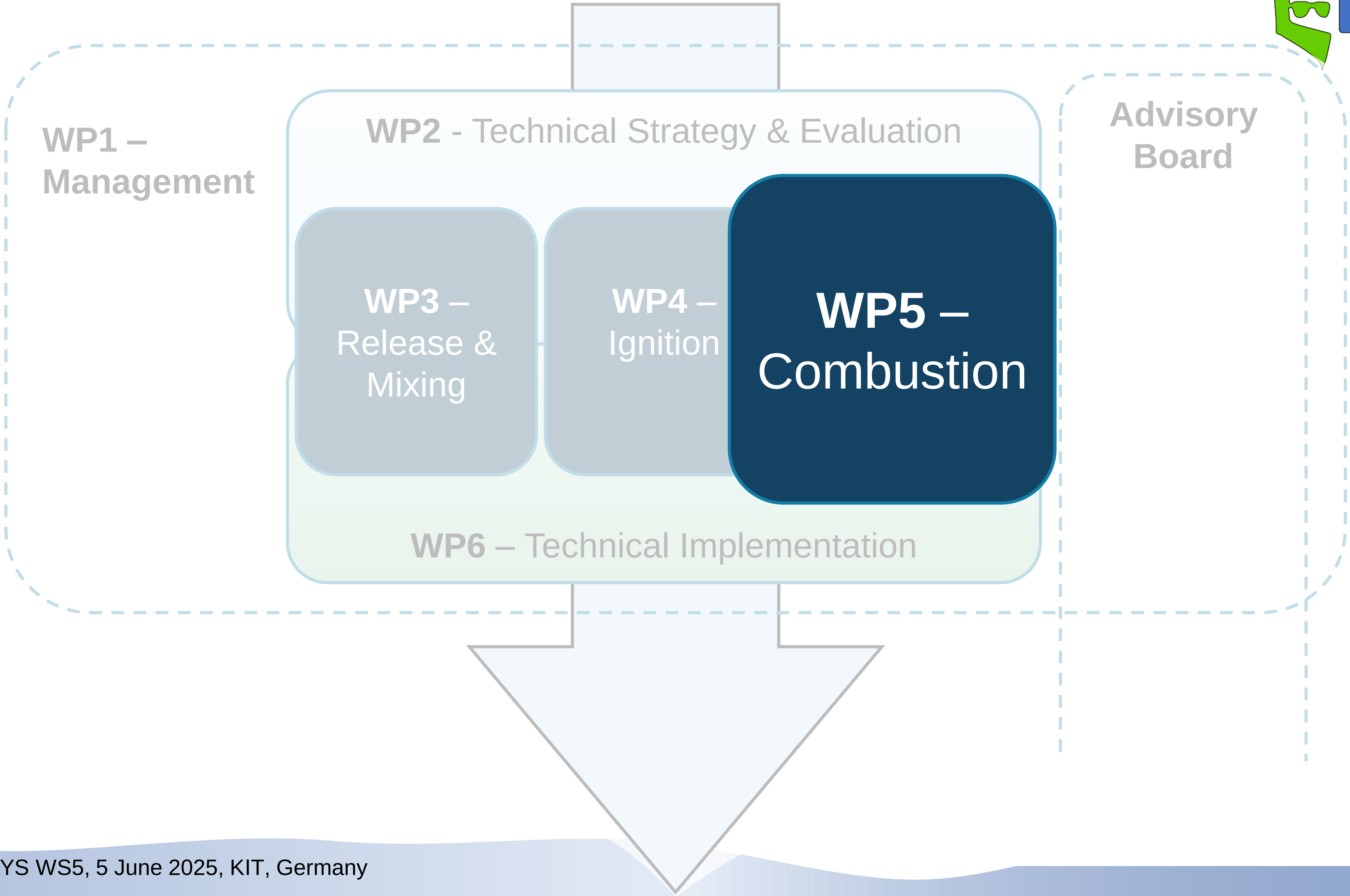
Aim: assess the electrostatic field built-up during hydrogen releases through a nozzle with circular aperture. The ElFiBU-correlation consists of two formulas:

Positive Field Built-up: $E(+) \leq (4 \cdot dNz + 1) \cdot p_{ini}$

Negative Field Built-up: $E(-) \leq (-14 \cdot dNz - 11) \cdot p_{ini}$



dNz=2mm, T=80K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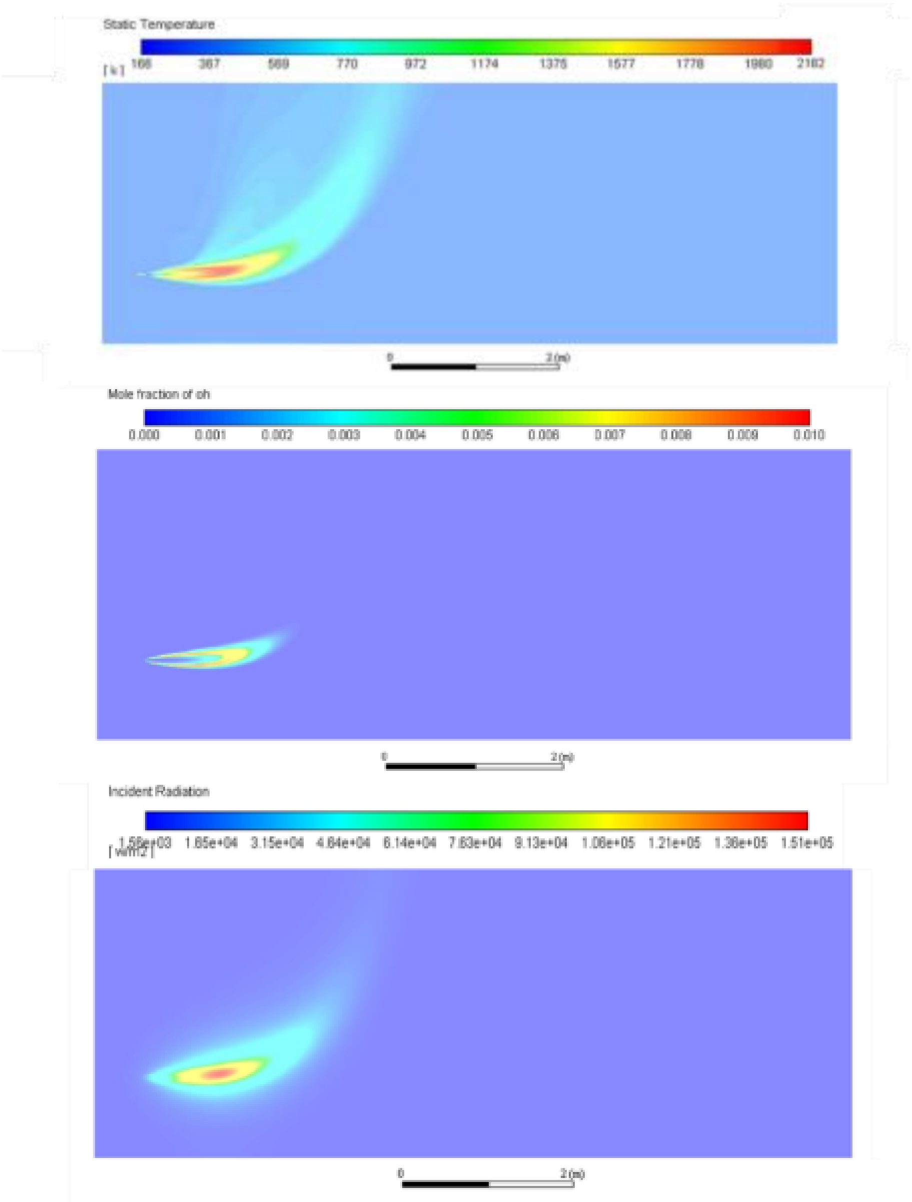
Cryogenic hydrogen jet fires: thermal hazards

- Validation of a CFD model to assess radiative heat flux from cryogenic hydrogen jet fires with vertical and horizontal orientation.
- The buoyancy of combustion products has a positive effect on the reduction of the “no harm” distance by temperature from x=3.5L_f for vertical jet fires to x=2.2L_f for horizontal jet fires.
- Thermal radiation leads to longer “no-harm” distances in the direction of the jet (x=3.0-3.2L_f) compared to hazard distance defined by temperature.
- Thermal dose provides to be a useful parameter to define hazard distances for emergency personnel.
- Use of flame length dimensionless correlation can be expanded to cryogenic releases.



Correlations/Tools for Jet Fires

Flame length correlation and hazard distances for jet fires (UU)

The dimensionless correlation for hydrogen jet flames calculates the flame length knowing the storage conditions. Hazard distances for people can be defined as:

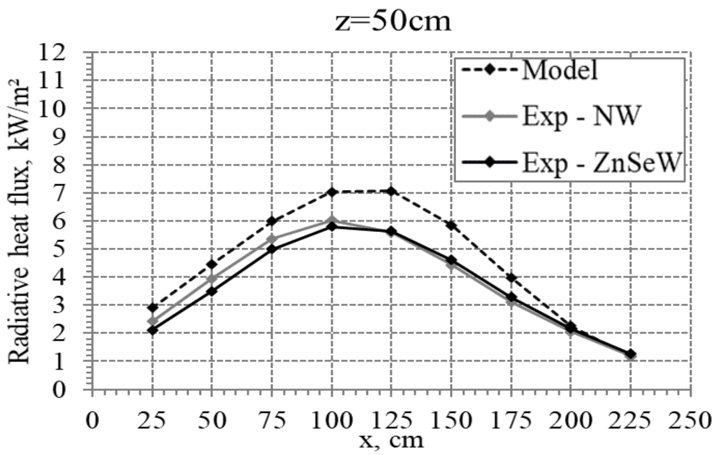
- No harm (70°C) hazard distance, $X_{70} = 3.5L_f$;
- Pain limit (5 mins, 115°C) hazard distance, $X_{115} = 3L_f$;
- Third degree burns (20 sec, 309°C) hazard distance, $X_{309} = 2L_f$.

The tool is available on e-lab platform developed within NET-Tools (https://elab-prod.iket.kit.edu/).

Assessment of thermal load from hydrogen jet fires (UU)

Aim: assess the radiative heat flux from vertical and horizontal hydrogen jet fires.

- The reduced tool is based on the weighted multi source flame radiation model developed by Hankinson and Lowesmith (2012) and further expanded by Ekoto et al. (2014).
- The model was adapted to use the dimensionless correlation to estimate flame length and expand the validation range to cryogenic hydrogen jet fires.

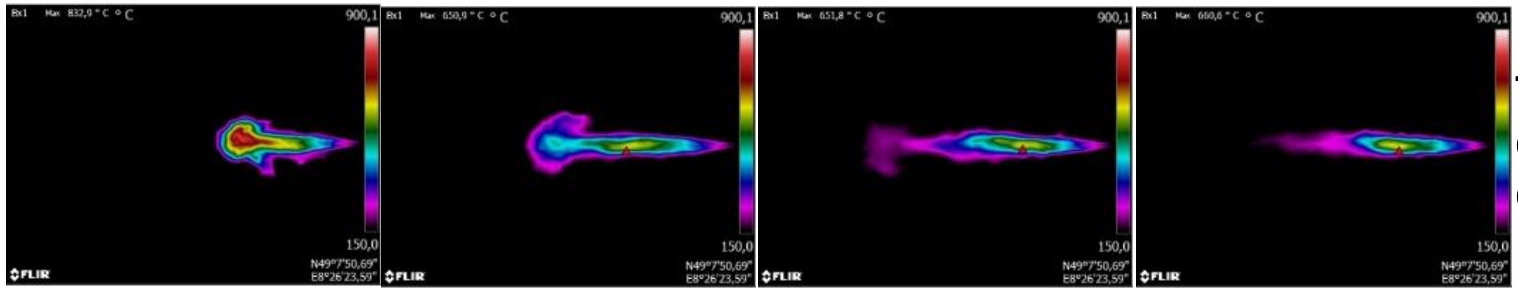


Test: T=80 K, P=3 bar, d=4 mm

Heat radiation of cryogenic jet fire

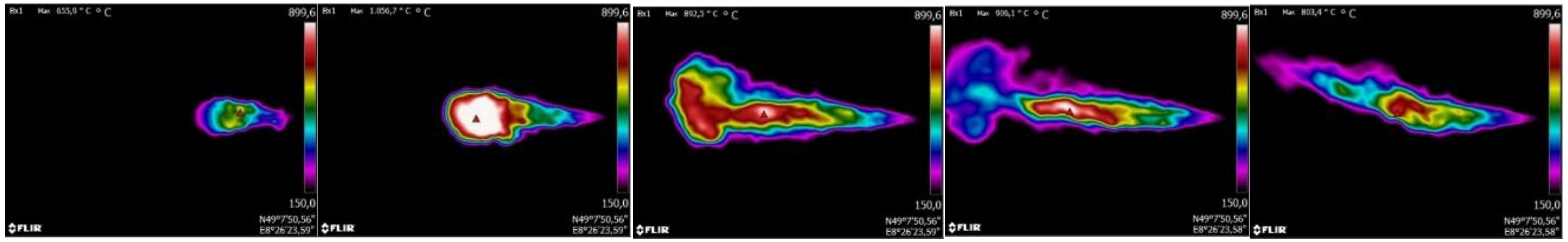
Temperature distribution (FLIR Thermo-camera)

P=100bar, d=2mm, T=285K



Tmax=540-1100K
qmax=85kW/m2
qav=6.5kW/m2

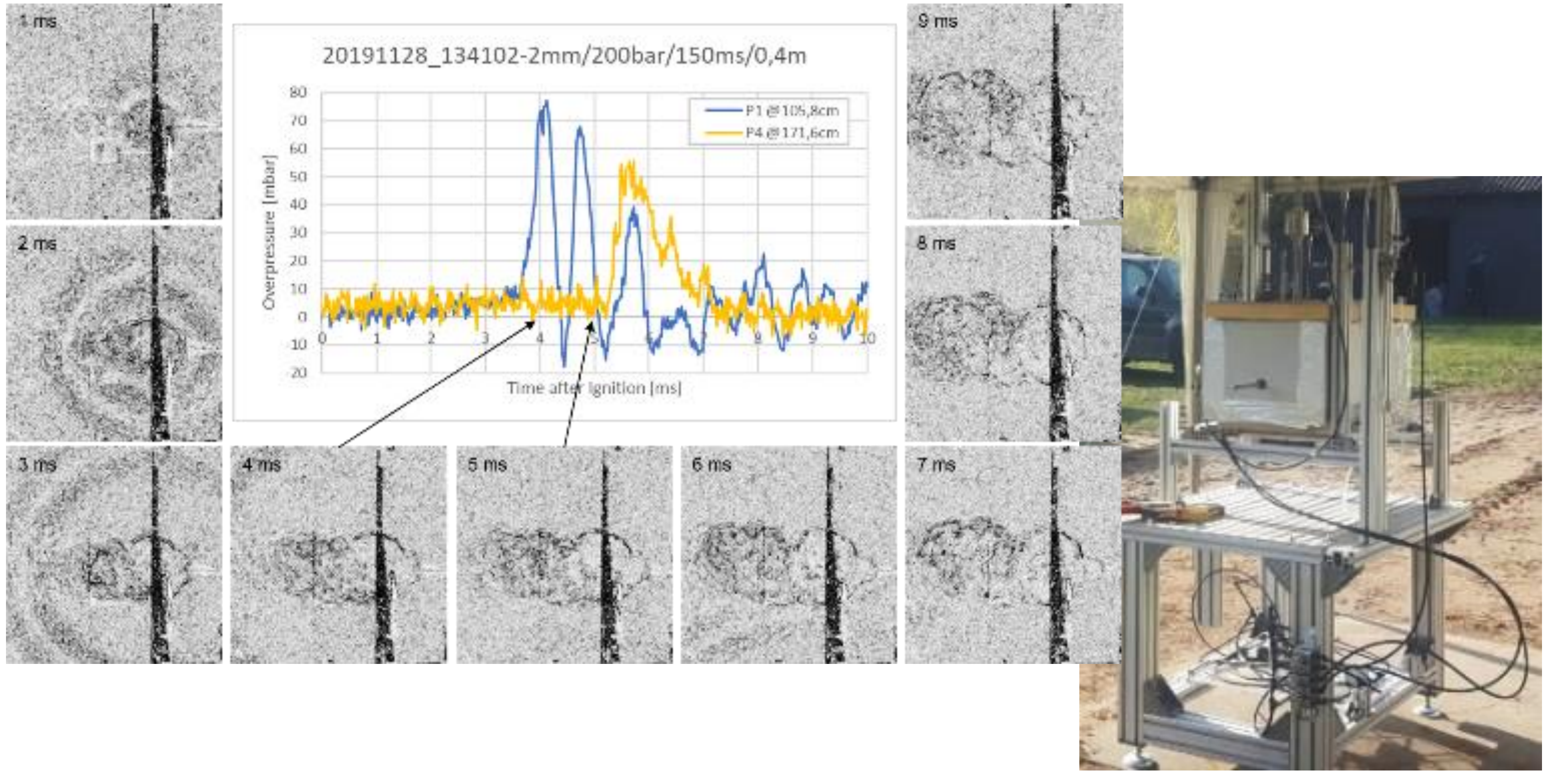
P=100bar, d=2mm, T=80K



Tmax=710-1330K; qmax=177kW/m2; qav=11kW/m2

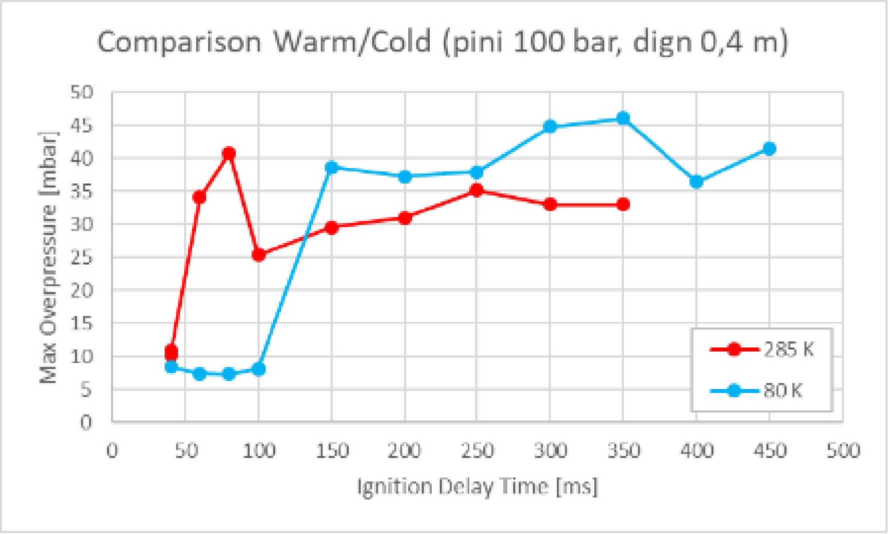
- **Four times larger hydrogen inventory and also 2.5 times higher mass flow rate at cryogenic temperature lead to 1.3 times higher temperature, 2 times higher heat flux of flame radiation, 1.5 times larger flame length and 1.4 times longer release time**

Transient combustion effects



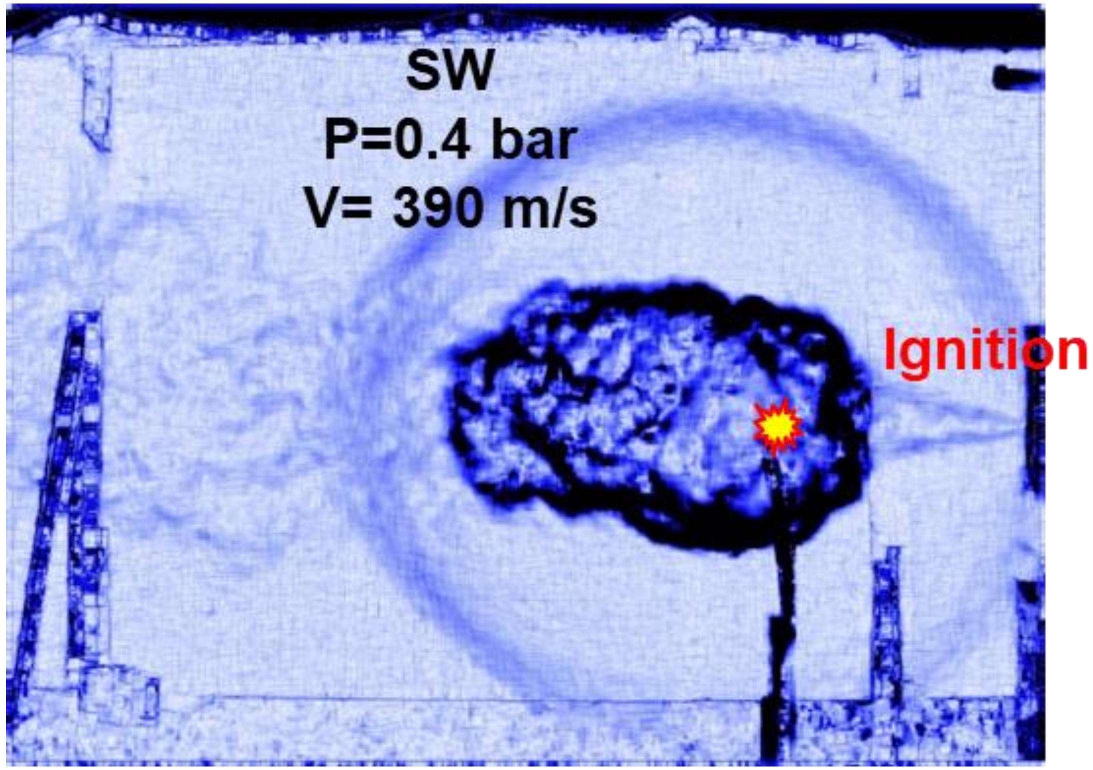
> 100 Ignited jet tests combined with discharge experiments E5.1
T = 80K, 280K
P = 5-200bar
D_{nozzle}= 1, 2, 4mm

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**

Jet ignition pressure



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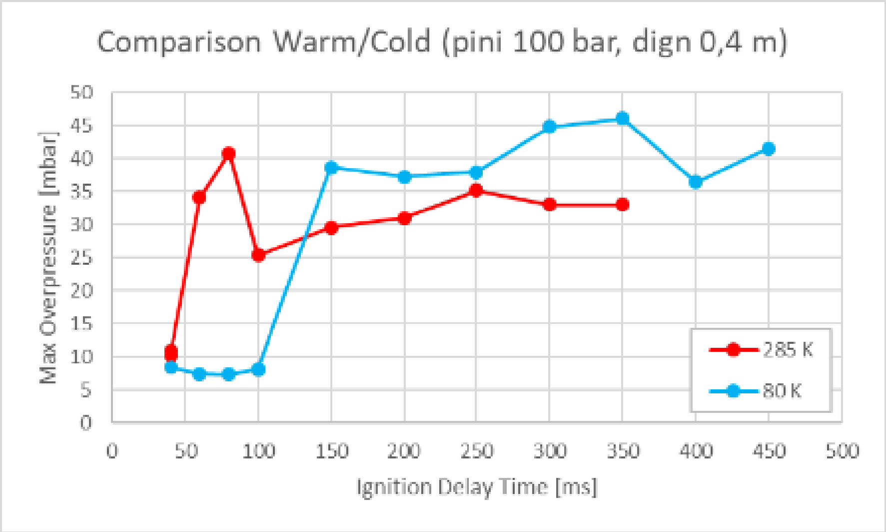


- Better understanding of transient jets and combustion processes
- **Inventory based map of worst effects** (pressure & thermal) **to be extrapolated to large inventories for RCS**

Correlations/Tools for Pressure hazards

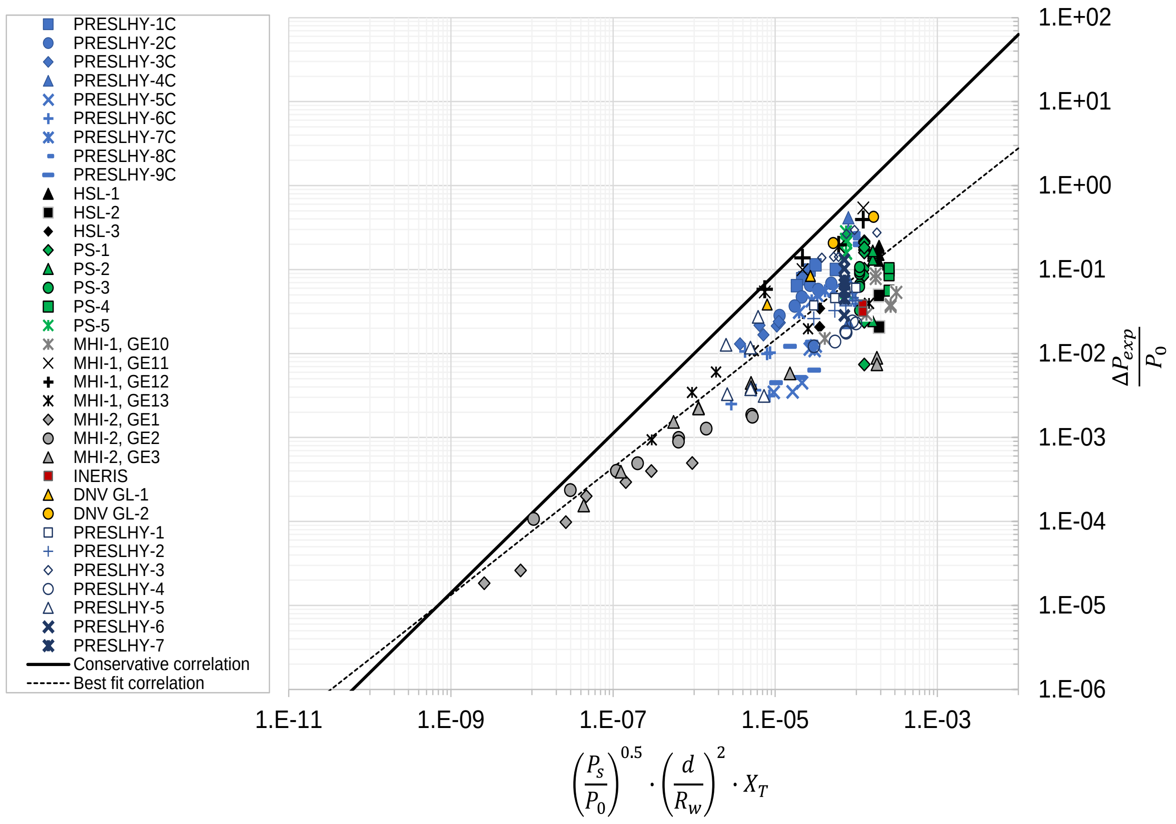
Maximum pressure load from delayed ignition of turbulent jets (UU)

Aim: predict the maximum overpressure generated by delayed ignition of a hydrogen jet at an arbitrary location for known storage pressure, P_S, and release diameter, *d*. The correlation is applicable only to free jets in open atmosphere.

The semi-empirical correlation was built by using overpressure measurements from about 80 experiments and the similitude analysis:

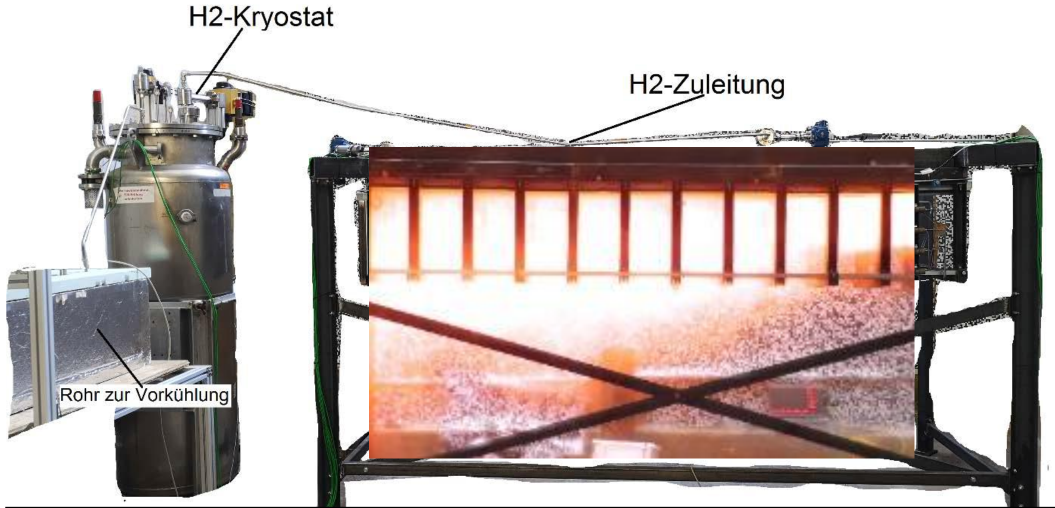
$$\Delta P_t = P_0 \cdot 5000 \cdot \left[\left(\frac{P_S}{P_0}\right)^{0.5} \cdot \left(\frac{d}{R_w}\right)^2 \cdot X_T\right]^{0.95}$$

- R_w: distance between the centre of the fast burning mixture (25-35% by volume) and the target location
- $X_T = 1$ for ambient temperature releases
- $X_T = \frac{T_S}{T_0}\frac{E_{i,T_S}}{E_{i,T_0}}$ for cryogenic releases, where E_{i,T_S} is the expansion coefficient at T_S.



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



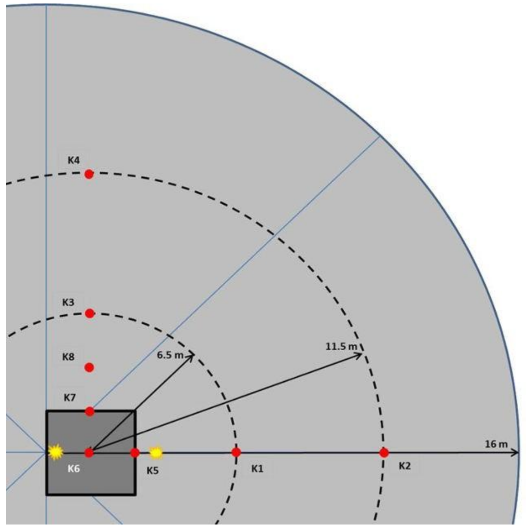
KIT/PS E5.3 semi-confined channel

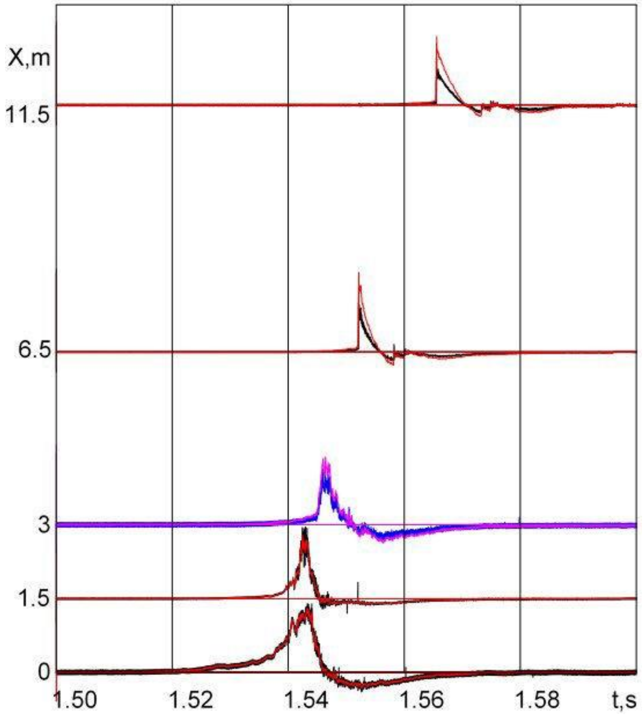
E5.5 Test set-up at HSE, Buxton

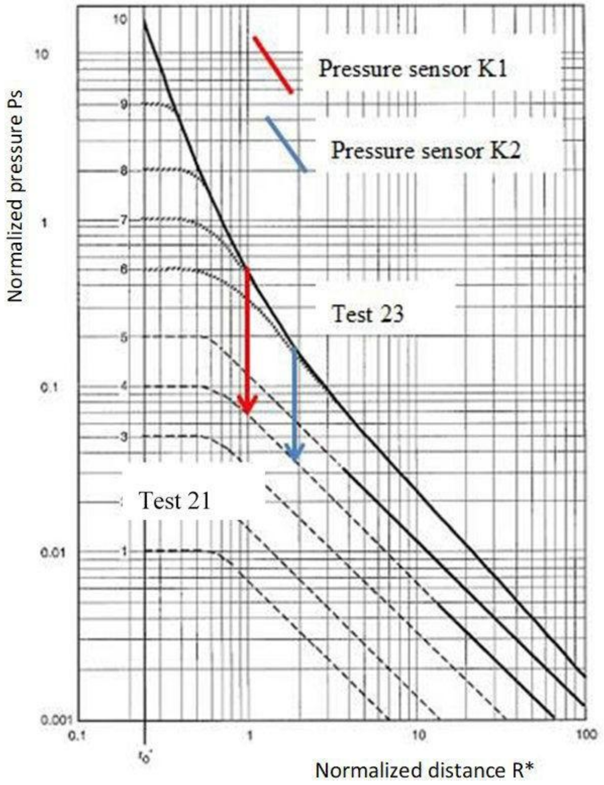
- Increase in critical and effective expansion ratios determine flame acceleration in cryogenic mixtures
- Reduced run-up distance for detonation transition DDT in cryogenic mixtures (← density effects)
- Influence of blockage ratio on DDT less pronounced
- Effects in free unconfined domains to be investigated

Explosions in cryogenic hydrogen

Test set-up at HSE, Buxton



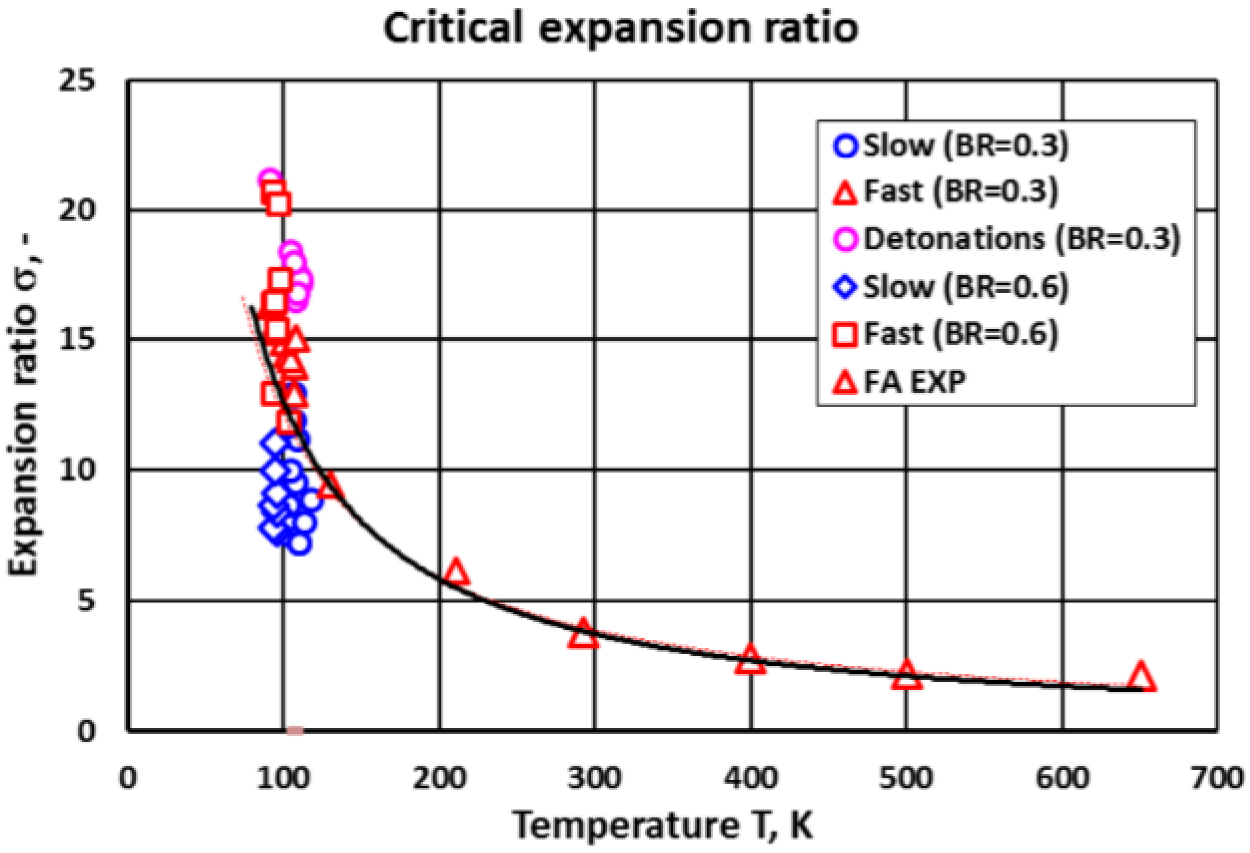




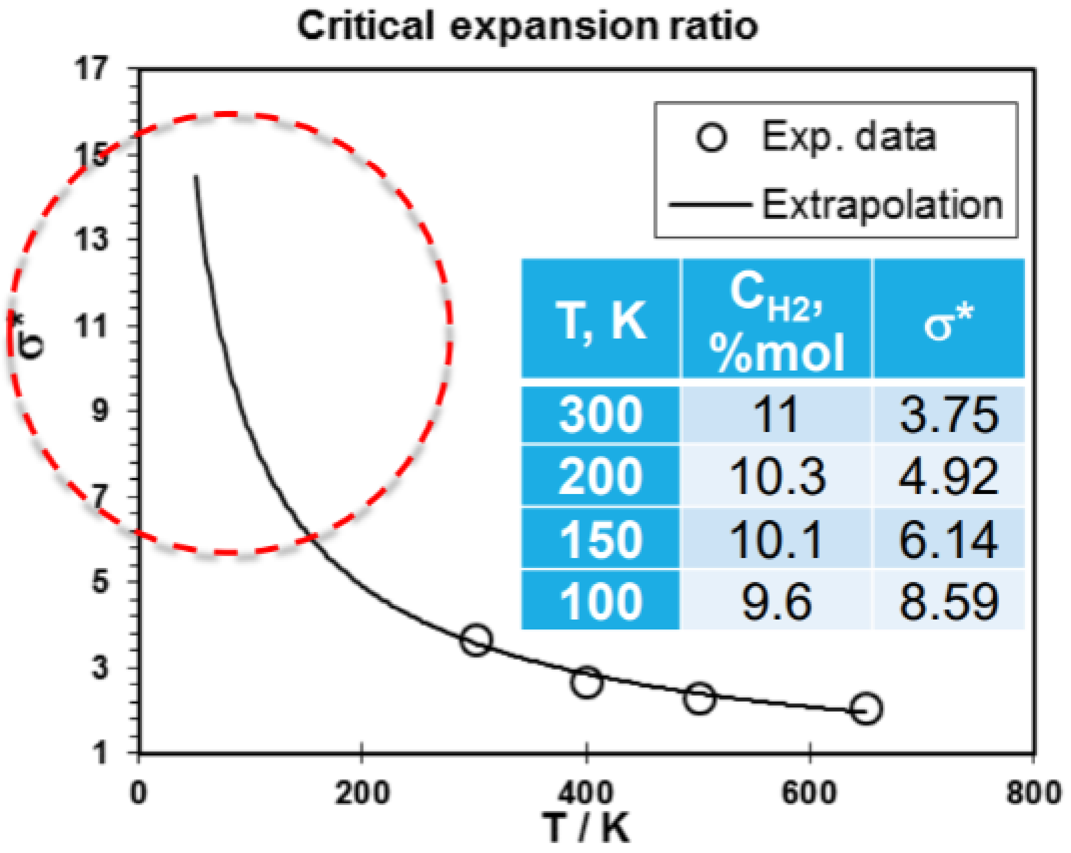
- In some experiments stong explosion occurs fot cryogenic hydrogen cloud
- A strong blast wave from 1.42 bar in the center to 0.25 bar at 11.5 m
- Shock wave velocity decreases from 940 m/s in the center to 370 m/s at 11.5 m
- Such blast wave paprameters correspond to 20 MJ of energy according to Multi-energy method

Critical Expansion Ratio for FA

Experiments



Predictions



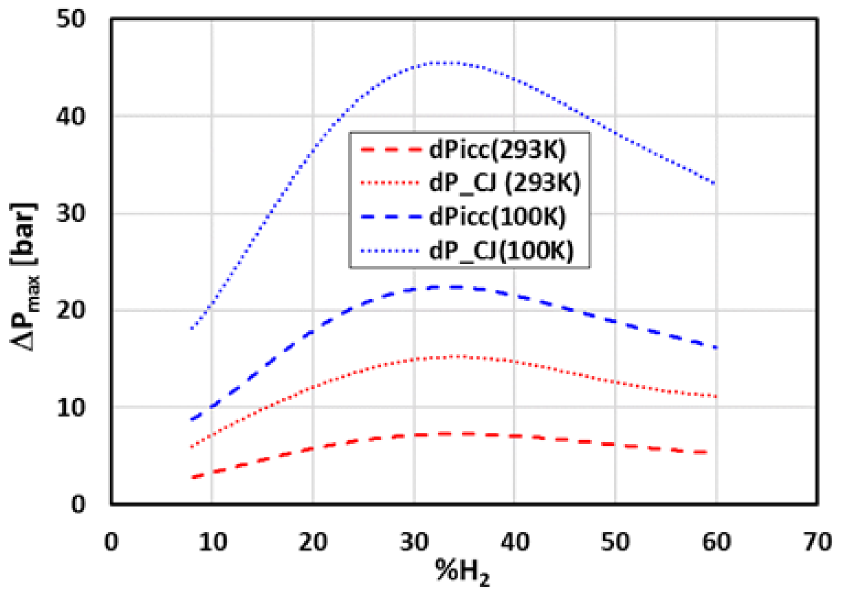
T, K	C_{H2}, %mol	σ*
300	11	3.75
200	10.3	4.92
150	10.1	6.14
100	9.6	8.59

- The critical expansion ratio at T=100K was experimentally found to be σ* =12.5 (16%H2), much higher than that predicted by far extrapolation σ* =8.6 (9.6%H2)
- Approximation line as a function of initial temperature can be used - or more simplified relationship (more conservative: σ*=11 instead of σ*=12.6 according to experimental correlation)

$$\sigma^* = 2200 \cdot T^{-1.12}$$

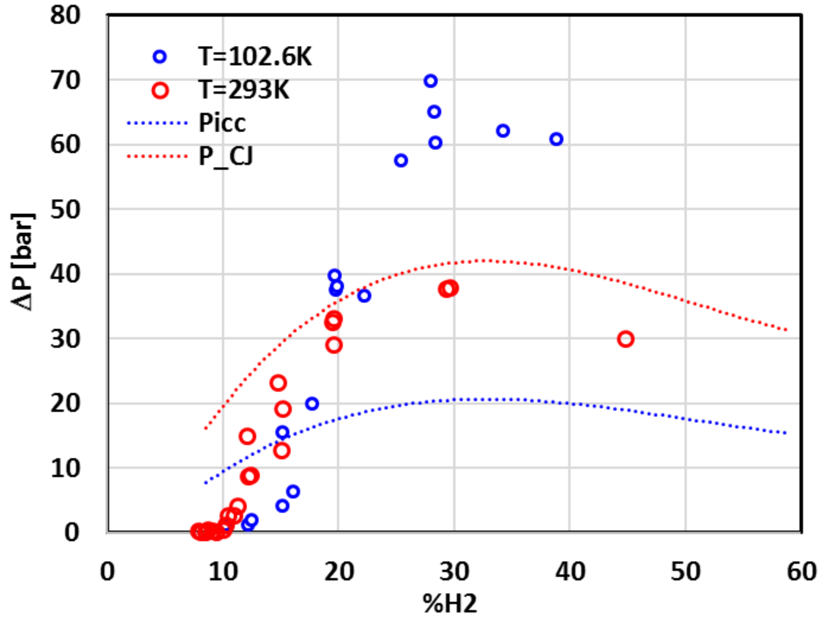
$$\sigma^*(T) = \sigma^*(T_0) \cdot \left(\frac{T_0}{T}\right)$$

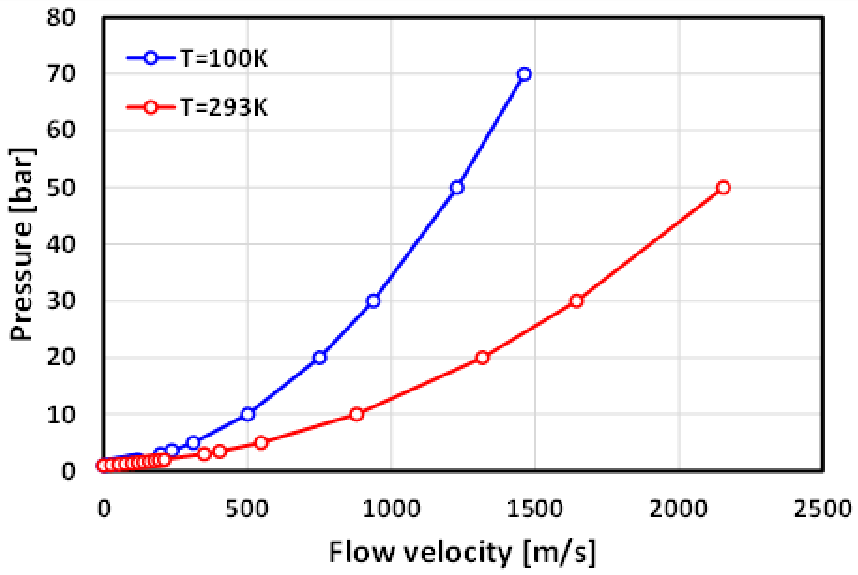
Maximum combustion pressure



$$P_{icc}(T) = P_{icc}(T_0) \cdot \left(\frac{T_0}{T} \right)$$

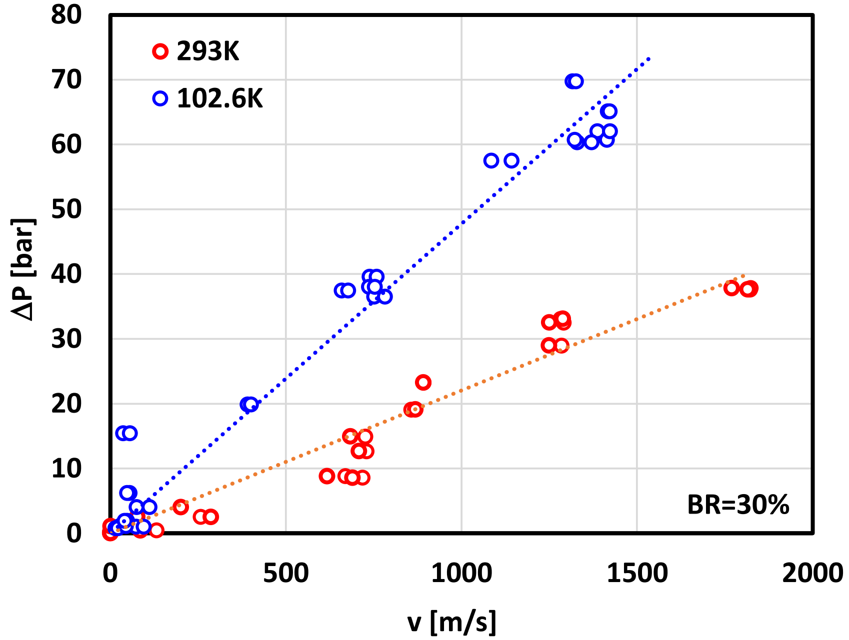
$$P_{CJ}(T) = P_{CJ}(T_0) \cdot \left(\frac{T_0}{T} \right)$$





$$\frac{P_2}{P_1} = \frac{2\gamma}{\gamma+1} M^2 - \frac{\gamma-1}{\gamma+1}$$

- Due to the density factor and two times lower speed of sound the maximum combustion pressure at cryogenic temperatures is 2-3 times higher than that for ambient conditions.
- The experiments demonstrate a higher level of the danger under cryogenic hydrogen combustion.



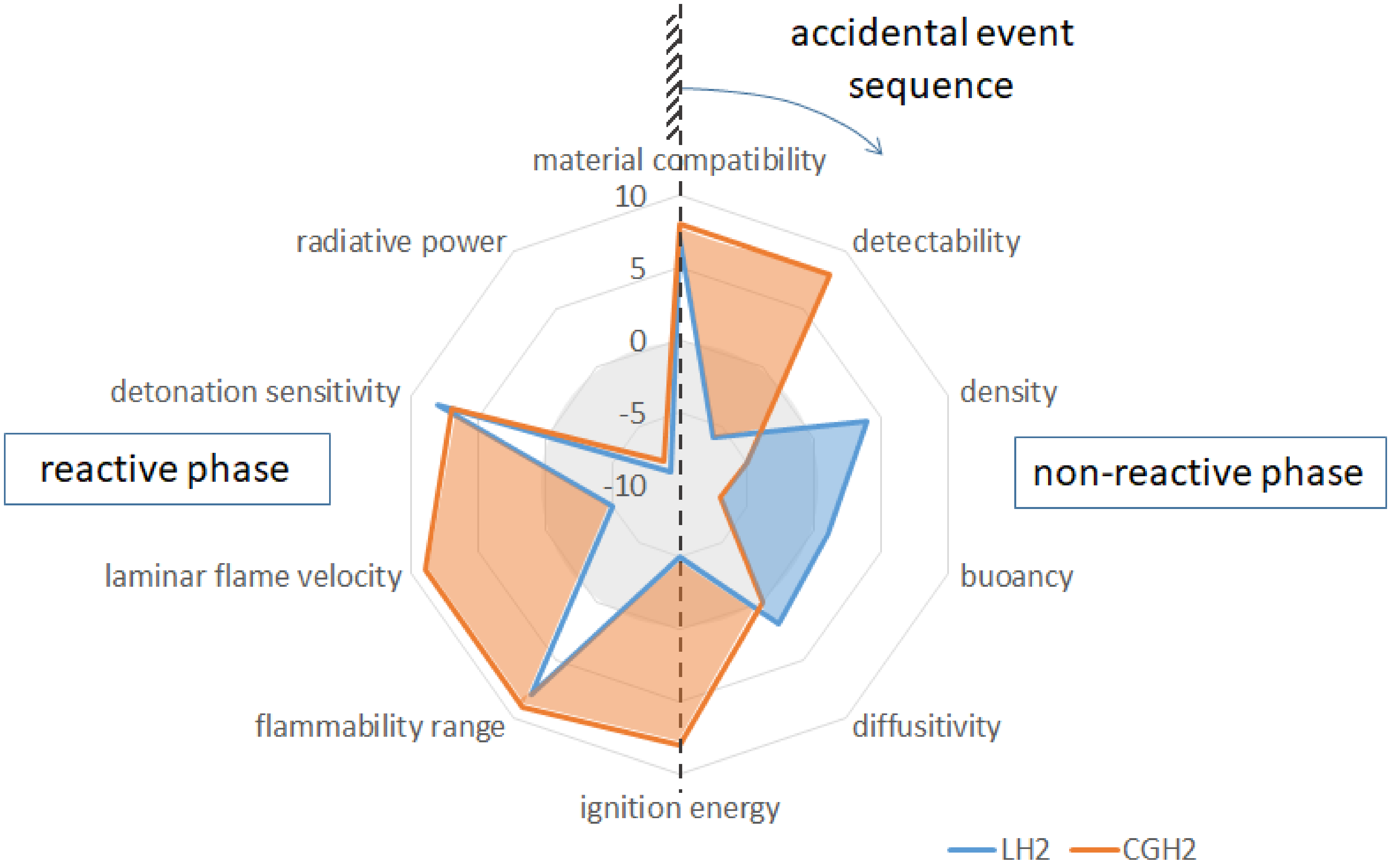
DDT and Detonation

- The detonation cell sizes at cryogenic temperature T = 100K are evaluated on the basis of existing criteria for detonation onset in smooth and obstructed tubes:

$$\lambda[mm] = 0.0006724[H_2]^4 - 0.1039[H_2]^3 + 6.0786[H_2]^2 - 159.74[H_2] + 1603.3$$

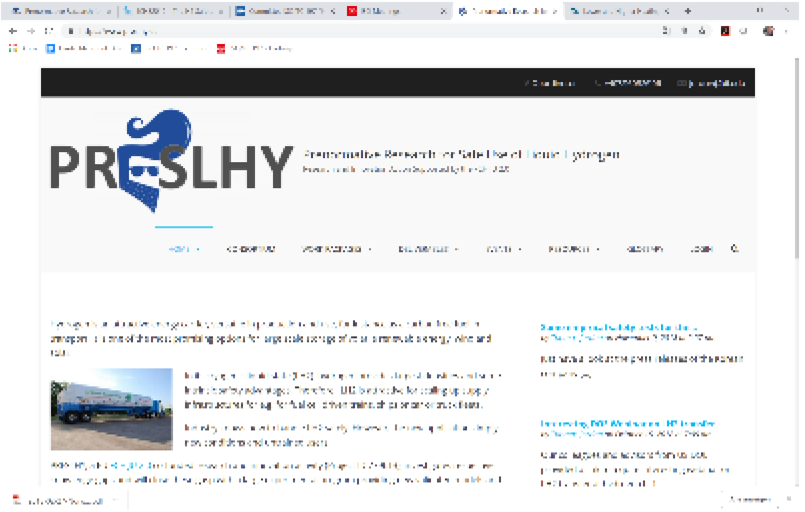
- Based on evaluated detonation cell sizes the well known criteria can be used to assess the detonability of hydrogen –air mixtures at cryogenic temperatures in different geometries and scales.
- The run-up distance to detonation at cryogenic temperatures was found to be two times shorter than at ambient temperature.
- For the first time, similar to obstructed channels, a steady-state flame propagation regime with the speed of sound in combustion products very often occurs in case if the detonation is suppressed.
- Higher probability for detonation onset at cryogenic temperatures

Risk Profiles LH2 vs CGH2



Exploitation

Outreach



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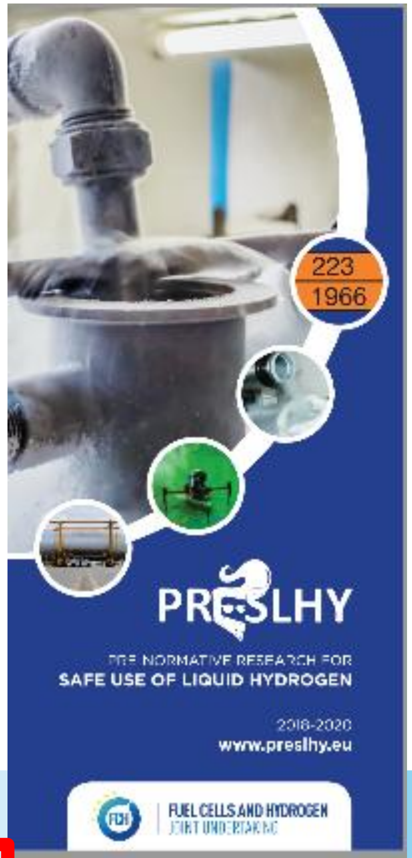
PRESLHY Exploitation & Dissemination Activities

- **Management (WP1)**
- **Implementation (WP6)**

Task 1.3 Website — **Data Management** — **Engineering tools** — **Handbook** — **Guidelines** — **RCS Recom-mendations** — **White Paper** — **Task 6.6 Dissemina-tion Conference**



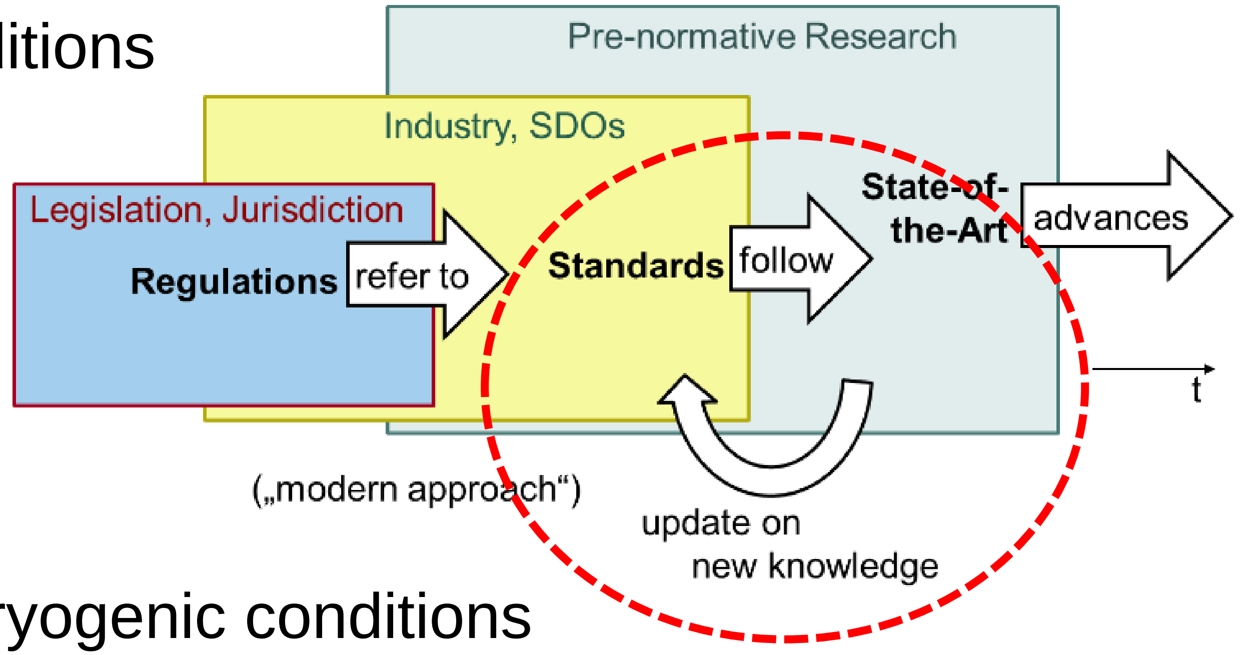
Recent achievements

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, σcrit and run-up distance for DDT determined at cryogenic conditions

All published in more than hundred public available datasets/publications

Future work, open issues, priorities

Fundamental/Modelling:

? Clarify **material issues** with cryogenic hydrogen

? improve **thermodynamic modelling** in multiphase, non-equilibrium, reaction kinetics (< 200K)

? determine **induction times** and **detonation cell sizes** (< 200K)

Dispersion phenomena:

? **Ventilation** of closed rooms and interaction with other mitigation concepts

? **Multiphase effects** on large scale dispersion with obstruction and/or (partial) confinement

Combustion phenomena:

? Broader assessment of FA and DDT for varying congestion and confinement at larger scale

? Evaluation of **detonation potential of solid O_2** in LH_2 pools

? Scaling of **BLEVE**s

Risk assessment and mitigation strategies:

? Proper **design and approval of safety valves**

? Integral (applied) tests (dispersion and combustion in closed rooms) for **mitigation strateg**ies, including sensor placement and performance

? **Crash test** for vehicle tank systems

From PRESLHY to ELVHYS

Outcomes & Recommendations

WP leader: Air Liquide

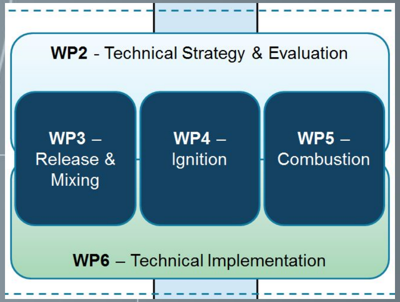
Workshop #5 - 2025.06.05

Karlsruhe - KIT

Co-funded by the European Union
Clean Hydrogen Partnership
UK Research and Innovation

PRESLHY project | 01/2018 - 12/2020+

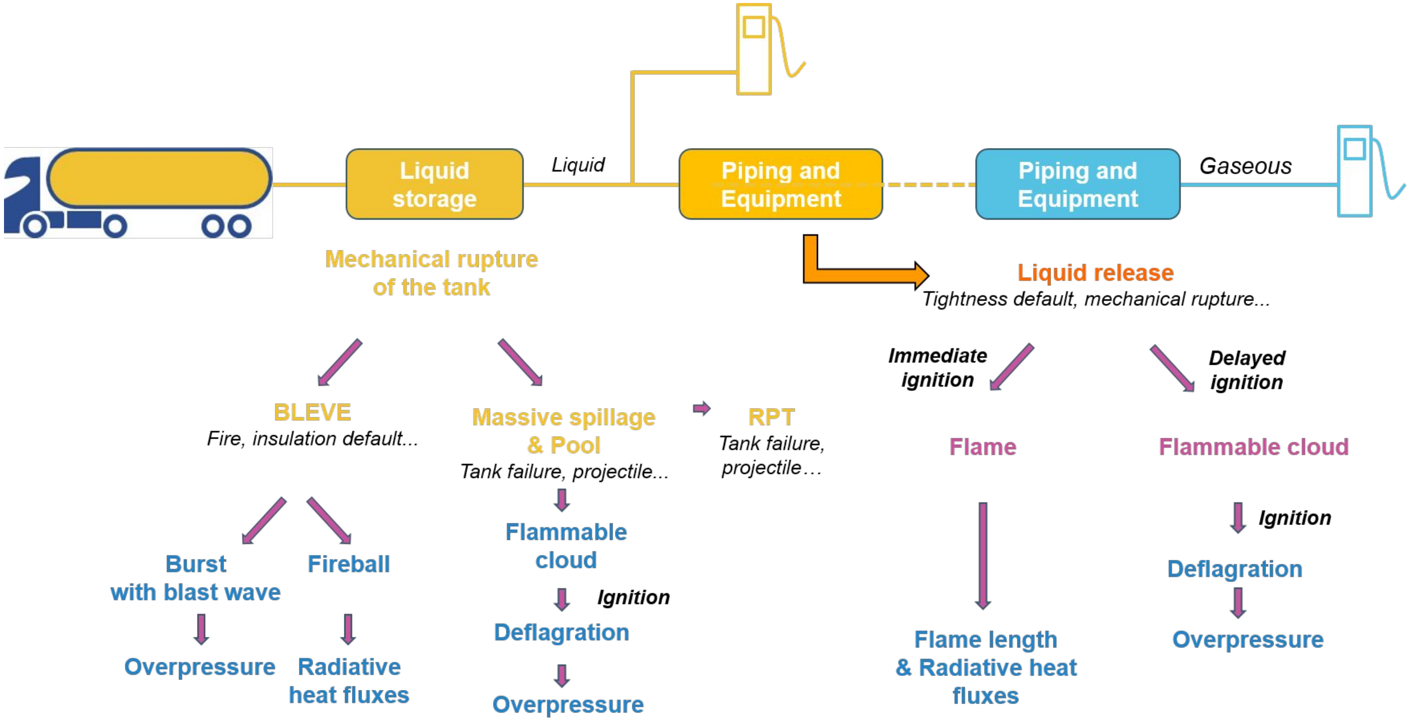
Main recommendations



Karlsruher Institut für Technologie

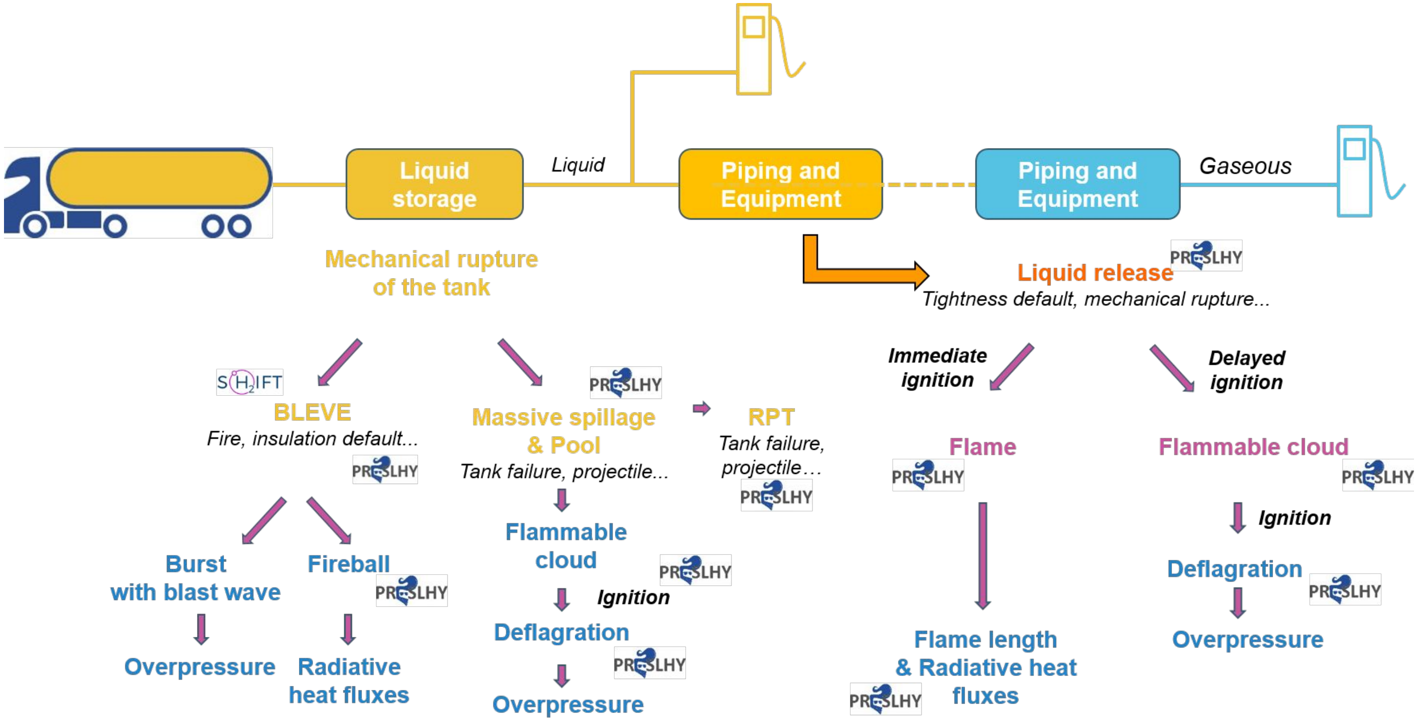
LH_2-based application

Main feared events



Studied phenomena in PRESLHY project

Main feared events



RCS recommendations from PRESLHY project

Context

- **Objective**
  - Provide general rules and good practices for a safe use of liquid hydrogen
  - Efficiently and widely communicate on PRESLHY findings and outcomes

- **Starting point: background on LH_2 risks**
  - Review of the knowledge gaps and PIRT (Phenomena Identification and Ranking Table)
  - Review of existing RCS on LH_2
    - To summarize: a lack of homogeneity, sometime inconsistency and potentially over-conservatism in RCS

- **Information used to formulate RCS recommendations is based:**
  - on PRESLHY new research results (experiments, analytical modelling, numerical simulation)
  - and on already published research work, as well, when applicable to LH_2

RCS recommendations from PRESLHY project

Overview

- **19 recommendations formulated**
  - Phenomena, concrete consequences and potential associated mitigation ways, for the following topics:
    - Release, flowrate, dispersion in free field
    - Ignition, flame and explosion
    - Burst of the storage vessel

- **Calculation means to evaluate consequences and define - when possible - hazard distances through:**
  - Analytical models
  - Engineering correlations
  - Numerical modelling

RCS recommendations from PRESLHY project

In detail (3/3)

Release, flowrate, dispersion in free field

	Topics	Specificities
#1	***Limit potential liquid release***	Good practice
#2	***Limit liquid release flowrate***	Good practice
#3	***Ground medium***	Good practice
#4	***Avoid retention pit***	Good practice
#5	***Leak detection***	Good practice
#6	***Cryogenic gaseous release rate***	Calculation
#7	***Multiphase release rate***	Calculation
#8	***Hazard distances assessment due to the formation of a flammable cloud***	Calculation

RCS recommendations from PRESLHY project

In detail (2/3)

PRESLHY

Ignition, flame and explosion

	Topics	Specificities
#9	***Avoid confinement***	Good practice
#10	***Avoid ignition***	Good practice
#11	***Avoid electrostatic charges***	Good practice
#12	***Limit congestion***	Good practice
#13	***Limit fire propagation***	Good practice
#14	***Avoid water deluge***	Good practice
#15	***Fire detection***	Good practice
#16	***Hazard distances assessment due to a jet fire***	Calculation
#17	***Thermal load assessment from a jet fire***	Calculation
#18	***Fireball size***	Calculation

RCS recommendations from PRESLHY project

In detail (3/3)

Burst

	Topics	Specificities
#19	***Measures avoiding storage burst*** *are required*	Good practice

RCS recommendations from PRESLHY project

To summarize

- **Good practices** have been defined or confirmed
- Some areas of LH_2-based infrastructures or activities required **specific attention (e.g. bunkering, storage, confinement…)**
- **Several tools or calculation approaches have been validated for consequence assessment**
  - New tools
  - And some existing tools developed for GH_2 have been validated for LH_2 as well
  - Advice for appropriate consequence assessment/modelling

RCS recommendations from PRESLHY project

PRESLHY Advisory Board Feedback

- **Main comments on recommendations**
  - **Useful, or not** → sometimes for the same recommendation
  - Already known / « **naive** »
    - For **existing** LH_2-based infrastructure
      - Good news: PRESLHY bring confirmation with « fresh » experimental, analytical and numerical studies
      - But is it systematically applied
        - If yes→ great
        - If no → why?
    - For **future** LH_2-based infrastructure
      - Important to find LH_2 « Golden Rules » quickly and easily
      - And in an « ideal » community, reach consensus… go towards uniformity…
  - Too specific, **not enough…**
  - **Not applicable**
  - **Cases missing** (right, but not dealt – or not enough – in PRESLHY project…)

RCS recommendations from PRESLHY project

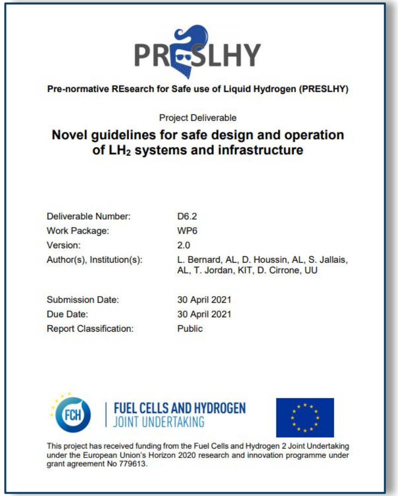
Dissemination - Initial programme

- **Dissemination ways**
  - Publications, conferences, technical reports
  - ISO/TC/197 WG29 Task Force
  - Connection with NFPA2 WG, EIGA, CGA, CEN…
- **Status**
  - What was really done?
  - What has been considered?

  Not easy to conclude…
- **And for ELVHYS project**
  - Learn from PRESLHY "experience"

PRESLHY project public reports

Focused on outcomes


PRESLHY

Pre-normative REsearch for Safe use of Liquid Hydrogen (PRESLHY)

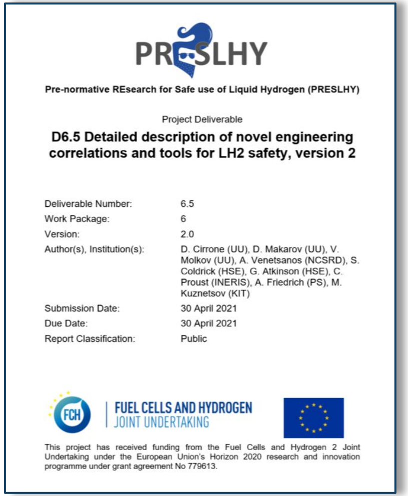
Project Deliverable

Novel guidelines for safe design and operation of LH_2 systems and infrastructure

Deliverable Number:	D6.2
Work Package:	WP6
Version:	2.0
Author(s), Institution(s):	L. Bernard, AL, D. Houssin, AL, S. Jallais, AL, T. Jordan, KIT, D. Cirrone, UU
Submission Date:	30 April 2021
Due Date:	30 April 2021
Report Classification:	Public

FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

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.


PRESLHY

Pre-normative REsearch for Safe use of Liquid Hydrogen (PRESLHY)

Project Deliverable

D6.5 Detailed description of novel engineering correlations and tools for LH2 safety, version 2

Deliverable Number:	6.5
Work Package:	6
Version:	2.0
Author(s), Institution(s):	D. Cirrone (UU), D. Makarov (UU), V. Molkov (UU), A. Venetsanos (NCSRD), S. Coldrick (HSE), G. Atkinson (HSE), C. Proust (INERIS), A. Friedrich (PS), M. Kuznetsov (KIT)
Submission Date:	30 April 2021
Due Date:	30 April 2021
Report Classification:	Public

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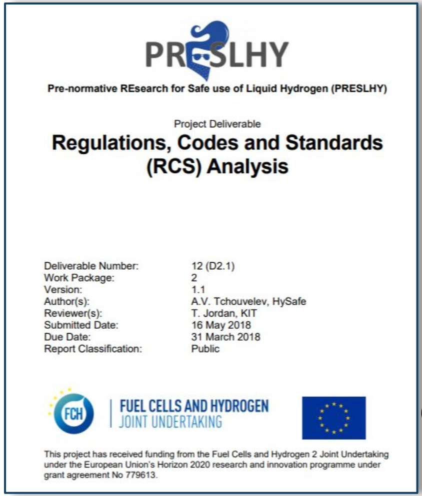
PRESLHY

Pre-normative REsearch for Safe use of Liquid Hydrogen (PRESLHY)

Project Deliverable

Regulations, Codes and Standards (RCS) Analysis

Deliverable Number:	12 (D2.1)
Work Package:	2
Version:	1.1
Author(s):	A.V. Tchouvelev, HySafe
Reviewer(s):	T. Jordan, KIT
Submitted Date:	16 May 2018
Due Date:	31 March 2018
Report Classification:	Public

FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

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PRESLHY

Pre-normative REsearch for Safe use of Liquid Hydrogen (PRESLHY)

Project Deliverable

D6.3 Recommendations for RCS

Deliverable Number:	6.3
Work Package:	6
Version:	2.0
Author(s), Institution(s):	
Submission Date:	
Due Date:	
Report Classification:	

FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

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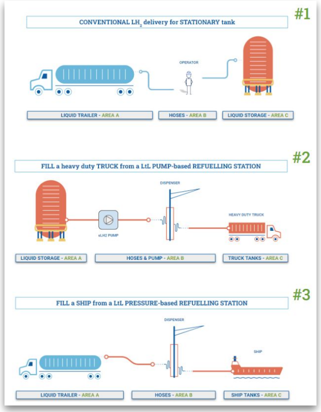
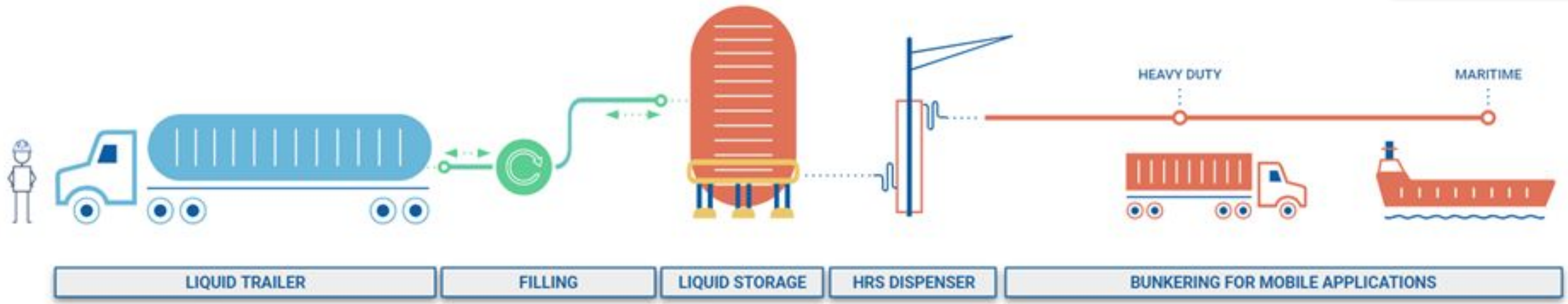
ELVHYS project | 01/2023 - 12/2025+

Trends for recommendations

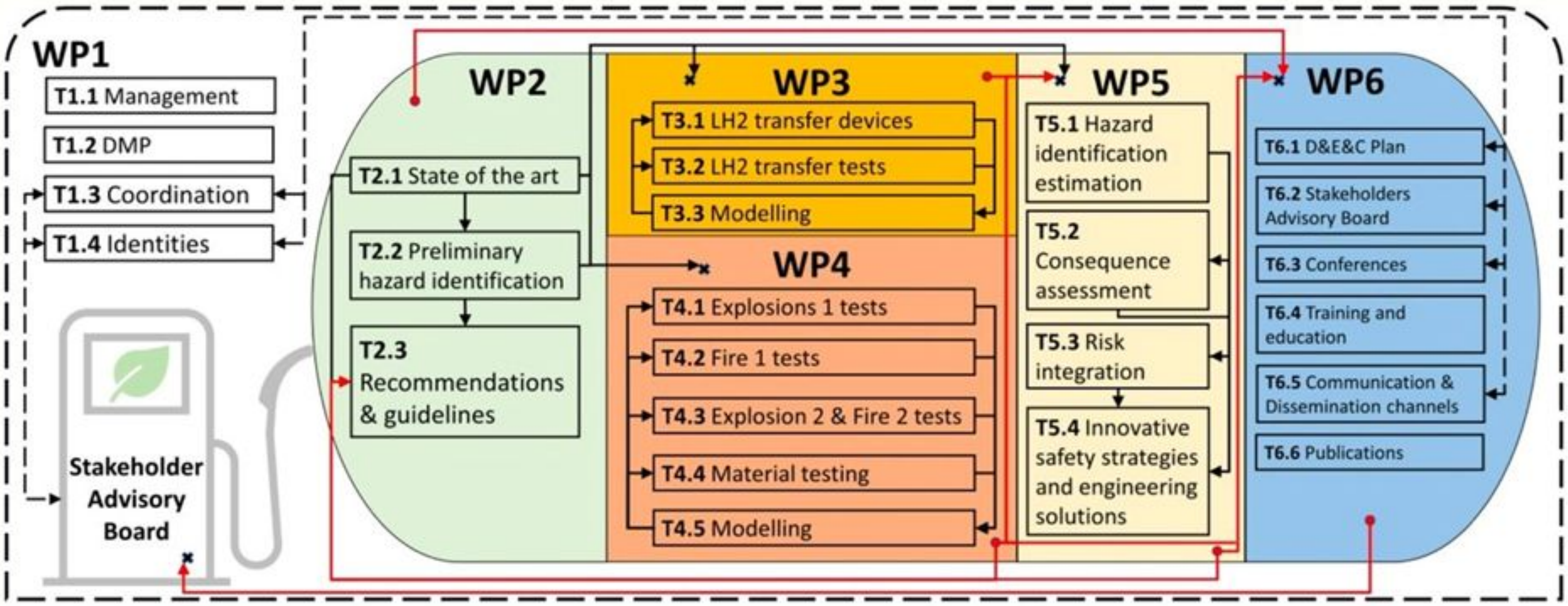
Studied context in ELVHYS project

- **LH_2 tranferring operations**
  - 3 defined configurations for the project
    - For stationary tanks,
    - For trucks
    - For ships





ELVHYS project
Organization

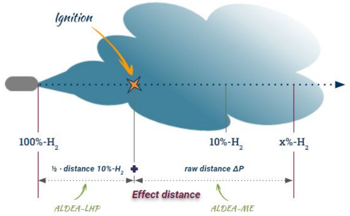


Studied phenomena

Considered feared events for preliminary consequences assessment

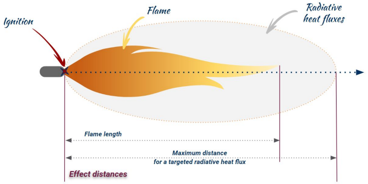
RELEASE
Jet ignition

- Delayed ignition - UVCE



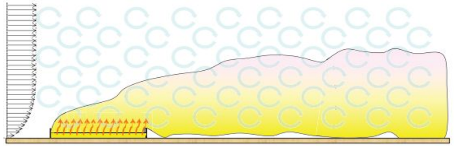
Or

- Immediate ignition - Jet fire

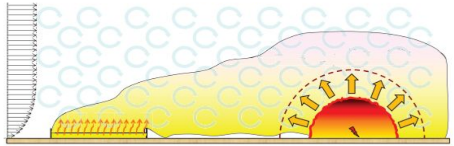


MASSIVE LH_2 SPILLAGE
Pool / Vaporization / Dispersion

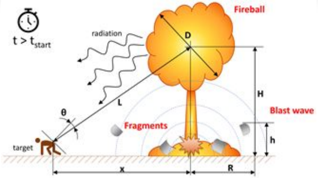
- Spreading and vaporization



- Explosion



TANK BURST



RELEASE IN CONFINED SPACE

- Accumulation & Explosion

Valorisation of ELVHYS outcomes

Main deliverables

- **Milestones**
  - MS9 - Discussion on the **drafting of RCS recommendations** - Report 28 | **End April 2025 - *Submitted***
  - MS10 - ToC of Guidelines for safe design and operation of LH_2 infrastructure - Report 30 | **End June 2025**

- **Deliverables**
  - D5.5 - **Innovative safety strategies and engineering solutions** for risk reduction in LH_2 transfer operations — Document, report PU - Public 36 | **End Oct 2025**
  - D2.3 - **Guidelines** for inherently safe design of LH_2 transferring facilities — Document, report PU - Public 36 | **End Dec 2025**
  - D2.4 - **Consensual loading procedures** for LH_2 transferring operations — Document, report PU - Public 36 | **End Dec 2025**
  - D2.5 - **RCS recommendations** for LH_2 transferring operations and facilities — Document, report PU - Public 36 | **End Dec 2025**

Outcomes from the project
Preliminary tracks

Concrete outcomes from WP3, 4 & 5 In progress

- **WP3: LH_2 transfer & modelling - Critical**
  Optimize LH_2 refuelling procedure for safety and efficiency of the systems
  - Transfer from 1 storage to another 1 - 2 types/volumes → Expected
  - Protocoles to be studied thanks to instrumentation - Purge, cooling, fuelling, blowdown…
- **WP4: Fires & Explosions - In progress, but some delays**
  - O_2 enrichment → Available
  - Source term: round vs non-round circumferential leaks → ?
  - Consequences of a release in a confined space / PPP → Available
  - Material behaviour against impinging jet → Expected
  - BLEVE → Expected
- **WP5: Risk analysis & Mitigation barriers - In progress**
  - Refine configurations for safety design / Critical analysis / Worst case scenarios → To be done
  - Methodologies for risk assessment including Master Logic Diagram approach → To be done
  - Engineering Tools / Numerical modelling with recommendations and availability range → To be done
  - Safety barriers efficiency / Impact on risk rate → To be done

Dissemination strategy

Proposal for efficient dissemination

- **Dissemination actions during ELVHYS project**
  - Workshops
  - Publications
  - ELVHYS Website

- **Dissemination and exploitation actions beyond ELVHYS project**
  - An inventory of Committees and Documents was done. Nevertheless, it is clear that some of them are more critical than other regarding topics, activities, timelines, documents drafting status… That is why, ELVHYS project defined its preliminary priorities for an efficient and optimized dissemination of its outcomes… will be updated - if necessary - in the continuation of the project

- **Priorities for ELVHYS project**
  - List of Committees and Targeted Documents…

- **Action plan**
  - Who (Federico and others)
  - When…

SDO	Who from ELVHYS project	Action	Targeted date

Next steps
Non-exhaustive

- **Continue to collect information from WPs**
- **Critical analysis of analytical and numerical approaches**
  - Be able to provide recommendations on
    - appropriate approaches with range of use
    - important parameters to be considered
    - …
- **Formulate relevant, useful and innovative recommendations for final deliverables**
- **Optimize - with WP6 - dissemination strategy**

- **Pain points**
  - Delayed experimental results
    - for fueling protocoles improvement/optimization
    - for BLEVE
    - for material testing
- **Main question**
  - How to **take into account and integrate the latest delayed project results** into final reports

Coming actions

Non-exhaustive

- **Involvement of SAB members**
  - In report reviews (not only for WP2)
  - Earlier
  - …

- **Potential extension of the project - Impact on WP2 outcomes**
  - The initial deadlines (i.e. 2025 december) for the WP2 deliverables will be respected
  - Later updating of the deliverables regarding the results from WP3 (DLR - fuelling) and WP4 (KIT - BLEVE and material resistance) → Need to be checked with PO

- **RCS**
  - A survey has been sent to Consortium and SAB members in order to collect more information on actively involved people in RCS and RCS-like Working Groups

Thank you for your attention

deborah.houssin@airliquide.com

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From PRESLHY to ELVHYS and beyond...

5th ELVHYS Stakeholders' Workshop

Federico Ustolin

05.06.2025

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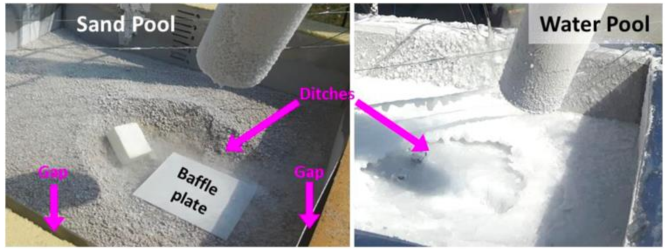
From PRESLHY to ELVHYS…

ELVHYS

PRESLHY

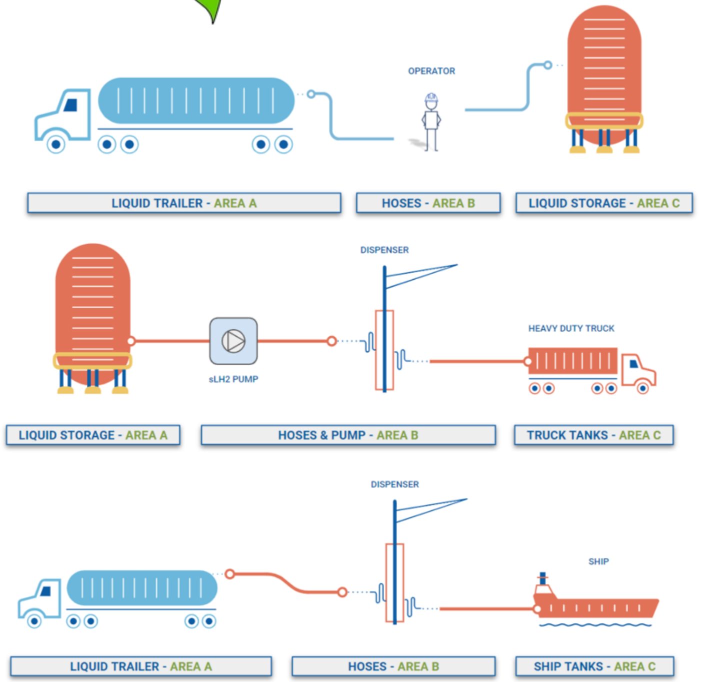
Fundamental/modelling of liquid and cryogenic H2

- Release
- Ignition
- Combustion



SH2IFT

ELVHYS



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…ELVHYS and beyond…

- Main goal of ELVHYS project is to **support the development of an international standard** on LH2 transfer operations.
- To achieve this goal, contact and collaboration with different networks and standard development organizations were established:
  1. **International standard organization** (ISO) TC 197 - Hydrogen technologies, WG1
  2. **European Committee for Standardization**, CEN/CLC/JTC 6/WG 3 ”Hydrogen safety”
  3. **Society of Automotive Engineers** (SAE) AE-5CH Hydrogen Airport Taskgroup
  4. **International Energy Agency** (IEA) TCP Hydrogen – Task 43
- ELVHYS consortium partners and advisory board members will support the exploitation of ELVHYS outcomes through **SDO activities**.

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Thank you for your attention

federico.ustolin@ntnu.no

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