GEXCON

# Hydrogen – recent and planned research

# Burning velocity methane-hydrogen mixtures

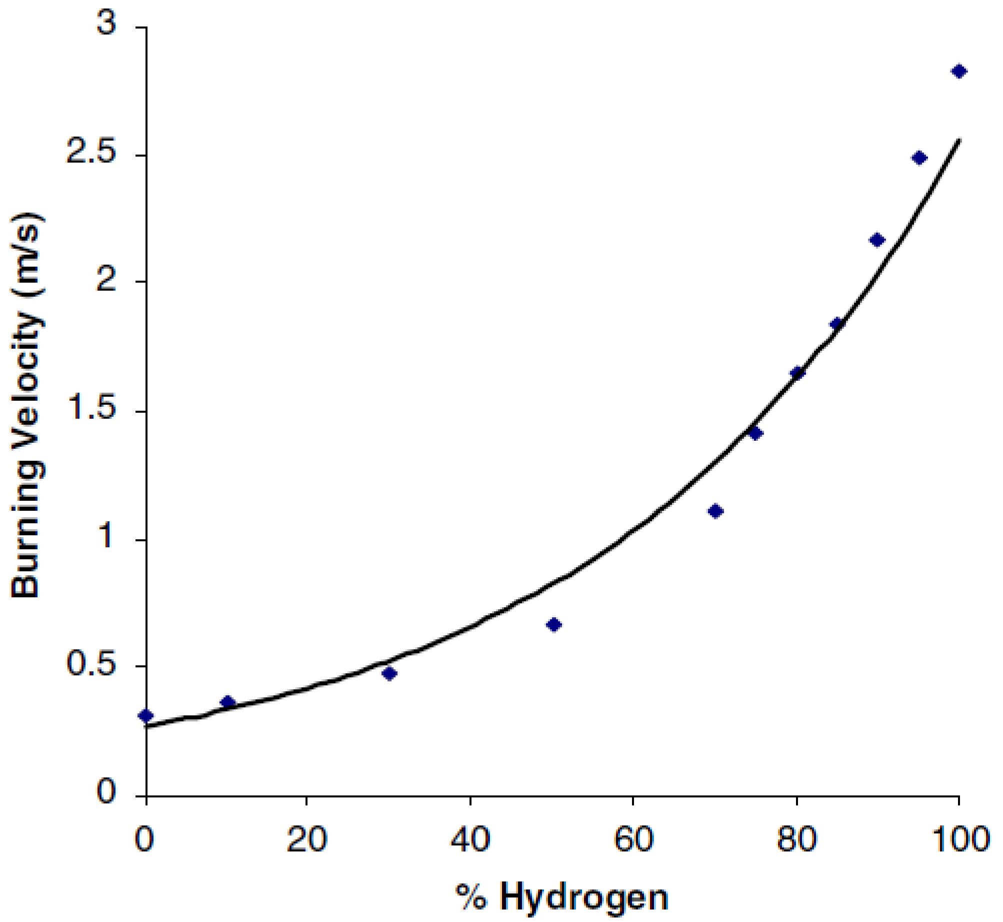



Fig. 16. Burning velocities for different percentage of hydrogen, $\varnothing = 1.0$.

From:Ilbas et al, Laminar-burning velocities of hydrogen–air and hydrogen–methane–air mixtures: An experimental study, International Journal of Hydrogen Energy 31 (2006) 1768 – 1779

# Minimum ignition energy methane-hydrogen mixtures

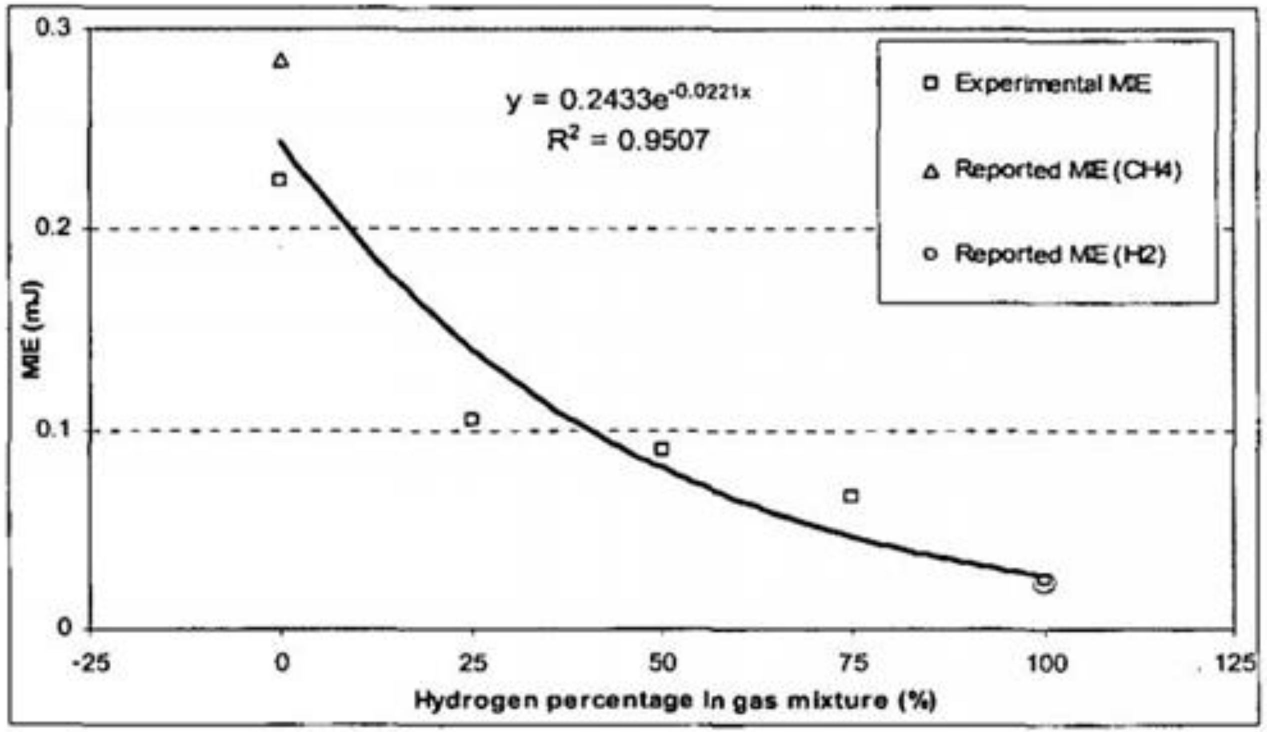



Figure 4.23 : MIE variation for various concentration of hydrogen in mixture

From: Mathurkar, H., Minimum ignition energy and ignition probability for Methane, Hydrogen and their mixtures, PhD Thesis Loughborough University, 2015

# Minimum ignition current methane-hydrogen mixtures

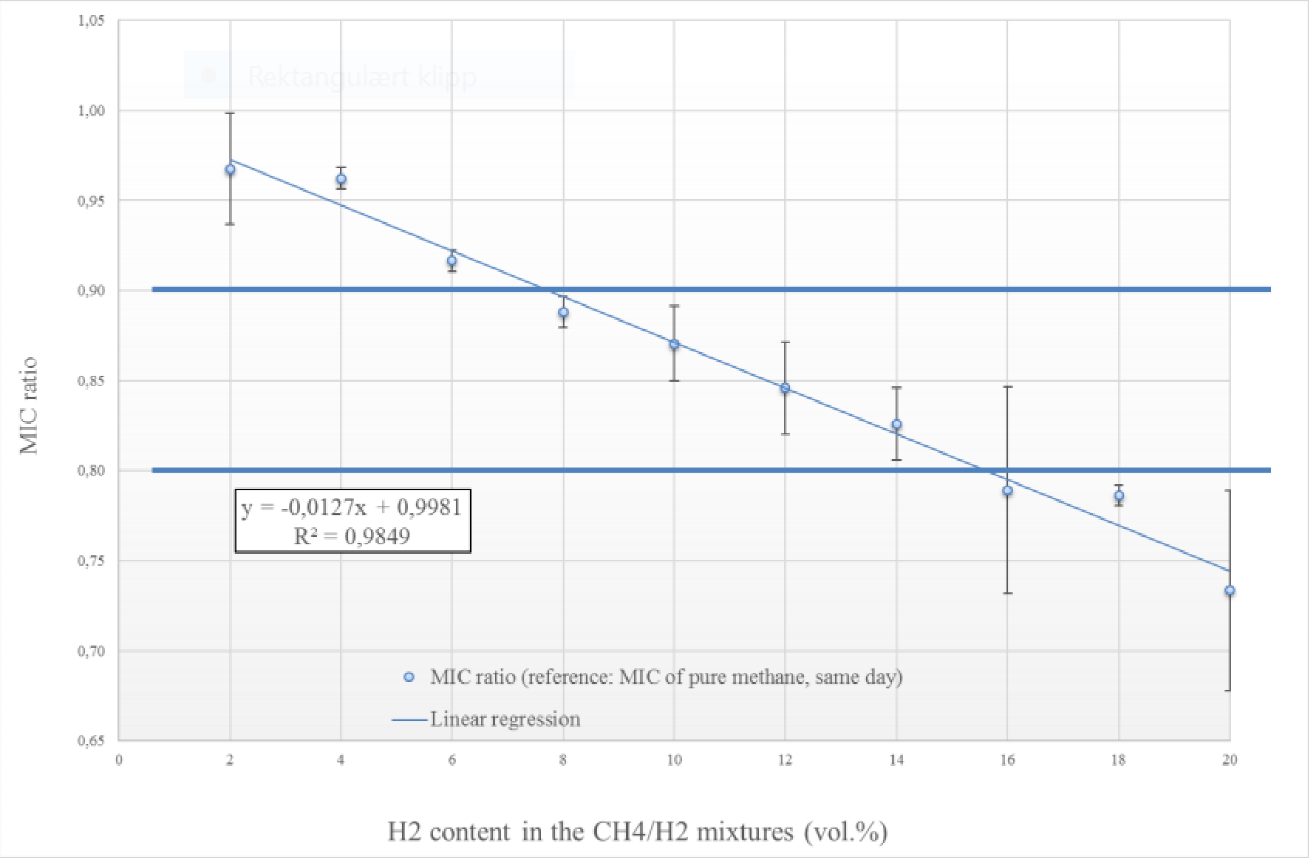



Figure 3: MIC ratio, as a function of hydrogen content in the methane/hydrogen mixtures.

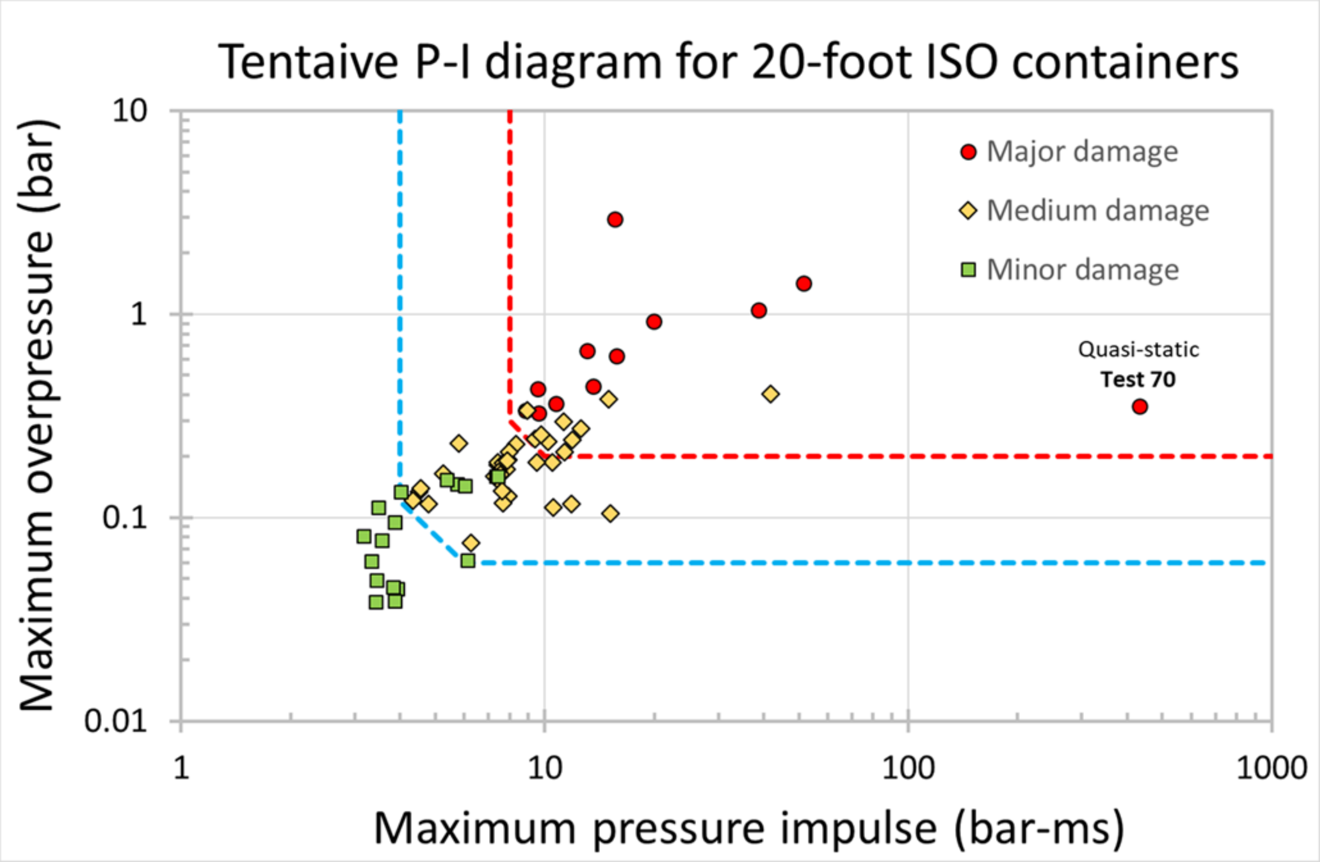
From: Janes et al: Experimental determination of minimum ignition current (mic) for hydrogen /methane mixtures for the determination of the explosion group corresponding to iec 60079-20-1 standard, International conference on hydrogen safety (ICHS 2017), Sep 2017, Hamburg, Germany. pp.54-64.

# The HySEA project: Main objective

- To conduct pre-normative research on vented hydrogen deflagrations with an aim to provide recommendations for European and international standards on hydrogen explosion venting mitigation systems

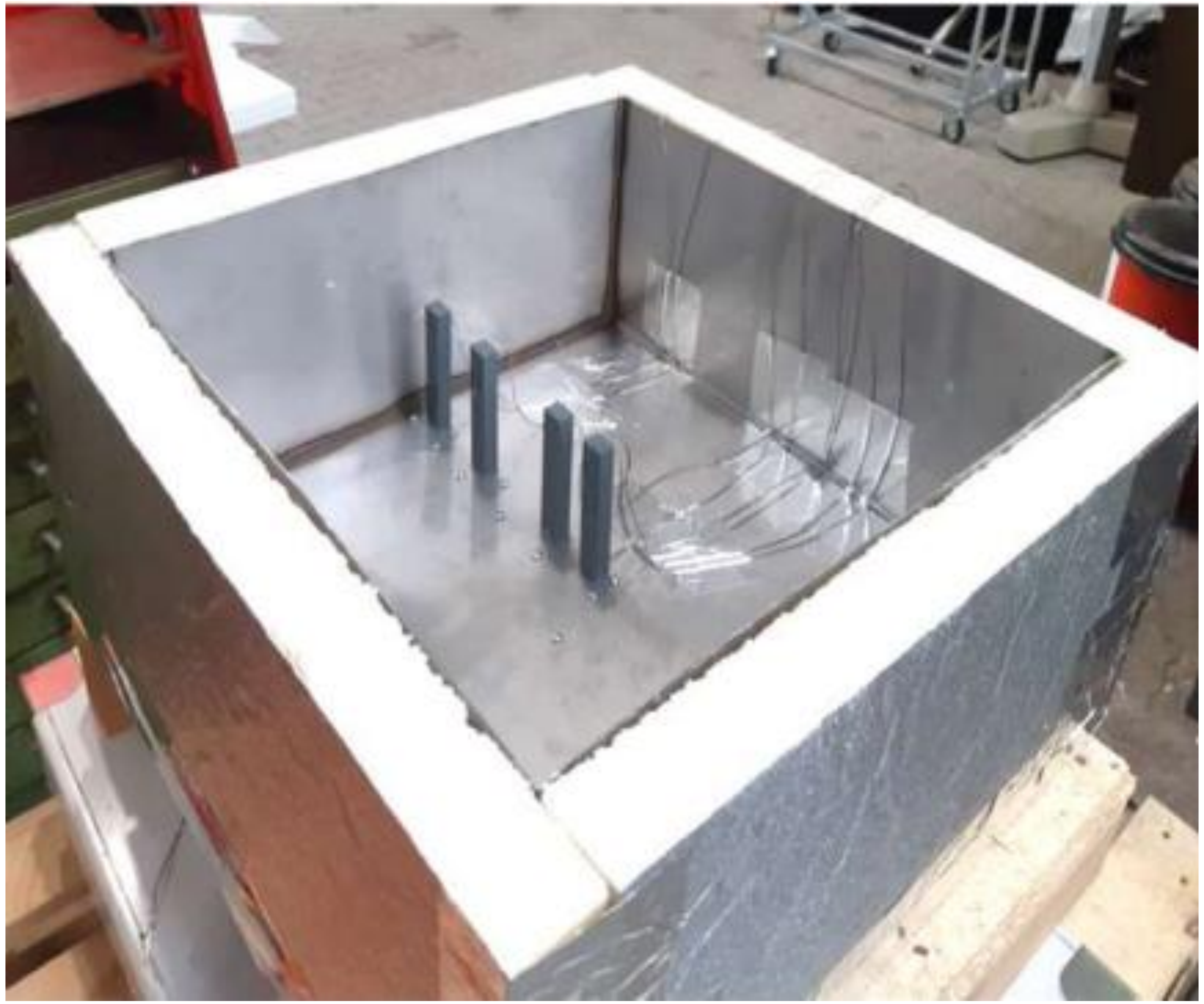
# Programme of work

- Homogeneous fuel-air mixtures and stratified mixtures
- Blind-prediction exercises
- Consequence assessment



# Experimental study on formation and evaporation of LH2 pools (unignited pool)

- Investigation of LH2-pool formation above different substrates,
- Investigation of evaporation rates from LH2-pool above different substrates,
- Investigation of oxygen, nitrogen, moisture carry-over within the pool and the potential for oxygen enrichment in the gas,
- Influence of cross wind conditions using a special ventilation system.

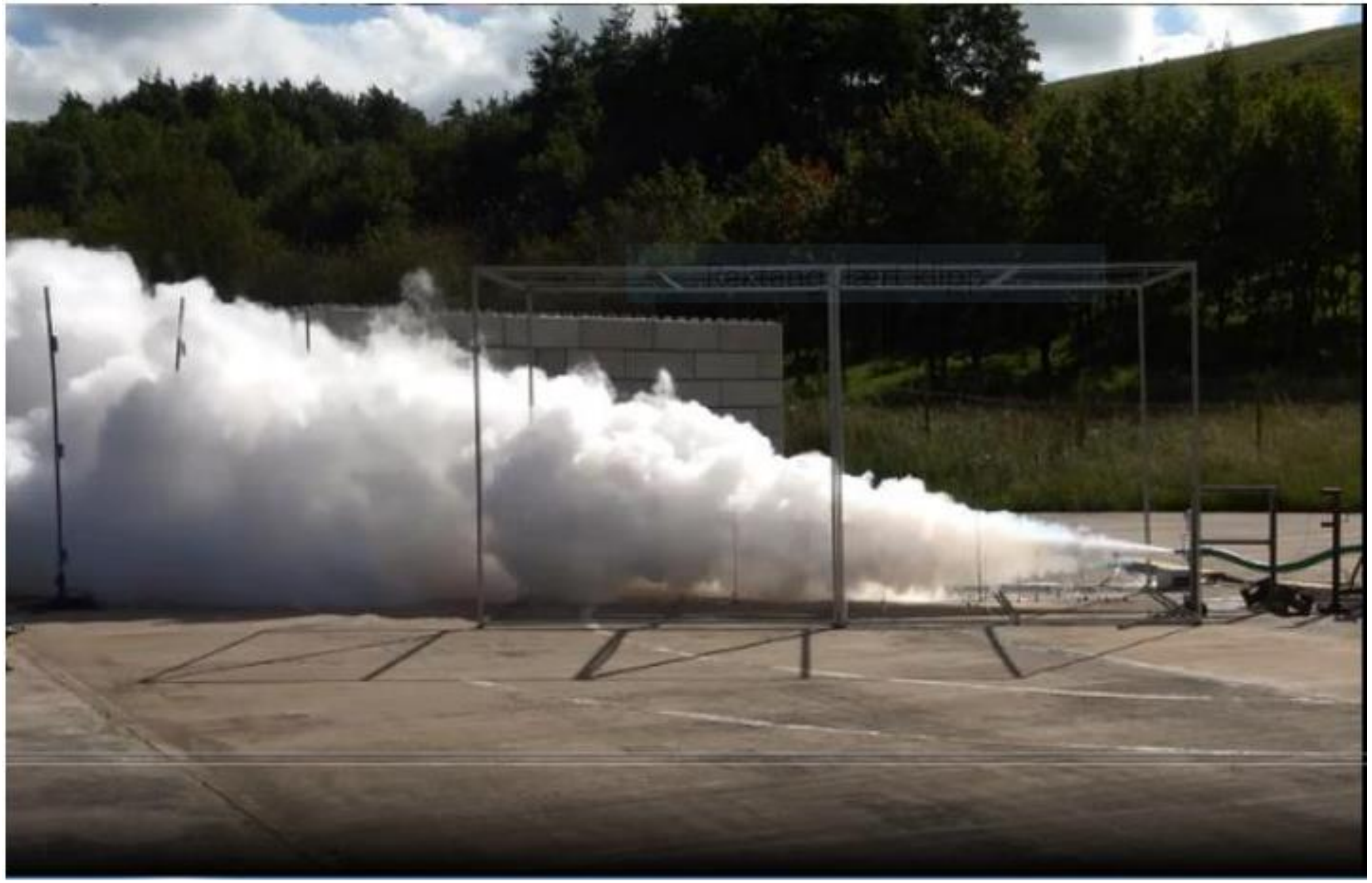


# Main findings

- Data to determine LH2-evaporation rates above different substrates is generated,
- Side wind mainly increases evaporation rate of pool,
- Pools above substrates with low porosity (water, concrete, sand) show quite similar behavior concerning pool formation and evaporation. Evaporation rates mainly governed by material properties of the substrate.
- For gravel pool different behavior was observed, since due to its high porosity (approx. 50% free volume in substrate layer) and the resulting large substrate surface the first pool formation takes much longer and consumes much higher LH2-quantities,
  - When pool evaporation has ended and cold gravel is exposed to ambient air, air components start to condensate/freeze out while the remaining LH2 from within the substrate evaporates,

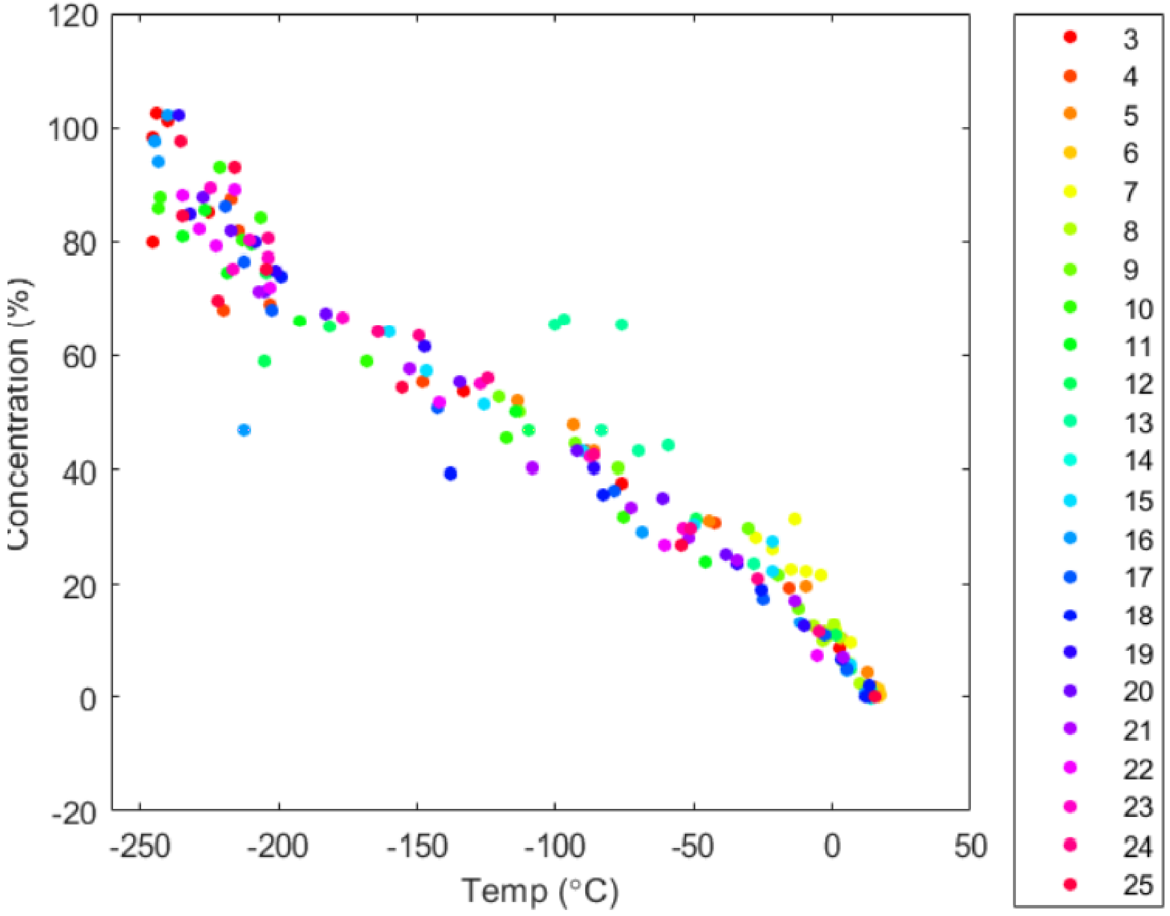
# Rain-out and dispersion from horizontal LH2 releases

- Mass flow release rates: 100 – 300 g/s



# Main findings

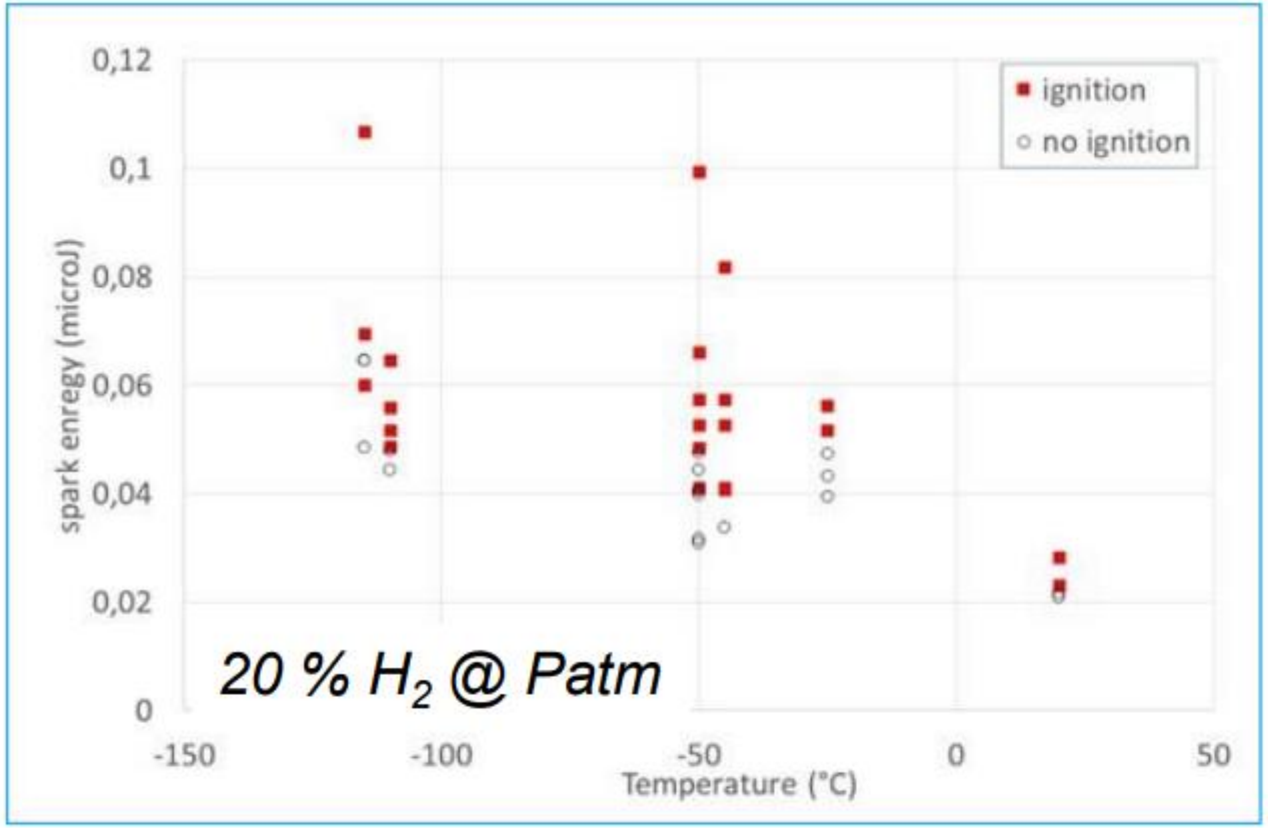
- Rainout did not occur during the established flow of these releases
- Pools can form with vertically downwards releases
- Near field dispersion: correlation of concentration with temperature
- Transient ignitable pockets (average H2 concentration > LEL) were measured at 14 m distance from LH2 releases through 12 mm holes or larger
- Following the initial region, approximately 1.5 m for the 1 bar releases and 3 to 6 m for the 5 bar releases, the dispersion of the hydrogen cloud is heavily dependent of the wind, including transient localised gusts



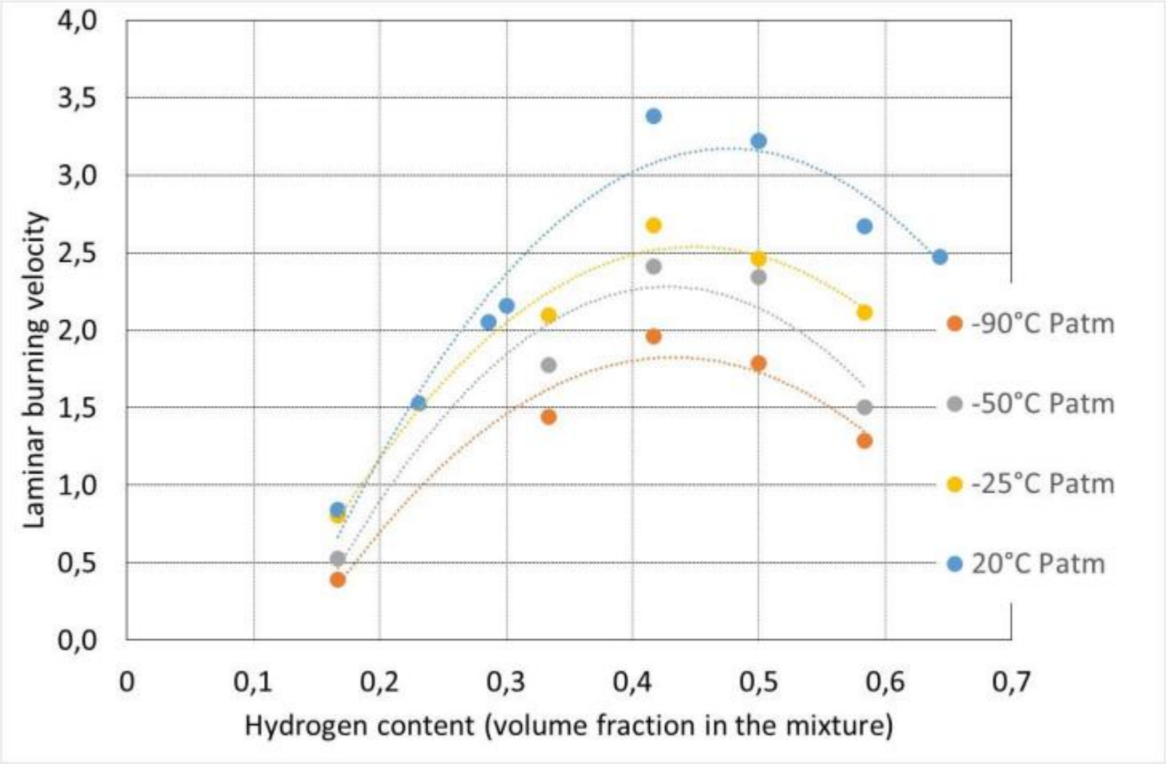
# Effect of temperature on explosion properties H2

| Temperature (°C) | LFL (% $H_2$ v/v) | UFL (% $H_2$ v/v) |
|---|---|---|
| 20 | 5 | 70 |
| -60 | 5.6 | 66 |
| -120 | 6 | 60 |

Explosion limits



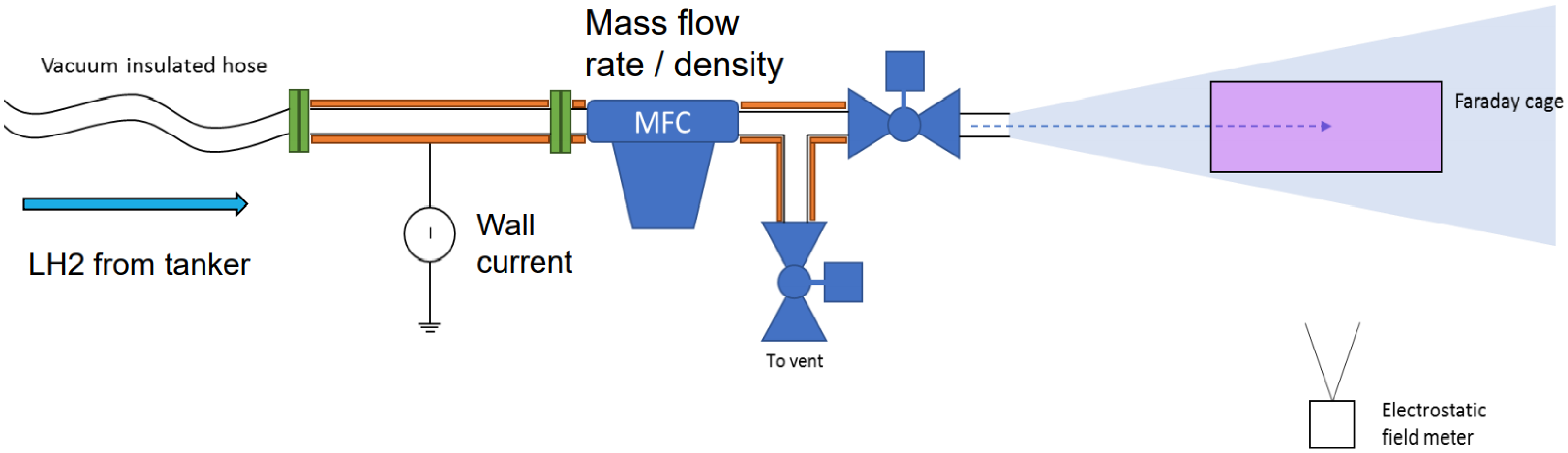

MIE




Laminar burning velocity

# Electrostatic charge in multiphase hydrogen releases

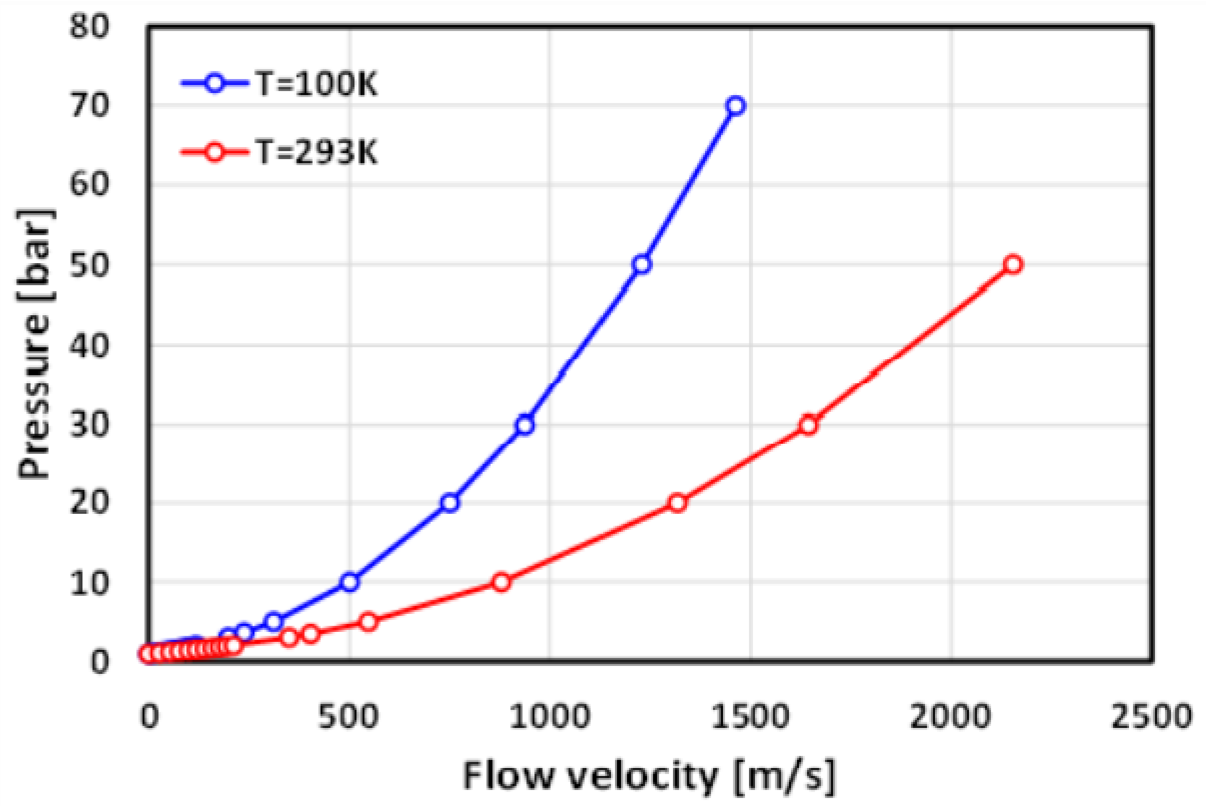
- Multiphase hydrogen flow can generate a current in pipework – especially when two-phase flow occurs
- Occasional spikes in electric field identified in plume of released LH2 (at up to 5 bar) – possibly caused by ice breaking off the nozzle or air being ejected from un-purged pipework
- Potential for electrostatic ignition as a result of accidental releases at up to 5 bar appears low providing plant / pipework are earthed.

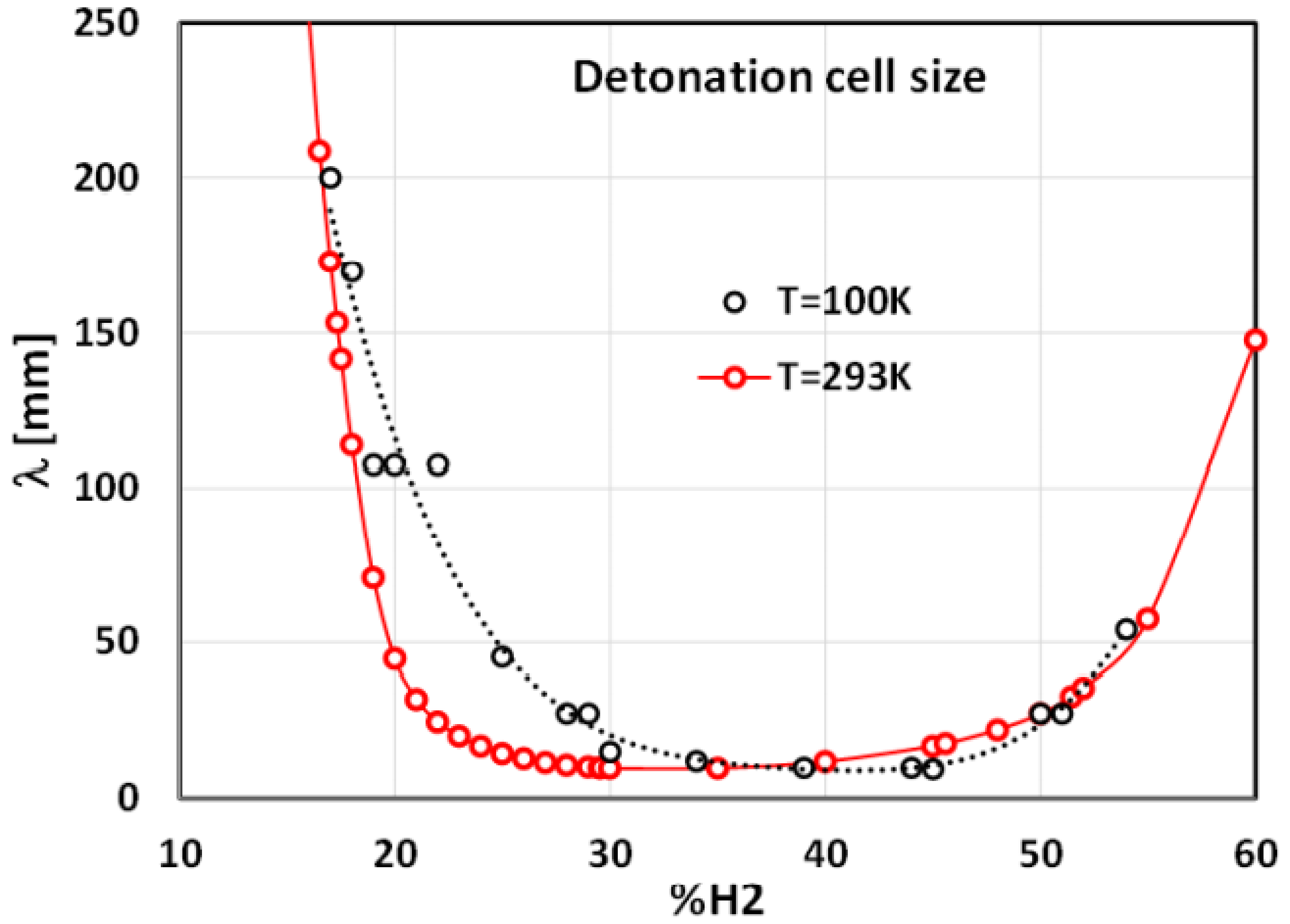


# Flame propagation regimes at cryogenic temperature

The run-up distance to detonation at cryogenic temperatures was found to be two times shorter than at ambient temperature.

Measurement of detonation cell sizes



# Ongoing research: SH2IFT

- Large-scale experiments to look into the possibility and effects of:
  - BLEVEs of storage vessels containing LH2
  - RPTs when LH2 is released onto or under water

# Ongoing research / new opportunities

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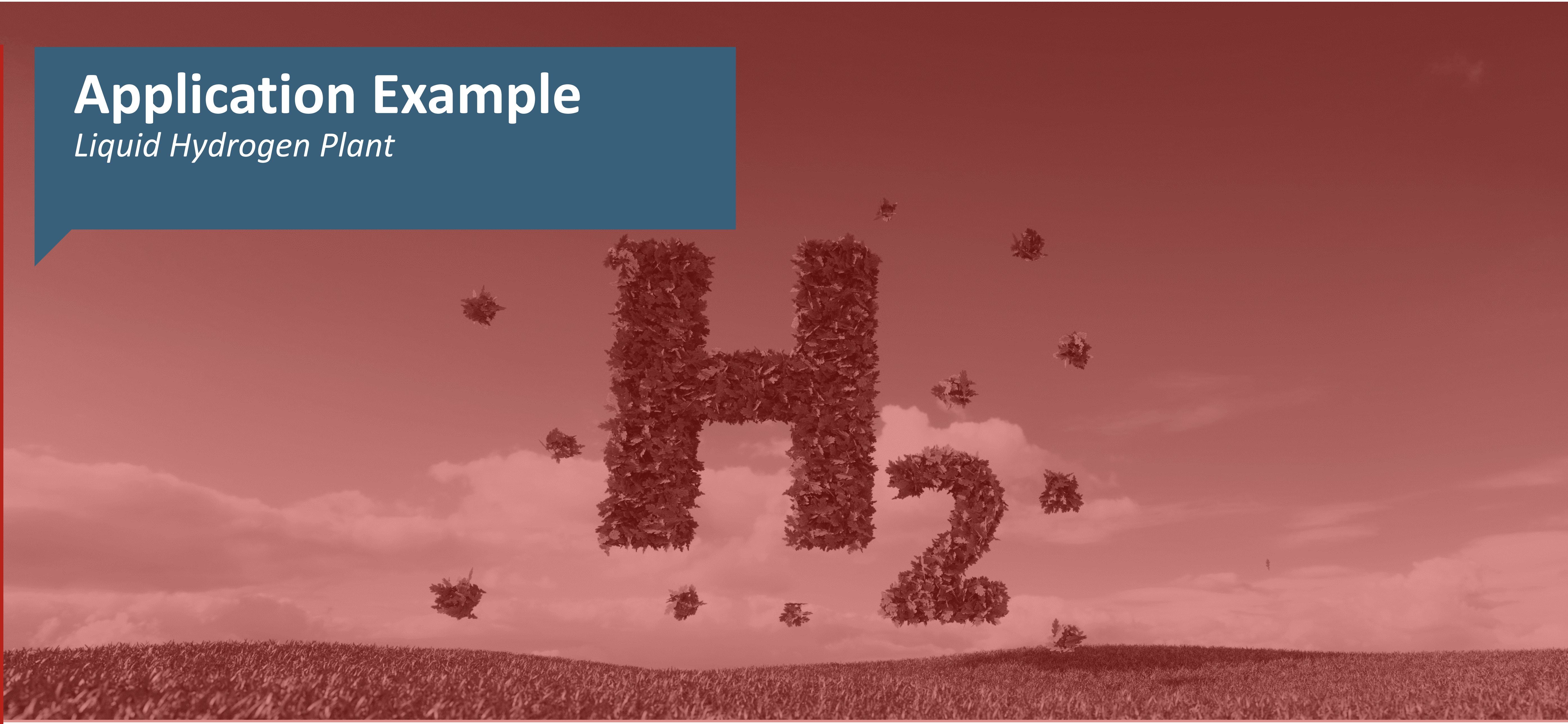
- Proposal for follow-up of SH2IFT: decision for granting work in course of June

## New opportunities

- Tests road tunnel
- Explosion experiments ethylene at high initial pressure and temperature
- Determination MIE Ethylene oxide at high initial pressure and temperature

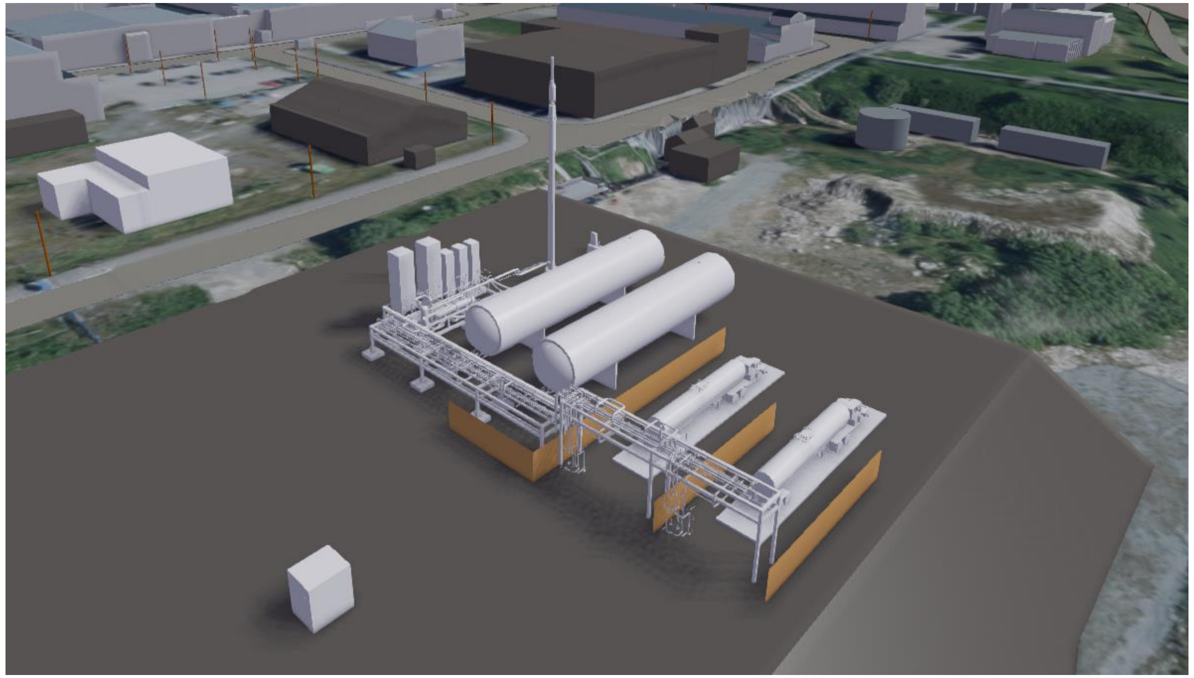
# Application Example

*Liquid Hydrogen Plant*

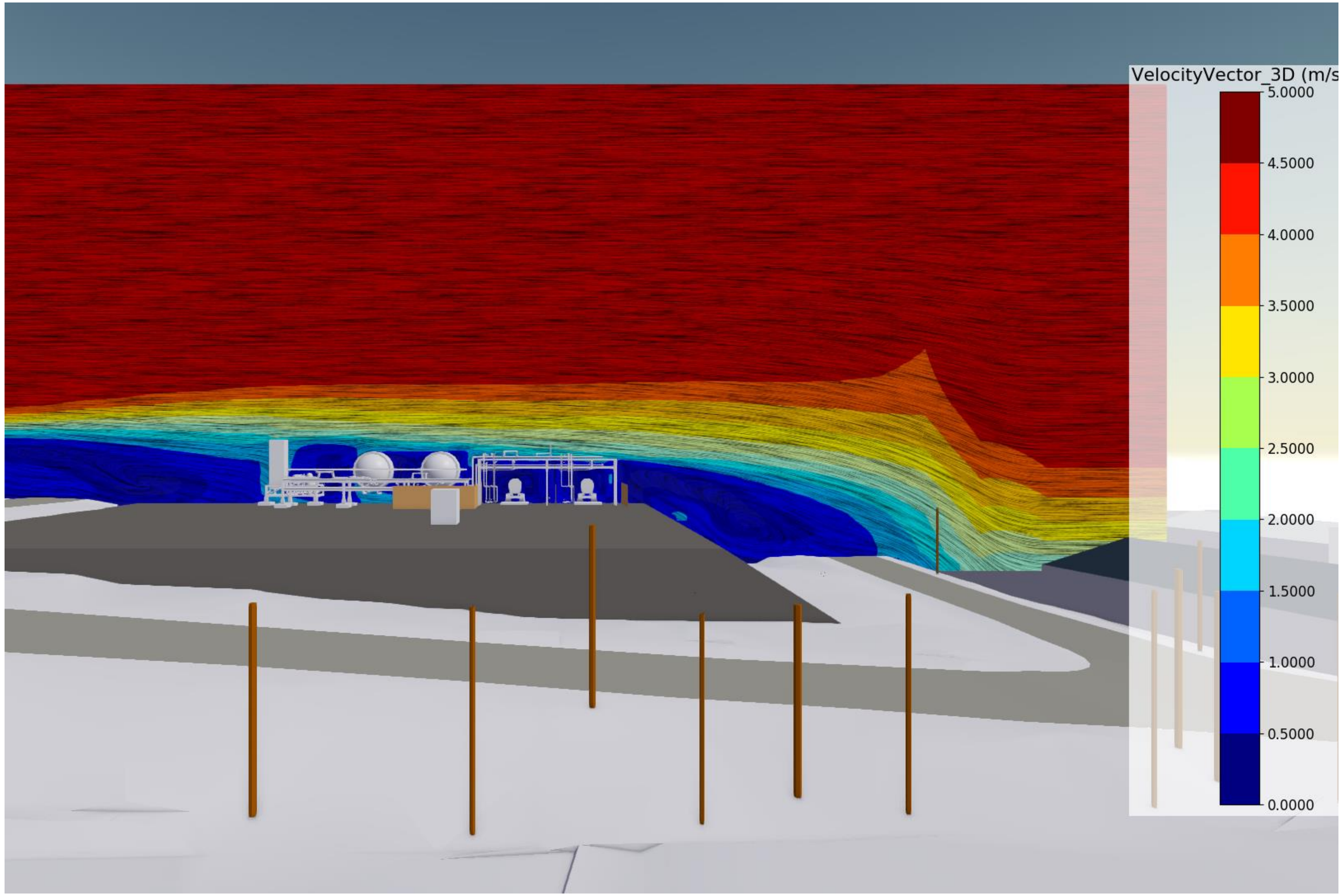


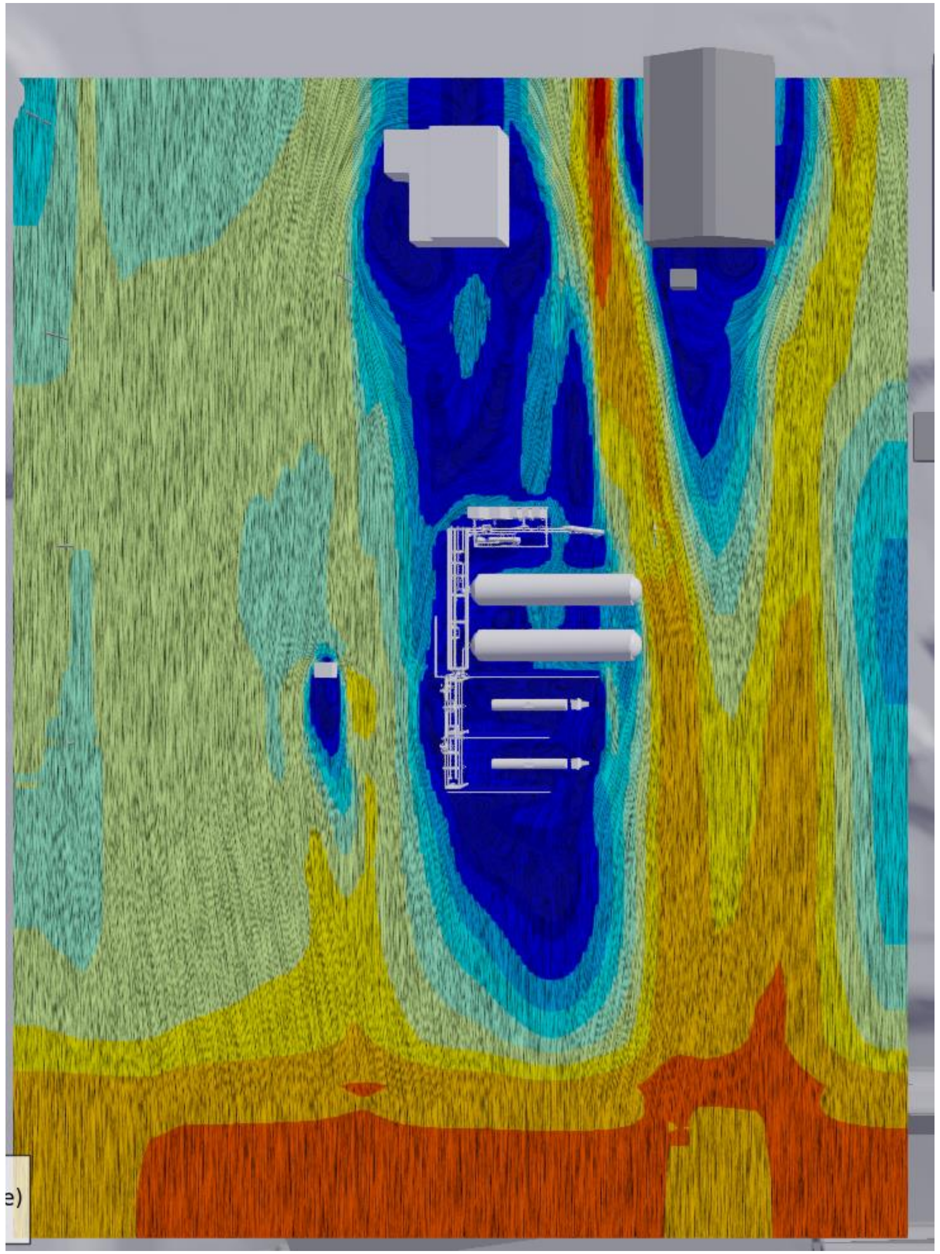
# FLACS geometry model

- 3D FLACS model generated by Gexcon, landscape and buildings included



# Ventilation Simulations



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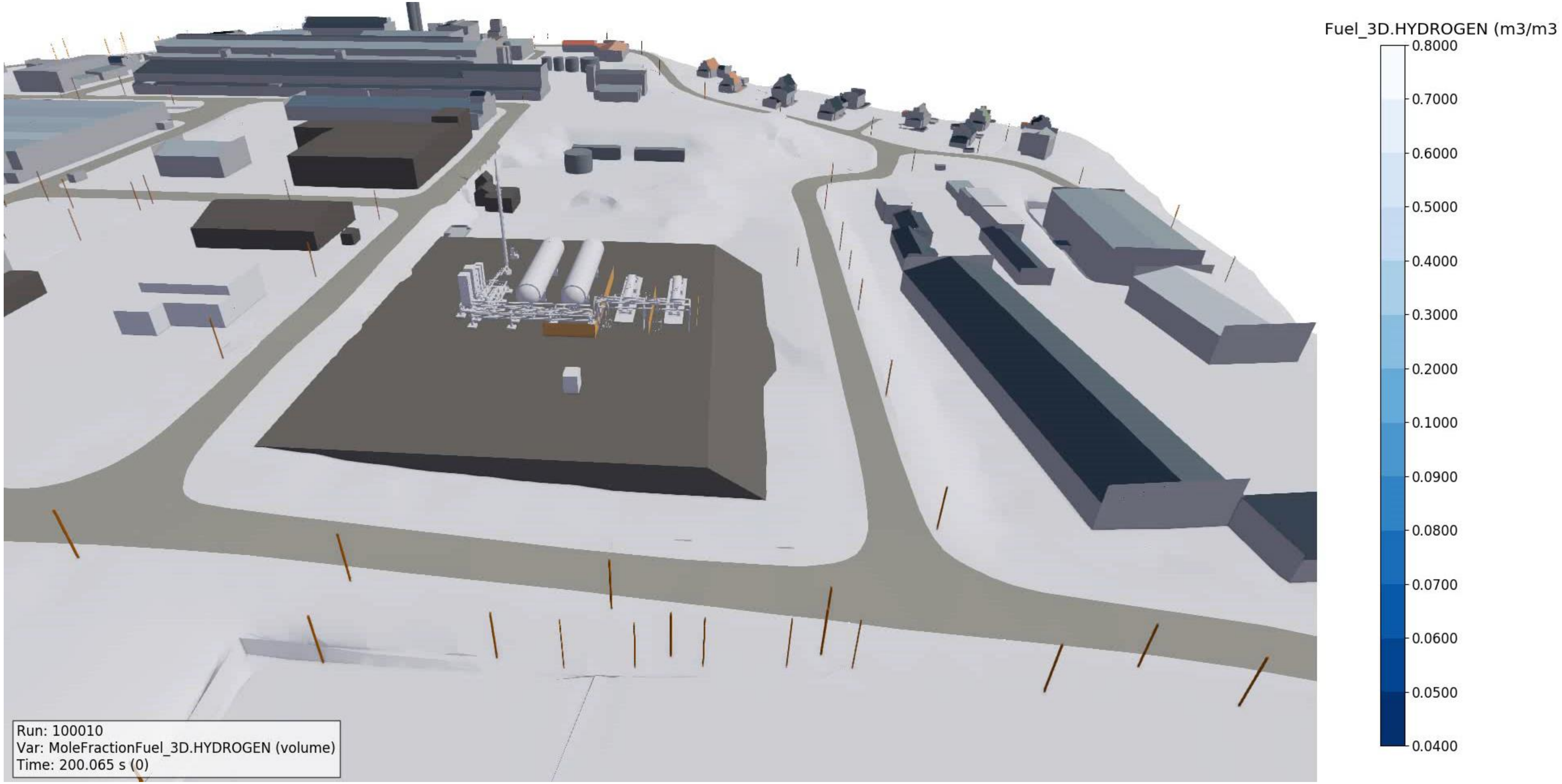
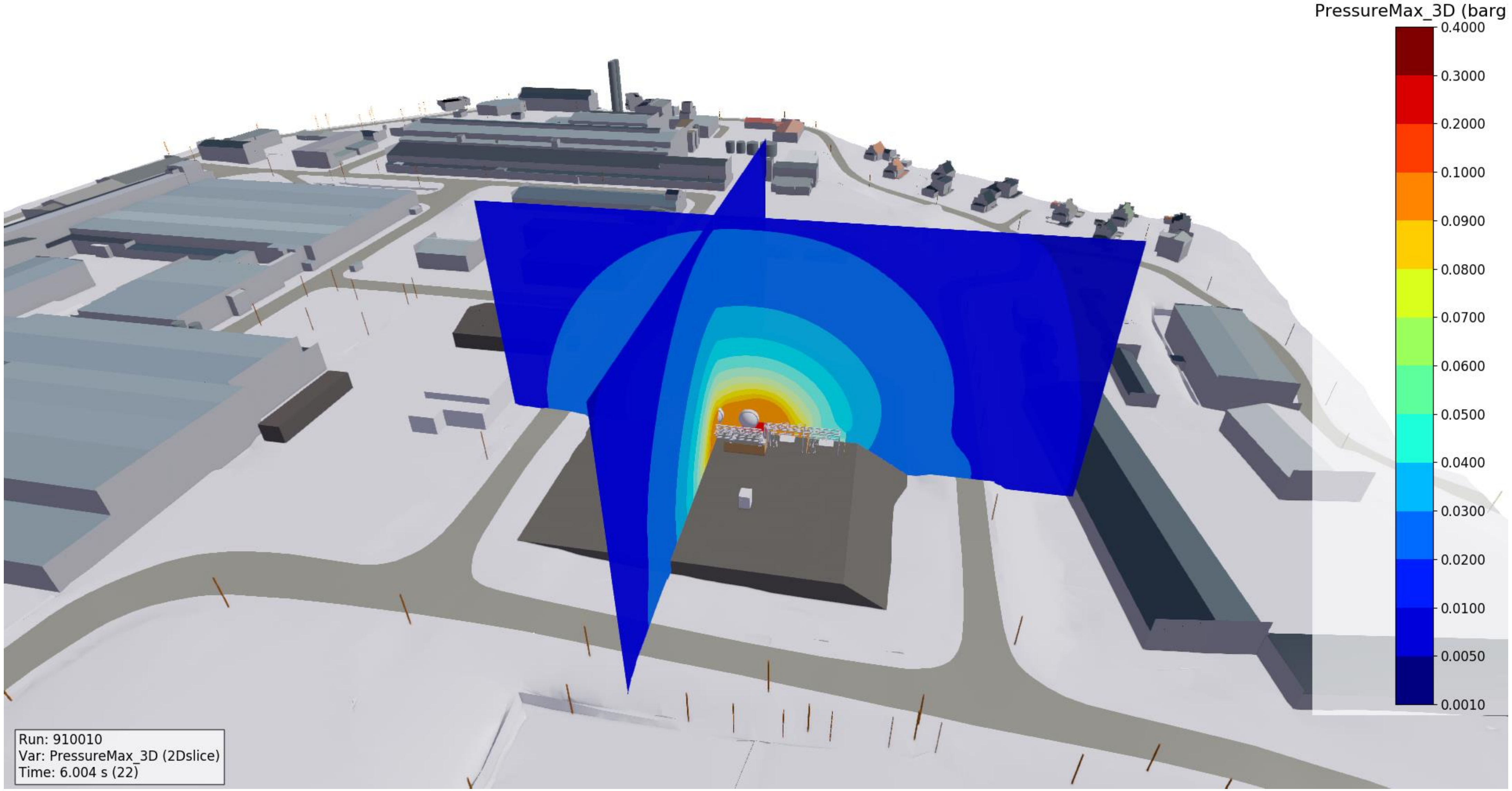
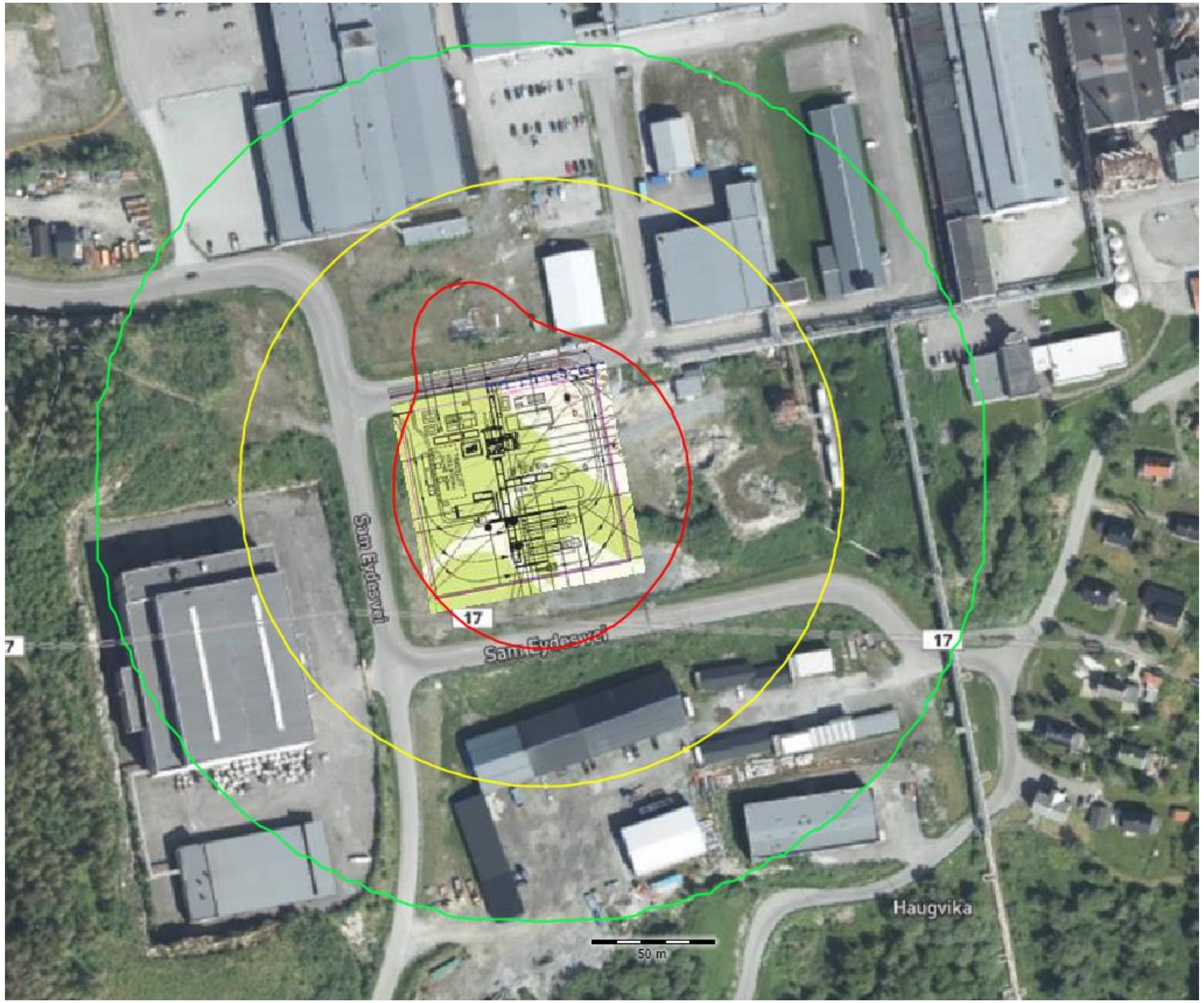
# Liquid H2 Dispersion



# Explosion simulations



# Risk Analysis for licensing




- Individual fatality risk contours
- Measurements against numerical risk acceptance criteria

# Thanks for your attention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