Explosive risk assessment for hydrogen use in domestic applications

Introduction

- The UK government aims to shift towards a green hydrogen based energy system by 2035 (Figure 1)
- Hydrogen is carbon neutral and more thermally efficient than natural gas, but it is also a dangerous option – very low ignition energy and very high flammability range
- To shift from natural gas to hydrogen, it is important to understand the difference in performance of hydrogen in different aspects of the infrastructure

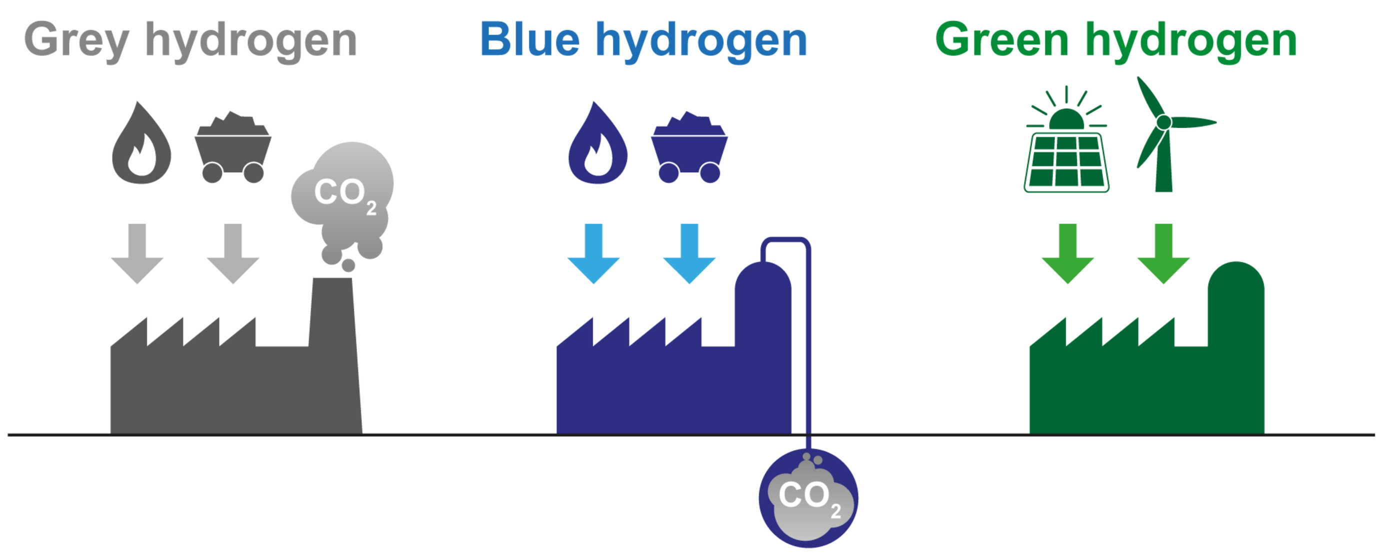

Fig 1. Schematic for different hydrogen production methods

Objectives

Understanding the effects of using pure hydrogen in the natural gas infrastructure and the subsequent change in risk profile

- Observing hydrogen transport in natural gas pipes and the differences in gas flow performance
- Simulating hydrogen leakage scenarios in enclosed spaces to observe deflagration-to-detonation transition, and the factors that influence it
- Experimental validation of simulations

Methodology

- Hybrid methodology with the use of mathematical modelling and numerical modelling for the estimation of pressure loss in pipe
- Numerical modelling used for the estimation and visualisation of gas leak into a confined volume

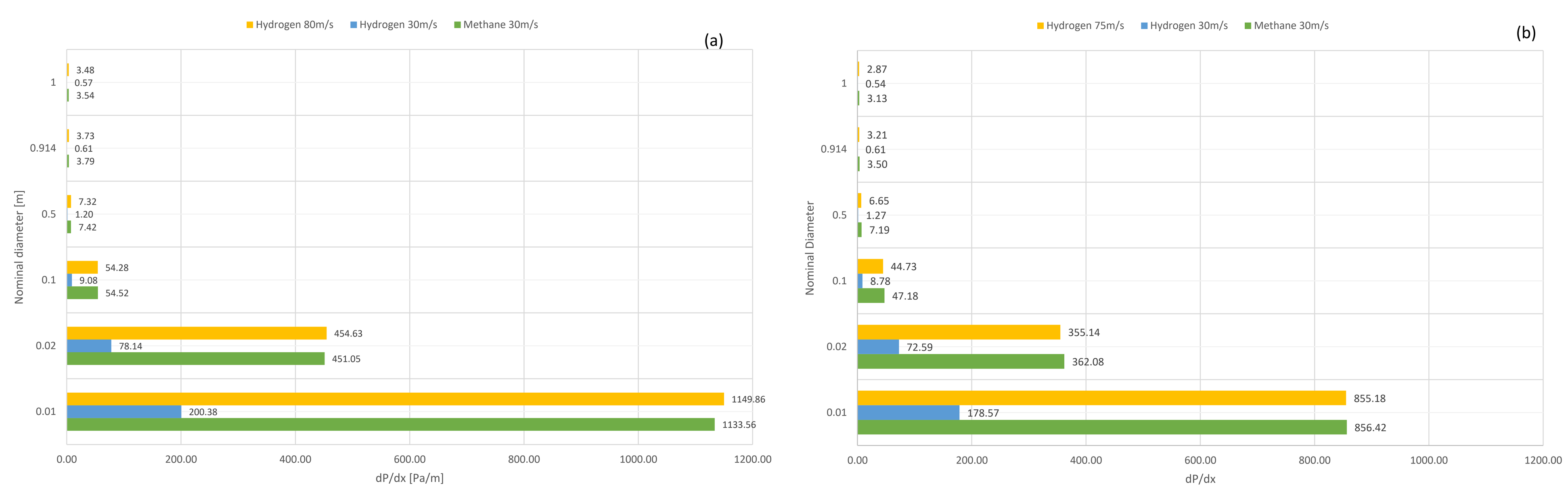

Fig 2. Estimation of pressure loss using the Darcy-Weisbach equation for methane and hydrogen gas flow in (a) Steel and (b) MDPE Pipes of different nominal diameters (0.01m-1m)

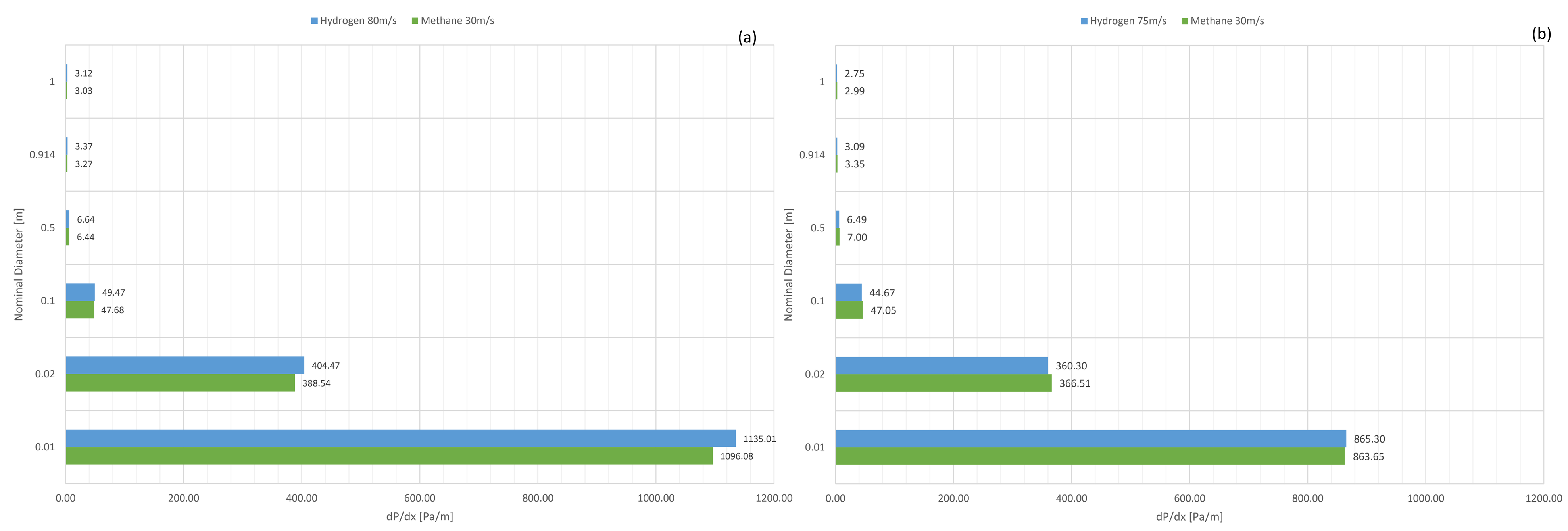

Fig 3. Comparison of gas flow and pressure loss in hydrogen (80m/s, 75m/s) and methane (30m/s) in (a) steel pipes; and (b) MDPE pipes using k-ε turbulence model

Results and Discussion

Flow of hydrogen and methane were compared for steel and MDPE pipes of a fixed length and varying diameters.

- Hydrogen has to be pumped at a much higher velocity to replicate flow conditions of methane (Figure 2)
- MDPE pipes have lower friction losses compared to steel due to lower roughness (Figure 3)

Flow of hydrogen and methane into a confined space were compared for a fixed volume and varying inlet diameters.

- For a constant inlet pressure, the velocity of hydrogen was 2.8 times more than that of methane
- Accumulation process for both gases is largely similar with the formation of a uniform layers against the walls followed by diffusion within the box (Figure 4)
- Higher volumetric fractions of hydrogen were observed compared to methane for the same inlet diameters

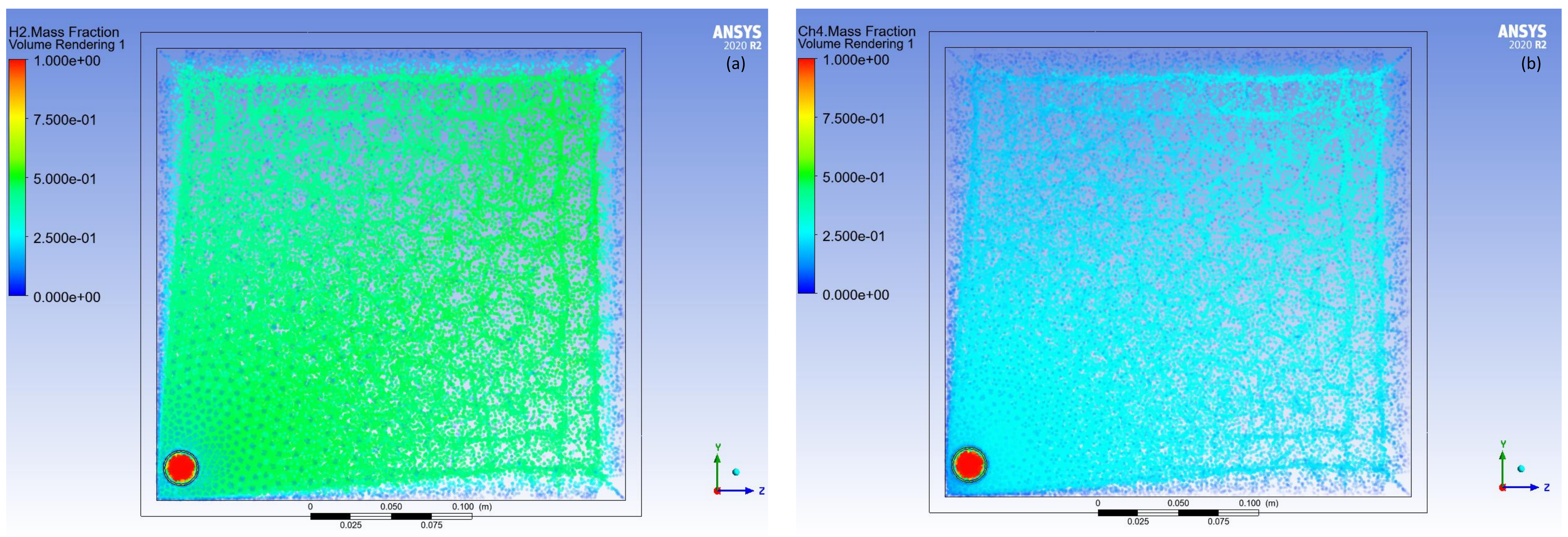

Fig 4. Estimation of the accumulation of (a) Hydrogen and (b) Methane in a confined space when released at a constant pressure on the basis of mass fraction

Conclusions and further work

- Changes are required in the natural gas infrastructure to safely accommodate the shift to hydrogen
- At a local scale, shifting gas transport from metal pipes to MDPE pipes is essential
- For constant inlet pressure, hydrogen has a higher volumetric flowrate – resulting in higher volumetric fractions for a given time

References

1. Kwarteng K., Trevelyan A-M. UK government launches plan for a world-leading hydrogen economy - GOV.UK. 2021. Available at: https://www.gov.uk/government/news/uk-government-launches-plan-for-a-world-leading-hydrogen-economy (Accessed: 4 June 2022)
2. DNV GL. Testing paves the way for hydrogen use in homes - DNV. Perspectives - DNV GL. 2020. Available at: https://www.dnv.com/oilgas/perspectives/testing-paves-the-way-for-hydrogen-use-in-homes.html (Accessed: 4 June 2022)
3. Wulf C., Reuß M., Grube T., Zapp P., Robinius M., Hake JF., et al. Life Cycle Assessment of hydrogen transport and distribution options. Journal of Cleaner Production. Elsevier Ltd; 20 October 2018; 199: 431–443. Available at: DOI:10.1016/j.jclepro.2018.07.180

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