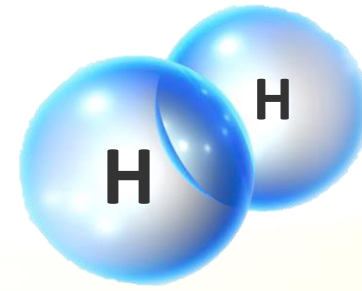
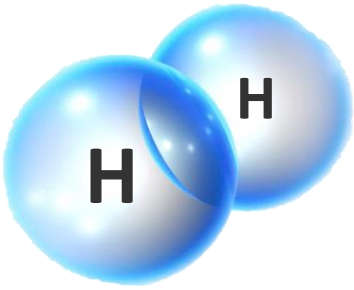


# Safety in design for (pressurised) hydrogen system in enclosed spaces



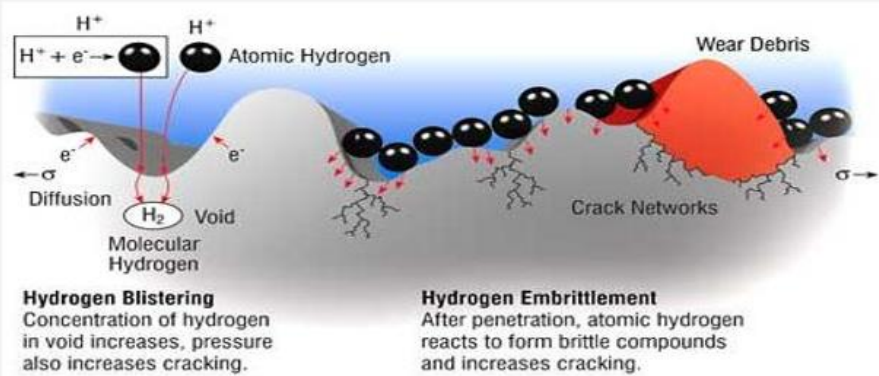
Olav Sæter



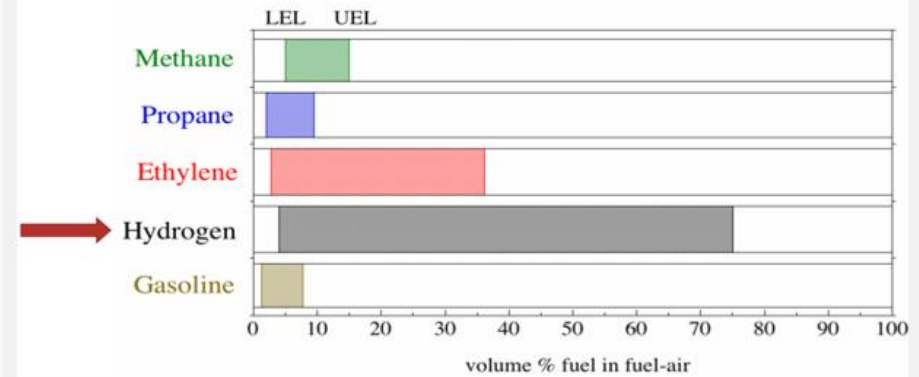


# Hydrogen Safety

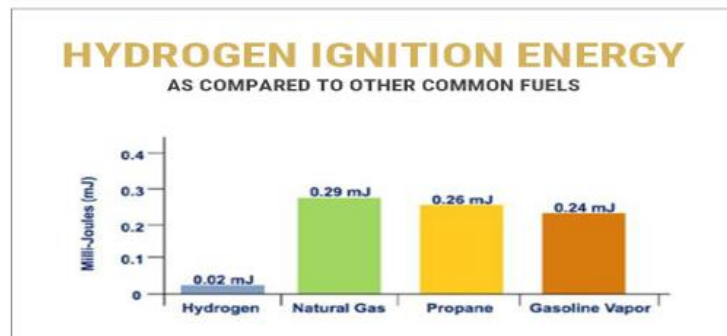
## Containment (small molecule + failure mech.)



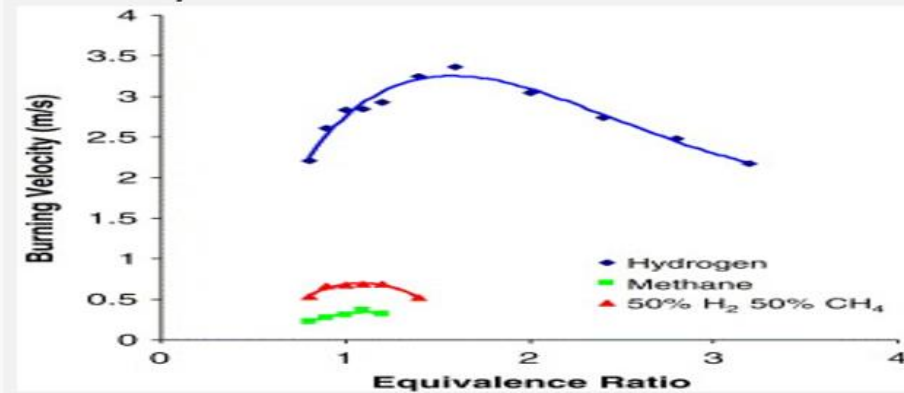
## Flammability (wide range)

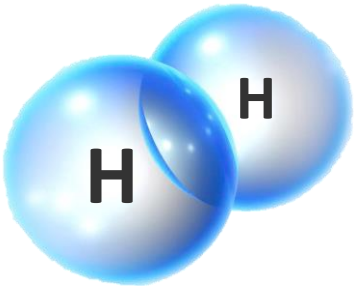


## Ignitability (low energies)

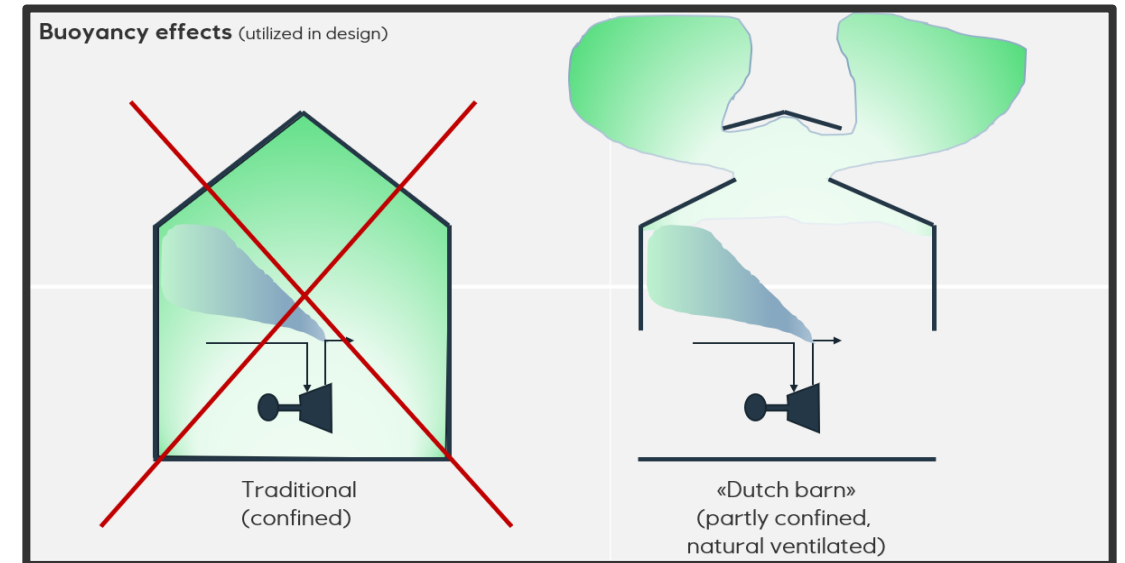
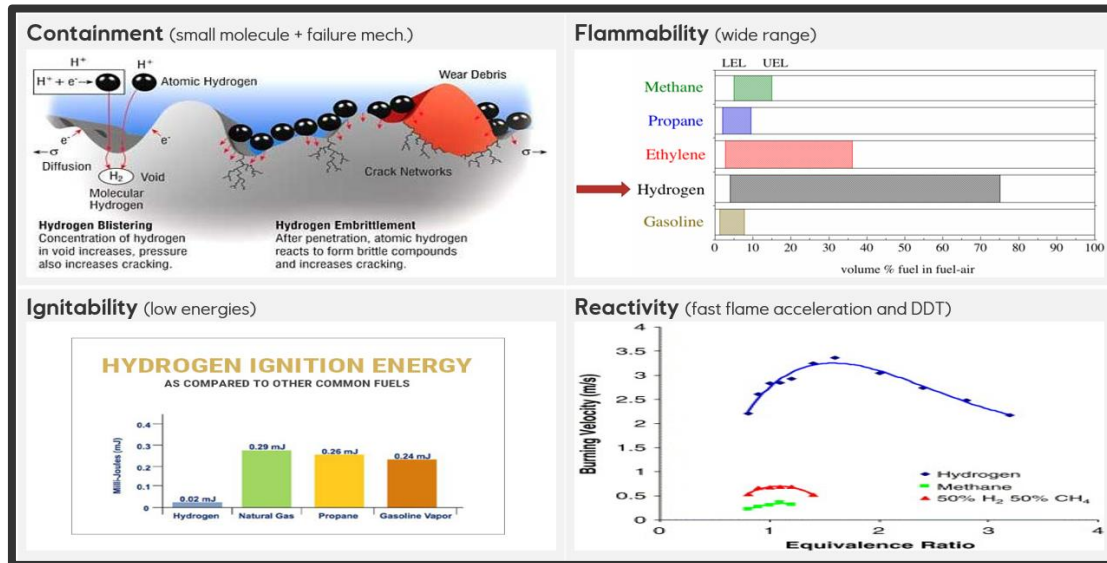


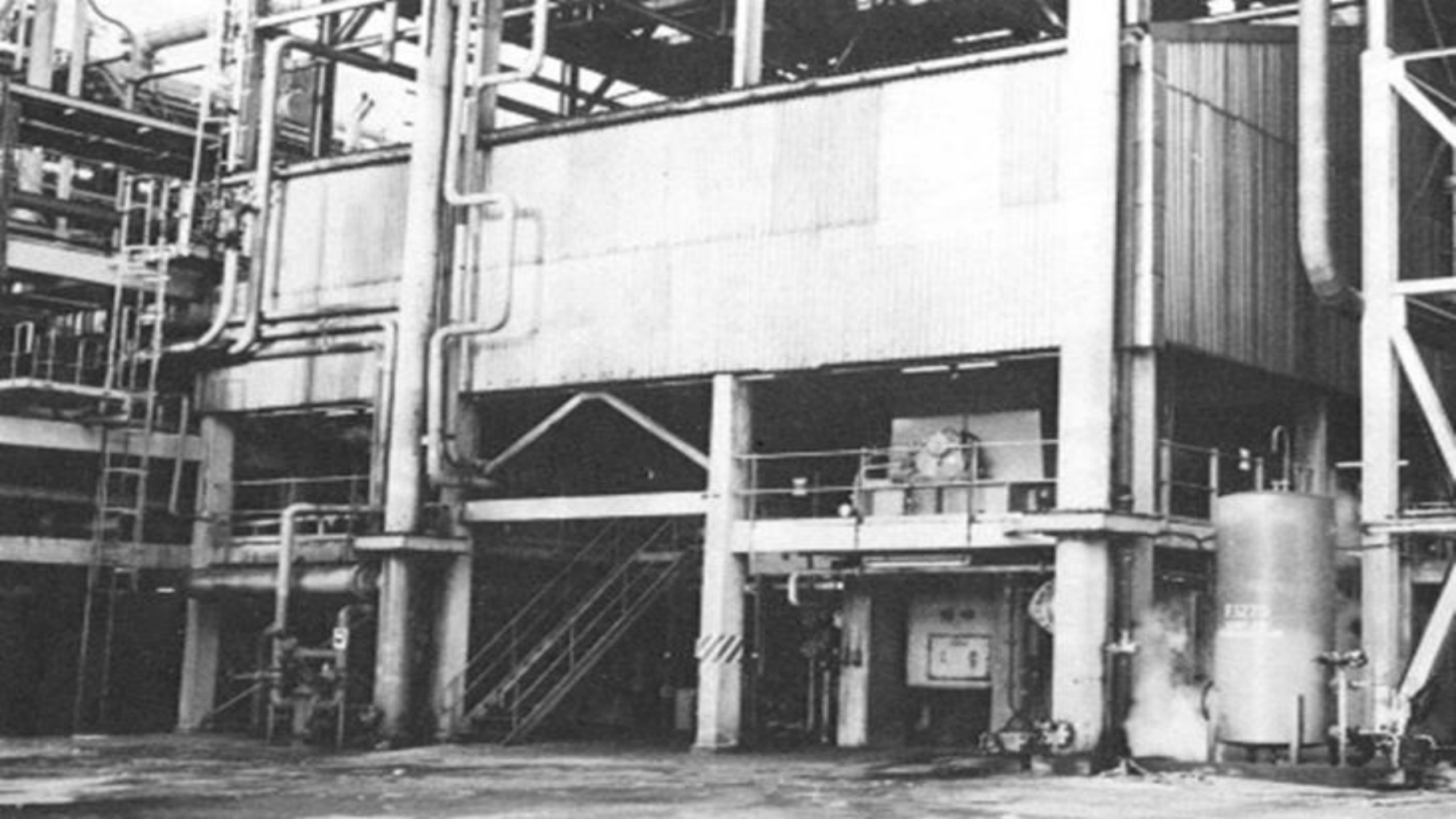
## Reactivity (fast flame acceleration and DDT)





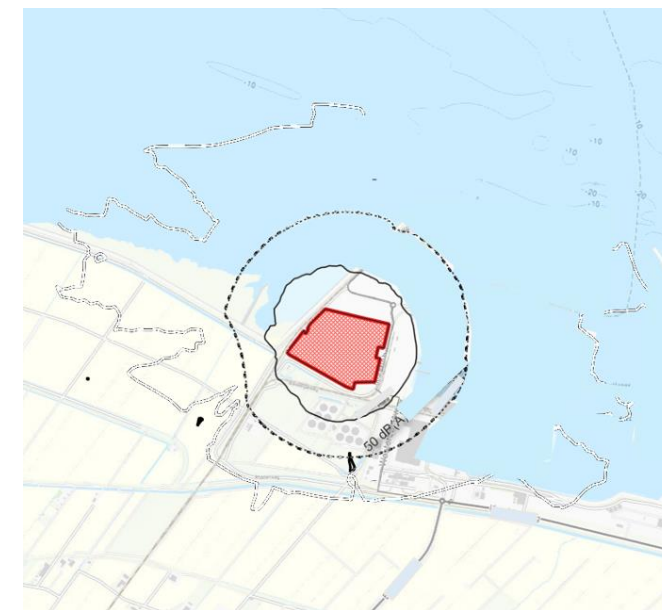
# Hydrogen Safety - risk approach







# The dilemma



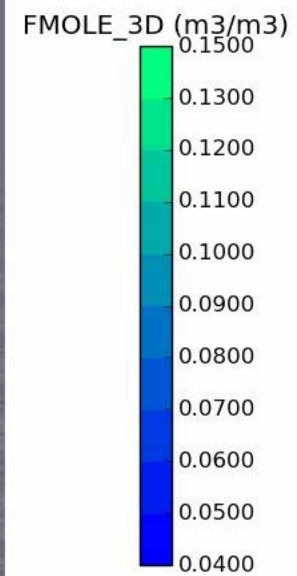
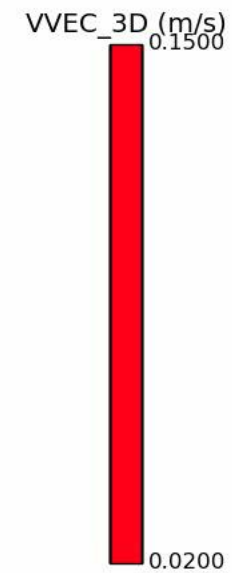
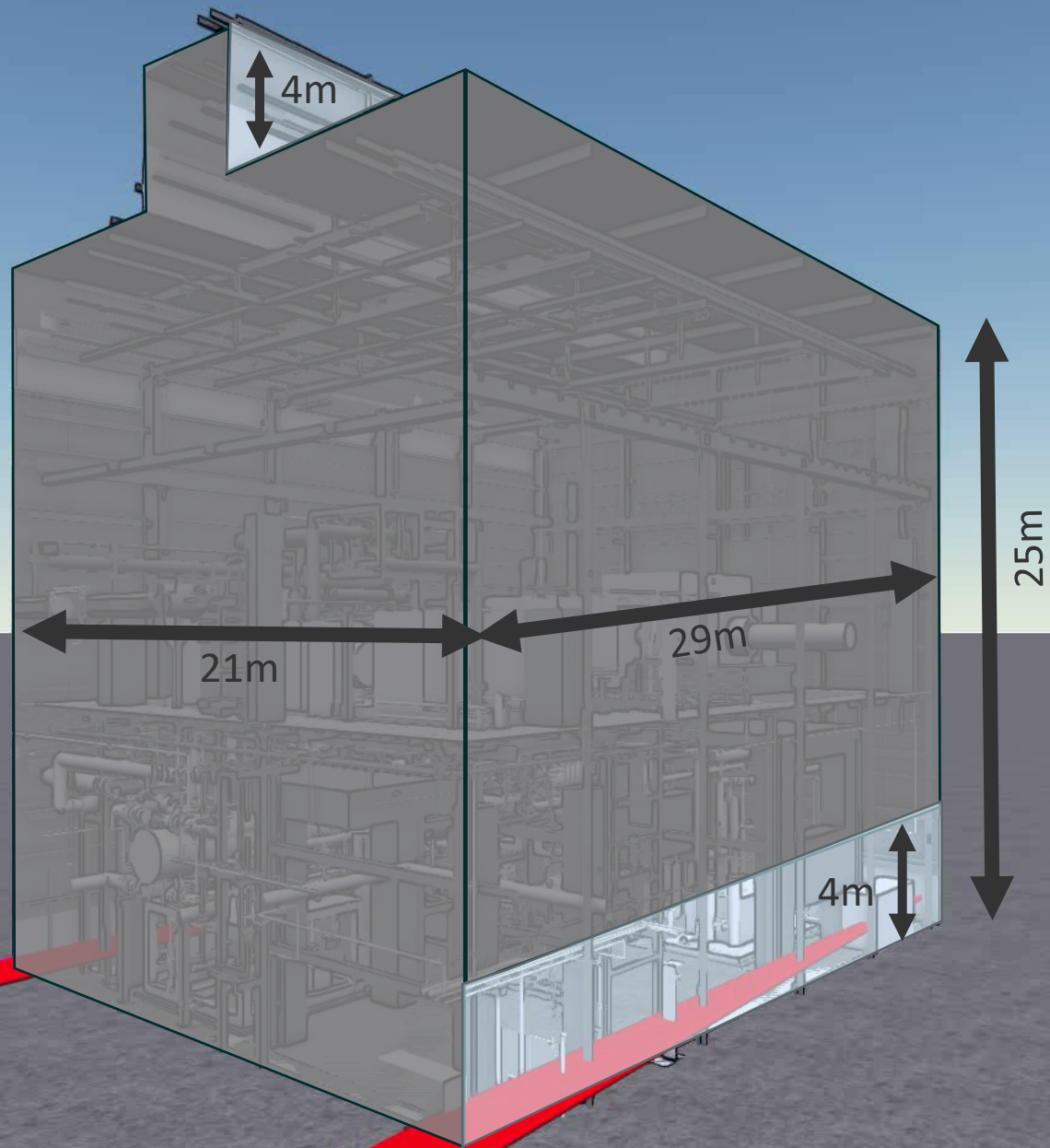
Full enclosure is required to meet area zoning requirements for noise

..... Area noise limit  
—— Actual noise contribution



3 kg/s  
constant rate

Ach = 42 1/h

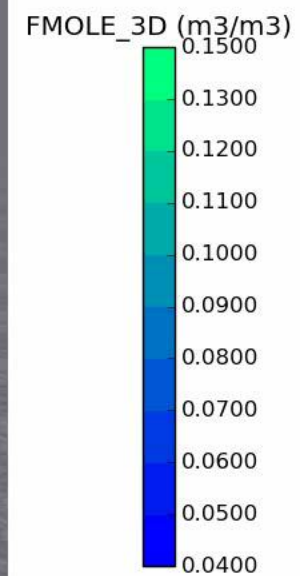
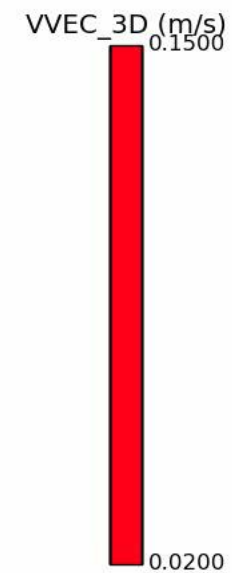
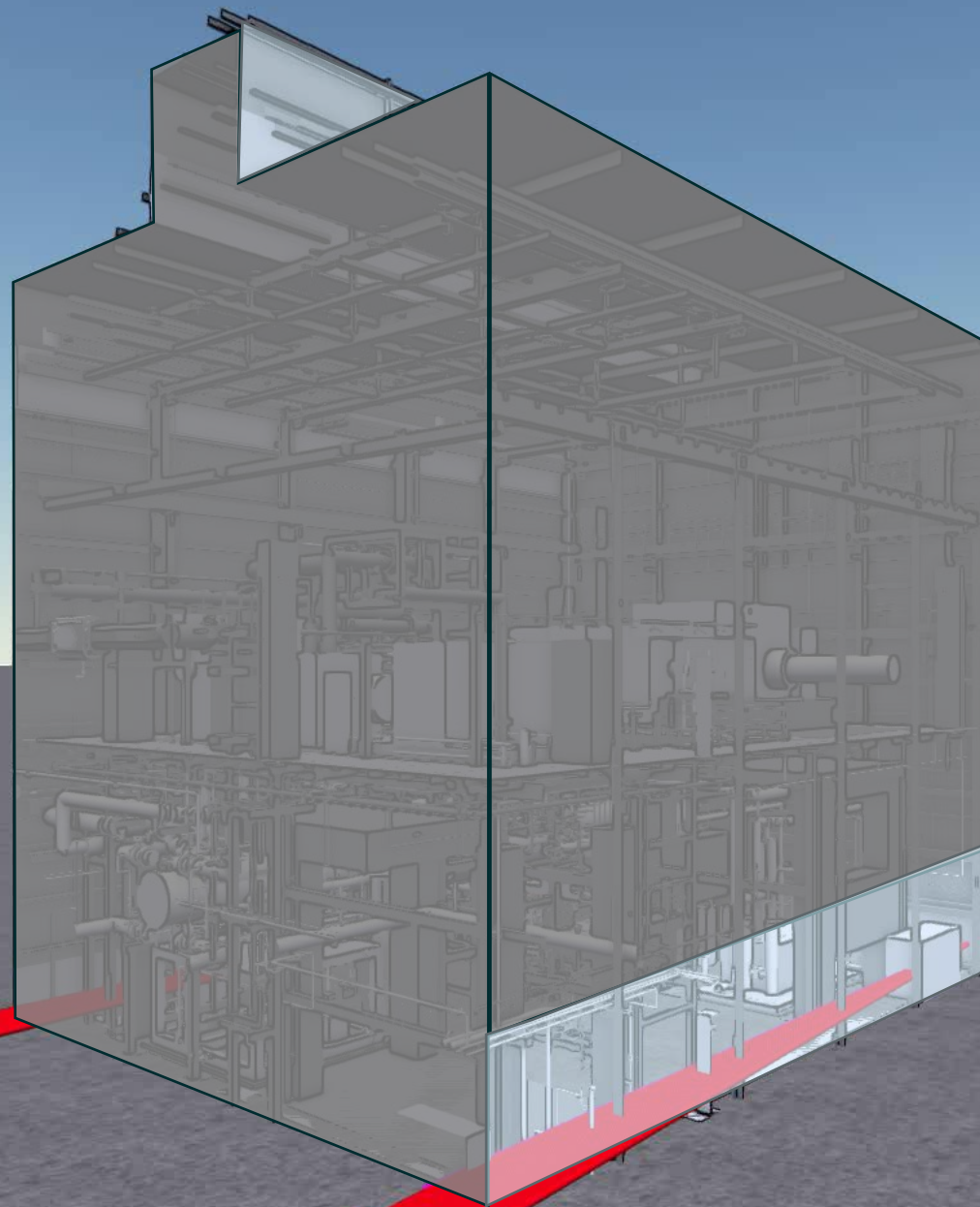


Run: 114411  
Var: FMOLE\_3D (volume)  
Var: VVEC\_3D (streamline)  
Time: 0.00 ms (0)

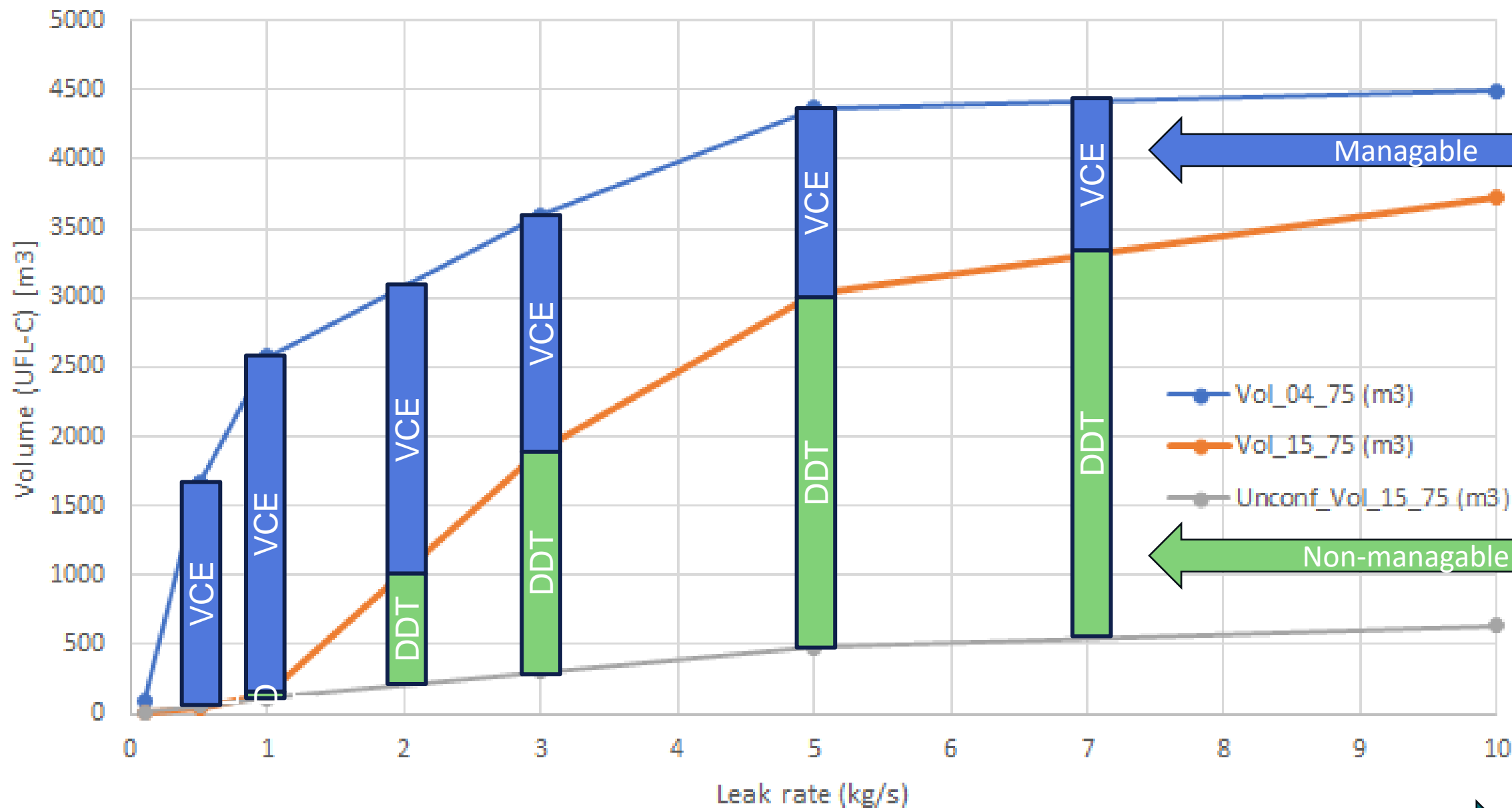


0.5 kg/s  
constant rate

Ach = 26 1/h



Run: 112411  
Var: FMOLE\_3D (volume)  
Var: VVEC\_3D (streamline)  
Time: 0.00 ms (0)



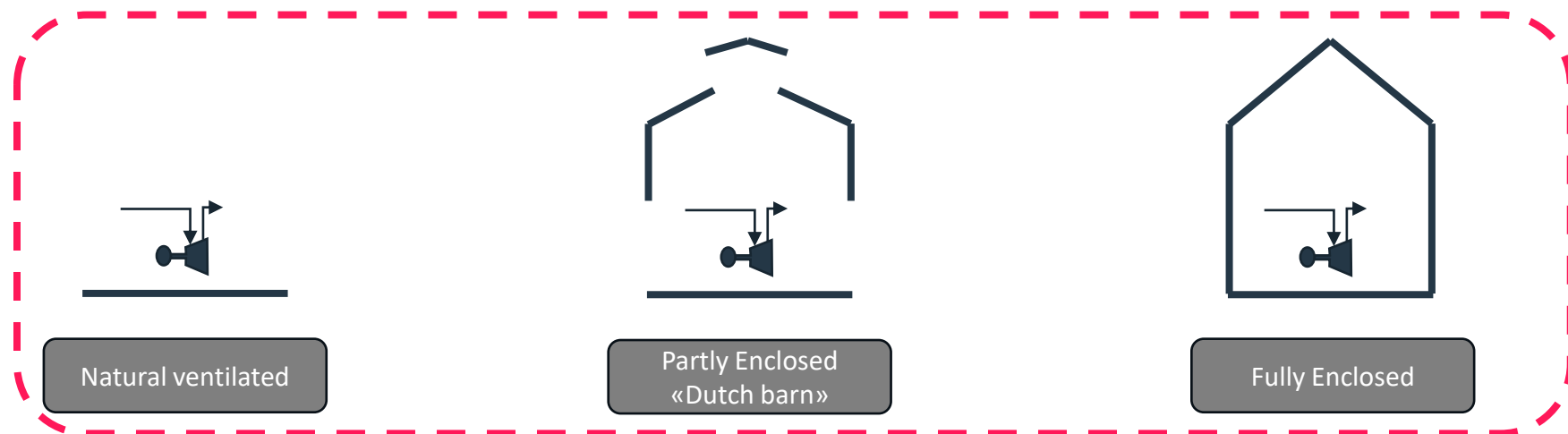
Increasing dimensioning event



For a *dimensioning leak*, the *ventilation shall ensure* that the size of the resulting *critical gas cloud* inside the area shall *not exceed the corresponding cloud size* from a similar leak in an *unconfined space*. This shall be verified by *CFD*.

A *critical gas cloud* is a cloud with hydrogen concentration above **15 vol%**

To be reflected



### Safeguarding controls that need special attention to ensure safety in design:

<p>Layout:</p> <p>Plant layout (minimise congestion in surroundings of leak sources)</p>	<p>Ventilation:</p> <p>Ventilation (ensure sufficient openings / ventilation)</p> <p>Layout:</p> <p>Layout and explosion barriers (internal layout; explosion louvres)</p>	<p>Ventilation:</p> <p>Ventilation (ensure sufficient mechanical ventilation)</p> <p>Isolation:</p> <p>Emergency shutdown (fast and automatic)</p> <p>Depressurisation:</p> <p>Depressurisation (automatic blowdown)</p> <p>Layout:</p> <p>Internal layout (minimise enclosed volume; leak sources located outdoors; explosion panels)</p>
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Increasing explosion risk