Hydrogen Safety and Risk Mitigation

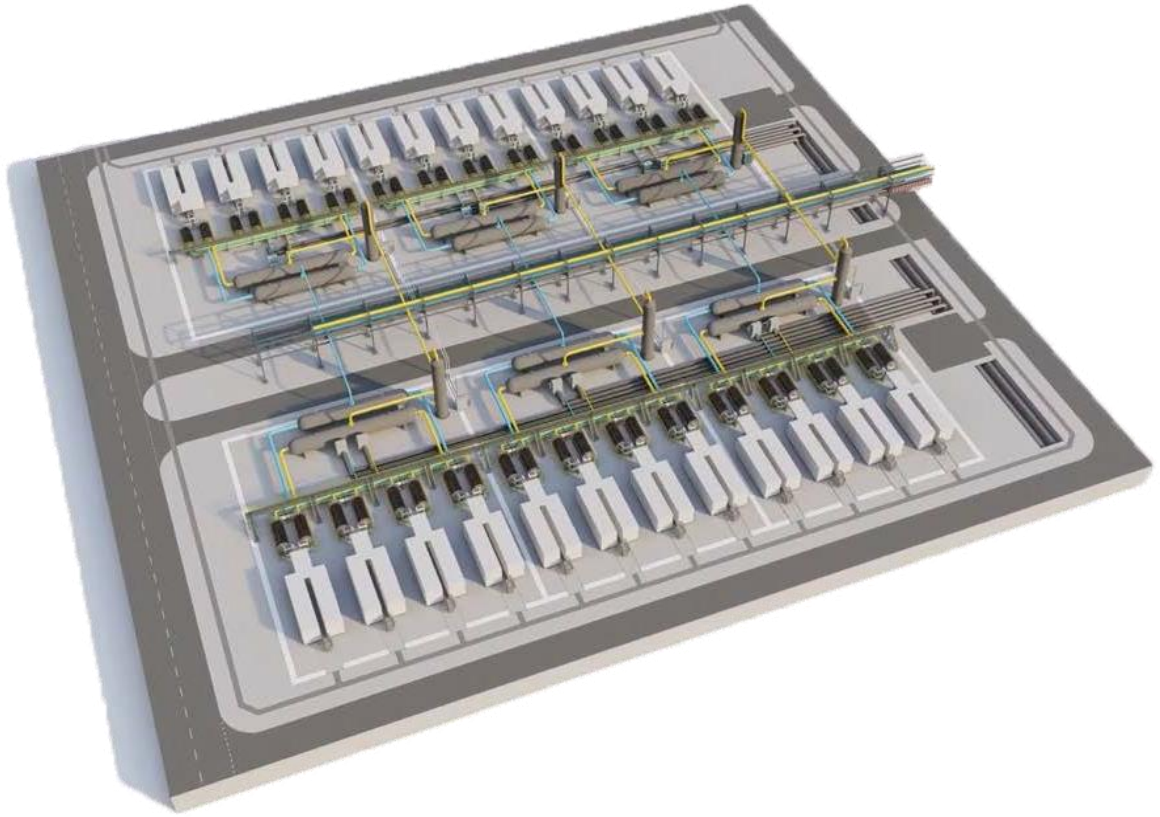
Hydrogen Tech World Conference

Magnus Killingland
Global Segment Lead Hydrogen

June 26, 2024

Hydrogen Safety and Risk Mitigation
Agenda

1. Hydrogen unique characteristics
2. Barriers and safety philosophy
3. Further developments



1. Introduction to DNV

A global assurance and risk management company

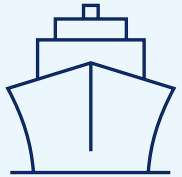
16,000
employees

160
years

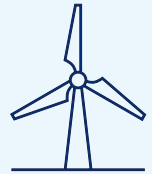
100+
countries

5%+
of revenue to R&D

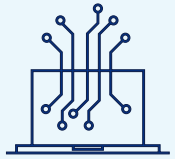
Ship and offshore classification and advisory



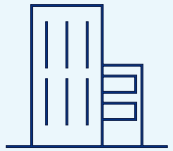
Energy advisory, certification, verification, inspection and monitoring



Software, cyber security, and digital solutions



Management system certification, supply chain and product assurance



Managing risk and complexity for hydrogen

Certify, verify and test

against standards, specifications and regulatory requirements

Qualify and assure

new technologies, systems, data, platforms, supply- and value chains

Give expert advice

on safety, technology and commercial risk, and operational performance

Co-create and share

new rules, standards, software and recommended practices

Hydrogen Properties and Implications

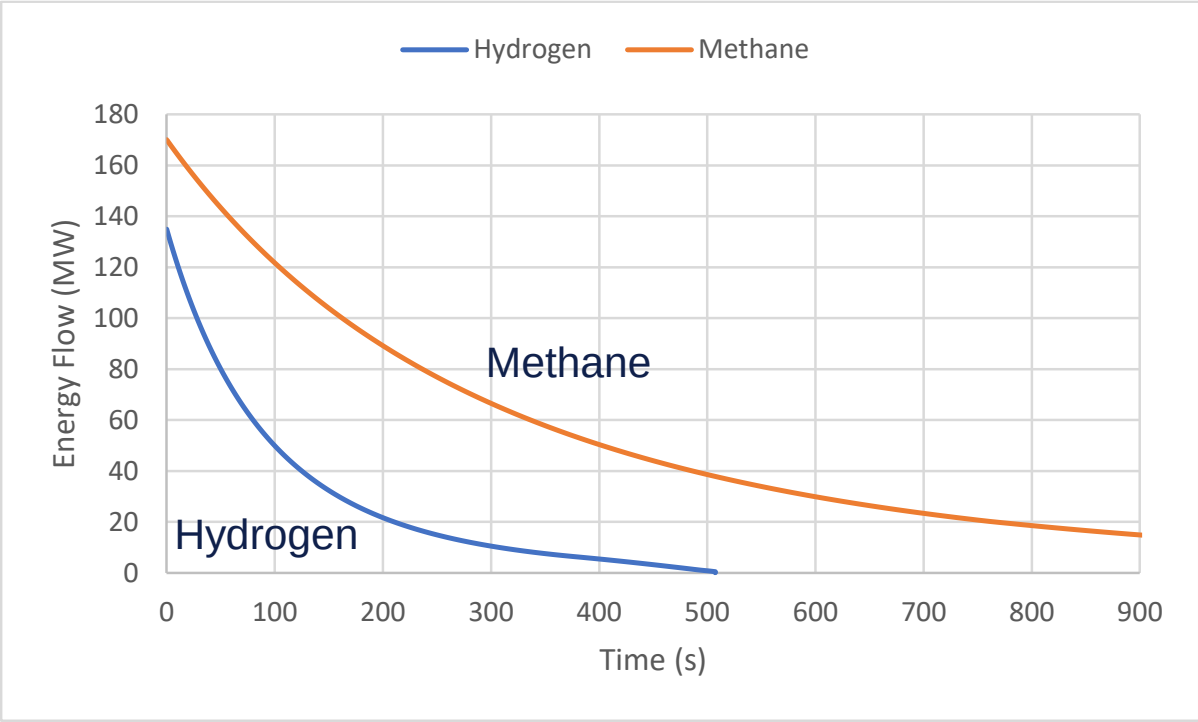
Natural gas versus hydrogen – selected features

	Hydrogen	Natural gas
Flammable range	Ignites in a much wider mix range (4% to 75% of volume)	Narrow flammability mix range (5,3% to 15% of volume)
Ignition energy	Ignitable by low energy sources - phones, and human static electricity (0.020mJ)	10 times higher than hydrogen (0.29mJ)
Flame velocity	3.2 m/s 8 times faster flame velocity than NG - much higher explosion pressure potential	0.4 m/s
Dispersion	Disperses much faster than NG. Limited potential for ground accumulation	Large gas cloud may form. In some conditions as heavy gas on the ground (LNG)

Hydrogen Outflow

$$Flowrate \propto \sqrt{\frac{Pressure}{Density}}$$

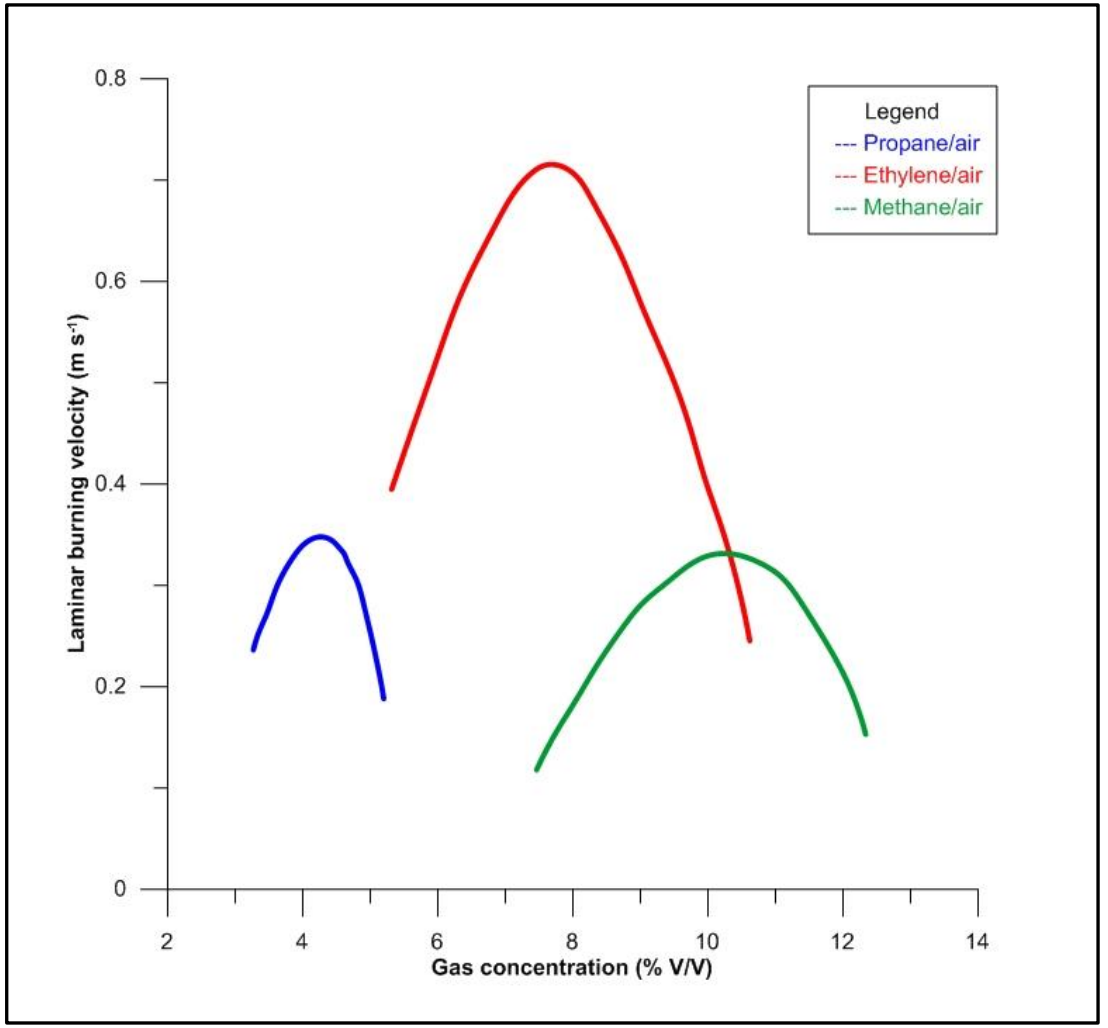
- For the same hole size and pressure
  - Hydrogen <u>volume</u> flow rate is 2.8 times that of methane
- For hydrogen compared to methane:
  - Like for like inventories will depressurize in a *shorter* time
    - Potentially bigger flammable clouds
    - Shorter duration fire loads



20 mm release from 27 m^3 vessel @70 bar

Burning Velocity Hydrocarbons

- Generally, the higher the burning velocity, the more severe the explosion
- Depends on fuel type and concentration
- So what about hydrogen?

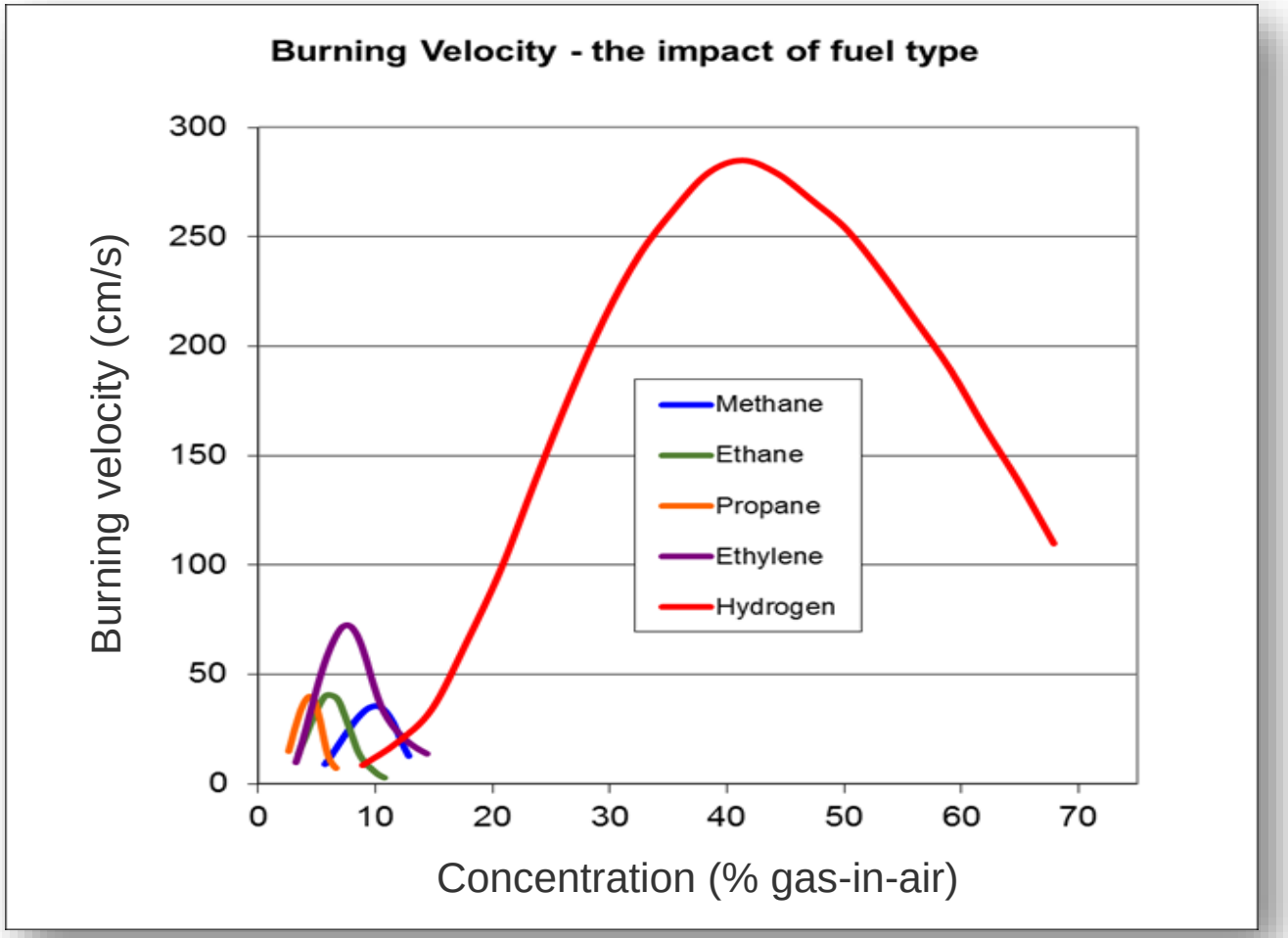


Key Hydrogen Properties - Burning Velocity

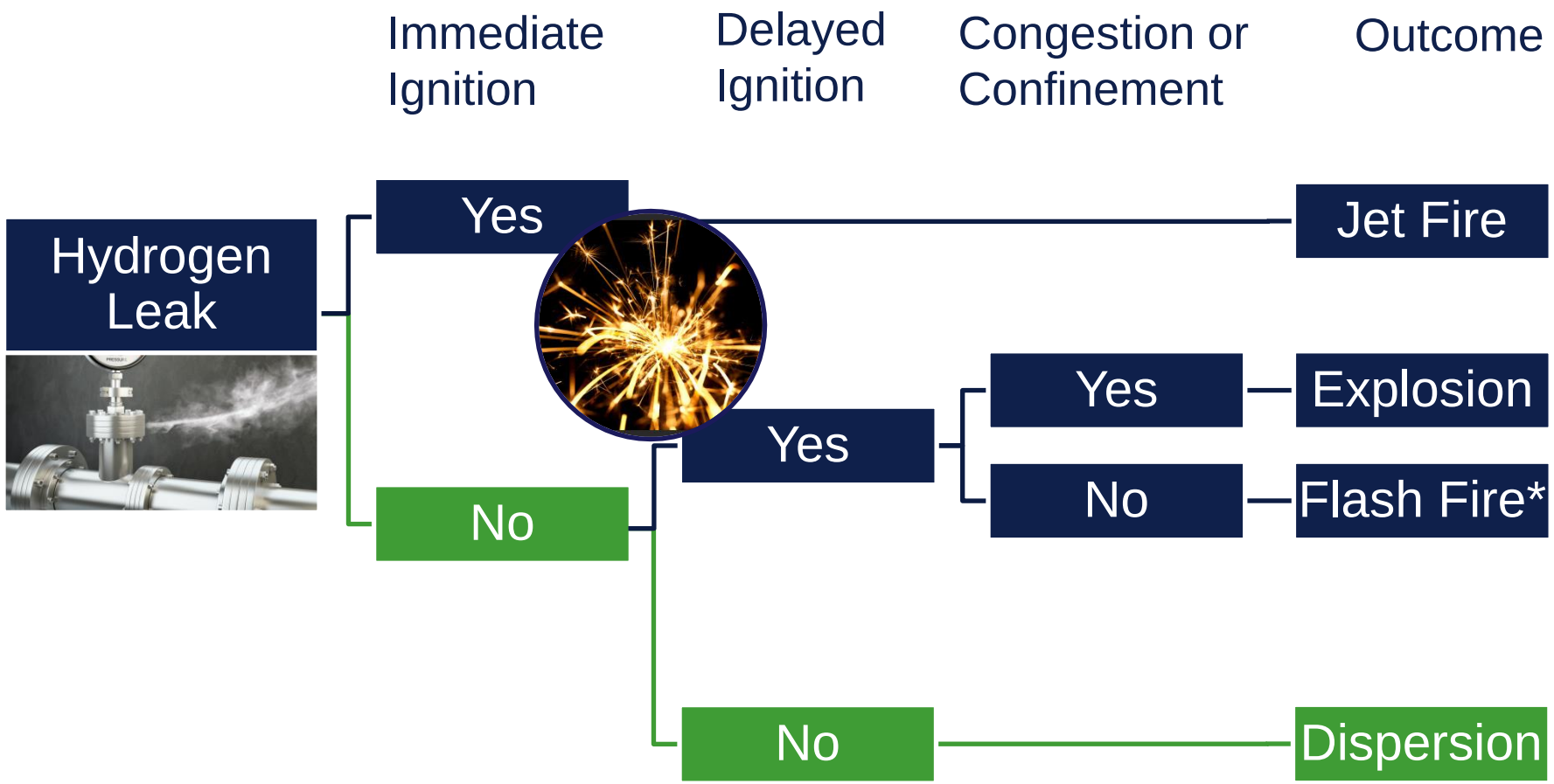
Hydrogen has a much higher burning velocity than hydrocarbons

The higher the burning velocity, the more severe the explosion

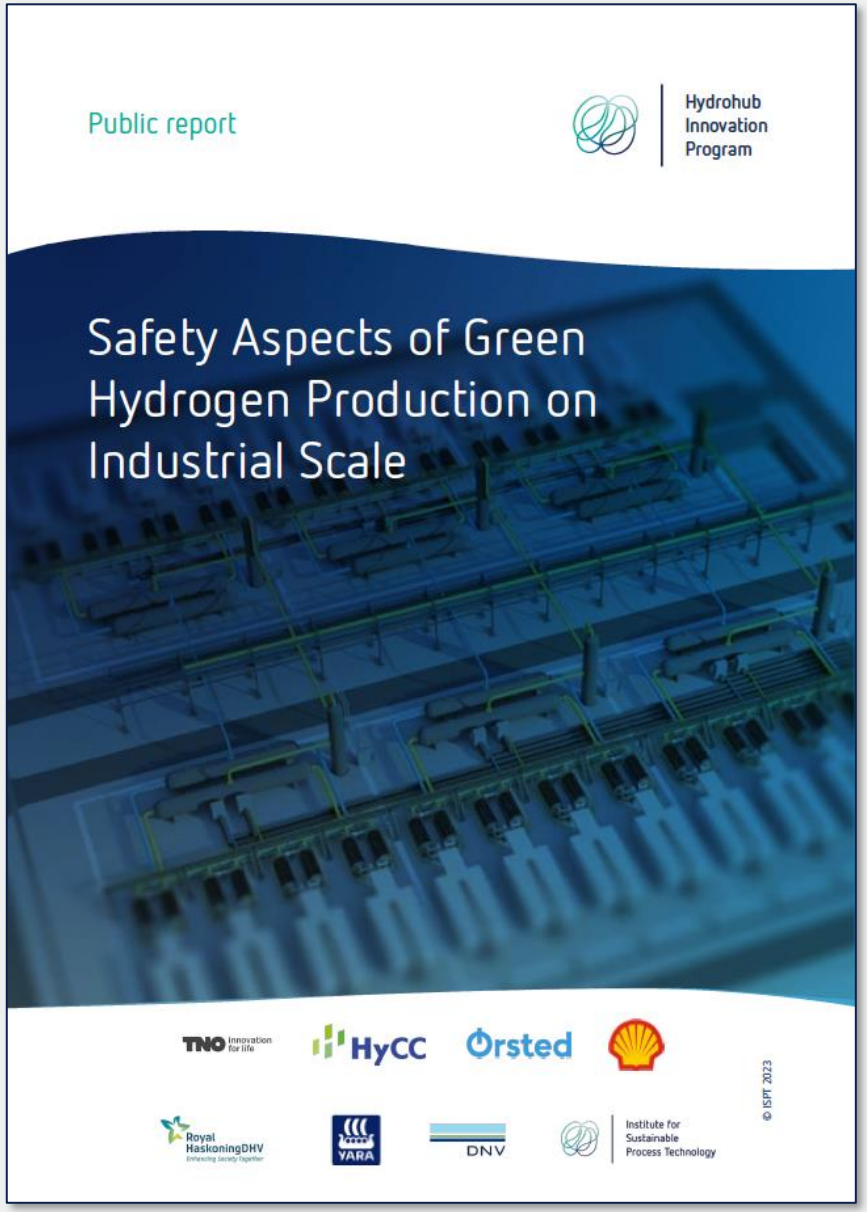
Keep the hydrogen concentration below <15%

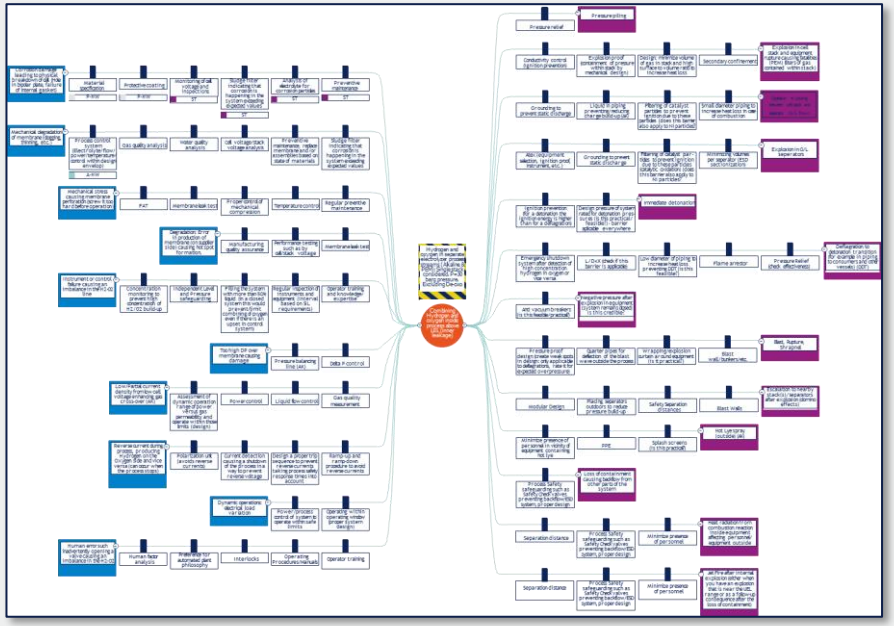


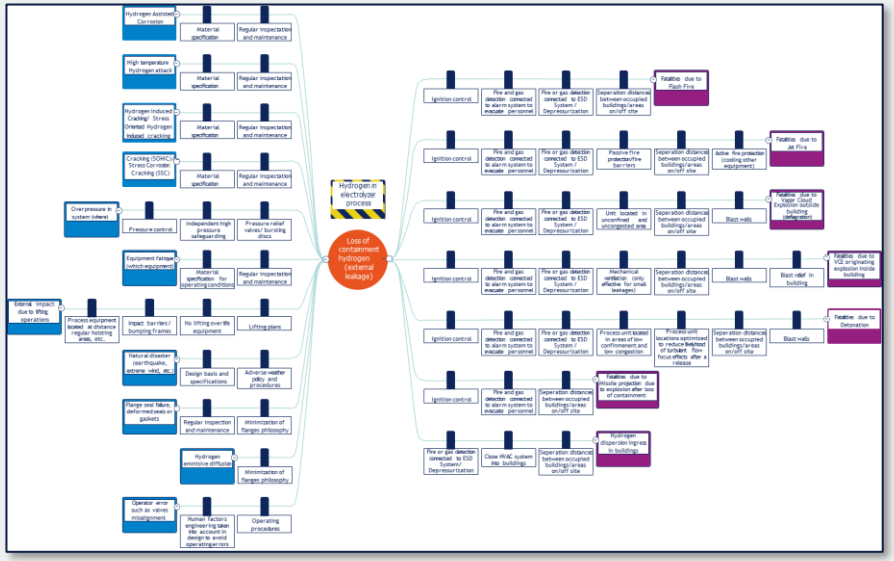
There will be leakage and incidents
– *but what consequence will these have?*



*For H2, jet turbulence alone may cause explosion


Public report
Hydrohub Innovation Program
Safety Aspects of Green Hydrogen Production on Industrial Scale
TNO Innovation for life
HyCC
Ørsted
Royal HaskoningDHV
YARA
DNV
Institute for Sustainable Process Technology
© ISPT 2023





Leakage and design philosophy

High level strategy for handling hydrogen

Explosion and fire protection

Primary
Avoidance of explosive mixtures

Secondary
Avoidance of ignition sources

Tertiary
Inherently safe design with barriers

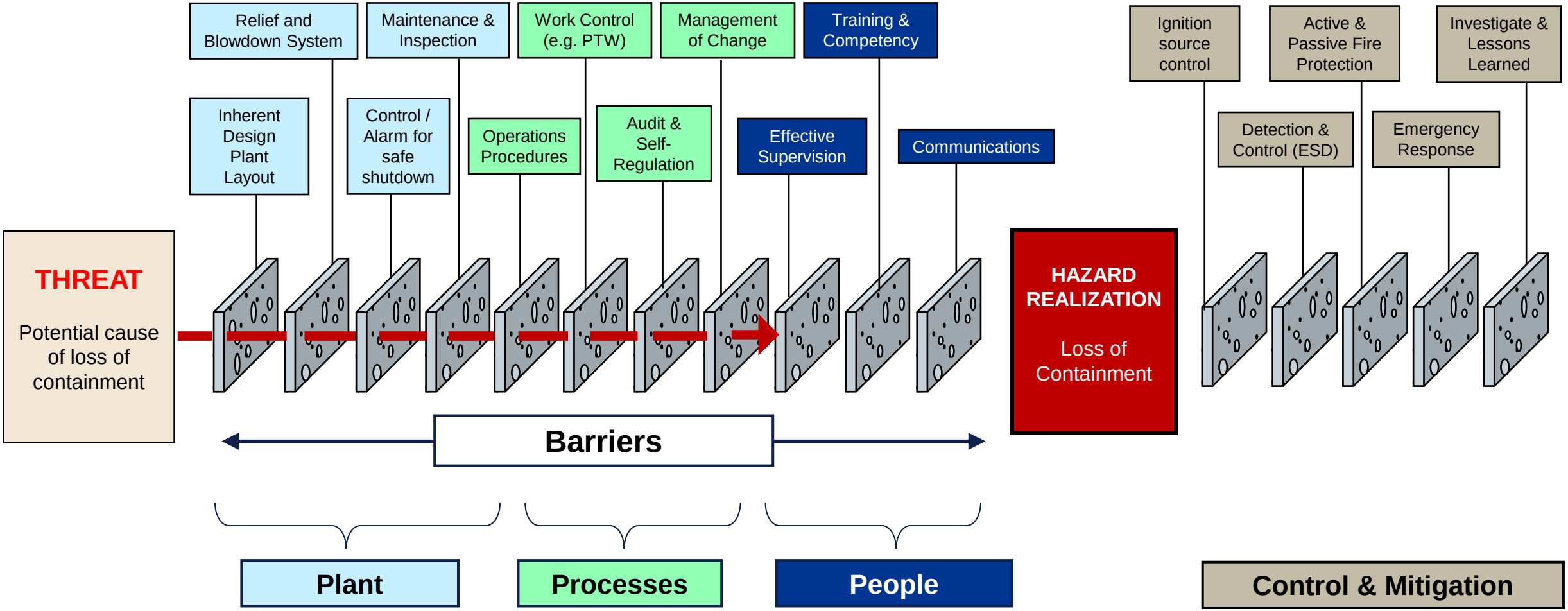
Design Philosophy Hierarchy

- **Avoidance** – elimination of the hazard
- **Prevention** – reducing the likelihood of loss of containment (LoC)
- **Control** – limitation of scale or duration of LoC event
- **Mitigation** – protection from effects, and avoidance of escalation from LoC event
- **Emergency Response** – e.g. evacuation of people, and involvement of emergency services

- Risk reduction measures have a hierarchy in terms of preference. In reality all of these measures are generally used

How to solve it

Design Philosophy - Barriers



Protection layers for hydrogen leaks with detectors

Leak (sound)

1. ULTRASONIC GAS DETECTION

LEAK DETECTION LAYER
Ultrasonic gas detection ensures the earliest possible response

Gas (molecules/vapor)

2. CONVENTIONAL GAS DETECTION

GAS DETECTION LAYER
Conventional gas detection technologies help mitigating risks

Fire (heat)

3. FIRE DETECTION

FIRE DETECTION LAYER
Undetected hydrogen leak can result in fire and explosions

Regulatory innovation and iteration at many levels

1
International Agreements and Protocols

2
Regional Directives and Strategies

3
National Laws and Acts

4
Local or Provincial Legislation

5
Local Ordinances and Regulations

6
Industry Standards
ISO, IEC, ANSI/ASTM, DIN, EN etc.

7
Recommended Practices and Guidelines

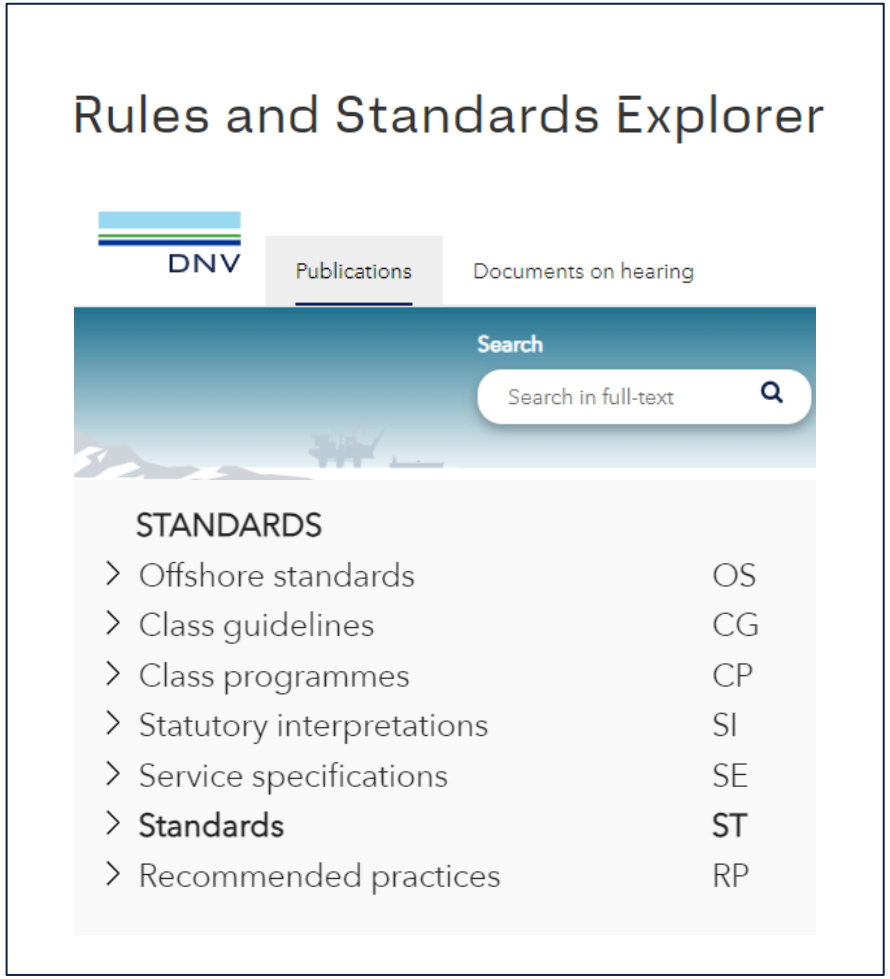
8
Certifications and Compliance Frameworks

9
Joint Industry Projects
Technical Reports and Studies

10
Private Sector Policies and Self-Regulation

Rules and standards for hydrogen

1. **Verification of PtX facilities** (service specification DNV-SE-0656)
2. **Electrolyser design and performance** (standard DNV-ST-J301)
3. **Hydrogen readiness and repurposing of pipelines and infrastructure** (DNV-SE-0657)
4. **Verification and Certification of power-to-x equipment** (DNV-SE-0674)
5. **Verification of attribute claims for hydrogen and ammonia**, e.g. GHG footprint, water use, ESG (service specification DNV-SE-0654)

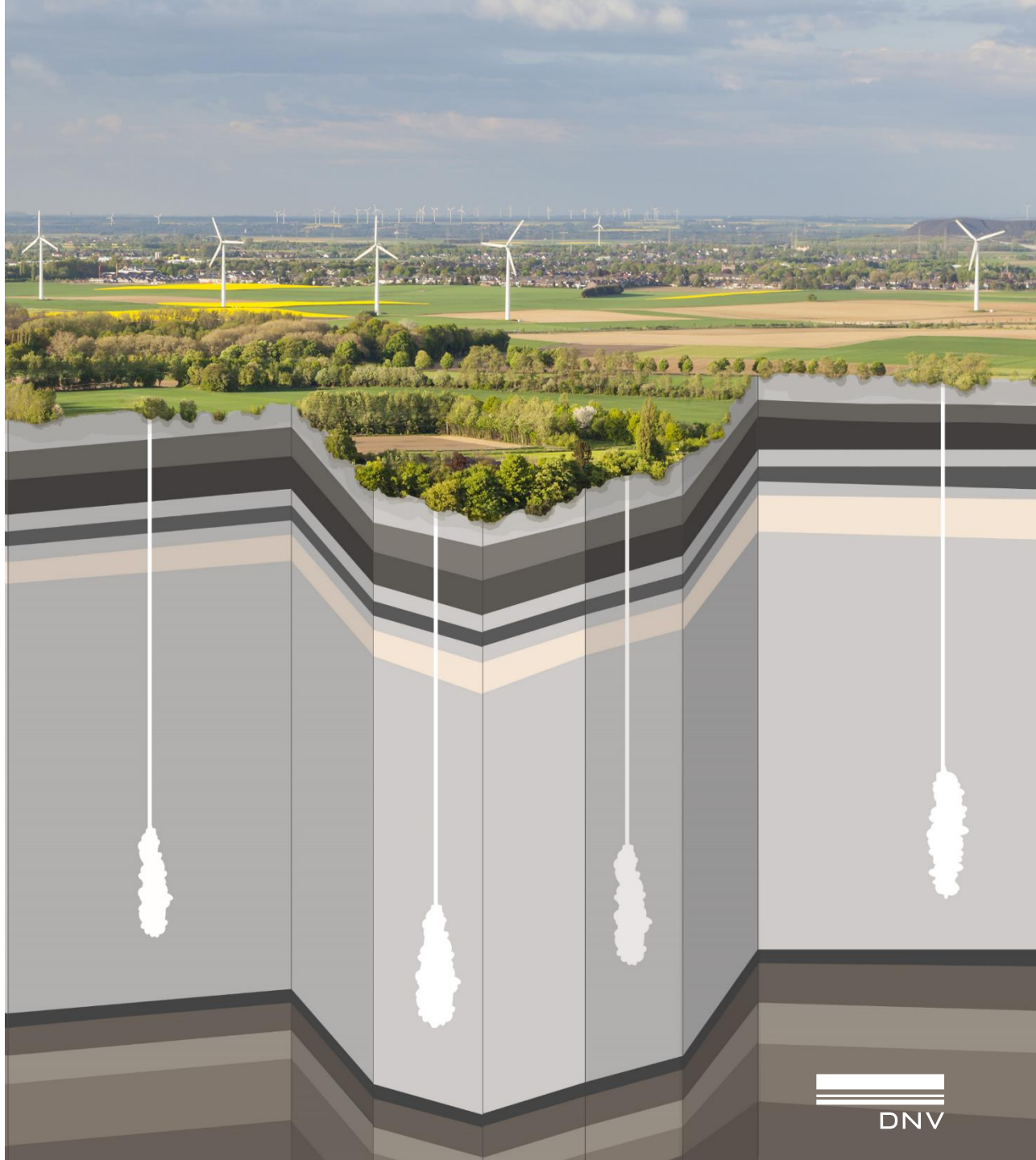


H2SaltCavern
Joint Industry Project

Aim:
Develop best practice for underground hydrogen storage safety in salt caverns

Main deliverable:

- JIP industrial guideline
- DNV Recommended Practice after JIP completion



Take-aways and summary

Unique characteristics for hydrogen

Testing, updating of best practices, and more standardization

Regulatory and legislative iteration with implementation

Thank you for your attention

Magnus Killingland
Global Segment Lead
Hydrogen and Sustainable Fuels
E-mail: magnus.killingland@dnv.com
Cel: +47 99 60 26 90

www.dnv.com