Swiss Re
Corporate Solutions

Understanding the risks of Hydrogen

The insurance perspective

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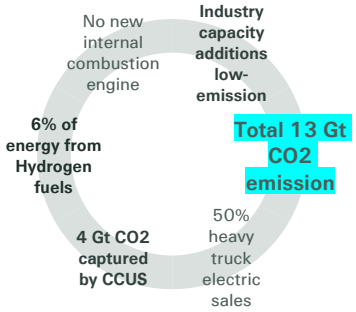
Risk Engineering Services

Understanding the risks of Hydrogen

A small molecule with a big potential

Hydrogen means
"Creator (-gen) of water (hydro-)":
its combustion releases only water

2035



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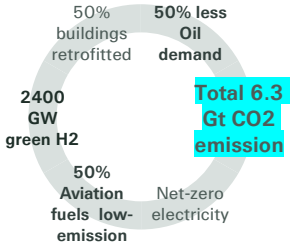

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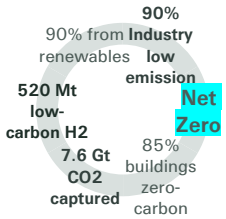

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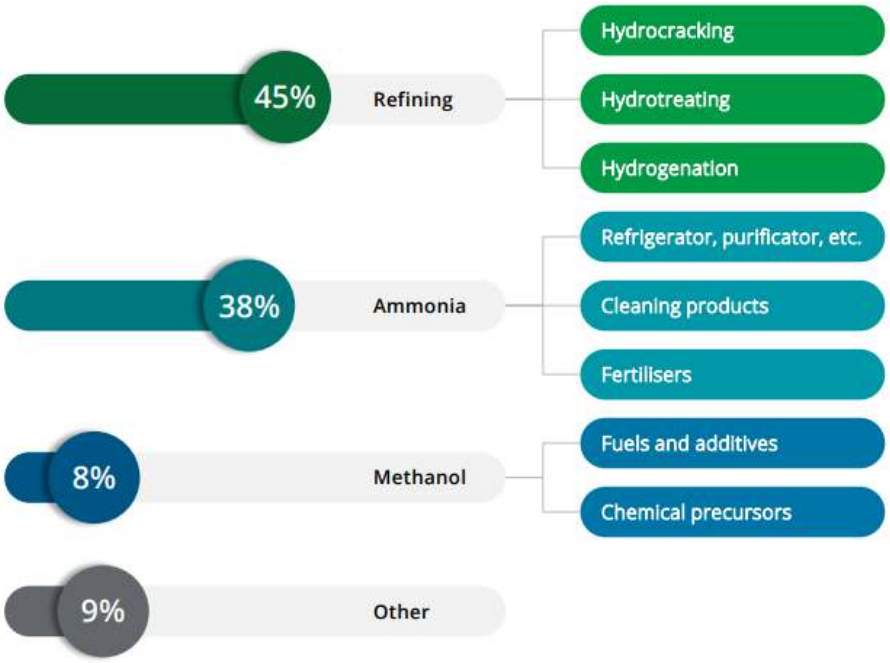
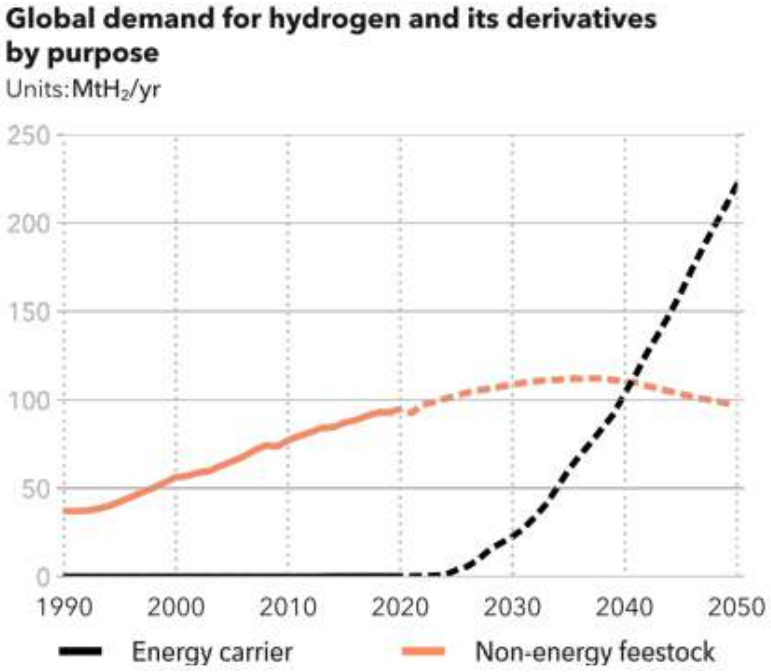
Understanding the risks of Hydrogen

Hydrogen demand

Weaknesses from the past.....



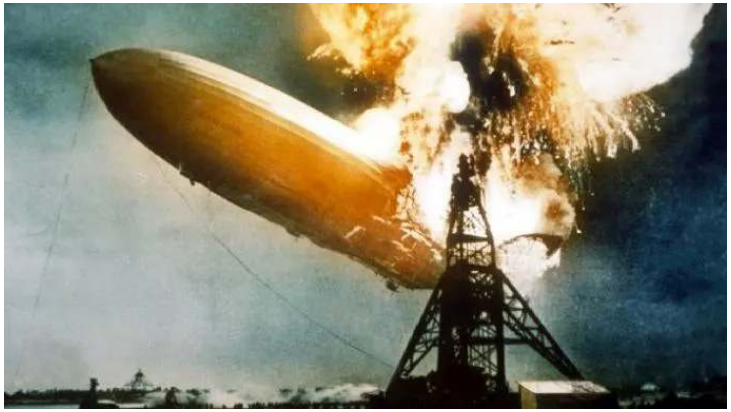
...Opportunities for the future



Understanding the risks of Hydrogen

Hydrogen reputation

False starts prejudiced our confidence



...and still influence people opinion

Norway, 2019
Hydrogen fuelling station explosion

South Korea, 2019
Hydrogen tank explosion

Illinois, USA, 2019
Hydrogen blast at AB Speciality Silicones factory

[YouTube - Incompatible Chemicals: Explosion at AB Specialty Silicones]

Understanding the risks of Hydrogen

A safety moment

Hydrogen has a much higher burning velocity than hydrocarbons

→ More devasting damage in an explosion scenario with concentration above 15%

- Much lighter
- Easier dispersion but wider ignition
- High energy per unit of mass
- Low energy density per unit of volume
- Boiling point is -252 °C

Property	Hydrogen
Density (gaseous)	0.089 kg/m^3 (0°C, 1 bar)
Density (liquid)	70.79 kg/m^3 (-253°C, 1 bar)
Boiling point	-252.76°C (1 bar)
Energy per unit of mass (LHV)	120.1 MJ/kg
Energy density (ambient cond. LHV)	0.01 MJ/L
Specific energy (liquefied, LHV)	8.5 MJ/L
Flame velocity	346 cm/s
Ignition range	4-77% in air by volume
Autoignition temperature	585°C
Ignition energy	0.02 MJ

Notes
cm/s = centimetre per second, kg/m^3 = kilograms per cubic metre,
LHV = Lower heating value, MJ = Megajoule, MJ/kg = Megajoule per kilogram,
MJ/L = Megajoule per litre

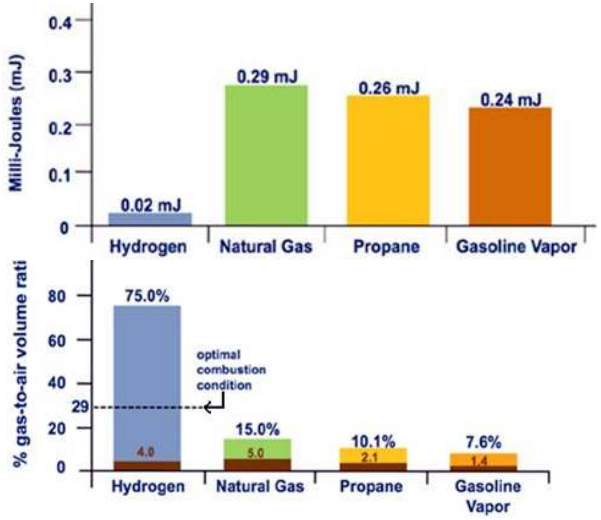
→ Hydrogen is unforgiving

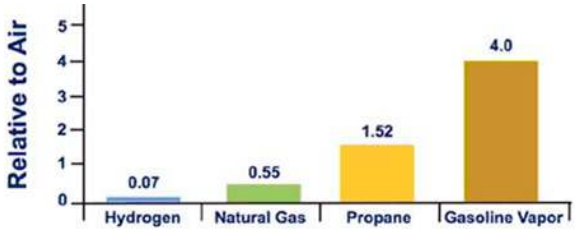
Understanding the risks of Hydrogen

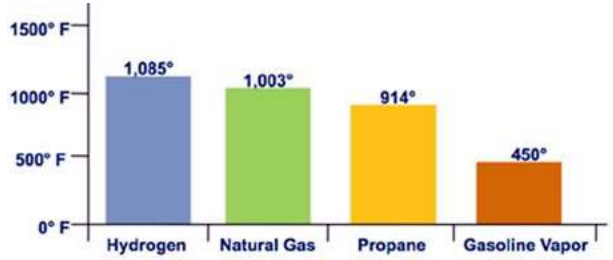
Hydrogen behavior

Comparison with commonly used fuels

- Hydrogen is about 57 times lighter than gasoline vapor → pros and cons depending on the openness of the environment → there are no known odorants light enough to travel with
- Hydrogen has the highest autoignition temperature but the wider flammability range (4 to 75% in air)
- In a situation of optimal combustion conditions, the energy required to initiate hydrogen combustion is much lower than that required for other common fuels

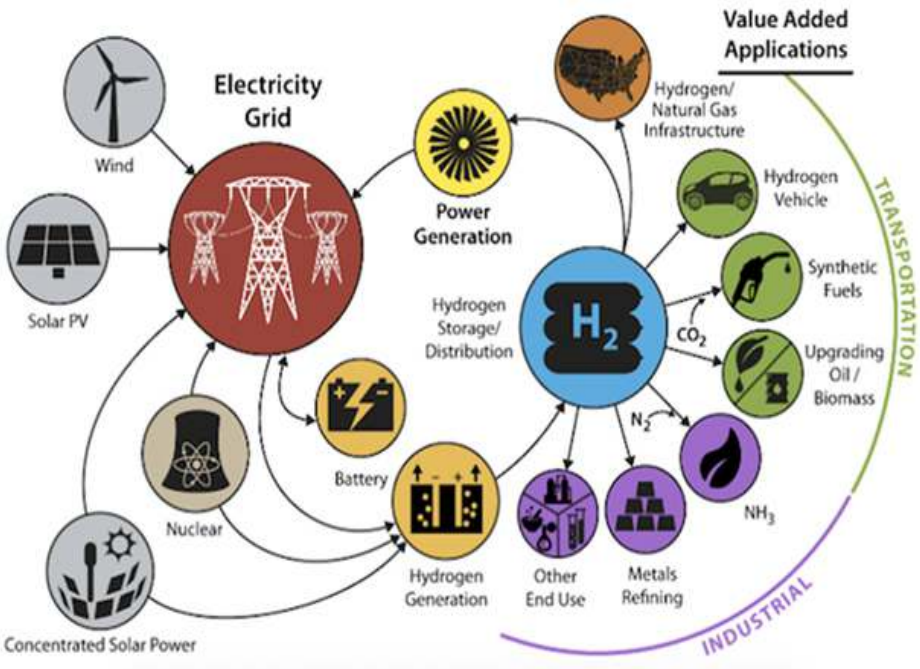


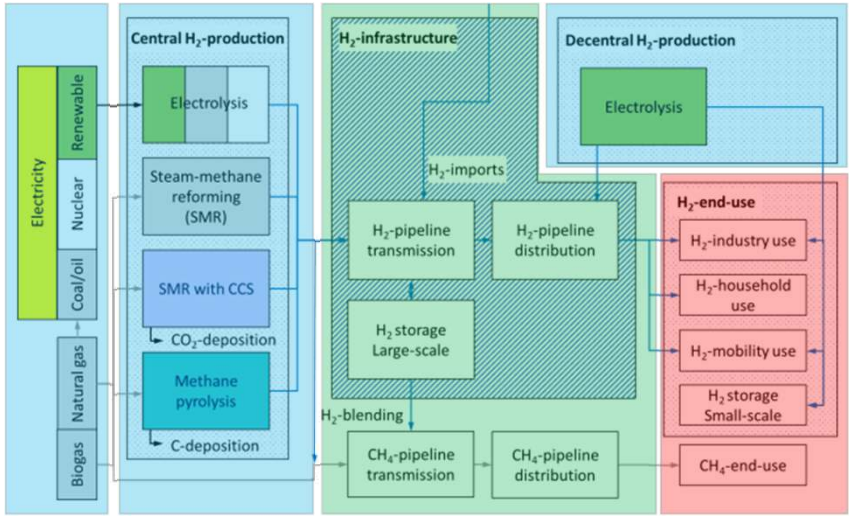




Understanding the risks of Hydrogen

Risk exposures and engineering considerations from well-to-end-use





Source of energy and production technologies

Distribution and storage

End users

Understanding the risks of Hydrogen

Donald Rumsfeld Quotes

Known knowns	Known unknowns	Unknown unknowns
Risk exposures are well acquainted and can be assessed for supporting insurers' risk appetite.	Awareness of unknown areas of risk pushes for greater attention/deeper engineering investigations and requires a cautious approach from an insurance perspective.	Risk exposures knowledge is very limited, and this rises barriers to insurers' risk appetite. Adequate expertise and understanding are mandatory to make a fully-fledged risk insurable.

Understanding the risks of Hydrogen

«Grey», «Black» or «Blue» Hydrogen: our industry expertise

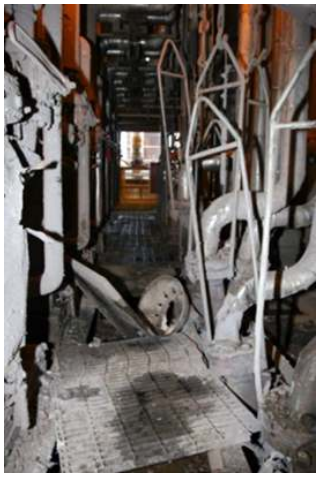
«Well-known» hazard

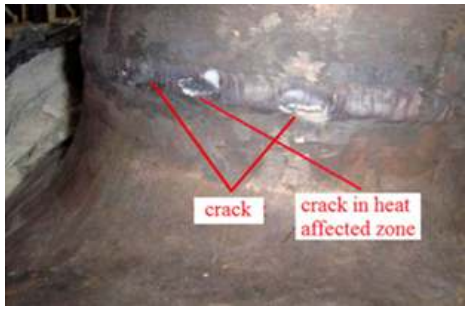
Steam reforming

- Creep damage or stress corrosion cracking mechanism leading to hydrogen leaks from tubes with potentials for reformer box explosion, refractory damage or hydrogen jet fire from piping rupture

Coal gasification

- Similar to steam reforming exposures including refractory damage or hydrogen jet fire from piping rupture, but also high-pressure rupture of the gasifier because of the higher operating pressure



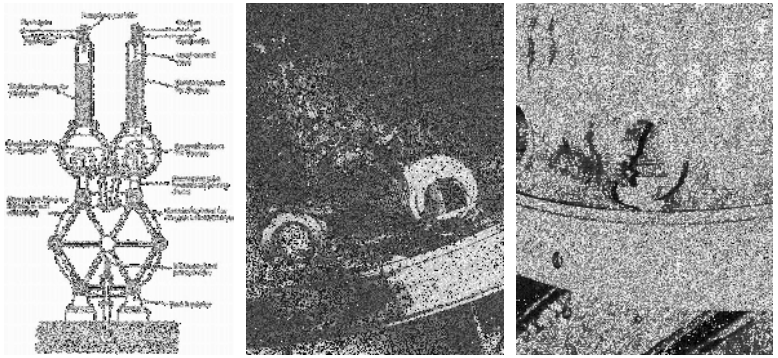


Understanding the risks of Hydrogen

«Green» Hydrogen: an "old" process under continuous development

«Aggravated» exposures

- Unknowns include upscaling of the capacities and "new" technologies. Cost reduction means:
  - Transition from atmospheric to pressurized Alkaline technology
  - Reduction of "rare" and "precious" iridium/platinum in favor of new prototypical materials
  - Steam employment for Solid Oxide Electrolysis (SOE)
- Membranes degradation and consequent hydrogen/oxygen contamination remain the driving hazard -> mechanical failures leading to room explosions
- De-oxo units required for further processing are "critical" due to catalyst dusting & runaway reactions

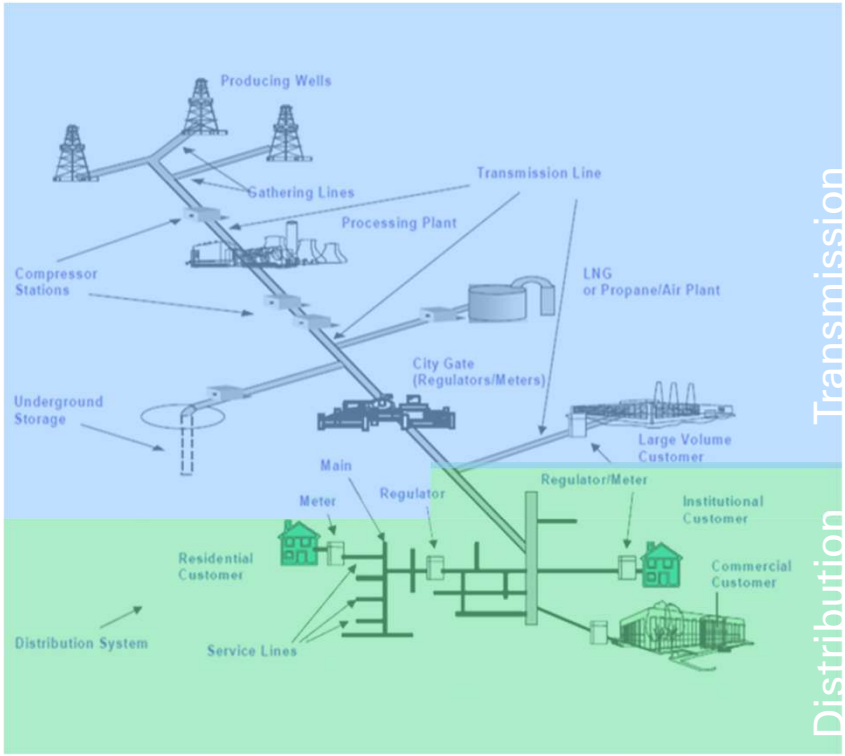


On 5 April 1975, an explosion occurred at the factory of Laporte Industries which resulted in extensive damage to an electrolytor plant and the subsequent death of the plant operator.

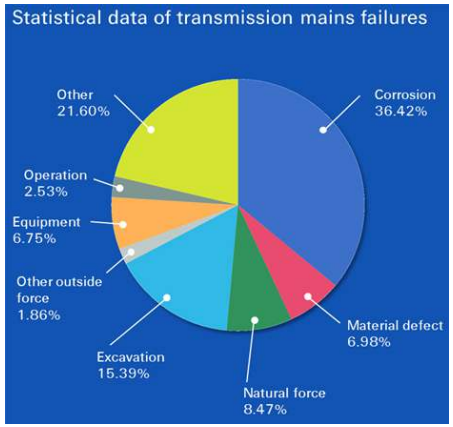
Explosion of an outdoor hydrogen tank at a water electrolyzer plant coupled with a solar photovoltaic power system (May 23th, 2019)
→ 2 fatalities and 6 injuries (USD 30-40 million damage)

Understanding the risks of Hydrogen

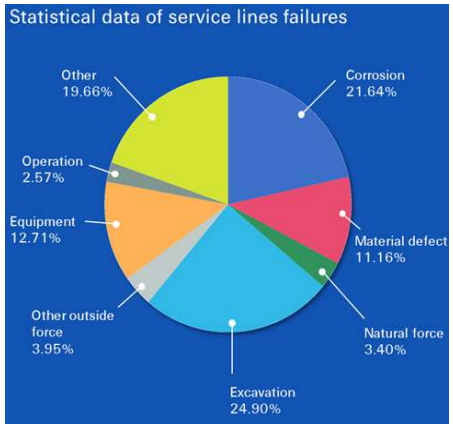
Infrastructure is the «heart»



- Almost consisting of steel pipelines
- Larger size with DN from 4-6 in up to 48 in
- Normal operating pressures in the range of 40-80 barg up to (in some cases) 140 barg
- Loss scenarios dominated by the rupture of the pipeline

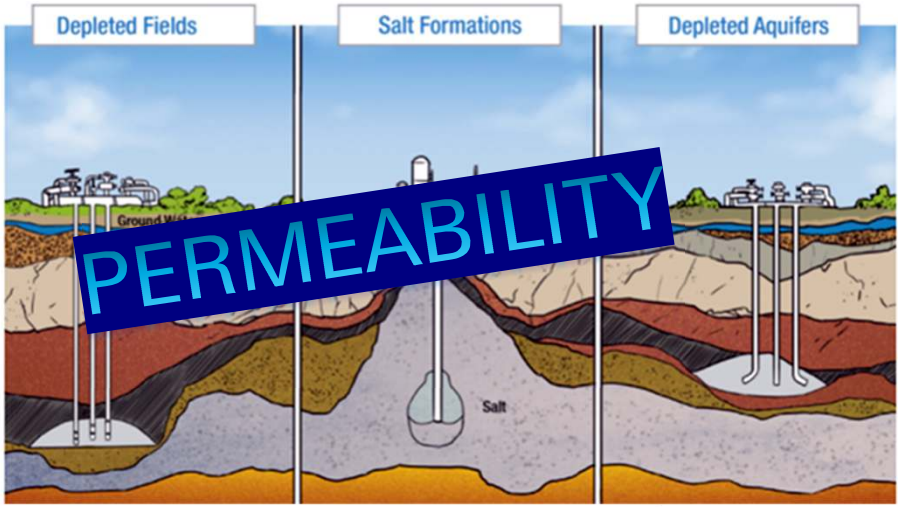


- Low alloy steel and polyethylene are the dominant materials
- Distribution and service lines are typically 1.5 – 4 in
- Normal operating pressures in the range of 1 - 5 barg up in some cases to 10 barg
- Distribution pipeline incidents typically result in leaks



Understanding the risks of Hydrogen

Hydrogen storage: risks against efficiency, security and resilience



Depleted reservoirs

Their imperviousness over geological time periods has already been proven and have already been very well researched (production activities). The suitability criteria include depth and adequate permeability and porosity of the reservoir rock.

- Seasonality
- Capacity

Salt caverns

Salt caverns are artificial cavities in underground salt formations, which are created by the controlled dissolution of rock salt. They are smaller and considered as one of the best ways to ensure hydrogen purity and tightness.

- Deliverability
- Cost per unit stored

Aquifers

Similar to depleted oil reservoirs in which originally there was a water-fille. Requirements: top sealed by a layer of rock, dome-shaped structure, high permeability with adequate pore space.

- Time to market
- Discharge duration

- Energy intensity
- Transportation

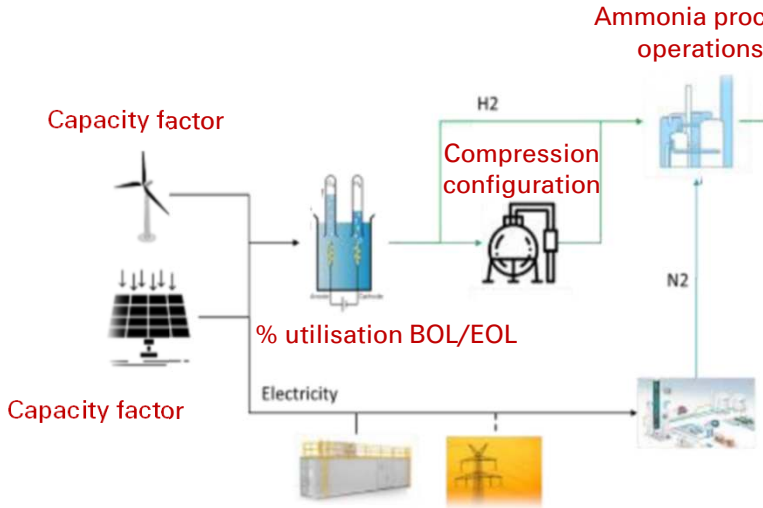
- Buoyancy
- Cooling down

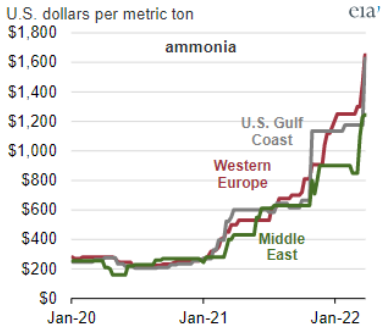
- Boil off
- Ignition mechanisms

Understanding the risks of Hydrogen

Business continuity & Mode of operations

Design Constraints





Understanding the risks of Hydrogen

Knowns and Unknowns

Known knowns	Known unknowns	Unknown unknowns
• Hydrogen production processes from fossils fuels (reforming and gasification) • Carbon capture & storage • Traditional electrolyzing technology • HP (up to 300 bar) storage	• Rotating equipment conversions and repurposing • Upscaling of capacity – R&D in new electrolyzing technology • Infrastructure retrofitting and high-high pressure storage (700 bar)	• Cryogenic hydrogen

“Leading in a new economy means patterning our future on the understanding and management of unknown risks. Acting knowingly is better than reacting boldly."

Massimo Giachino,
Manager Risk Engineering OPC

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Thank you!

Contact us

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