Hydrogen Transition

Aviation Firefighting awareness

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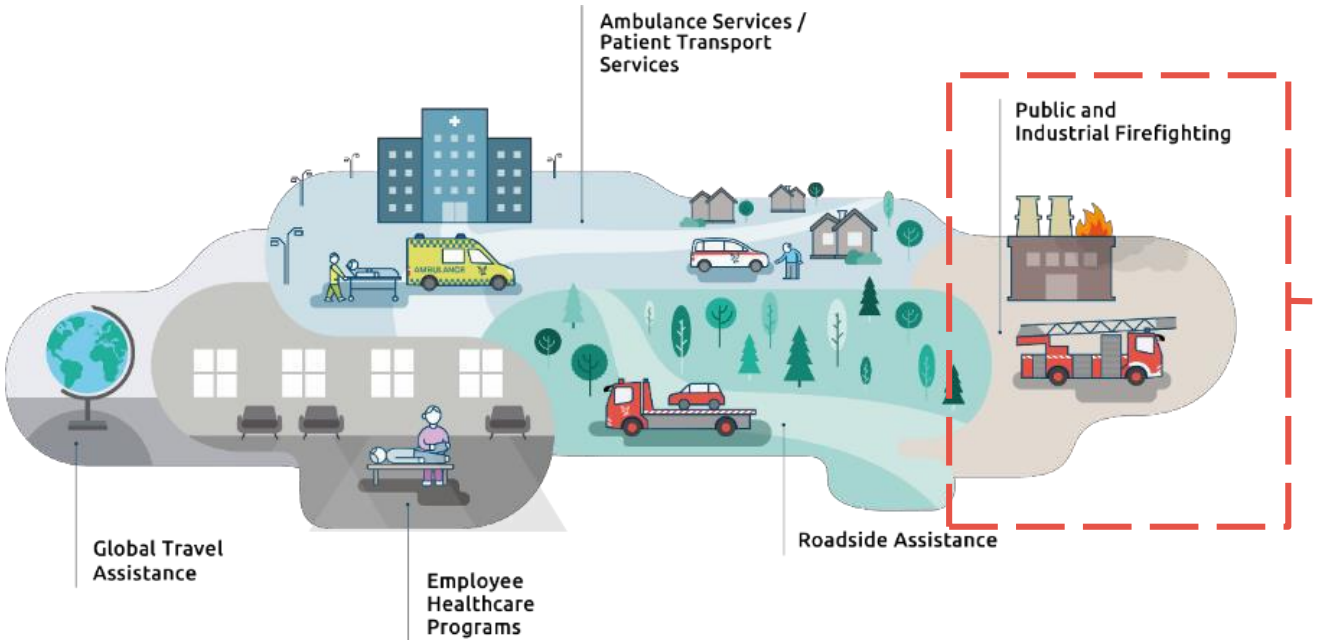
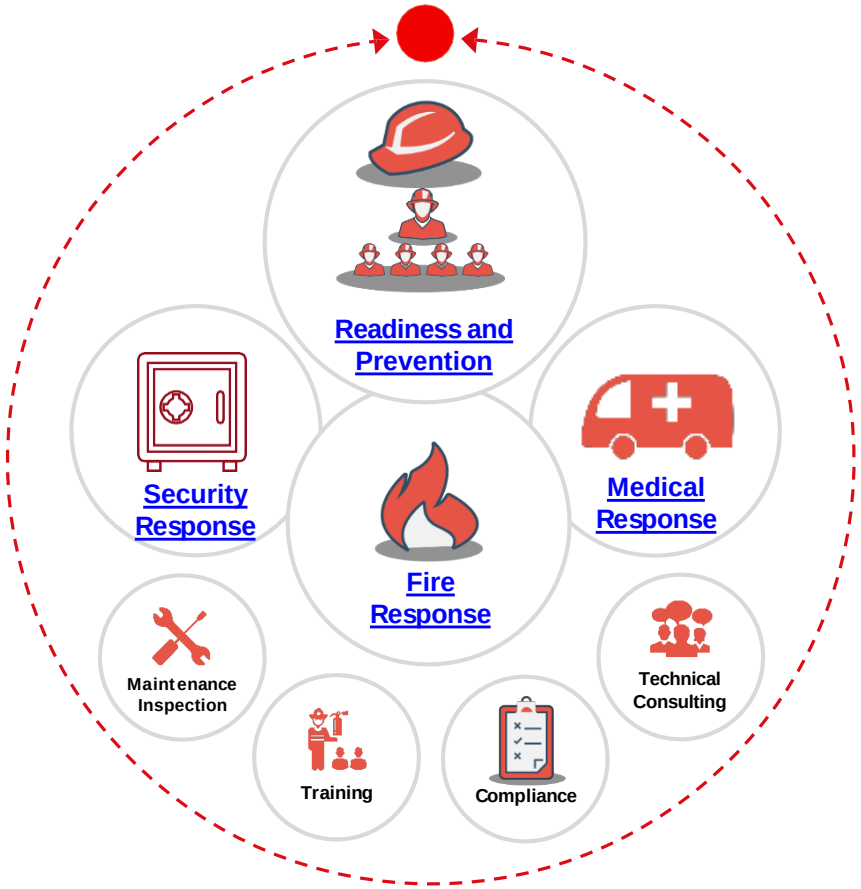
Our Services

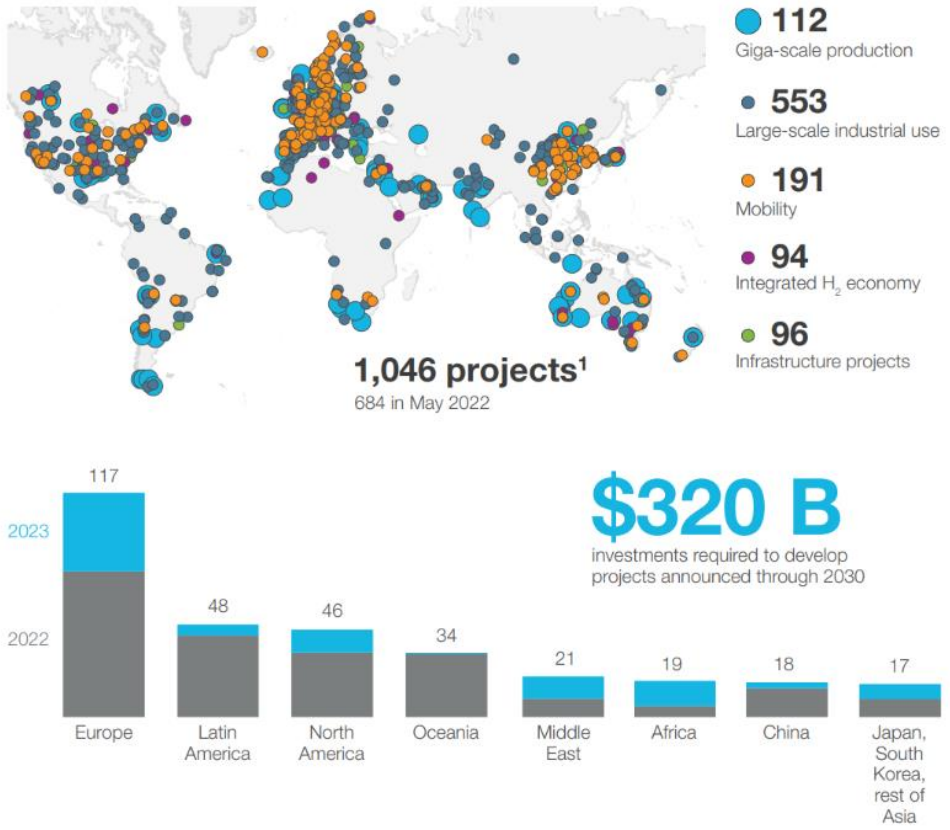




IFS Core Services

Prevention Services	Intervention Services	Rehabilitation Services
Emergency planning and testing	Aviation and Industrial Firefighting & Rescue	Infrastructure compliance tests and audits
Fire engineering and credible scenario development	Emergency Medical intervention	Equipment hire and maintenance
Review, design and training of Emergency Response	Short Term Resilience and Contingency Provision	After action data and response analysis

Hydrogen projects announced as of Jan 2023 until 2030



Source: Hydrogen insights
McKinsey & company

Different colours of hydrogen ways in which H2 is produced

- Green/clean — using renewable energy sources to split water into O2 and H2 using electrolysers
- Gray — burning fossil fuel to turn methane into hydrogen and carbon dioxide

  (CH4 + O2 -> 2 H2 + CO2)
- Blue — burning fossil fuel but capturing the CO2 in underground wells (low carbon hydrogen)
- Turquoise — mixture of blue and green hydrogen
- Pink or red — using nuclear energy to split water into O2 and H2

Current examples of H2 applications

- Hydrogen production and use as energy source in Rijnstate hospital (NL)
- Mass Hydrogen production plants such as those proposed by BP for Teesside cluster (UK)
- Hydrogen transport (pipeline network ready 2030)
- Hydrogen gas stations
- Hydrogen aggregates to supply backup power to data center
- Hydrogen powered (public) transport
  - Boats
  - Buses
  - Trucks

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What's hydrogen like?

- Hydrogen – H2
- It is colorless, odorless, tasteless, non-toxic, and highly combustible.
- Hydrogen is the most abundant chemical substance in the universe
- Broad flammability range: 4% to 75% by volume in air (5% to 95% by volume in chlorine gas)
- Videos show that hydrogen flames are visible at night/in the dark https://youtu.be/r-8H5u4YzuY

What’s hydrogen like?

- 1Kg of Hydrogen is roughly equal to 1 Gallon of diesel. 1Kg of Hydrogen cost £40 (liquid H)
- 5 litres of petrol has same energy density as 11 cubic meters of hydr
- For use in aircraft engines hydrogen will need to be 99.999% pure. measurement is known as “ 5 Nines”
- Target introduction into aviation operations 2035
- Hydrogen may not be as environmentally friendly as first thought bec it destroys hydroxide radicals in the upper atmosphere. Hydroxide radicals are important because they neutralise methane.
- Because a hydrogen flame is almost invisible in daylight, use of TIC’s essential when approaching a suspect hydrogen fire.
- Water must not be used near hydrogen storage tank pressure relief valves as water will freeze and block the valve.

Hydrogen risks for fire fighters

1. **Invisible flame**:

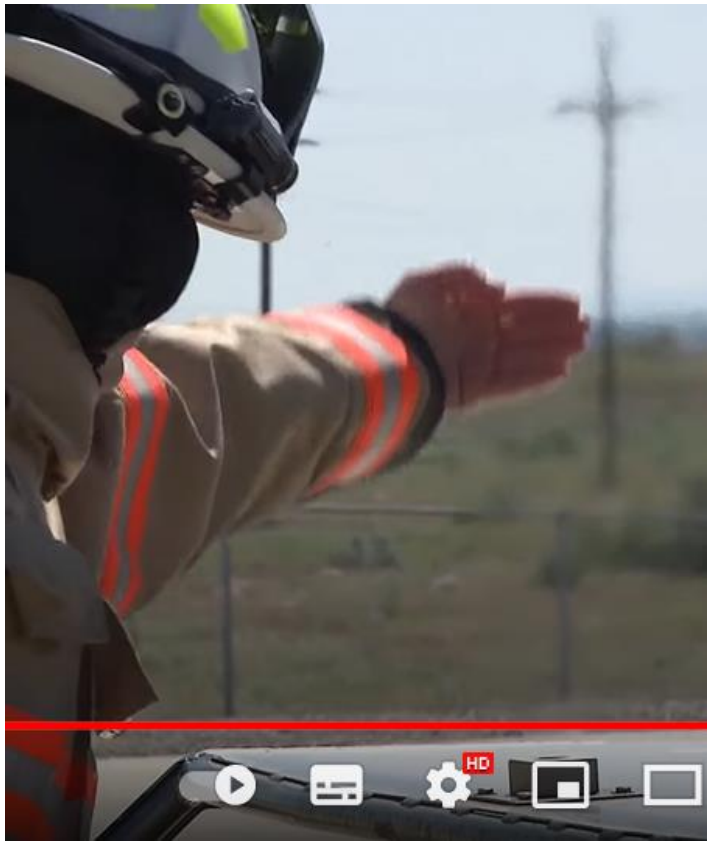
Hydrogen burns with a nearly invisible flame, which can make it difficult to visually detect fires. Firefighters should be aware of this and use thermal imaging cameras or other flame-detection technologies to identify and assess the extent of a hydrogen fire.

2. **High flame temperature**:

Hydrogen fires can have flame temperatures over 2000 degrees C, but have a low radiant heat, much less than with conventional fuels. This makes a hydrogen flame seem approachable

3. **Wide flammability range**:

Hydrogen's wide flammability range (4% to 75% by volume in air) increases the risk of fires and explosions. Firefighters should be aware that even small leaks can create a flammable mixture in a confined space.



Hydrogen risks for fire fighters

4. **Low ignition energy**:

Hydrogen has a very low ignition energy, meaning it can ignite easily with a small spark, static discharge, or even a hot surface.

5. **Extinguishing:**

Gas fires should be extinguished by closing the supply of gas instead of using water. Water on a hot fire will always cause steam and related hazards. Furthermore, due to the invisibility of the flame, there's no way of knowing where to aim a fire hose.

As with any gas fire, once you put out the flame, you still might have a source by means of a leaking pipe for example

Risk of reignition of a hydrogen gas fire is high, due to the low ignition energy.

Hydrogen risks for fire fighters

6. Burst pressure:

- Steel tanks have rupture disks so that the hydrogen is released before the pressure of the tank reaches burst level
- Composite cylinders have a thermally activated pressure relieve device (TPRD) which will melt open and release the entire content of the cylinder.

7. Buoyancy and ventilation:

- Due to its low density, hydrogen rises and disperses rapidly in air. This can cause hydrogen fires to spread vertically, making them difficult to extinguish. Firefighters should be aware of the importance of proper ventilation in controlling and extinguishing hydrogen fires.
- On the other hand, the rapid rising of hydrogen is used as a safety advantage in the application of PRV on hydrogen tube trailers.
- https://www.youtube.com/watch?v=3ChDyDLpnfw

Potential impact to Fire Services

- **Outside risks**
  - Vehicles
  - Aircraft
  - Passenger cars, busses, trucks
  - Transport of H2
  - (stacks of) cylinders, tube trailers
  - H2 gas stations
  - Underground H2 distribution pipelines
  - Stationary application of Energy storage and supply systems (H2ESS)
- **Inside / confined space risks**
  - (Industrial) buildings
  - Parking garages
  - Tunnels
  - Inside application of H2ESS
  - Internal transport of H2 operated vehicles such as forklifts

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Hydrogen cars

Emergency venting of H2 gas

1. If the temperature near the safety valve located at the rear under vehicle is over 110°C caused by a fire or other reasons, the safety valve will open to vent hydrogen gas. Venting the hydrogen gas makes a loud noise because the venting speed is very fast. Stay well away from the vehicle. This jet stream of hydrogen gas could ignite.

2. Do not attempt to extinguish a hydrogen gas fire. Allow the fire to burn until tanks are empty, about 5 minutes

Hydrogen venting position

Storage of H2 gas

The hydrogen storage system is comprised of two separate tanks that are interconnected and filled with hydrogen gas. The tanks contain hydrogen gas under high pressure. When the tanks are full the corresponding tank pressure is approximately 10,000 psi (700 bar, 70 MPa). Each tank is made of an aluminum inner liner wrapped in carbon fiber. Temperatures inside the tank can range from -40°C up to +85C [-40°F to 185°F]. A pressure regulator located near the front (smaller) tank in the vehicle reduces the line pressure to approximately 145 psi (10 bar, 1000 kPa)..

Hydrogen Transport

Composite or steel containers at pressures 165-420 bar

Hydrogen transition

Hydrogen Storage

Emergency response Do's and Don'ts

A. In case of fire, first establish what type of trailer it is

B. Establish presence of leaks using suitable measuring devices and thermal imaging camera

C. Do not use water on vents or Pressure Relief Devices:

- The water might freeze on cryogenic containers
- Prevents the hydrogen from safe release.

D. Cooling with water only when you can effectively reach the entire container while avoiding vents and PRD

E. Otherwise protect surroundings and let PRD and vents function

F. When hydrogen is already venting:

- Safest option is to let the hydrogen burn off

The future of airport firefighting in a hydrogen infrastructure

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What might change?

Cue	What may change with hydrogen aircraft?	What may remain the same?
Smoke	**Hydrogen fires do not produce the large volumes of black** smoke produced by the carbon content of hydrocarbon fuels like kerosene.	Smoke will still be produced by combustible materials on the aircraft or the aircraft itself.
Fuel	**Hydrogen cannot be seen and is buoyant** unlike kerosene fuels. Sources of hydrogen are likely to be under pressure and as such, new technology may be required to identify temperature differentials that would indicate that hydrogen is present. Explosive atmospheres may also be produced by concentrations of hydrogen gas representing new threats and different management techniques.	Fuel will still present a key fire risk and threat to life.
Fire	Hydrocarbon fuels burn in a visible and well-known way. No such assumptions can be made with hydrogen. **Hydrogen may dissipate rapidly prior to combustion** or indeed be manually released by the aircrew in response to a predicted crash-landing. Hydrogen fires do not burn with a visible flame and so more use of FLIR technology may be needed.	Fire will still present a key risk and threat to life. Fire will still be sustained by combustible materials on the aircraft or the aircraft itself.
PPE Requirements	As hydrogen has a very low minimum ignition energy and is easily ignited, **anti-static and fire-retardant PPE** will be required when responding to hydrogen incidents. This could include; - Cryogenic eye protection - Gloves - Boots and anti-static overalls	Risks that include fire, falling objects, heights, un-survivable environments will still be present in the fire service role. PPE will still need to mitigate these risks and protect crew.
Technology	It is likely that **greater use will be made of imaging technology** for both lower and higher temperatures to detect hydrogen leaks and fire.	The fire service currently use thermal imaging technology to assess risk.

Falck H2 Training facility

PPE awareness

ZEROe Hydrogen combustion demonstrator

A380 multimodal test platform with its capacity to store large hydrogen tanks

Hydrogen combustion engine located along the rear fuselage

4 liquid hydrogen tanks stored in a caudal position

Liquid hydrogen distribution system

AIRBUS

Beyond the airport fire service

- Fuelling procedures
- Aircraft design and evacuation
- Airport fuel farms
- Airport stand design
- Fire warning systems and airport evacuation procedures

Conclusions

- Hydrogen is a viable fuel for sustainable aviation
- Airport fire services represent a key mitigation for hazards associated with fuel and fuel systems
- The fire service training, knowledge and expertise is focused on hydrocarbon fuels in line with their properties and hazards.
- To achieve hydrogen fuelled operations by 2035, this will need to change: new procedures and equipment are needed to maintain high levels of safety.
- The future is ragged and dirty – We find it likely that hydrocarbon fuelled, electrical propulsion and hydrogen will need to co-exist.

Any questions