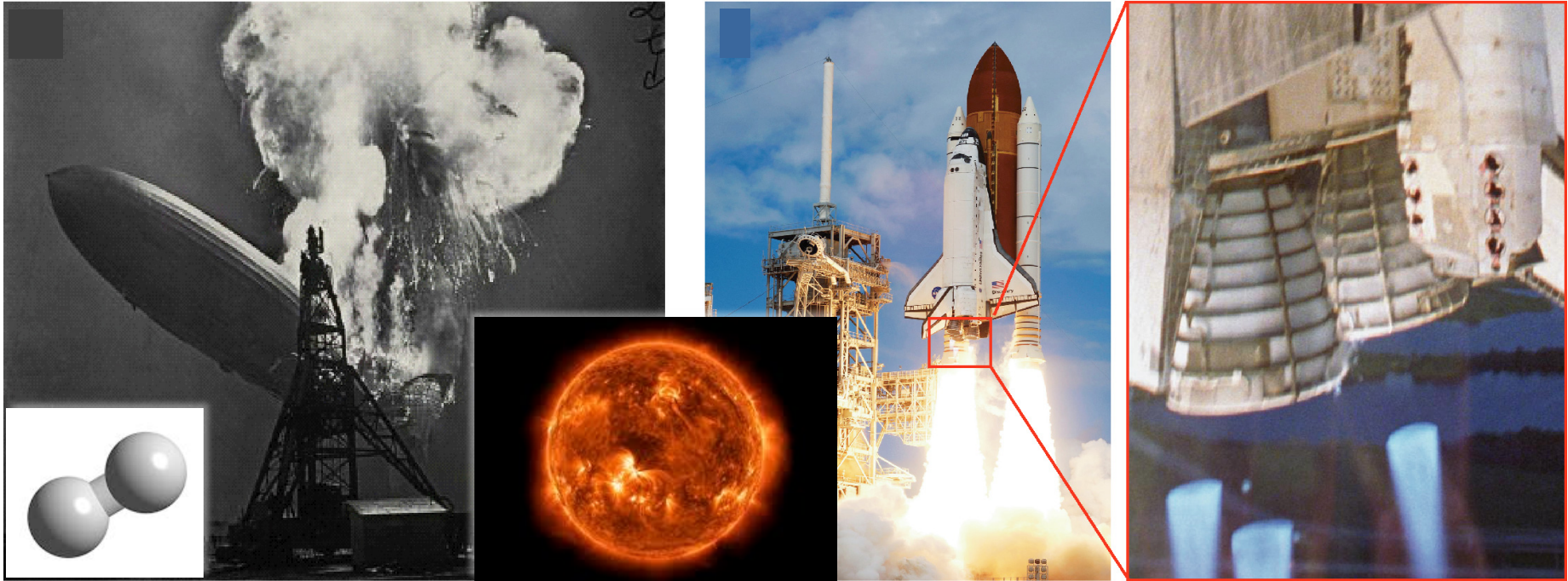


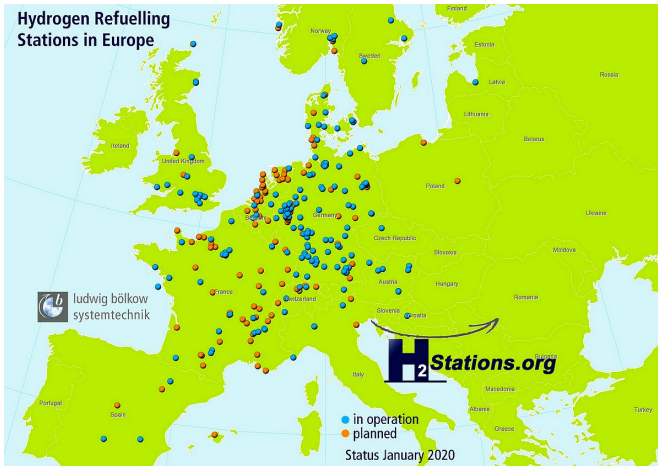


# What do we know about hydrogen?

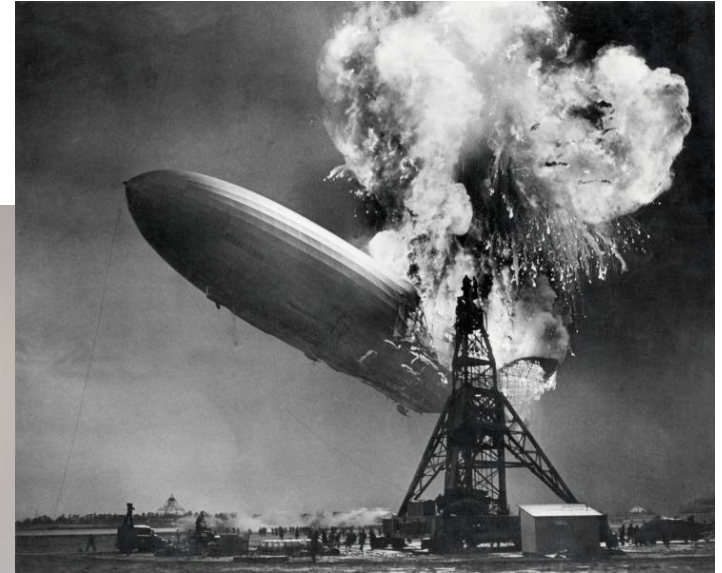


- Molecular form is  $H_2$
- Most abundant element in the universe
- Lightest element in the universe, fueling nuclear fusion in stars
- On earth hydrogen is bound mostly in C-H chemical bonds
- Generally known that  $H_2$  is highly explosive when mixed with air - “knallgas”
- Rocket fuel with high energy density

# Why we need to sense it!



TOYOTA  
FCV



- Hydrogen fuel will soon be omnipresent?!
- Leaks must be detected timely!

# A recent concrete reminder from Norway

**HYDROGEN STATION EXPLODES, TOYOTA HALTS SALES OF FUEL CELL CARS — IS THIS THE END?**

Date: 12/06/19 | Electrek

**A hydrogen refueling station exploded in Norway on Monday and the company operating the station has suspended operation at its other locations following the explosion.**



<https://www.netzerowatch.com>

# Hydrogen vs. Methane vs. Petrol

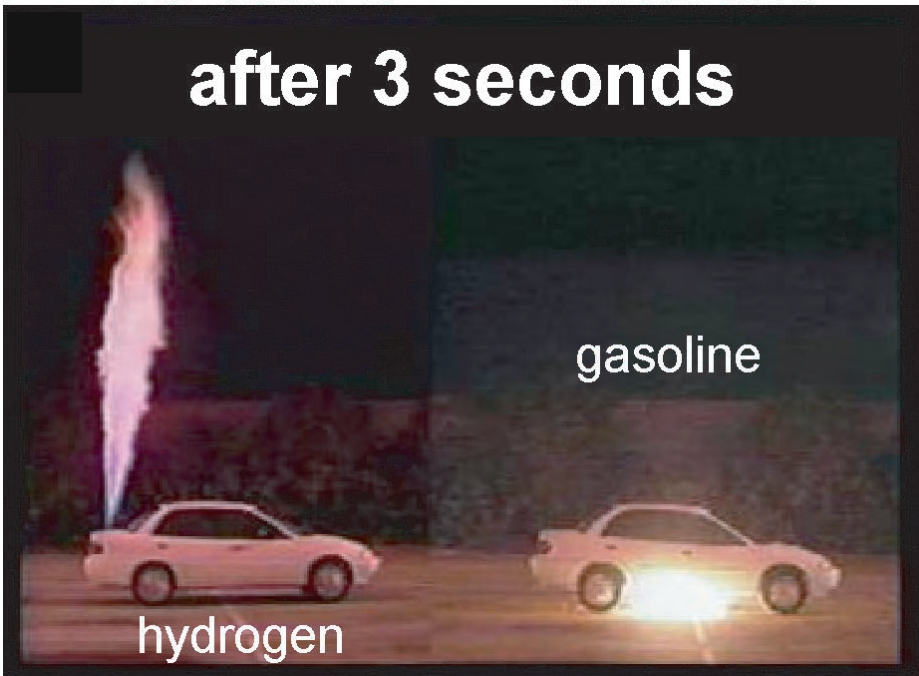
**Table 1 Physical and chemical properties of hydrogen, methane and petrol**

Properties	Hydrogen (H <sub>2</sub> )	Methane (CH <sub>4</sub> )	Petrol (-CH <sub>2</sub> -)
Lower heating value (kWh kg <sup>-1</sup> )	33.33	13.9	12.4
Self-ignition temperature (°C)	585	540	228–501
Flame temperature (°C)	2,045	1875	2,200
Ignition limits in air (Vol%)	4–75	5.3–15	1.0–7.6
Minimal ignition energy (mW s)	0.02	0.29	0.24
Flame propagation in air (m s <sup>-1</sup> )	2.65	0.4	0.4
Diffusion coefficient in air (cm <sup>2</sup> s <sup>-1</sup> )	0.61	0.16	0.05
Toxicity	No	No	High

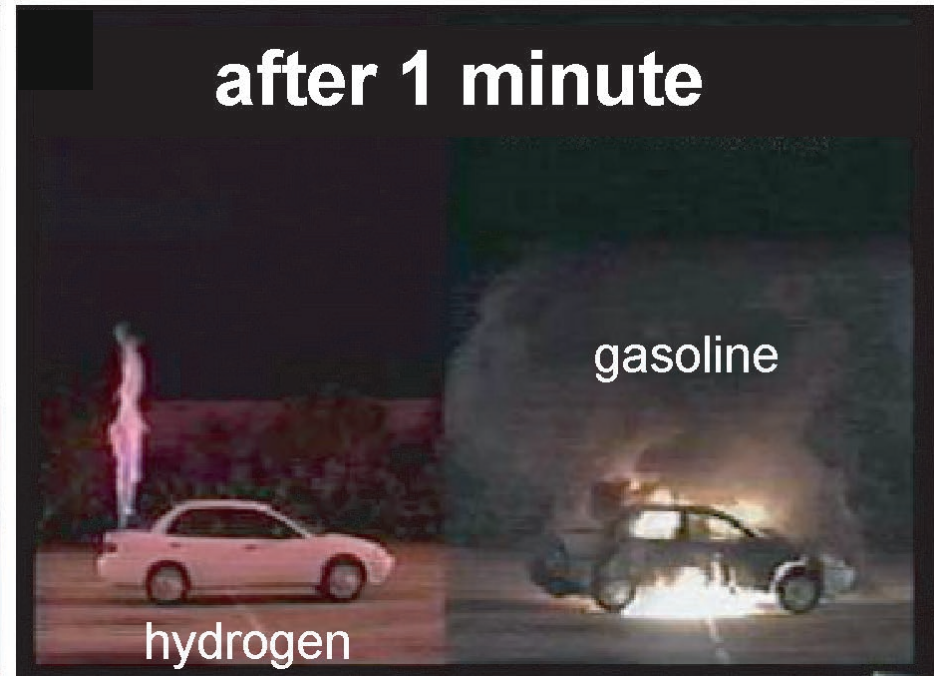
All in all, hydrogen compares quite OK.

# Storing Hydrogen in a Pressure Tank...

after 3 seconds



after 1 minute



...is connected to inherent safety concerns  
but not by default much worse than gasoline.

# US DoE H<sub>2</sub> Sensor Performance Targets



**> 15 H<sub>2</sub> sensors!**

Parameters	Stationary	Automotive
Measuring Range	Up to 4 vol. % H <sub>2</sub>	Up to 4 vol. % H <sub>2</sub>
Lower Detection Limit	< 0.1 vol %	< 0.1 vol %
Response Time (t <sub>90</sub> )	< 30 s	< 1 s
Accuracy	± 10 %	± 5 %
Ambient Temperature	-20 to +50 °C	-40 to +125 °C
Ambient Pressure	80-110 kPa	62-107 kPa
Ambient Humidity	20-80 %	0-100 %



**Current solutions don't meet targets. New solutions needed!**

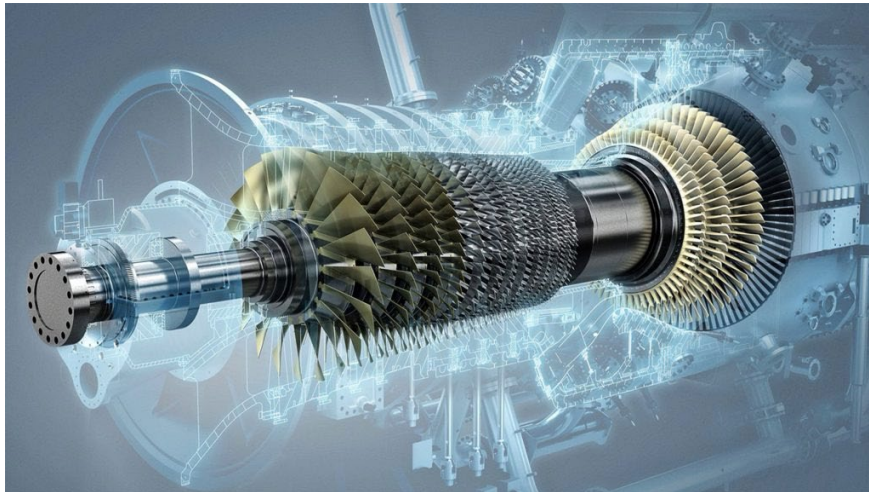
# But not only for leaks...



Monitoring fuel cell operation



Process monitoring in (hydrogen) chemical industry



Monitoring hydrogen powered gas turbines



Medical diagnostics



# ... and not only in cars!



# Beyond safety – is hydrogen a climate gas?!

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Home / News / Energy & Environment / Energy / Scientists warn against global warming effect of hydrogen leaks

## Scientists warn against global warming effect of hydrogen leaks

By Nikolaus J. Kurmayer | EURACTIV.com

📅 14 Oct 2021 (updated: 📅 19 Oct 2021)

### Supporters



The global warming potential of hydrogen and the impact of leaks may imperil climate goals like the 1.5° target. EPA-EFE/FRIEDEMANN VOGEL

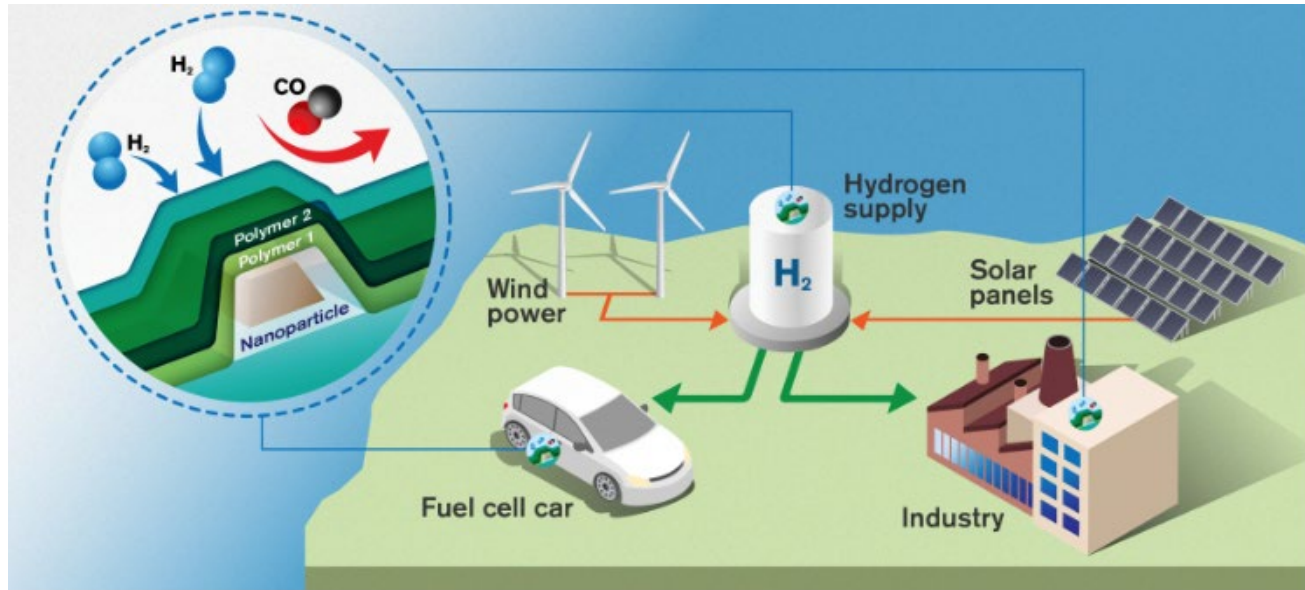
Languages: Français

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Scientists have warned that hydrogen could be a significant "indirect" contributor to the greenhouse effect when it leaks through infrastructure and interacts with methane in the atmosphere.

Yet another reason to minimize leaks and detect them early and fast!

Utan vätgassensorer inga  
vätgasteknologier!!!



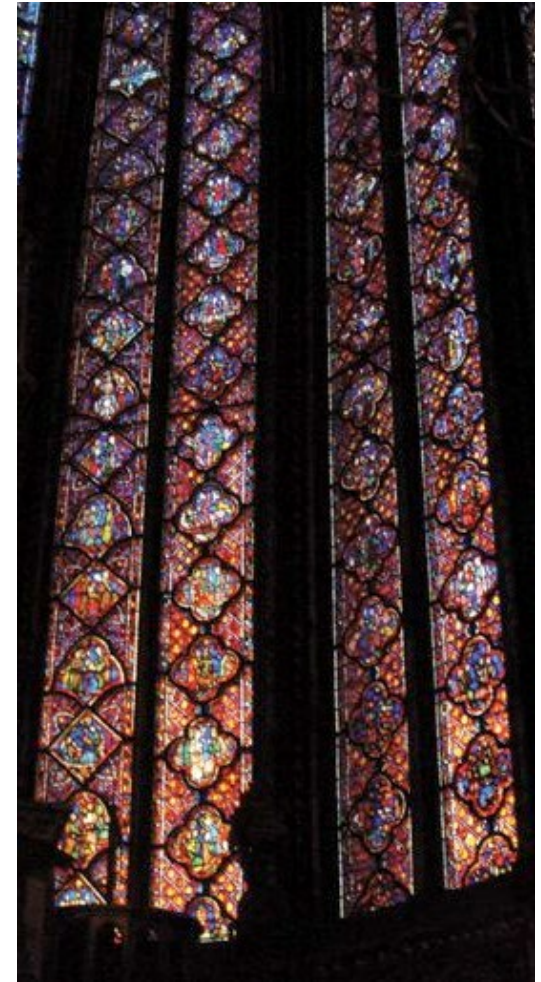
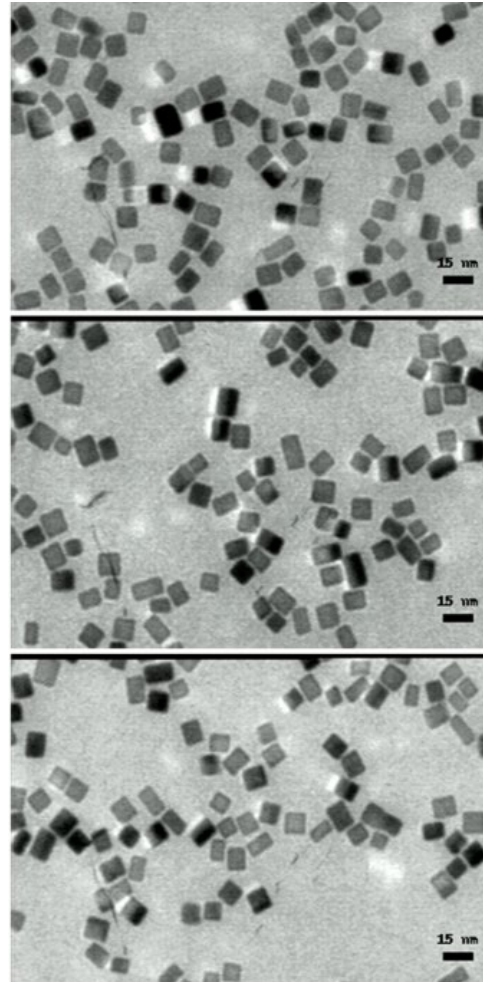
Fast and accurate sensors are crucial in a sustainable society where hydrogen is an energy carrier. Hydrogen gas is produced by splitting water with the help of electricity that has been produced with wind power or solar cells. The sensors are needed both when the hydrogen is produced and when it is used, for example in cars powered by a fuel cell. To avoid the formation of flammable and explosive "knallgas" when hydrogen is mixed with air, the hydrogen sensors need to be able to quickly detect leaks.

Illustration: Yen Strandqvist

## World's fastest hydrogen sensor could pave the way for clean energy

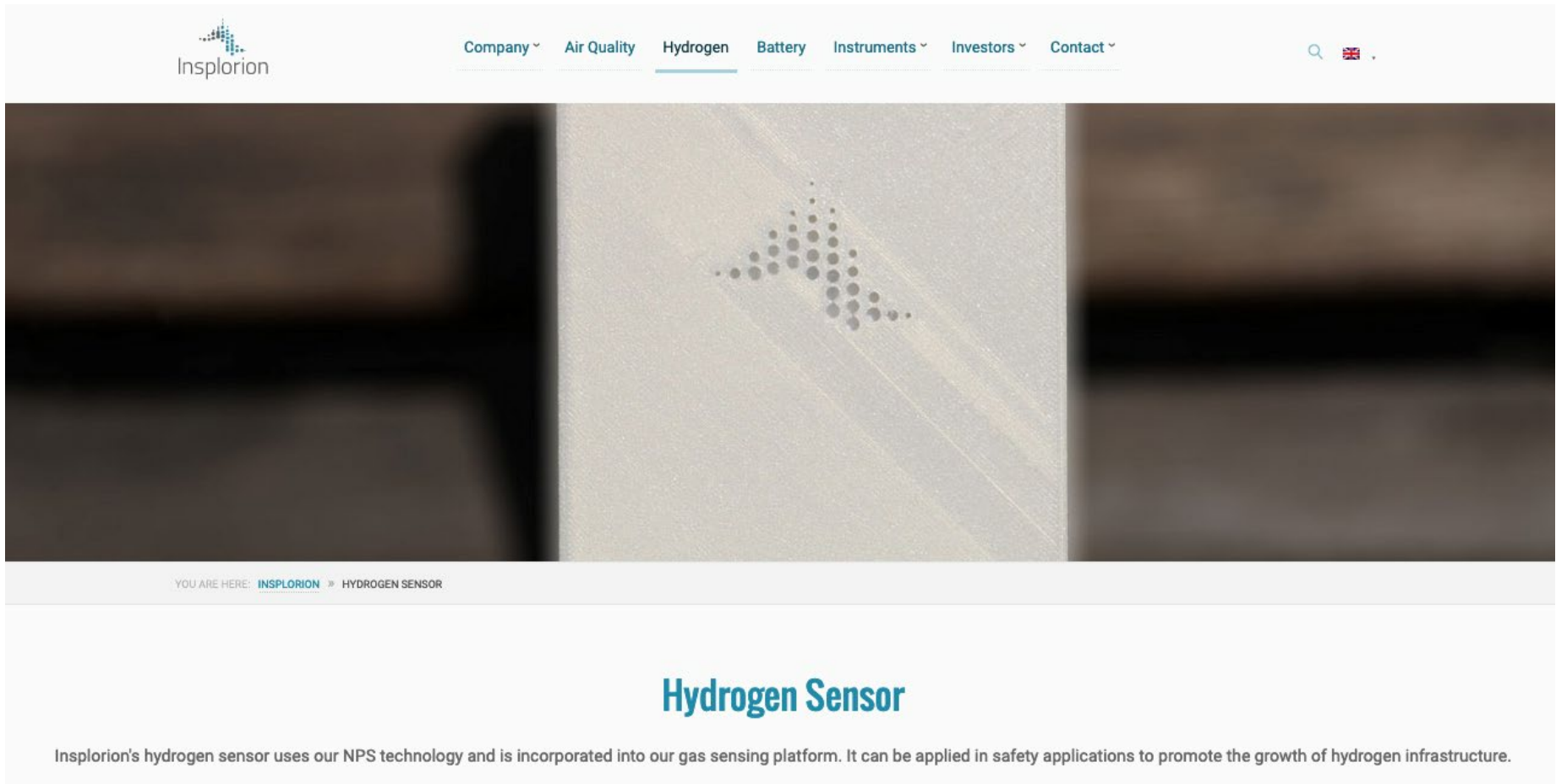
Hydrogen is a clean and renewable energy carrier that can power vehicles, with water as the only emission. Unfortunately, hydrogen gas is highly flammable when mixed with air, so very efficient and effective sensors are needed. Now, researchers from Chalmers University of Technology, Sweden, present the first hydrogen sensors ever to meet the future performance targets for use in hydrogen powered vehicles.

# So, how do we do it?

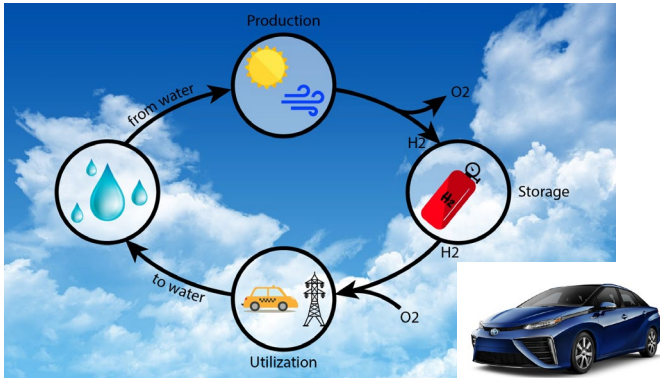


**Use a solution from Roman and Medieval times - metal nanoparticles and light!**

# Bringing this technology to the market



# To summarize....



- When the hydrogen economy is reality, H<sub>2</sub> will be present in our daily lives.
- H<sub>2</sub> is prone to leak because it is small.
- H<sub>2</sub> may become a negative climate gas in the atmosphere if too much leaks.

- Hydrogen-air mixtures are very flammable.
- Hydrogen leaks must be detected timely.
- Monitoring hydrogen along the entire value chain is important.

