

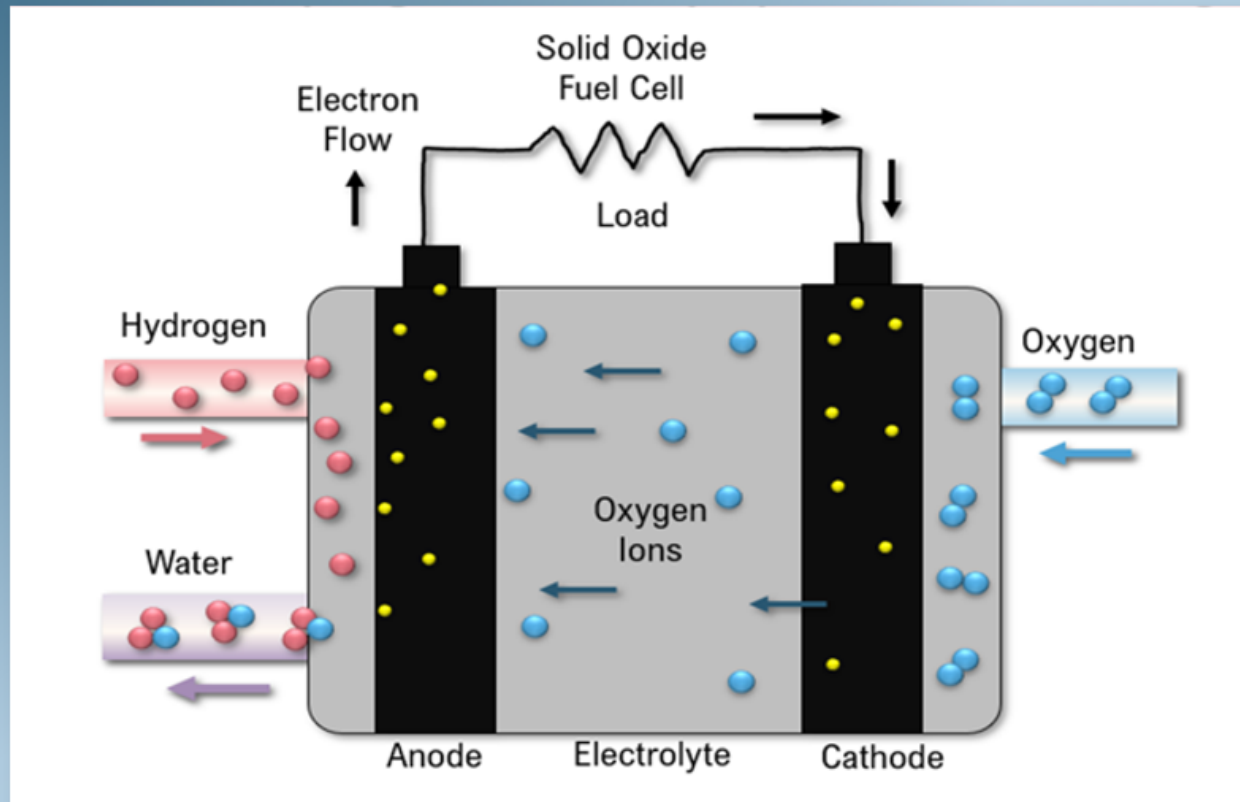
Recent Advances in Fuel Cell Applications

FOCUS ON HYDROGEN ECONOMY

- Overview of Fuel Cell Types and Properties
- Industry Applications
- Current Research



FUEL CELL OPERATION



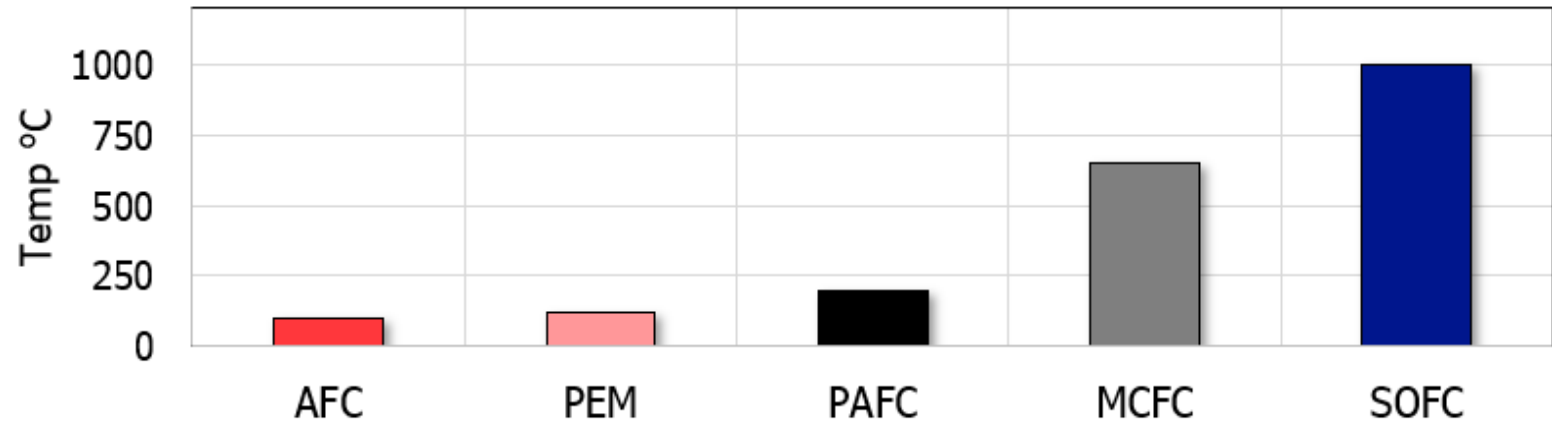
Hydrogen Economy Challenge:
find low-cost, efficient and non-polluting ways to
generate, store, and distribute a hydrogen supply



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Fuel Cell Operating Temperature by Type



	AFC	PEM	PAFC	MCFC	SOFC
Electrolyte	Liquid	Solid	Liquid	Liquid	Solid
Fuel Cell Type	Alkaline Potassium Hydroxide	Polymer Electrolyte Membrane	Phosphoric Acid	Molten Carbonate	Solid Oxide
Applications	Military and Space	Portable Power	Distributed Generation	Stationary Power Generation	Auxiliary Power

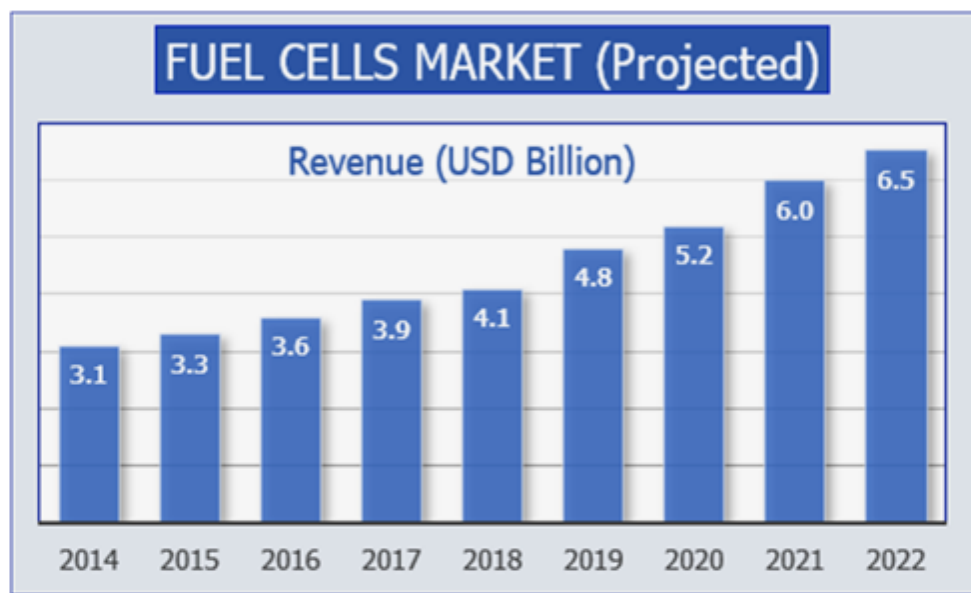


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FUEL CELL MARKET AND APPLICATIONS

- Limited success in commercial markets due to more fully developed and well-established technologies.



- Specialty applications growing where electric grid is unstable or unavailable.
- With substantial government investment there has been important advances into industrial applications.

INDUSTRY APPLICATIONS OF HYDROGEN FUEL CELLS

WAREHOUSE LOGISTICS— clean trucks, forklifts, pallet jacks



<http://www.grahamsherwinstudio.com/innovation/hydrogen/>

GLOBAL DISTRIBUTION— long-haul and local distribution semi-trucks and vans (Toyota, Kenworth, and UPS)



<https://fleetimages.bobitstudios.com>



<https://gmauthority.com/blog>

INDUSTRY APPLICATIONS OF HYDROGEN FUEL CELLS

TRAINS— fuel cell trains in Germany & planned for United States, Great Britain, France, Italy, Japan, South Korea



<https://www.alstom.com/press-releases-news/2019/>

BUSES— fuel cell buses in Orange County, Champaign-Urbana, Vancouver, London, Beijing



<https://www.sustainable-bus.com/news/new-flyer-xcelsior>



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INDUSTRY APPLICATIONS OF HYDROGEN FUEL CELLS

PERSONAL VEHICLES— Hydrogen Fuel Cell Electric Vehicles (HFCEVs) models include the Toyota Mirai, Honda Clarity, Hyundai Nexo, and BMW i Hydrogen Next.



BMW i Hydrogen Next
<https://www.designnews.com/>



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INDUSTRY APPLICATIONS OF HYDROGEN FUEL CELLS

BACKUP POWER GENERATION
uninterruptible power supply (UPS)
systems, hospitals and data centers



<https://energy.sandia.gov/wp-content/uploads/>

MOBILE POWER GENERATION
NASA to provide electricity for rockets and
shuttles in space



https://www.nasa.gov/centers/glenn/technology/fuel_cells.html



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INDUSTRY APPLICATIONS OF HYDROGEN FUEL CELLS

BOATS AND SUBMARINES—long range, silent cruising, and low exhaust heat



Hydrogen fuel cell Ferry for
the San Francisco Bay

<https://cdn.arstechnica.net>



German ThyssenKrupp Marine
Systems has developed
4th generation fuel cell system
with metal hydride cylinder

<https://www.navaltoday.com/2019/09/09>



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CURRENT RESEARCH WITH HYDROGEN FUEL CELLS

UNMANNED AERIAL VEHICLES (UAVS) — From package delivery to scientific research to search and rescue operations



Advantages of Fuel Cells in Drones:

- Low Vibrations & Quiet Operation
- Fast & Easy Fuel Canister Replacement (compared to battery recharging)
- Longer Flight Times & Lower Maintenance

<http://uasmagazine.com/articles/>

PLANES— aerospace designs



Students from Technical University of Delft, Netherlands are designing a manned aircraft with liquid hydrogen at -253°C in a tank with 20 cm thick insulation.

<https://fuelcellsworks.com/news>



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Aerospace and ECE at UIUC Center for Cryogenic High-Efficiency Electrical Technologies for Aircraft (CHEETA)



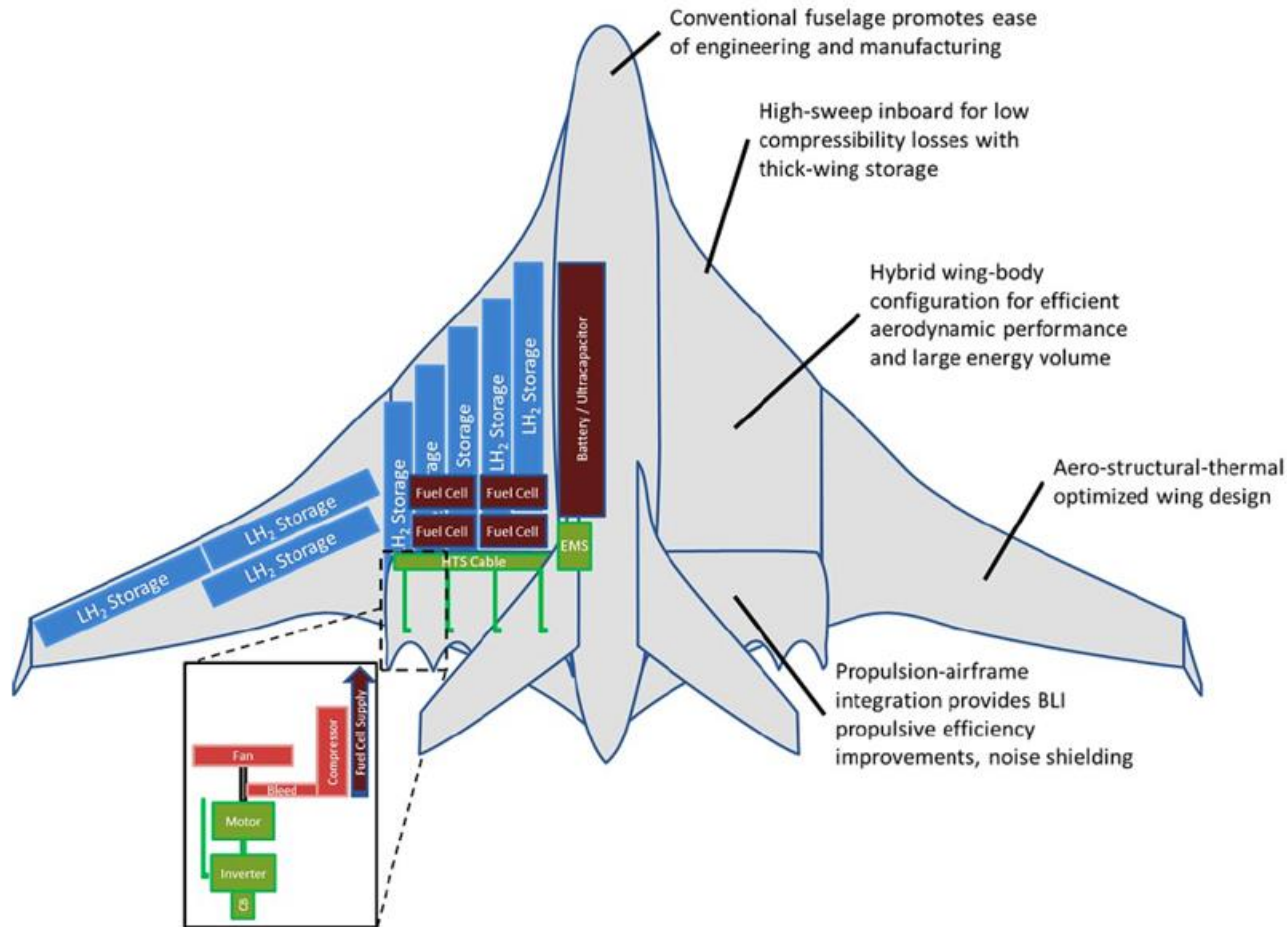
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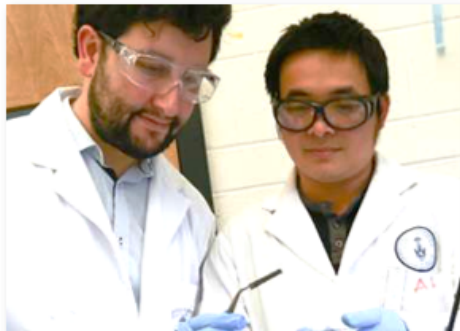
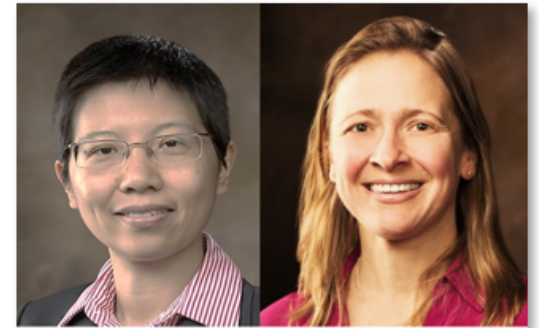


ELECTROLYSIS BREAKTHROUGHS



Dr. Alexandr Simonov from the Monash School of Chemistry: Because all metals dissolve during electrolysis, the researchers developed an electrode surface where the *dissolved material* could be **redeposited** on the electrode during operation. (11)

University of Arkansas researchers Jingyi Chen, and Lauren Greenlee: **nanoparticles** an iron and nickel shell around a nickel core are applied, they interact with the hydrogen and oxygen atoms to weaken the bonds, increasing the efficiency of the reaction by allowing the generation of oxygen more easily. (12)



Drs Cao-Thang Dinh, Pelayo Garcia De Arquer and Ankit Jain: a new **catalyst** made from copper, nickel and chromium, which are all more abundant and less costly than platinum and performs well under pH-neutral conditions. (13)



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THE HYDROGEN ECONOMY CHALLENGES

REFUELING INFRASTRUCTURE

1. Initially focusing on applications that are less dependent on the number of hydrogen refueling stations
 - Trains, commercial fuel cell electric buses and trucks
2. Ideal locations to conform to use and minimize construction costs
 - Bus depots, Train stations, Truck Stops



<https://calenergycommission.blogspot.com/2016/03/first-hydrogen-refueling-station-in.html>

THE HYDROGEN ECONOMY CHALLENGES

PRODUCTION AND STORAGE SAFETY



Faulty piston caused explosion at Wacker's U.S. polysilicon plant



6:34 51°
Flammable Hydrogen Explodes on Truck

DIAMOND BAR



PLEASE USE #CBSLA IN YOUR POSTS I-210 W/B: ACCIDENT AT EXIT 3 POLK ST



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THE HYDROGEN ECONOMY CHALLENGES

PRODUCTION AND STORAGE SAFETY



Hydrogen Refueling Station in Norway Exploded



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THE HYDROGEN ECONOMY CHALLENGES

PRODUCTION AND STORAGE SAFETY



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<https://www.fchea.org/regulations-codes-standards>

Hydrogen/Fuel Cell Codes & Standards



Home	Stationary F/C	H2 & F/C Vehicle	Portable & Micro F/C	H2 Infrastructure	Misc	North America	International	Europe	Pacific Rim	So. America / Africa / Australia
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This website tracks the world-wide development of about 400 hydrogen and fuel cell standards, and its matrix can be searched, using the TABS above, by the following applications or geographic areas:

[Stationary Fuel Cells](#)

[Hydrogen & Fuel Cell Vehicles](#)

[Portable & Micro Fuel Cells](#)

[H2 Infrastructure](#)

[Misc.](#) (Forklift Trucks, Aviation, Marine & Bicycle Applications, Other Fuels and Definitions)

[International](#)

[North America](#)

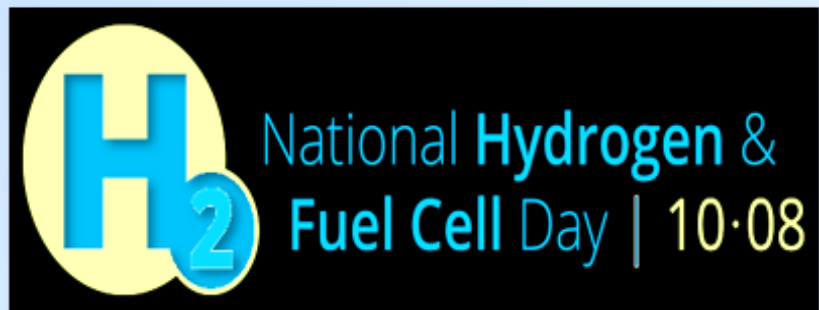
[Europe](#)

[Pacific Rim](#)

[South America /Africa / Australia](#)

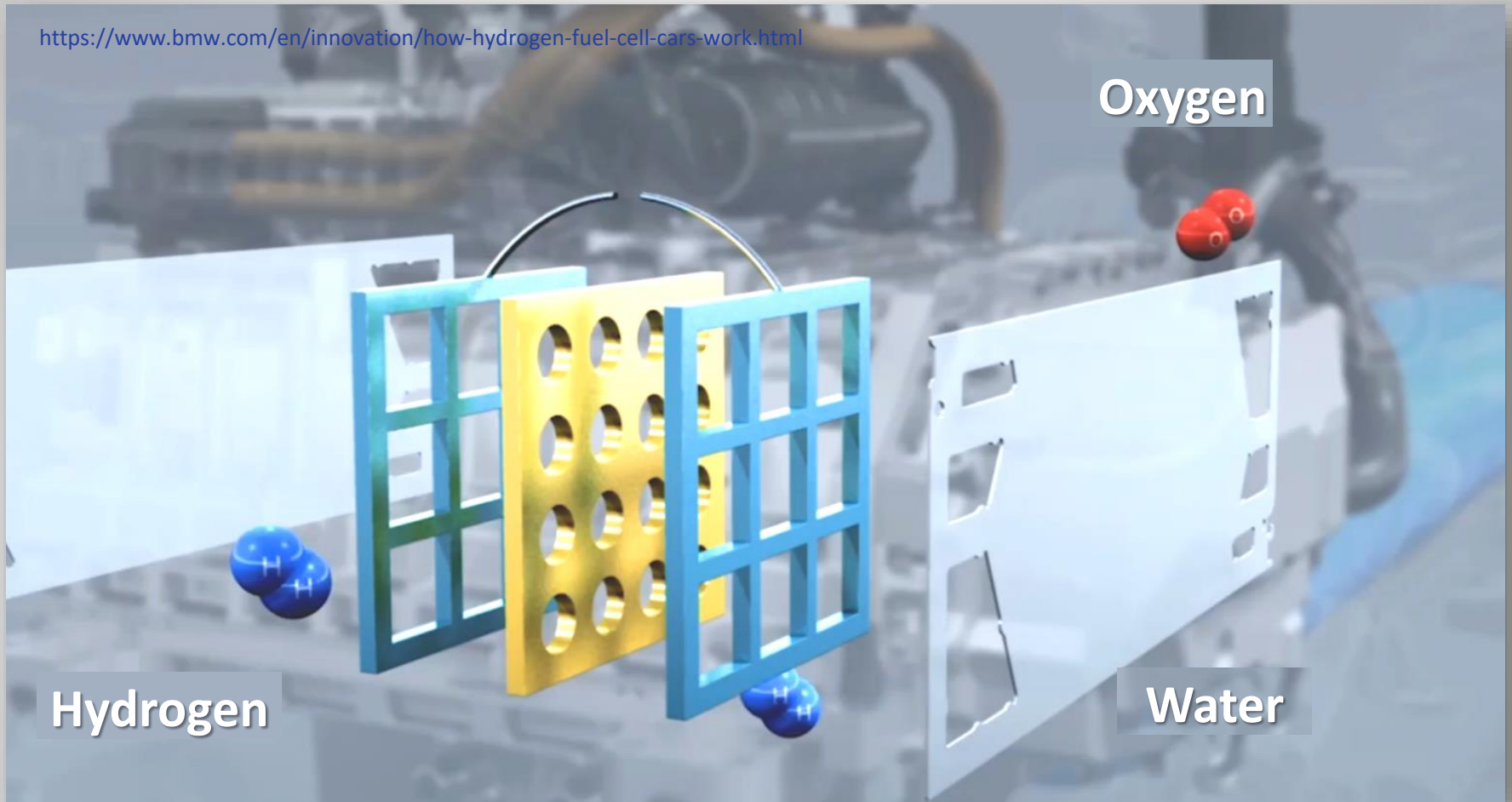
Detailed information for each standard is provided.

Comments can be addressed to: editor@fuelcellstandards.com



Atomic Weight of Hydrogen 1.008

<https://www.bmw.com/en/innovation/how-hydrogen-fuel-cell-cars-work.html>



THANK YOU for WATCHING!
Yolonda Newman



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- (11) <https://phys.org/news/2019-09-electrolysis-breakthrough-hydrogen-conundrum.html>
- (12) <https://phys.org/news/2019-03-cost-effective-method-hydrogen-fuel-production.html>
- (13) <https://techxplore.com/news/2018-12-low-cost-catalyst-boosts-hydrogen-production.html>
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