Hydrogen Power for Monorail?

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Market trends

Why monorail?

Urbanisation and congestion

- Increasing need for mass transit systems
- Space/land resources becoming scarce
- 24/7 Operation

Automation and digital solutions

- More automation, less manual work
- Big data collection and analysis
- Virtual reality
- Artificial intelligence

Comfort

- Seamless and integrated transport connections
- Physical and digital passenger amenities available

Environmental awareness

- Carbon neutral, emission-free transport
- Higher efficiency and less energy consumption

Value for money

- Life cycle cost optimization
- New revenue possibilities

Safety / cyber security

- Increasing safety and security levels
- High availability

Monorail propulsion

Self-powered monorail?

Monorail systems typically operate with 3rd rail electricity

- Close to urban area with good power supply and distribution (PS&D) system
- Use of existing power collector and power rail
- Proprietary track (closed network)

Some niche manufacturers offer battery/self-powered vehicles

- Direct storage of recuperation energy with minimal losses
- Less dependent from availability from traction power station (TPS)
- Cost savings by not using TPS, PS&D, simplified SCADA
- Cost off-set by charging stations

The Metrail Monorail train has something that most monorails don't, a fuel cap and diesel engine! Frazer-Nash has found a way for smaller cities to build monorails without investing an extraordinary amount of money: the Hybrid-powered monorail.

https://www.monorails.org/tMspages/Metrail1.html

The Poços de Caldas Monorail was a monorail system that served the city of Poços de Caldas in the state of Minas Gerais, Brazil. Privately owned, the single elevated line connected the bus station to the centre of the city, a total of 6 km (3.7 mi) and 11 stations.

https://en.wikipedia.org/wiki/Po%C3%A7os_de_Caldas_Monorail#/media/File:Monotrilho_de_Po%C3%A7os_de_Caldas.jpg

Self-Powered Monorail

Niche, potential to fit integrated solutions

Future connected cities

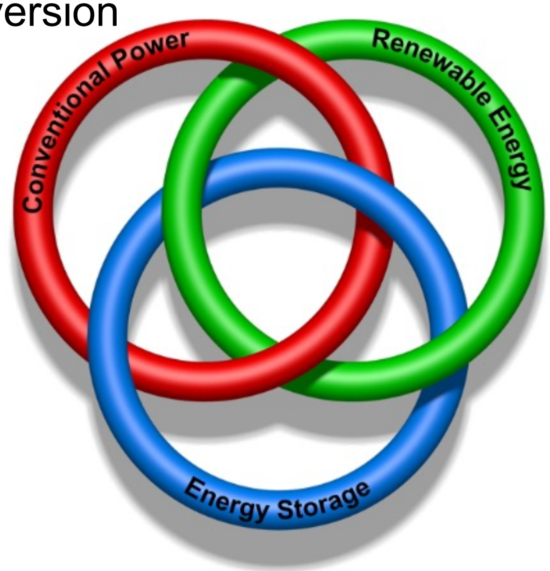
- Localised energy hubs
- Integrated transport systems and modes
- Hydrogen & battery buses
- Private taxis & delivery fleets

Energy Systems

- Electricity / Batteries
- Hydrogen
- Biogas / biofuels
- Mechanical (flywheels, etc)
- Cryogenics

Integrated local renewables

- Wayside energy storage
- Localised generation & conversion



Why Hydrogen?

A flexible energy vector

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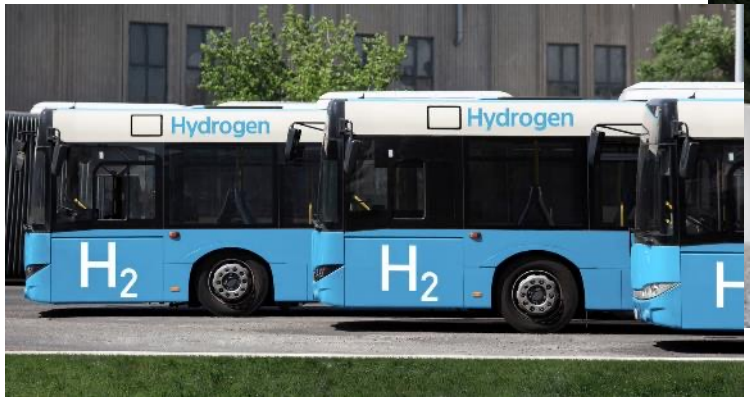
Global hydrogen economy being developed for core future transport systems

- Long distance/high energy consumption applications (rail, heavy duty trucks, bus/coach, aviation, marine)
- Centralised hydrogen hubs with range of modes likely
- Monorail may be link to de-centralised hubs – airports, ports, out of town destinations
    - Likely to have other hydrogen users



Hydrogen Options

Fuel cells, combustion engines

Fuel Cells (H2FC)

- Generate electricity directly
- Quiet
- “zero” emissions (only H_2O)
- Good efficiency quoted

Technology still immature for rail applications

Combustion Engines (H2ICE)

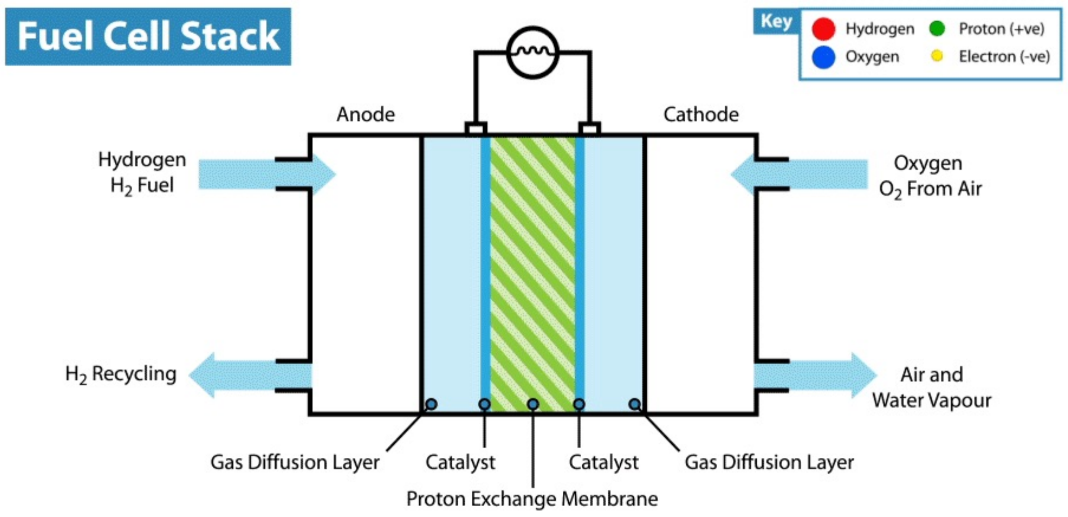
- Stable, known technology
- Tolerant of fuel quality
- Robust to poor air quality
- Durable & reliable

Growing interest across commercial power sectors

H2FC: Hydrogen Fuel Cell
H2ICE: Hydrogen Internal Combustion Engine

How do these systems work?

H2FC and H2ICE – what's the difference?

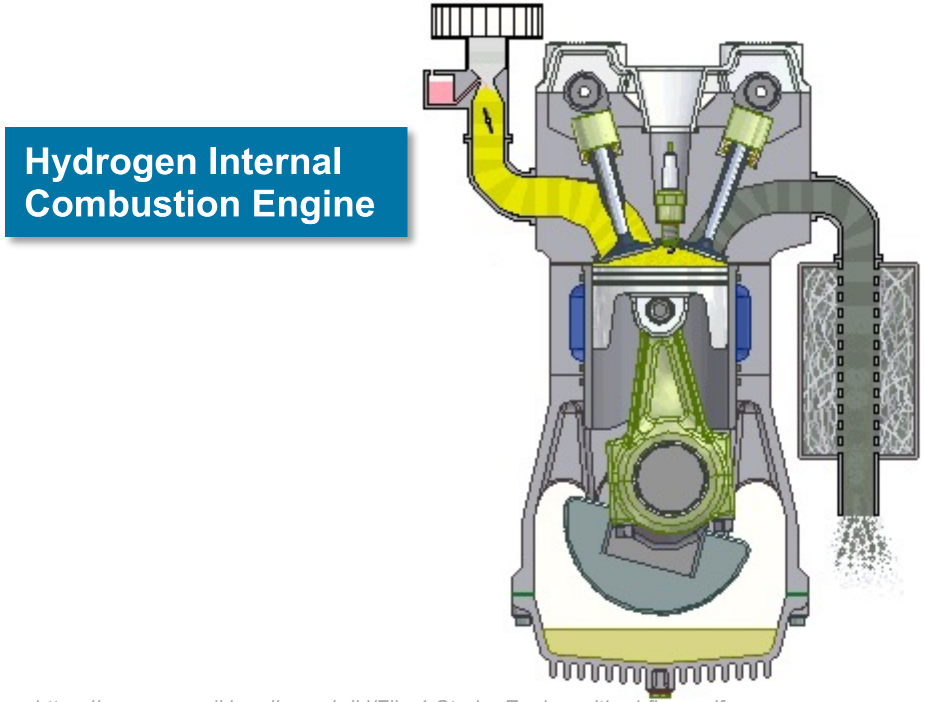


Source: Intelligent Energy, https://www.intelligent-energy.com/our-products/stationary-power/fuel-cells/

Additional parts of the system include

- Balance of Plant (hydrogen/air handling; pumps, compressors, filtration, environmental conditioning)
- Thermal conditioning (cooling, heating for startup)

Multiple difference fuel cell stack technologies. Most common for transport applications is Proton-Exchange Membrane (PEM)



Source: https://commons.wikimedia.org/wiki/File:4-Stroke-Engine-with-airflows.gif

Conventional 4-stroke internal combustion engine technology

- Gasoline or diesel-type combustion systems viable
- Dual-fuel operation with diesel-hydrogen or methane-hydrogen possible, but not ideal
- Limited aftertreatment necessary due to NOx formation from combustion temperature and PM from lubrication oils (lower emissions than diesel/gasoline)

The right time for H2ICE?

Many benefits outside the technology

H2ICE has key advantages for a rail environment:

- Proven technology, robust (H2FC not mature)
- Can be retrofitted/converted from existing hardware
- Reduces initial capital cost for system conversion to hydrogen
    - Allows for capital to be invested in *infrastructure & operational logistics*, by reducing cost of vehicle propulsion system
- ‘Stepping stone’ technology
- Increases time for skills transition

H2ICE for rail reduces the initial investment requirements and pain of transition to hydrogen

Challenges, opportunities

Moving forward

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Challenges remain for use of hydrogen in rail & monorail systems

- *Safe use and operation*
- On-board storage volume
- Cost
- Supply

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But, opportunities exist to be realised; hydrogen opening up new markets?

- Reduces requirement for grid connectivity
- Supports business case for multi-modal hydrogen hubs
- Facilitates renewables energy storage & utilisation
- Consistent hydrogen consumer for supply chain

Ricardo

Monorail projects

Examples of Ricardo monorail project work

- **Dubai Monorail:** RAMS Engineering
- **Kuala Lumpur:** Driveline Engineering
- **BYD Monorail:** Brake System Certification
- **Bangkok Monorail:** Independent Verification & Validation
- **Daegu Line Monorail:** Independent Verification & Validation
- **Beijing TCT:** Certification of Monorail CBTC system

Thank you

Questions?