Hydrogen for Transport

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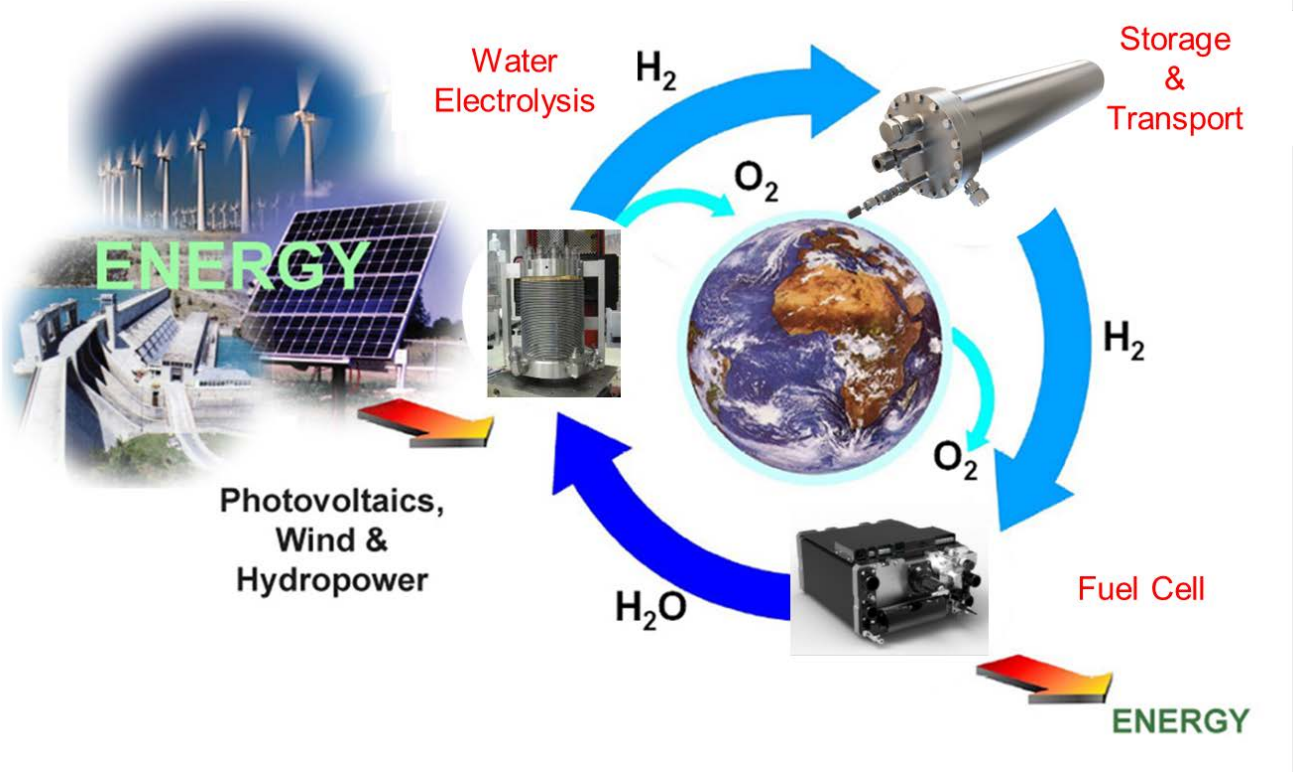
Vision


ENERGY
Water
Electrolysis
H_2
O_2
Storage
&
Transport
H_2
O_2
Photovoltaics,
Wind &
Hydropower
H_2O
Fuel Cell
ENERGY

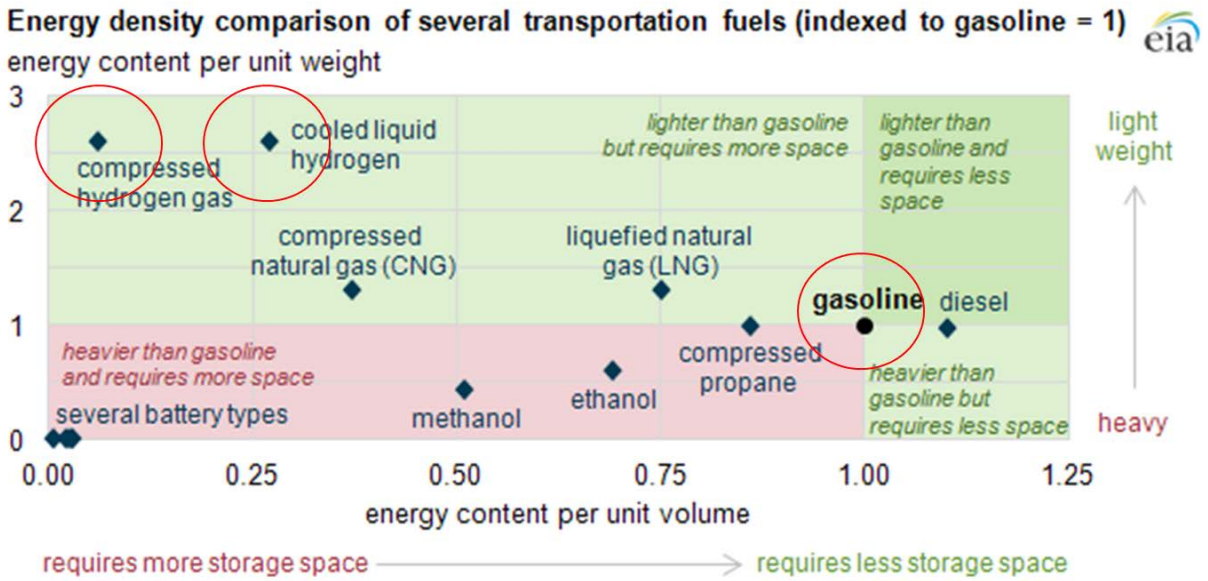
Water Electrolysis

- **State-of-the-Art**: Dynamic operation of PEMWE at >70% efficiency
- **Challenge**: Overall System Costs

Source: Hydrogenics

Hydrogen Storage

- **Challenge**: Low Energy Content per Volume → High Storage System Costs



Source: U.S. Department of Energy

Energy Storage – Volume and Weight

Batteries (Li-ion)

3 MWh

60 000 kg
40’ container

460 battery modules

1-hour charging:
*1 C → **3 MW***

Hydrogen (250 bar)

20 MWh

12 000 kg
40’ container

4 × 12 m H_2-tanks

Fuel Cell (PEM)

1 MW

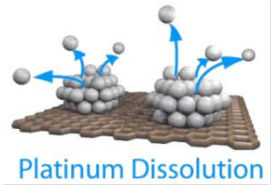
3 600 kg
10’

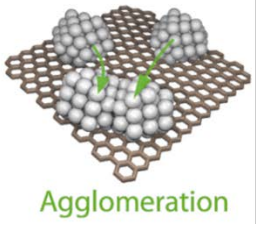
1-hour charging:
150 kg/h per H_2-tank
*→ **20 MW***

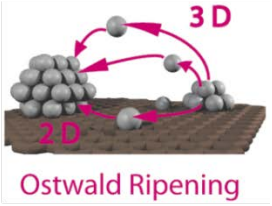
Fuel Cells

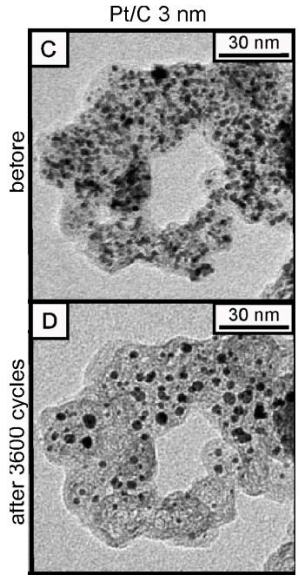
- **State-of-the-Art**: >50% efficiency
- **Challenges**: Fuel Cell degradation → Reduced FC Stack Lifetime → High FC System Costs


PowerCell MS-100



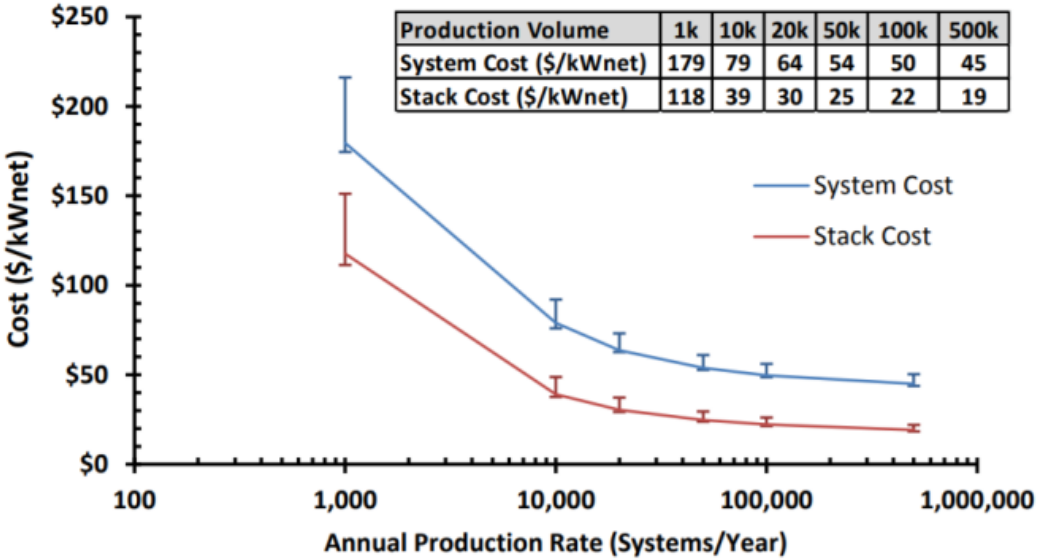






Fuel Cell – Costs

- **Challenges**: CAPEX (mass manufacturing) & OPEX (stack lifetime)



Cost of 80 kW automotive FC stacks as a function of number of units (1000 – 500,000)

Source: U.S. Department of Energy (2017)

Fuel Cell Electric Vehicles – 25 years with R&D

NECAR (1994) F-CELL (2009) F 125 (2025)

Source: Daimler Mercedes-Benz (2010)

Fine-Comfort Ride (Concept Car)

Source: Toyota (2018)

Fuel Cell Electric Vehicles – Norway 2008-2012

HyNor

H2Moves

Toyota Prius H2 ICE
15 vehicles

Hyundai ix35 FCV
2 vehicles

THINK H2EV
5 vehicles

Mercedes B-Class F-cell
10 vehicles

Source: IFE (2012)

Fuel Cell Electric Vehicles – Today

FC stacks:
ca. 100 kW

600 km

550 km

800 km

400 km

625 km

420 km

Source: Norwegian Hydrogen Forum (2018)

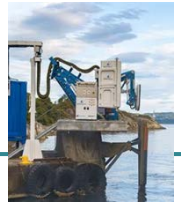
RE Power & Hydrogen → Maritime transport

Hydro Electric

Wind Power

EL

Power Grid



Battery Charging

EL

Hydrogen Supply

H_2

Electrical & Maritime Transport
Batteries & Fuel Cells

FC stacks:
ca. 100 kW

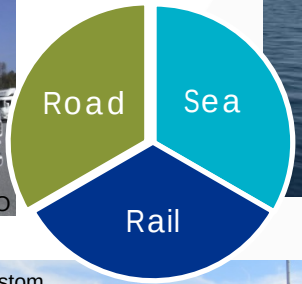
MoZEES – A Research Center on Zero Emission Mobility

FME MoZEES – 1 of 8 National Centers


Foto: NFR (2016)

Heavy Duty Transport
– New Areas for Innovation & Value Creation

ASKO




Brødrene Aa

Battery & Hydrogen – Technology Value Chains

Illustration: NFR


Alstom

Materials → Components → Batteries & Fuel Cells → Modules → Systems

MoZEES
Mobility Zero Emission Energy Systems

www.mozees.no

MOZEES

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CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH

The Research Council of Norway