PLENARY SESSION

Sustainable mobility challenges for the transition targets: The role of hydrogen and fuel cell vehicles

Amela Ajanovic
Energy Economics Group
Vienna University of Technology (TU WIEN)
✓ Introduction
✓ Historical developments
✓ Economic and environmental assessment
✓ Green hydrogen as an energy storage option
✓ Conclusion
Transport sector

- oil products
- least-diversified
- energy import dependency

Countries with largest conventional oil reserves

Global energy consumption in road transport
Hydrogen

➢ Hydrogen is the simplest, lightest and most abundant element in the universe

➢ high energy density

➢ less flammable than gasoline

➢ non-toxic

➢ hydrogen combustion produces only water

➢ secondary energy carrier …. It can be produced from different energy sources
Major historical steps and milestones in the development of hydrogen and FCV

1838: Discovered fuel cell effect
1766: Hydrogen was first identified as a distinct element
1874: Vision of hydrogen economy
1958: The first PEM fuel cell
1959: The first fuel cell vehicle – farm tractor powered by an alkaline fuel cell
1966: General Motors used fuel cell technology in production of the Electrovan
1993: The first PEMFC car
2008: Commercialization begins (FCX Clarity – first FCV commercially available)
2011: > 100 fuel cell buses worldwide
2013: > 4000 fuel cell forklifts worldwide
2015: First hydrogen fuel cell powered tramcar
2021: The global FCV stock >31000

Water will be the coal of the future. – Jules Verne

“Water will be the coal of the future.”

Jules Verne

“Visions of a Hydrogen Economy” 1874
Hydrogen vision

- H₂ production plant
- Fuel cell plant
- Power generation plant
- Thermal solar
- Wind turbine
- Biomass
- PV plant
- Natural gas
- Depleted gas well
- Deep saline aquifer

Source: EU, 2003
Electric vehicles

- ICE
- PHEV
- REX
- BEV
- FCV

0% electrification

Rechargeable electric vehicles

100% electrification
The global stock of electric vehicles, 2010-2019

Global EV stock (thousands of cars)

- Total
- BEV
- PHEV
- FCV
Refuelling stations

Number of hydrogen fueling stations for road vehicles worldwide as of 2021, by country

- Japan: 134
- Germany: 90
- United States: 46
- South Korea: 43
- China: 39
- France: 18
- England: 9
- Canada: 9
- Denmark: 6
- Norway: 5
- Austria: 5
- Netherlands: 5
- Sweden: 4
- Australia: 4

STATISTA, 2021
Global hydrogen production and use

- Gas: 68%
- Oil: 16%
- Coal: 11%
- Electricity: 5%
- Methanol: 10%
- Refining: 25%
- Other: 10%
- Ammonia: 55%
Colors of hydrogen

Biomass
Hydro
Wind
Solar

Green H2

Oil
Coal
Natural gas

Grey H2

With Carbon Sequestration

Blue H2
Cost of hydrogen production for different production pathways

[Bar chart showing the cost of hydrogen production for blue, grey, and green hydrogen.]
Emissions of hydrogen

- Grey H2
- Blue H2
- Green H2
Economic assessment

The costs per km driven $C_{km}$ are calculated as:

$$C_{km} = \frac{IC \cdot \alpha}{skm} + P_f \cdot FI + \frac{C_{O&M}}{skm}$$

[€/100 km driven]

IC……investment costs [€/car]
α……..capital recovery factor
skm…..specific km driven per car per year [km/(car.yr)]
Pf……..fuel price incl. taxes [€/litre]
$C_{O&M}$……operating and maintenance costs
FI……..fuel/energy intensity [litre/100 km; kWh/100 km]

A capital recovery factor ($\alpha$) is the ratio of a constant annuity to the present value of receiving that annuity for a given length of time. Using an interest rate (z), the capital recovery factor is:

$$\alpha = \frac{z(1+z)^n}{(1+z)^n - 1}$$

n…..the number of annuities received.
Mobility costs

![Graph showing mobility costs for different vehicle types: FCV, BEV, Diesel ICE, Gasoline ICE. The costs are categorized into capital costs, O&M costs, and fuel costs.](image-url)
Mobility costs vs emissions per km driven

- BEV
- FCV
- ICE

EUR/100 km vs gCO2/km
FCVs vs BEVs

- Costs
- Infrastructure
- Fuel efficiency
- Refuelling time
- Driving range
- Weight of energy storage
- Environmental benefits
Policy framework

- Targets and long-term vision
- Standards, regulations, coordinated actions
- Demand creation
- R&D, Demonstration projects
- Investment risk mitigation
Renewable energy sources

- increase the use of renewable energy sources
  - sufficient and secure energy supply
  - reduction of energy-related greenhouse gas emissions
- how to cope with excess electricity from RES
Integrating large shares of renewable electricity

Surplus ele.

D > S

Price of ele.

Demand
Hydrogen: storage and fuel

Energy supply chains: Storage and/or use of RES for mobility
Conclusions

✓ …decarbonisation of the transport sector
✓ …integration of renewables
✓ …enhance energy security
✓ …major challenge – cost and infrastructure
✓ …policy framework
✓ …full environmental benefit – green hydrogen
ajanovic@eeg.tuwien.ac.at


https://doi.org/10.1002/fuce.201800171