PLENARY SESSION

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

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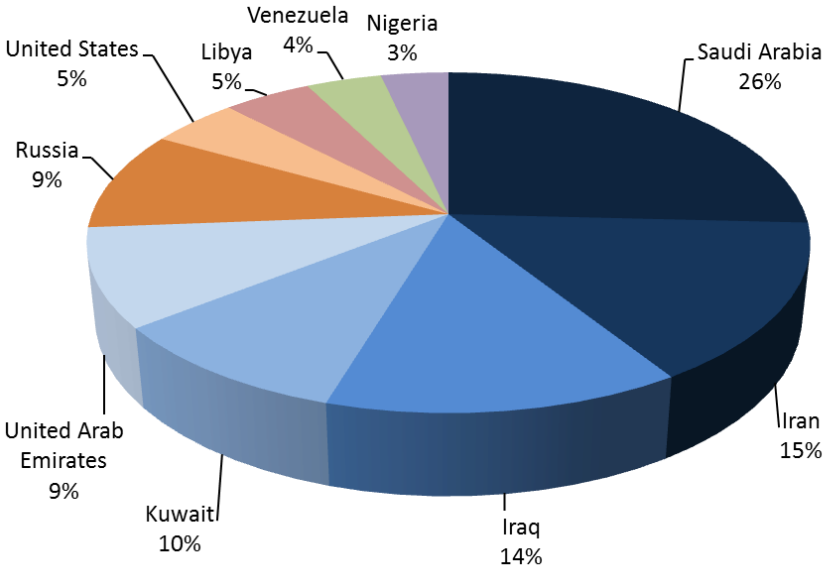
Content

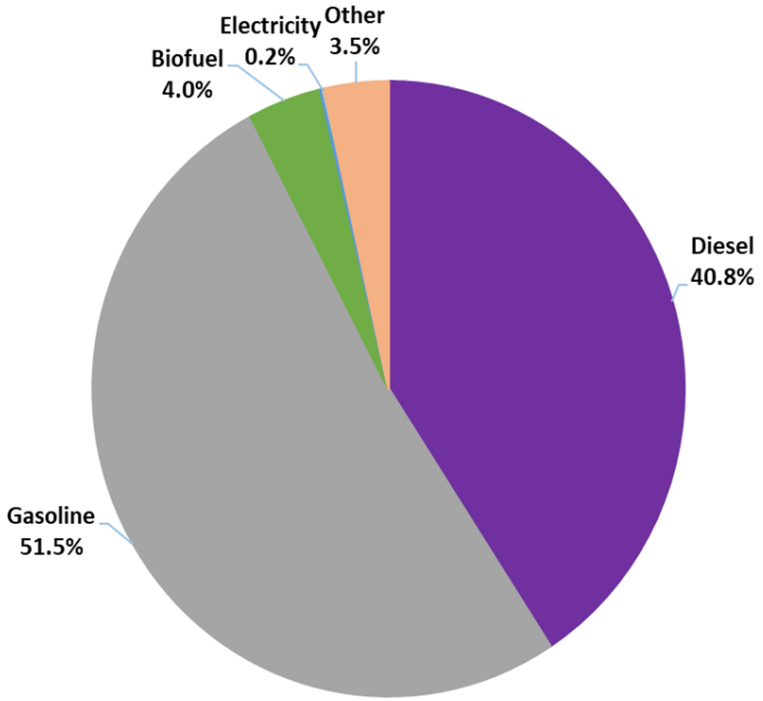
- ✓ Introduction
- ✓ Historical developments
- ✓ Economic and environmental assessment
- ✓ Green hydrogen as an energy storage option
- ✓ Conclusion

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

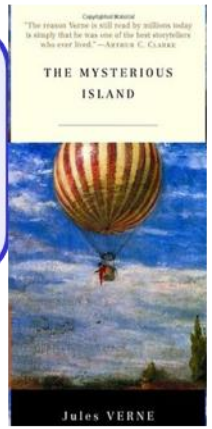
- secondary energy carrier …. It can be produced from different energy sources

Major historical steps and milestones in the development of hydrogen and FCV

1766: Hydrogen was first identified as a distinct element

1838: Discovered fuel cell effect

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

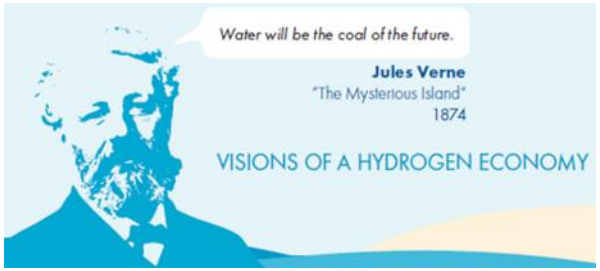
2008: Commercialization begins (FCX Clarity – first FCV commercially available)

2011: > 100 fuel cell buses worldwide

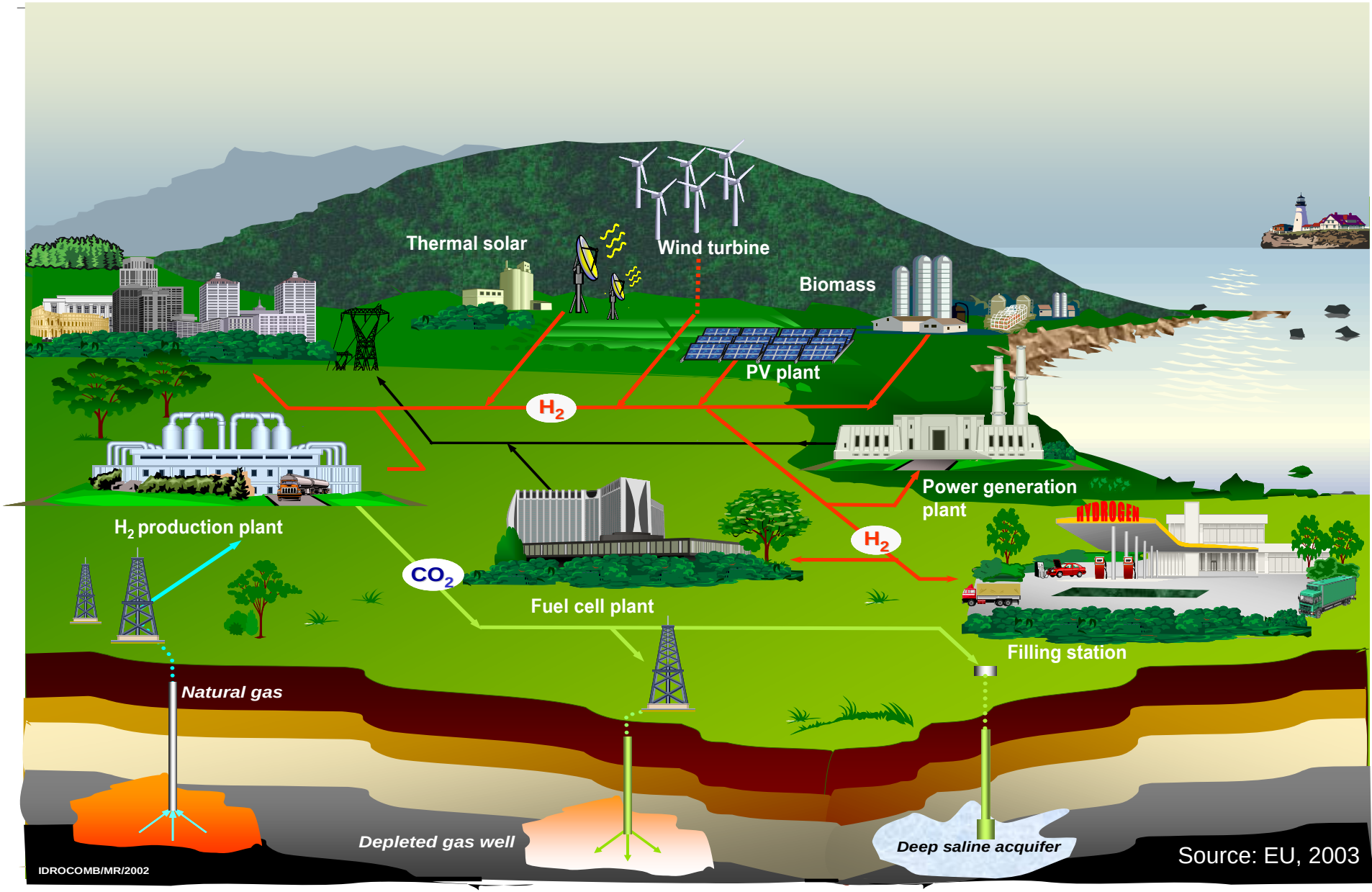
2013: > 4000 fuel cell forklifts worldwide

2015: First hydrogen fuel cell powered tramcar

2021: The global FCV stock >31000

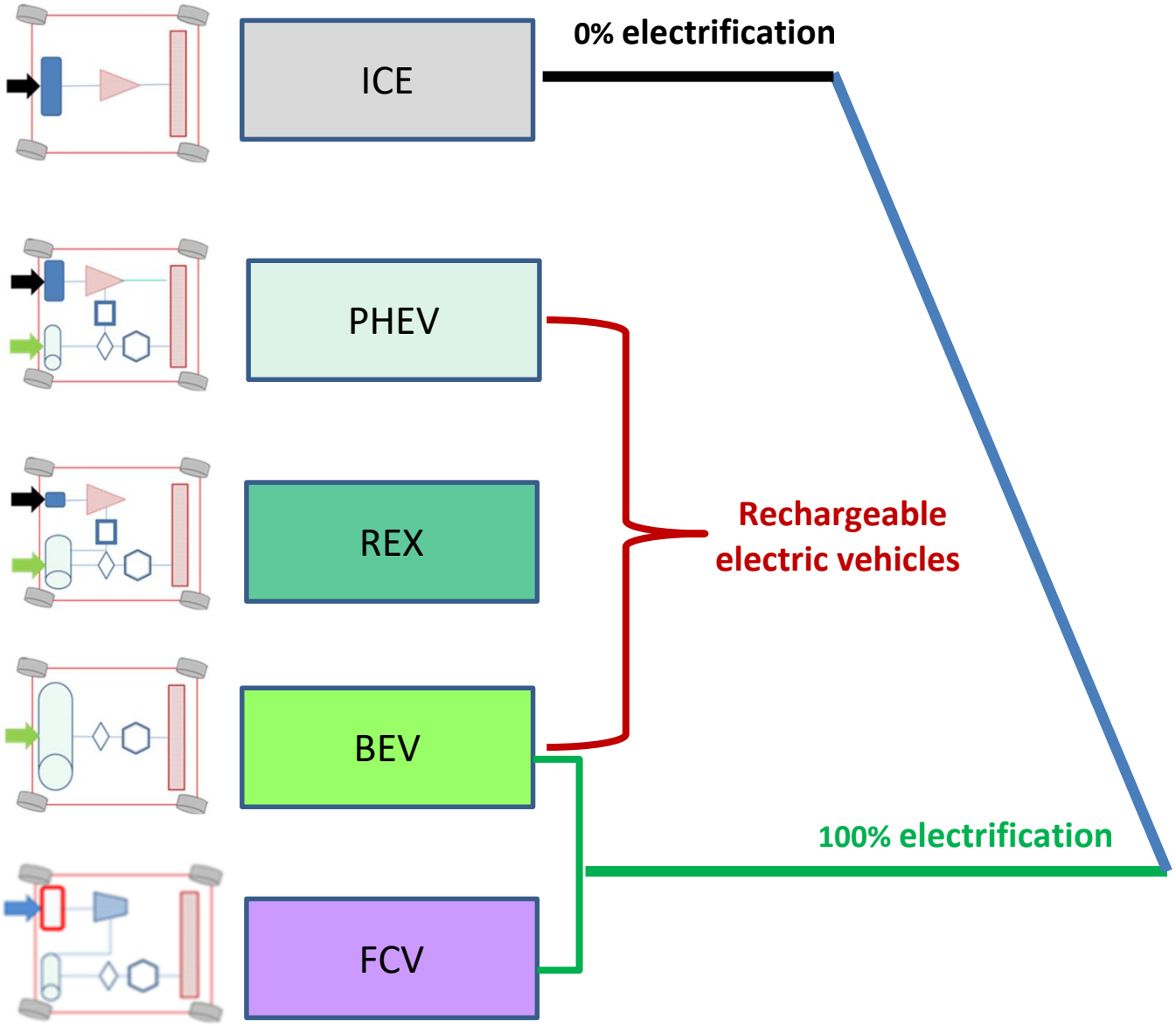


Hydrogen vision

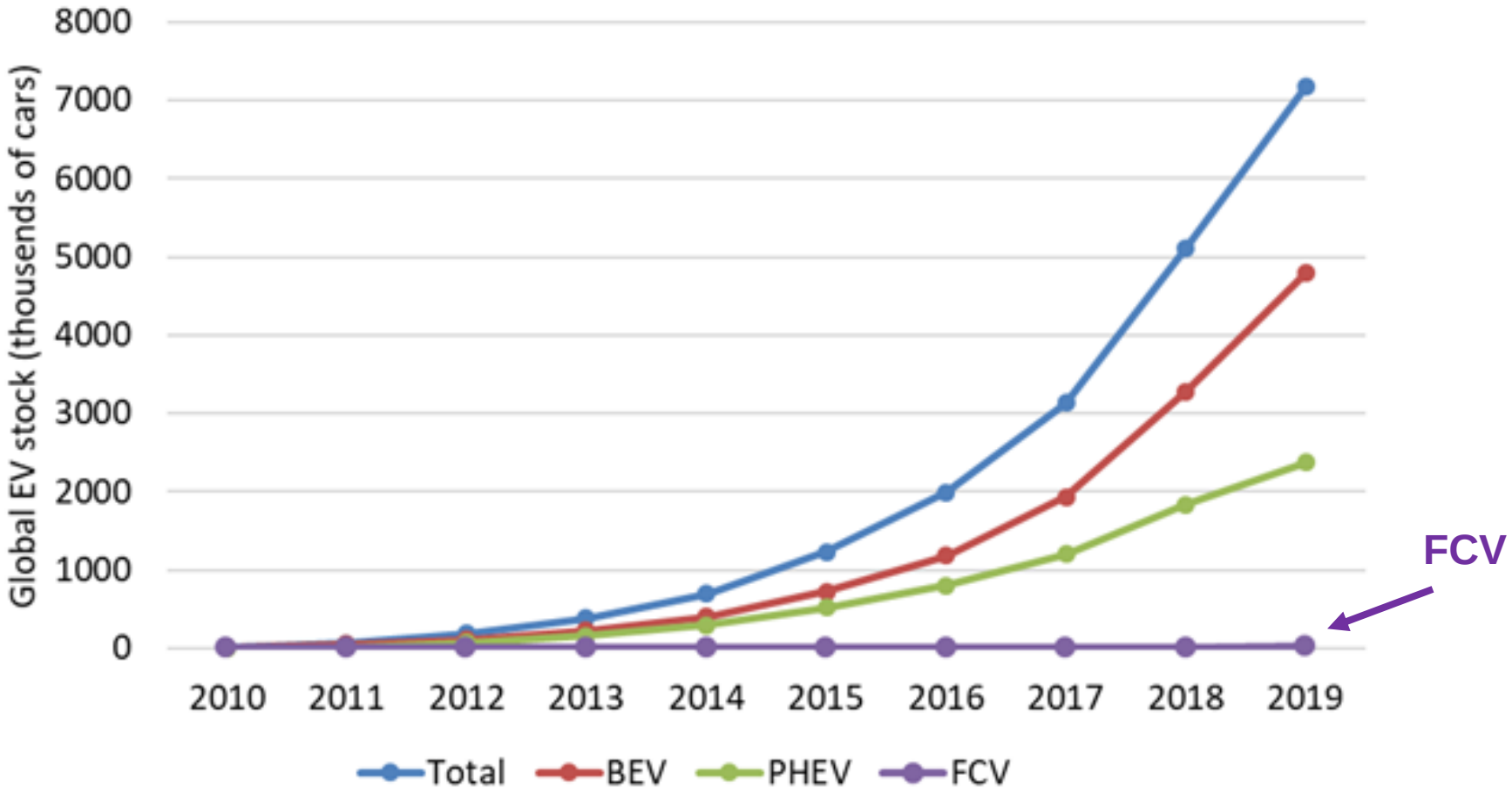


Source: EU, 2003

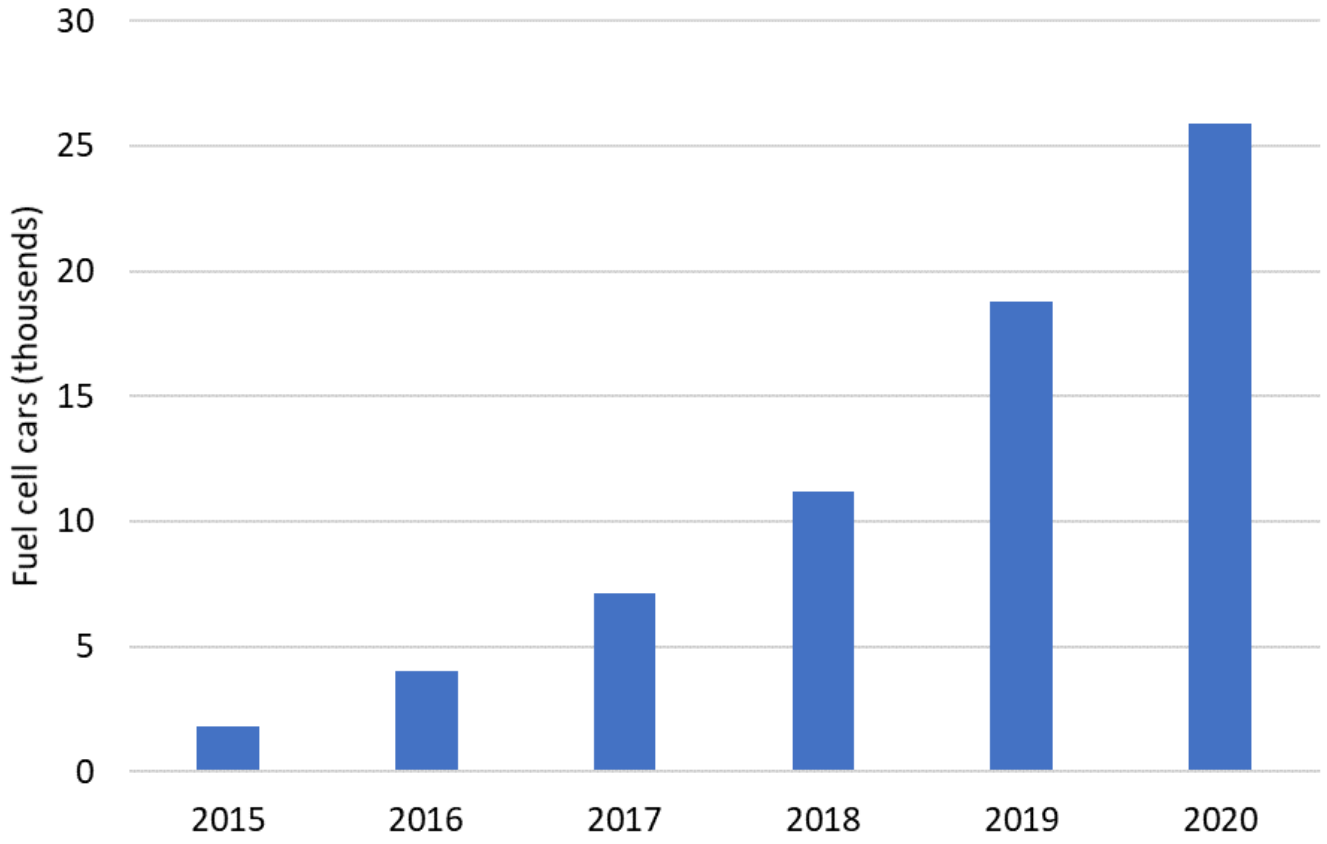
Electric vehicles



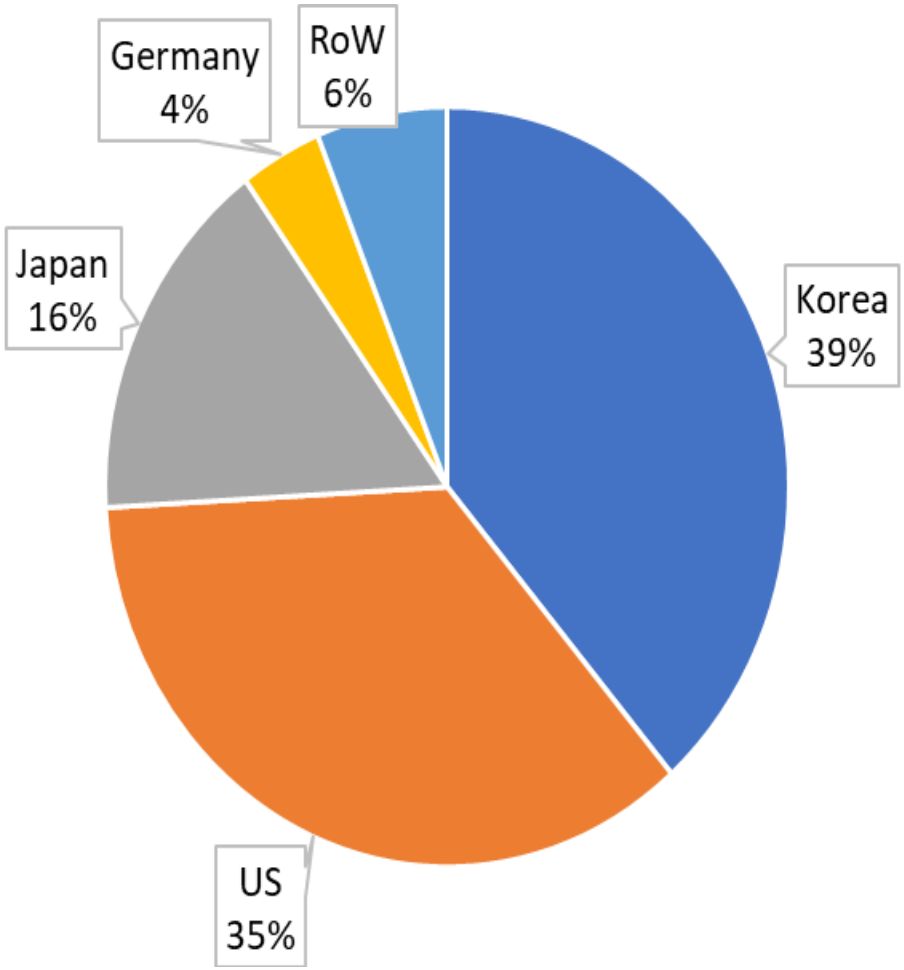
The global stock of electric vehicles, 2010-2019



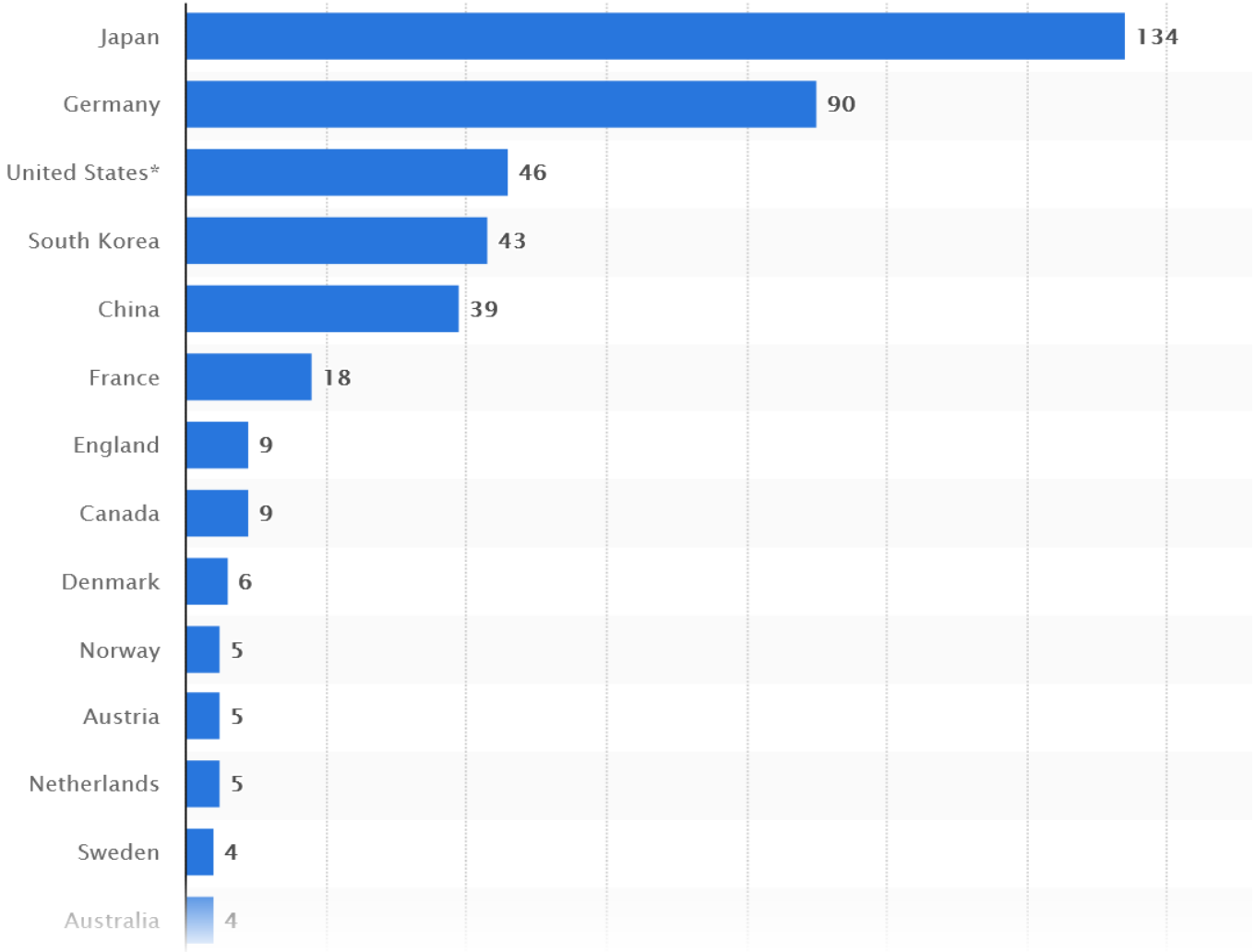
FCV


30
25
20
15
10
5
0
Fuel cell cars (thousends)
2015
2016
2017
2018
2019
2020

FCV



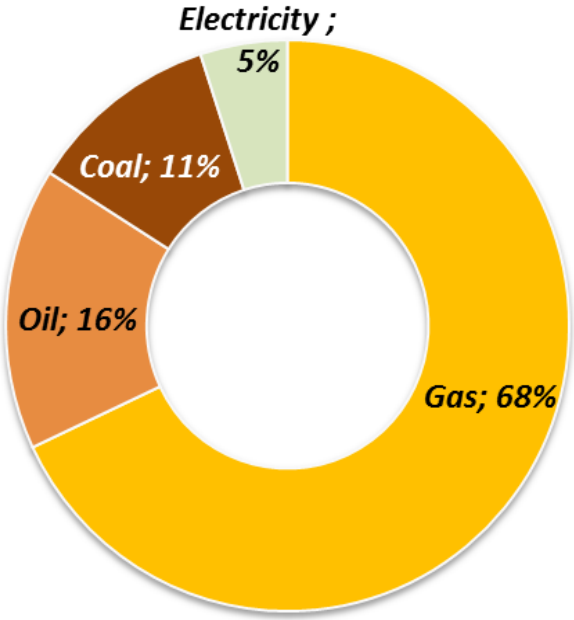
Refuelling stations

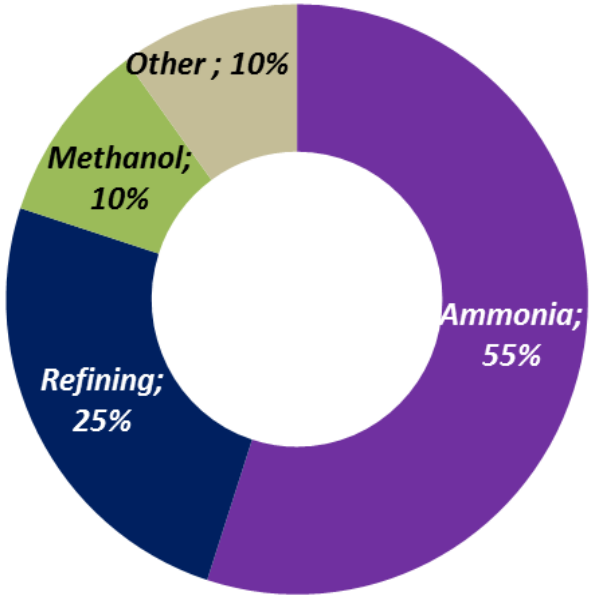


STATISTA, 2021

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

Global hydrogen production and use





Colors of hydrogen

Biomass
Hydro
Wind
Solar

→ Green H2

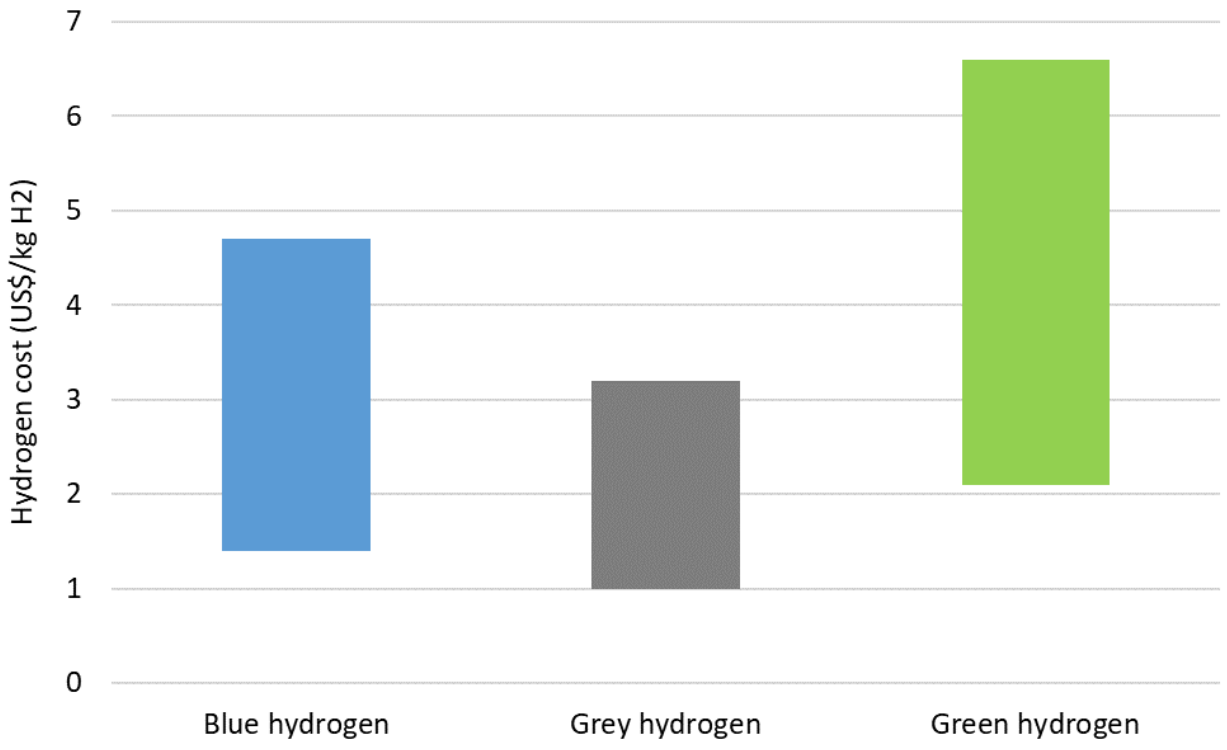
Oil
Coal
Natural gas

→ Grey H2

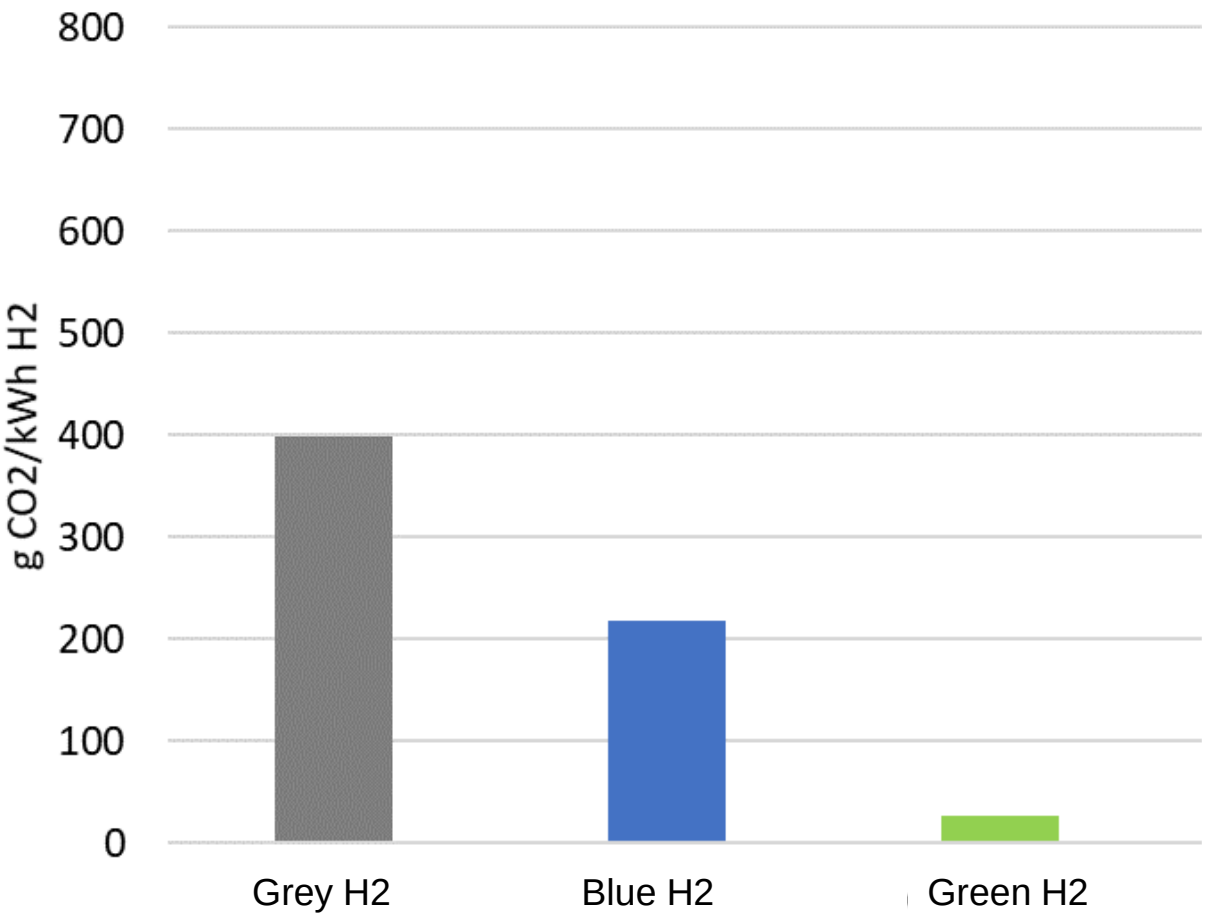
With Carbon Sequestration →

Blue H2

Cost of hydrogen production for different production pathways



Emissions of hydrogen



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]

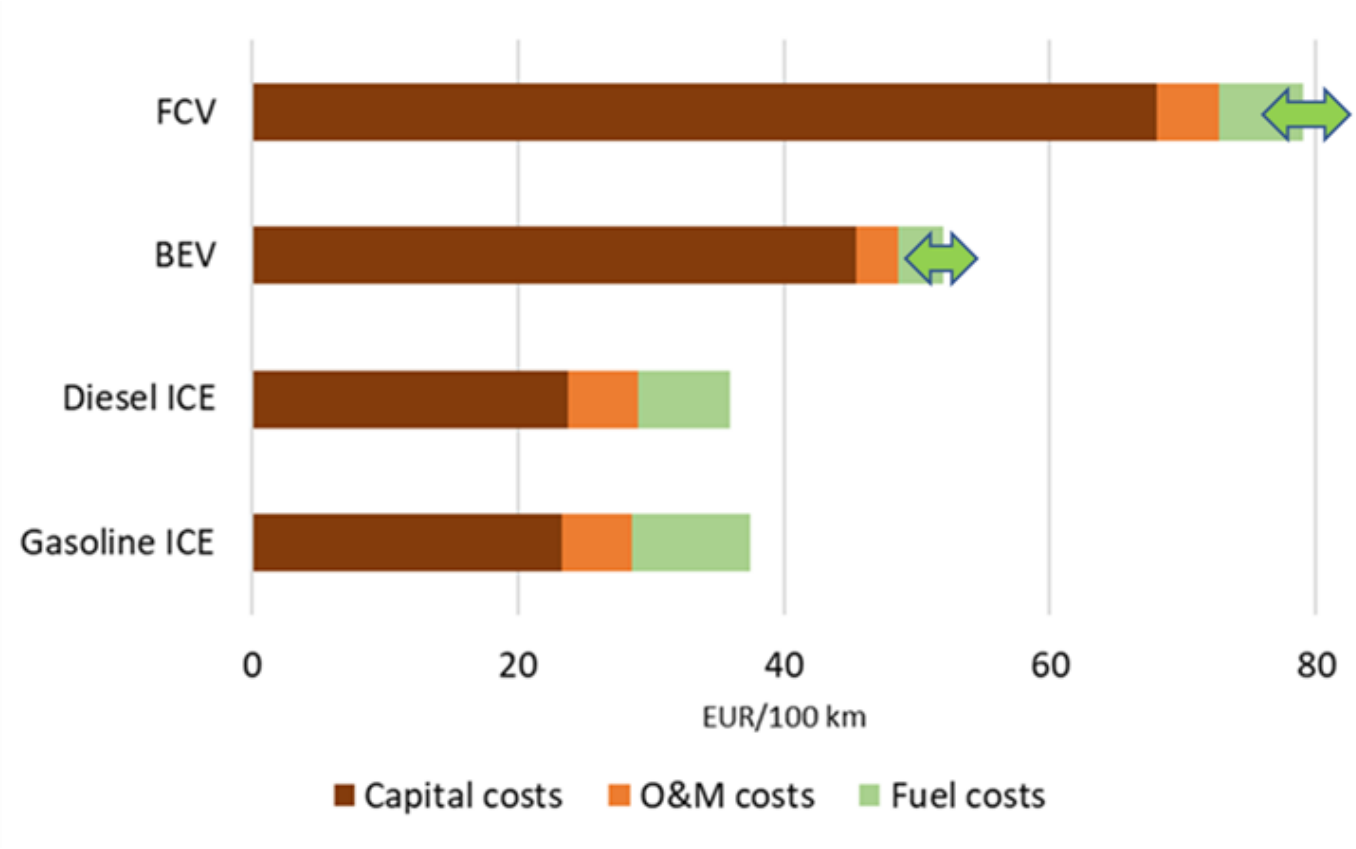
IC……investment costs [€/car]
α……..capital recovery factor
skm…..specific km driven per car per year [km/(car.yr)]
Pf……fuel price incl. taxes [€/litre]
$C_{O\&M}$…operating and maintenance costs
FI……..fuel/energy intensity [litre/100 km; kWh/100 km]

A capital recovery factor (α) 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:

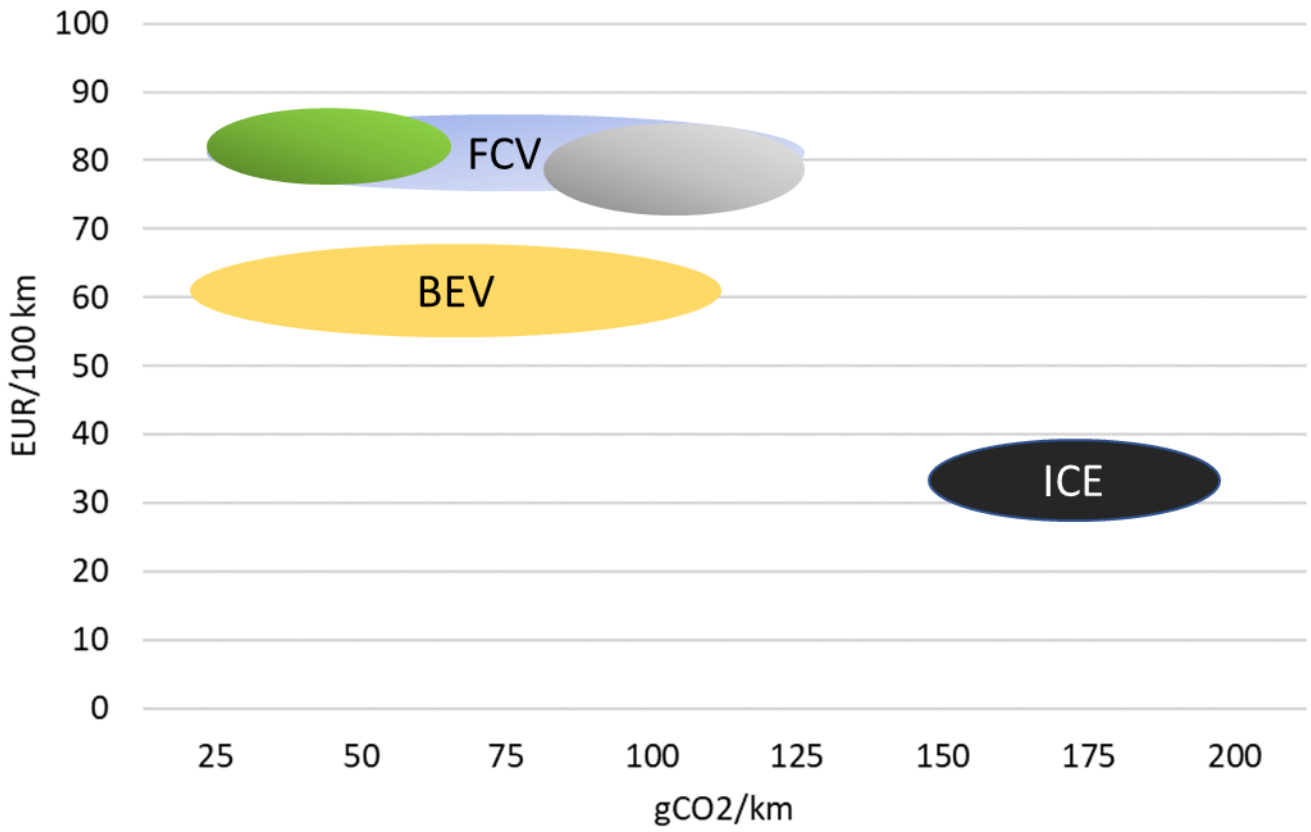
$$\alpha = \frac{z(1+z)^n}{(1+z)^n - 1}$$

n…..the number of annuities received.

Mobility costs

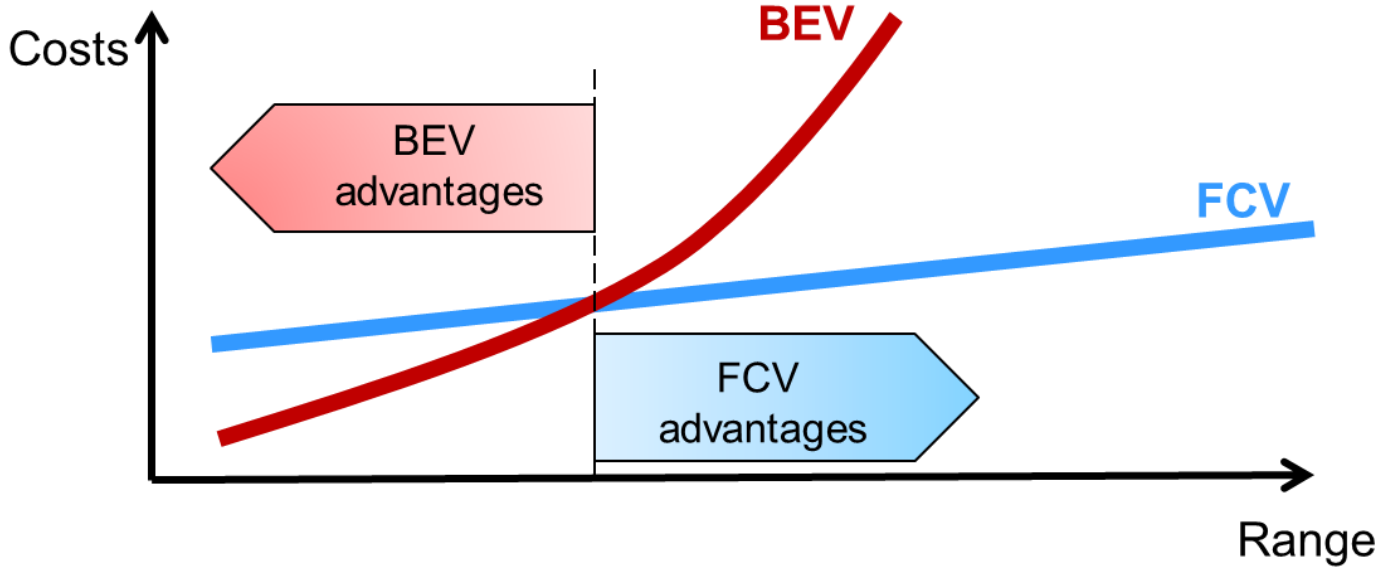


Mobility costs vs emissions per km driven

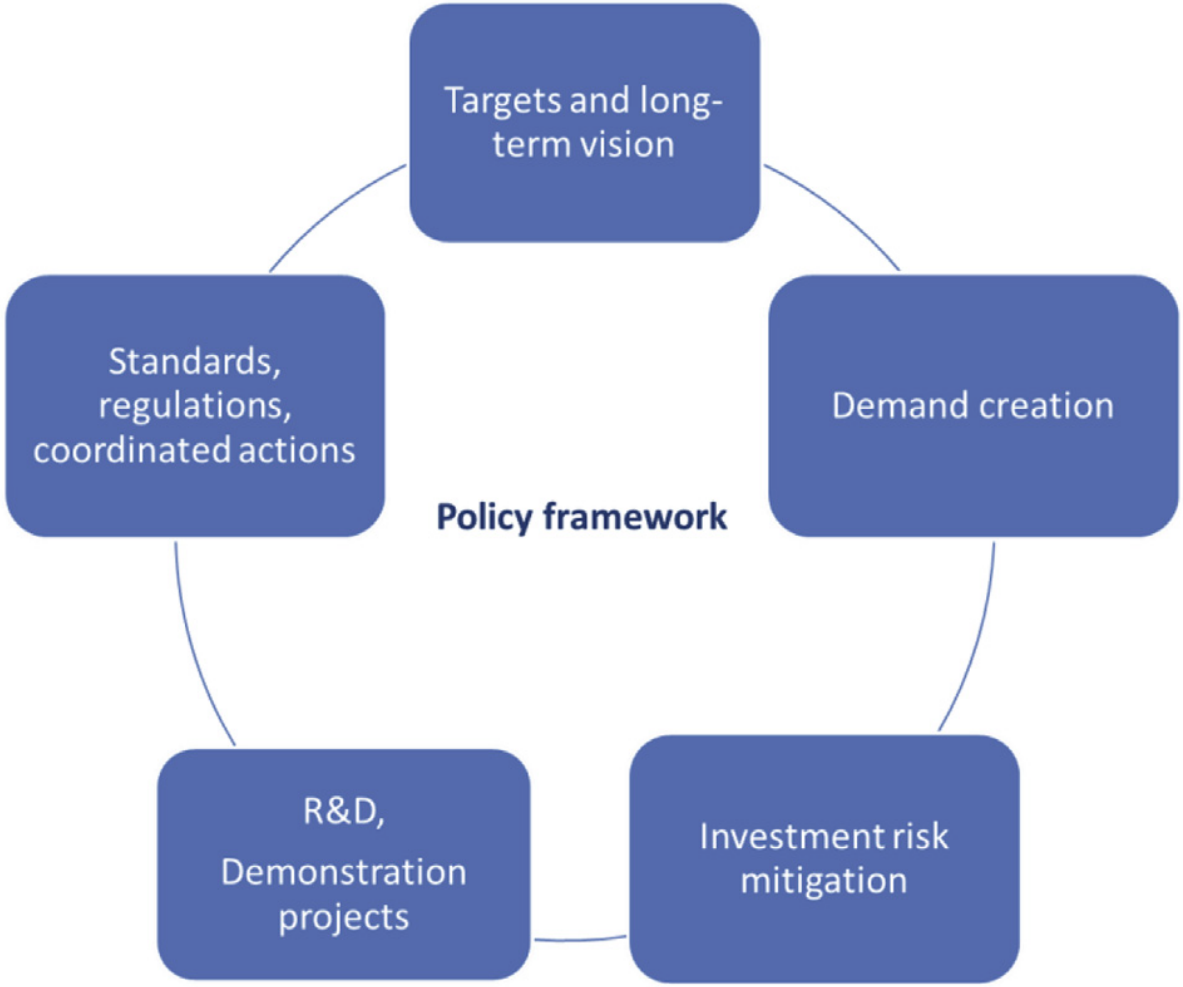


FCVs vs BEVs

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



Policy framework

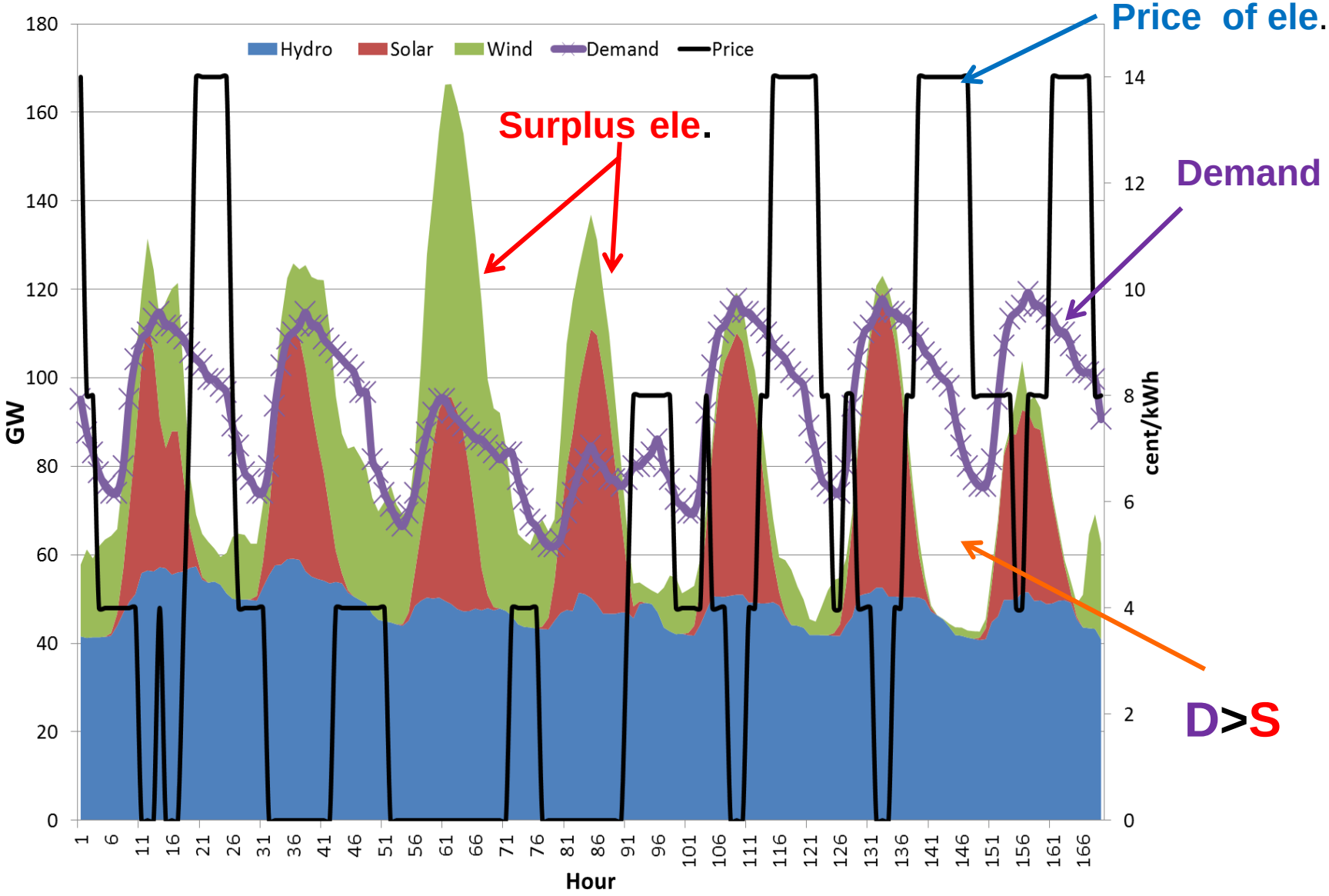


Renewable energy sources

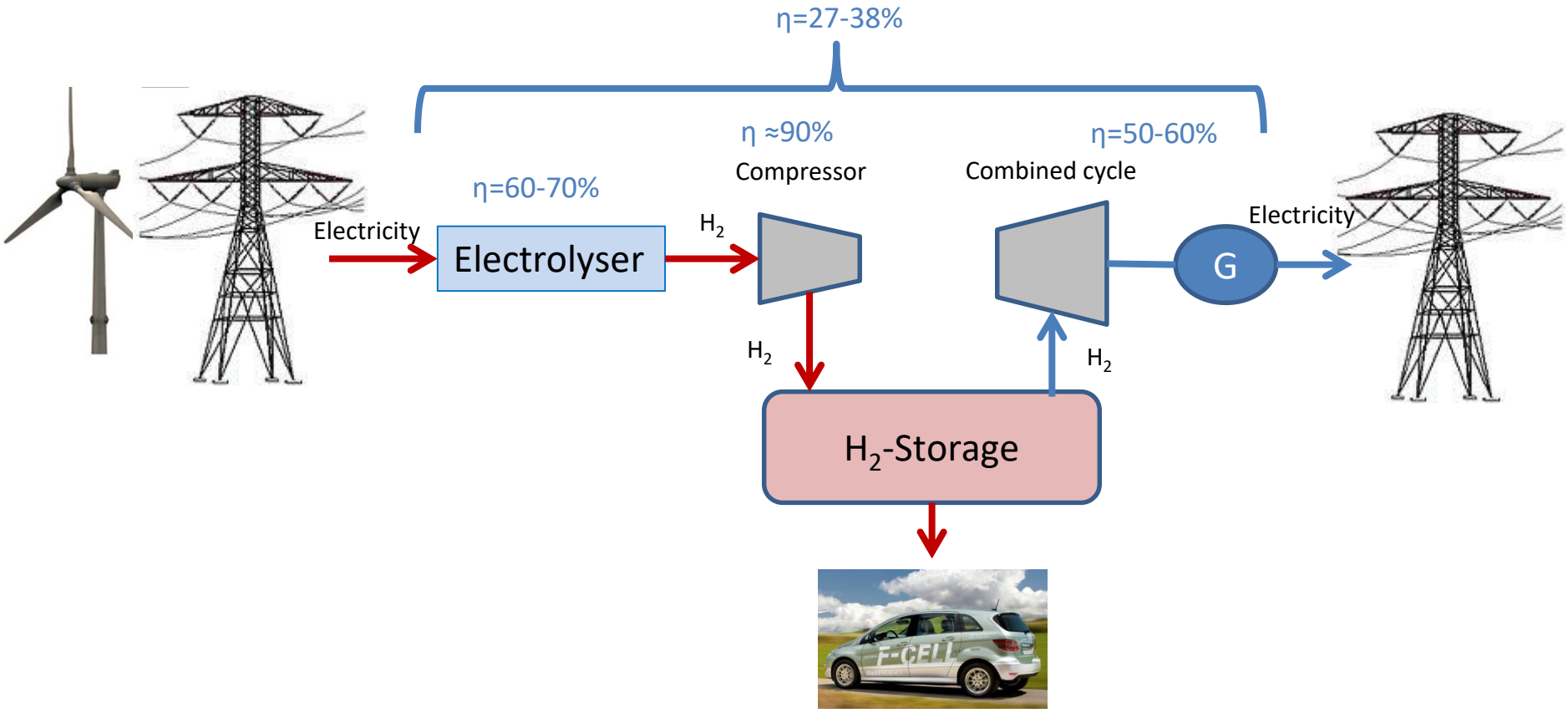
- ✓ increase the use of renewable energy sources
  - sufficient and secure energy supply
  - reduction of energy-related greenhouse gas emissions

- ❖ how to cope with excess electricity from RES

Integrating large shares of renewable electricity



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

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Ajanovic A., Haas R. (2021), Prospects and impediments for hydrogen and fuel cell vehicles in the transport sector, International Journal of Hydrogen Energy, Volume 46, Issue 16, 3 March 2021, Pages 10049-10058, https://doi.org/10.1016/j.ijhydene.2020.03.122

Ajanovic A., Hiesl A., Haas R. (2020), On the role of storage for electricity in smart energy systems, Energy, Volume 200, 1 June 2020, 117473, https://doi.org/10.1016/j.energy.2020.117473

Ajanovic A., Haas R. (2019). Economic and Environmental Prospects for Battery Electric- and Fuel Cell Vehicles: A Review, FUEL CELLS 19, 2019, No. 5, 515–529 https://doi.org/10.1002/fuce.201800171