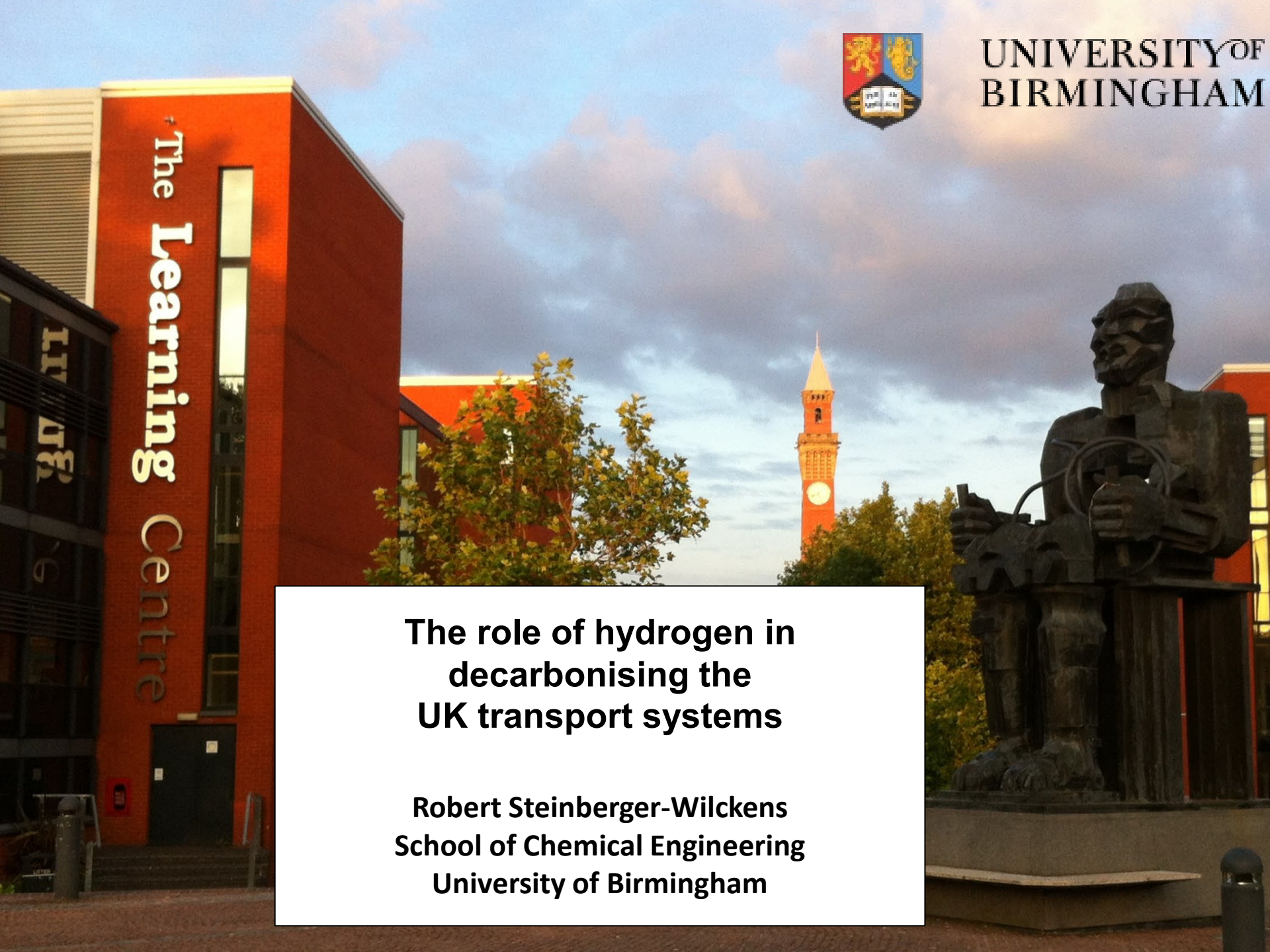

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The role of hydrogen in decarbonising the UK transport systems

Robert Steinberger-Wilckens
School of Chemical Engineering
University of Birmingham

Quantifying the real cost of fossil fuels

Toxic air a 'national health emergency' responsible for 40,000 early deaths and £20bn in costs each year, MPs warn

'It is unacceptable that successive governments have failed to protect the public from poisonous air'

Each car in London costs NHS and society £8,000 due to air pollution, report finds

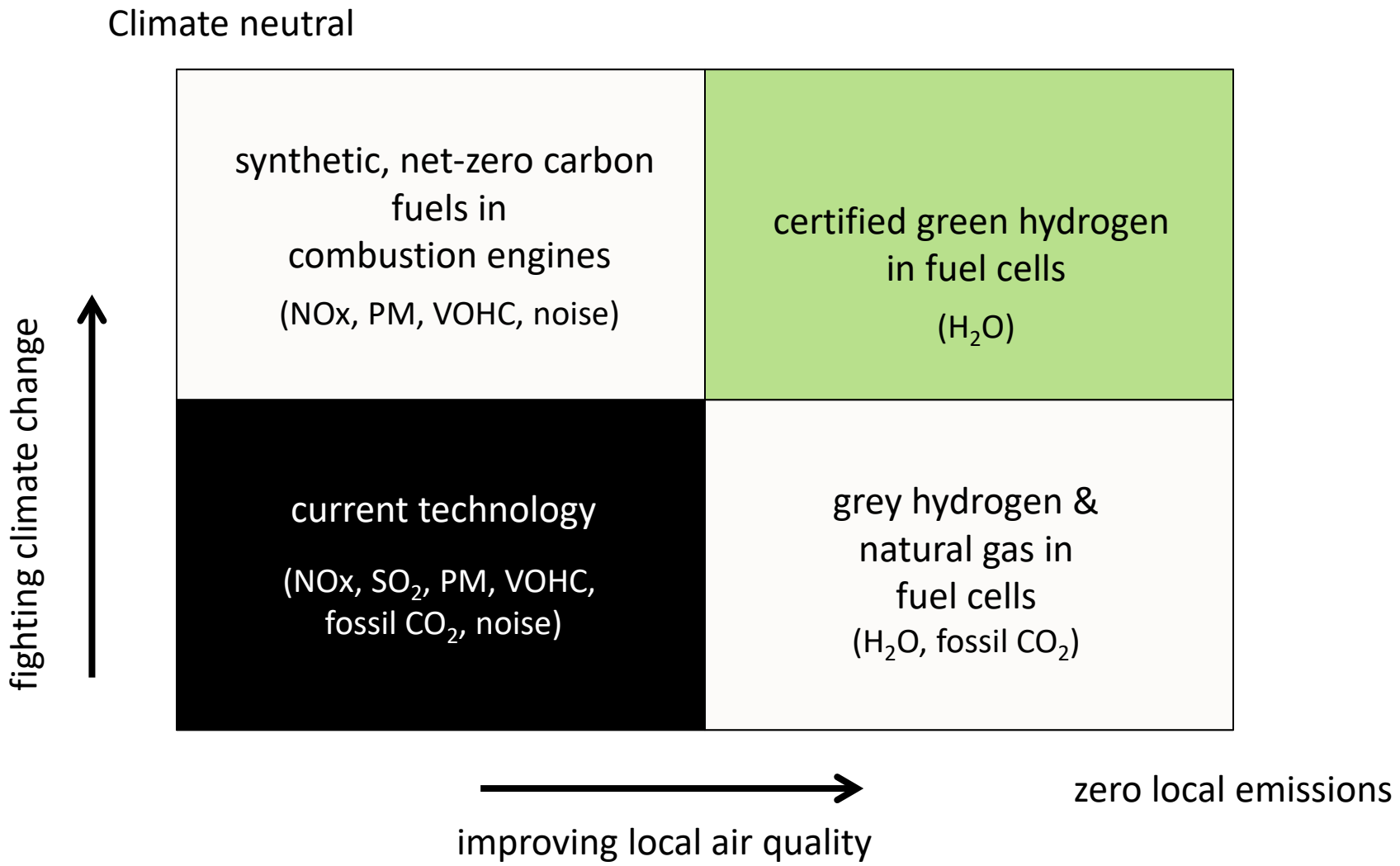
'We know the health impacts of air pollution, and now the economic case for cleaning up the air we breathe has been laid bare'

Extreme weather to cost UK billions and leave 2.5m homes at risk of flooding unless ministers take action, warns WWF

Report on the risks posed by climate change in 2050 warns there could be significant damage to the economy if it is not 'future-proofed'

Sources: Independent/Dan Kitwood/Getty

Global vs. Local Zero Emissions



Hydrogen Production: Variety of Sources

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Natural Gas / Crude Oil → **Reforming** →

Biogas → **Reforming** →

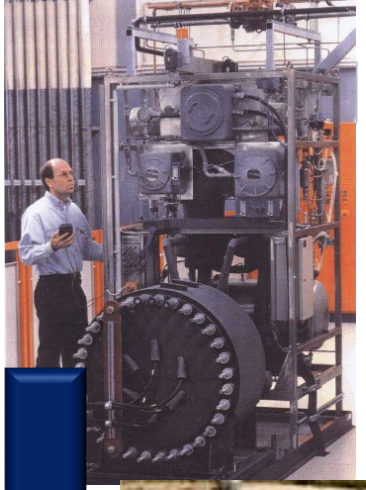
Electricity → **Electrolysis** →

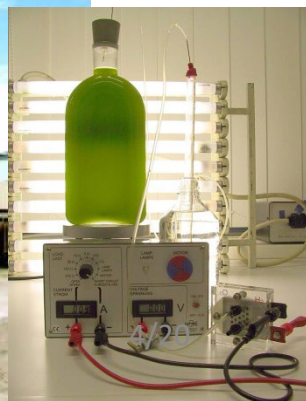
Biomass / Wastes → **Gasification** →

Sunlight + Water → **Photocatalysis** →

Sunlight + Nutrients → **Bacteria** →

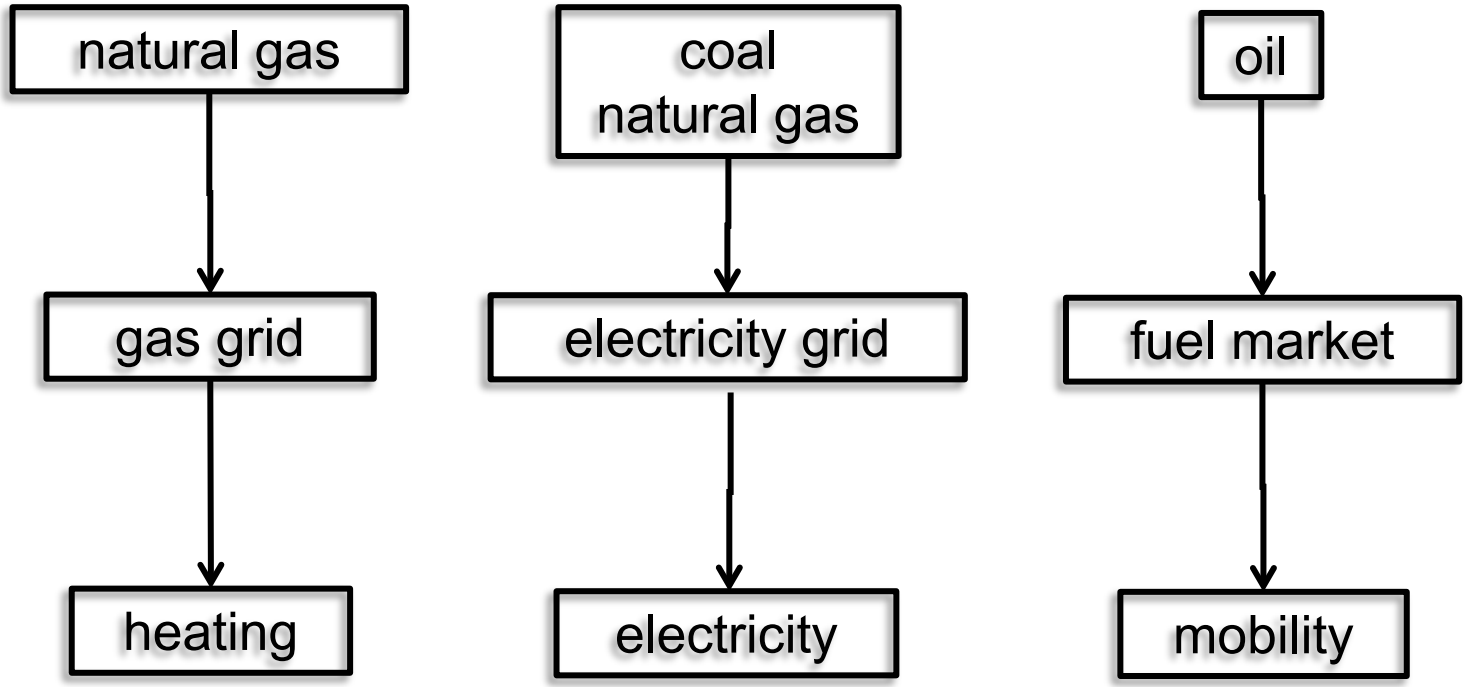
HYDROGEN





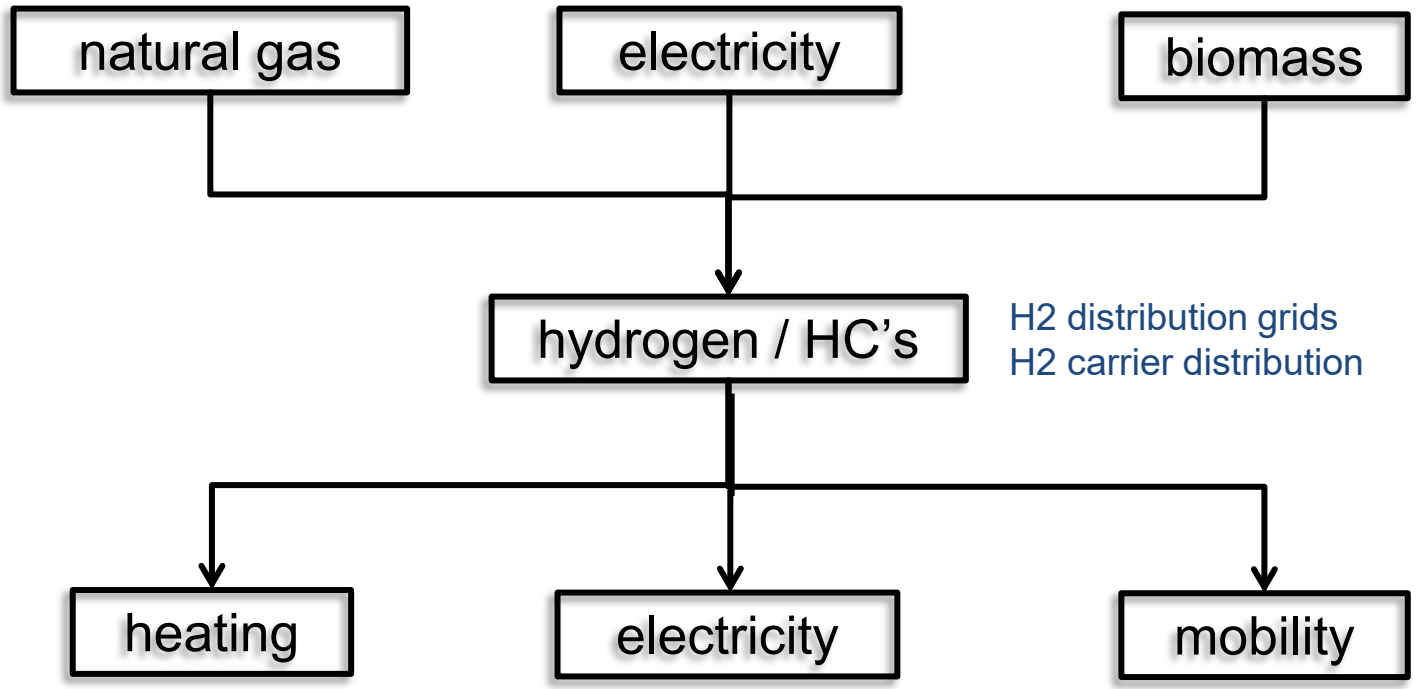
Conventional Energy Infrastructure

Risks: import dependence, loss of GDP to imports, political influencing



Future Hydrogen Energy Markets

Achievements: increase in flexibility, reduction in import dependence, reduction of supply shortages



Hydrogen Comparisons

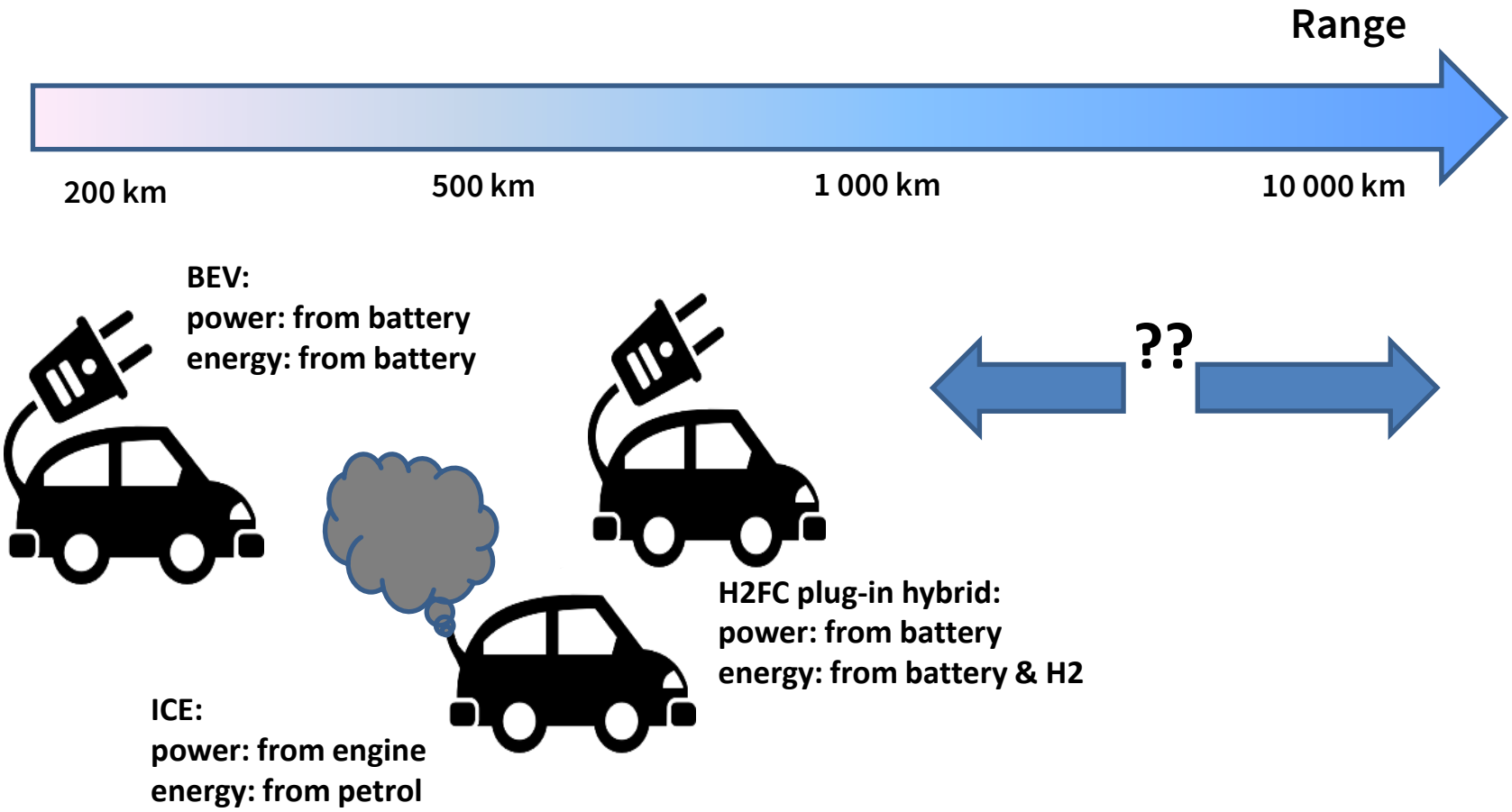
	Energy density	
lower heating values	volumetric	gravimetric
Hydrogen	3.00 kWh/Nm³	33.33 kWh/kg
Methane	9.97 kWh/Nm³	13.90 kWh/kg
Natural Gas	8,8 - 10,4 kWh/Nm³	10,6 - 13,1 kWh/kg
Propane	25.89 kWh/Nm³	12.88 kWh/kg
Buthane	34.39 kWh/Nm³	12.70 kWh/kg
Ammonia	3.9 kWh Nm^3 / 3.2 kWh/L	5.20 kWh/kg
Crude Oil	10.44 kWh/l	11.60 kWh/kg
Diesel	10.00 kWh/l	11.90 kWh/kg
Gasoline	8.80 kWh/l	12.00 kWh/kg
Methanol	4.44 kWh/l	5.47 kWh/kg

1 Nm³ hydrogen corresponds to 0,34 l petrol

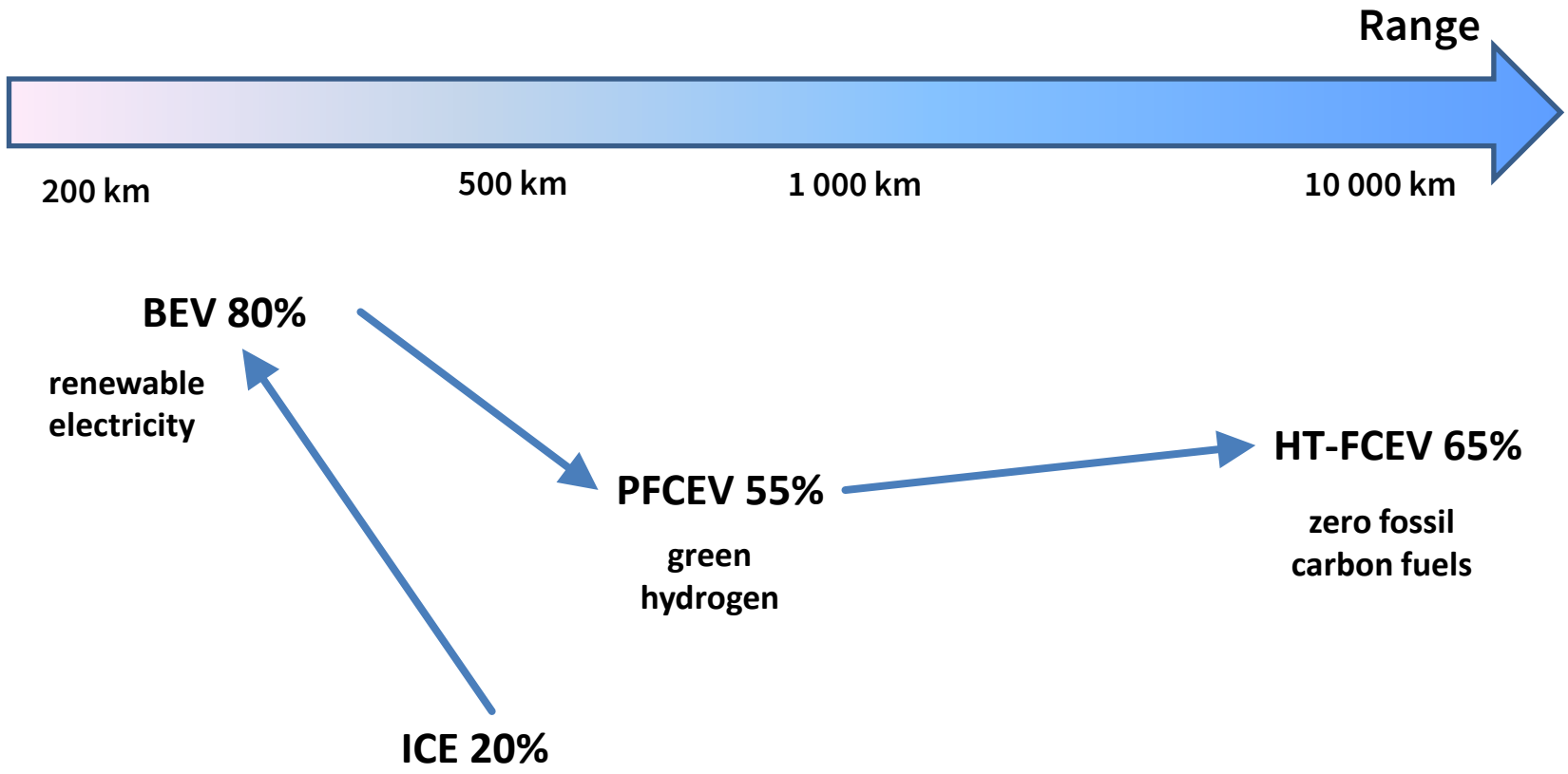
1 l liquid hydrogen corresponds to 0,27 l petrol

1 kg hydrogen corresponds to 2,75 kg petrol, 2,1 kg NG etc.

Electric Transport Solutions

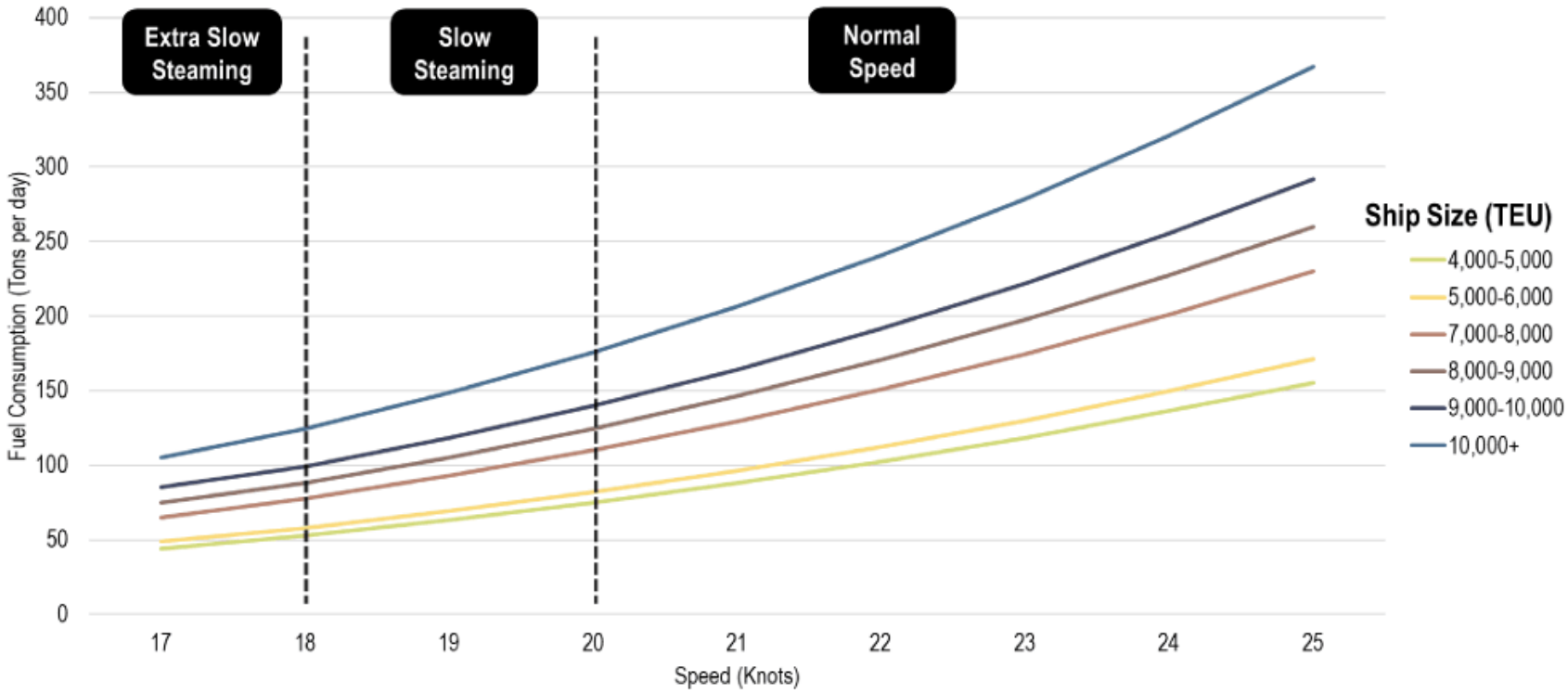


Vehicle Efficiencies



Comparison: Shipping Fuel Consumption

- steaming distance 10 days, 150 to/dy, 16 500 MWh



source: transportgeography.org

Comparison: Fuel Bunkering Volumes

- steaming distance 10 days, 150 to/dy, 16 500 MWh

	Boil. Temp. [K]	Heat.Val. [kWh/kg]	Heat.Val. [kWh/L]	Heat.Val. [kWh/ Ncbm]	bunker-volume [cbm]	Fuel weight [to]
H2 (70 MPa)	---	33	---	3	9900	500
CH4 (25 MPa)	---	14	---	9	8900	1300
LH2	20	33	2.3	---	7000	500
NH3	240	5.2	3.2	3.9	5200	3350
CH3OH	---	5.5	4.4	---	3750	3250
LNG	120	12.5	5.6	---	3500	1300
LSNG	111	14	6.3	---	3200	1200
M.Diesel	---	12	10	---	1500	1500

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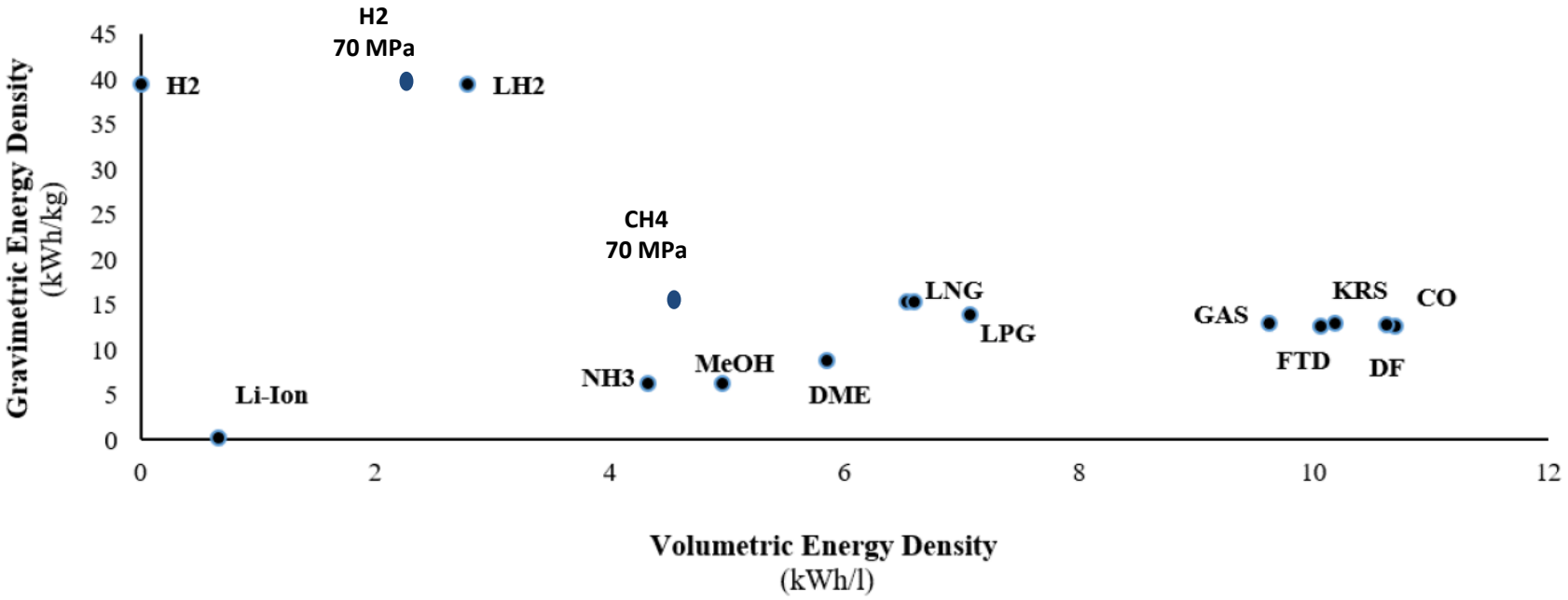
Energy Density Comparisons

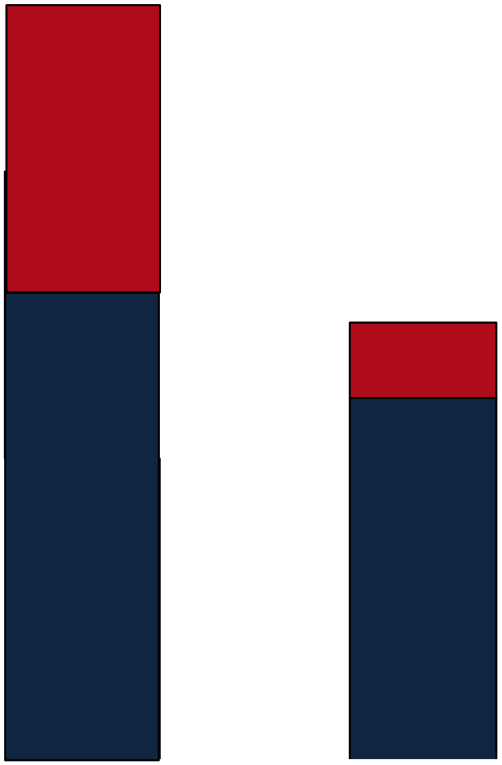


Where: GAS is gasoline, KRS is kerosene, DF is diesel fuel and CO is crude oil.

From: Samuel Sogbesan/Robert Steinberger-Wilckens

Externalities of Passenger Vehicle

values for Daimler A-class (2007) / (2022)



8.25 £/100 km

source: INFRAS

8 £/100 km

externalities (environmental component)

fuel cost (pump price)

9 £/100 km

Petrol **hydrogen**

Customer Choices

range

efficiency

pump price

availability / vehicles

industry adoption

availability / infrastructure

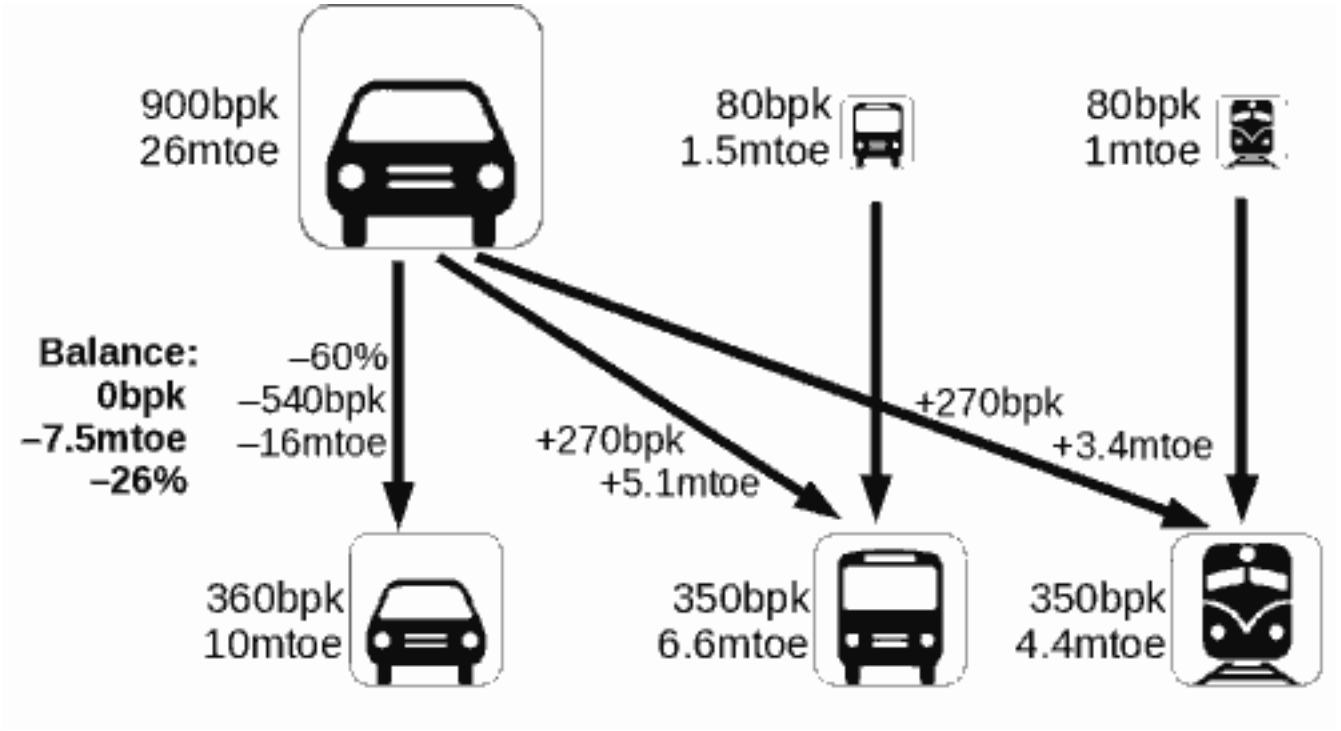
Source: imgflip.com

Customer Choices (2)

petrol
diesel
(bio)diesel (B3)
gasohol (E25)
ethanol (E100)
compressed natural gas (CNG).

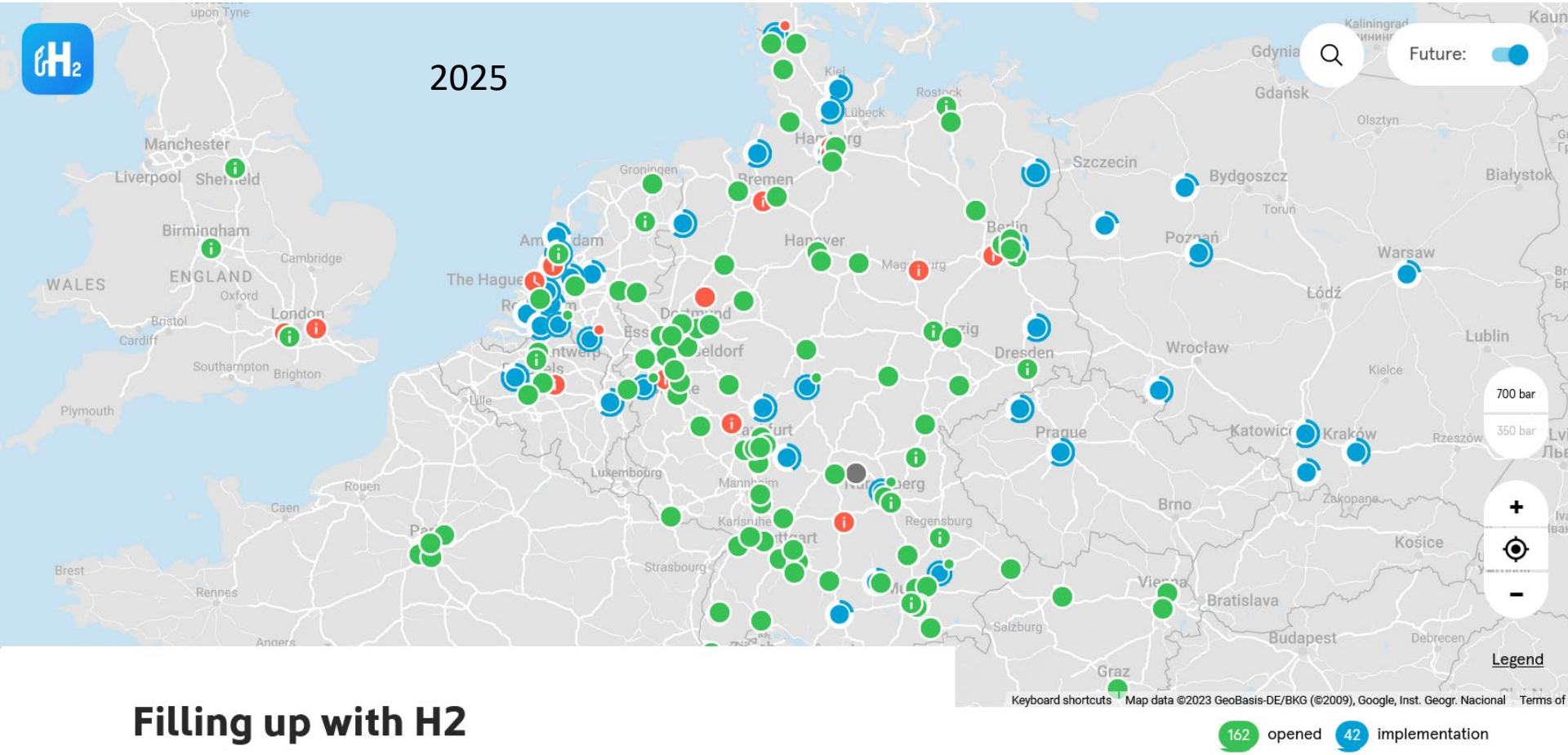
source: wikipedia

Modal Shift



Source: fraw.org.uk

European Hydrogen Infrastructure



Filling up with H2

- hydrogen refuelling infrastructure is cheaper than public electrical charging and has less impact on the electricity grid operation

Source: h2.live

Building a Hydrogen Infrastructure: Painful

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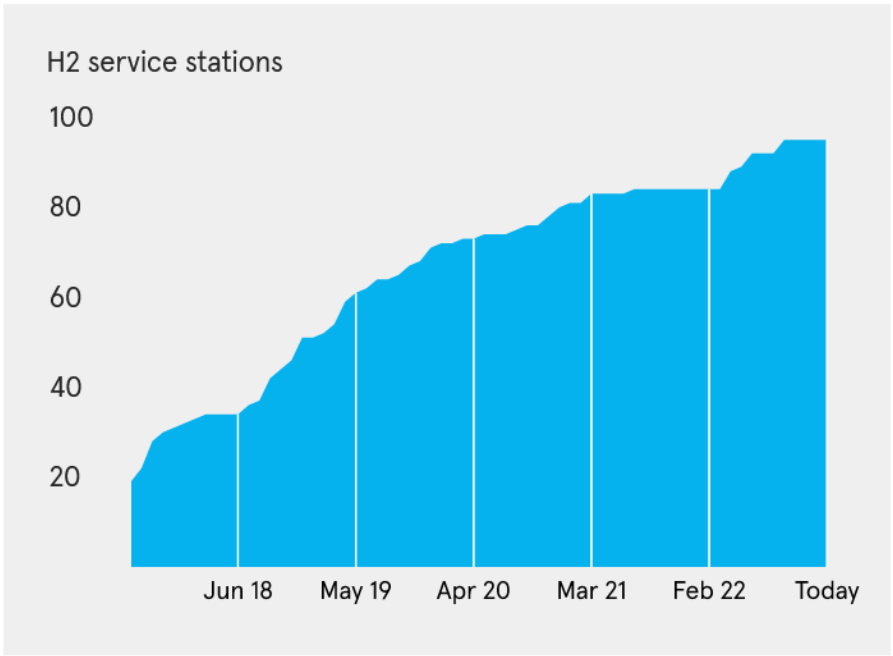
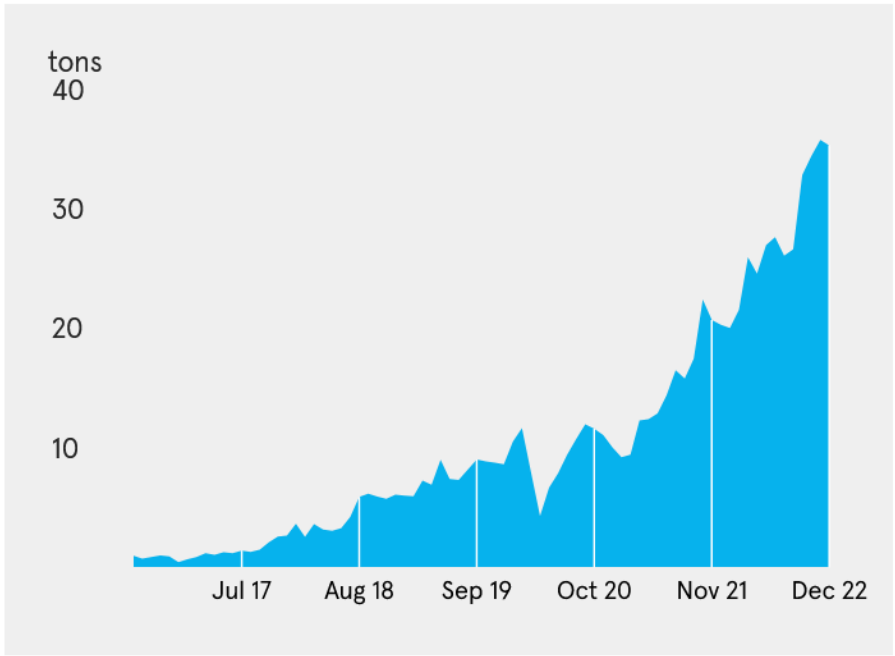
As of today: 95 H2 service stations are open
in Germany



Hydrogen demand
in Germany



(Based on the fuel stations operated by H2 MOBILITY.)

- forward investment is considerable and risky

Source: h2.live

Current Trends

- simplification of infrastructure requirements:
  - HGV transport
  - fleet operators
- liquid fuels for long-range transport
  - ammonia
  - liquified synthetic natural gas
  - methanol
- Europe:
  - establishment of hydrogen refuelling network
  - Intercontinal ‘corridors’ (TenT)

Thank you for your Attention!

Upcoming events:

JESS 2023 – Joint European Summer School,
10 to 15 & 17 to 22 Sept 2023,
Athens

www.jess-summerschool.eu

Any Questions?

contact:
r.steinbergerwilckens@bham.ac.uk

C-DICE is planning a sandpit on hydrogen and we would like YOUR help to generate the research problem to solve.

Scan the QR code to find out more.

The closing date for applications is 27 January 2023.

C-DICE/HyDEX Hydrogen Town Hall

https://www.cdice.ac.uk/events/c-dice-hydex-hydrogen-town-hall/