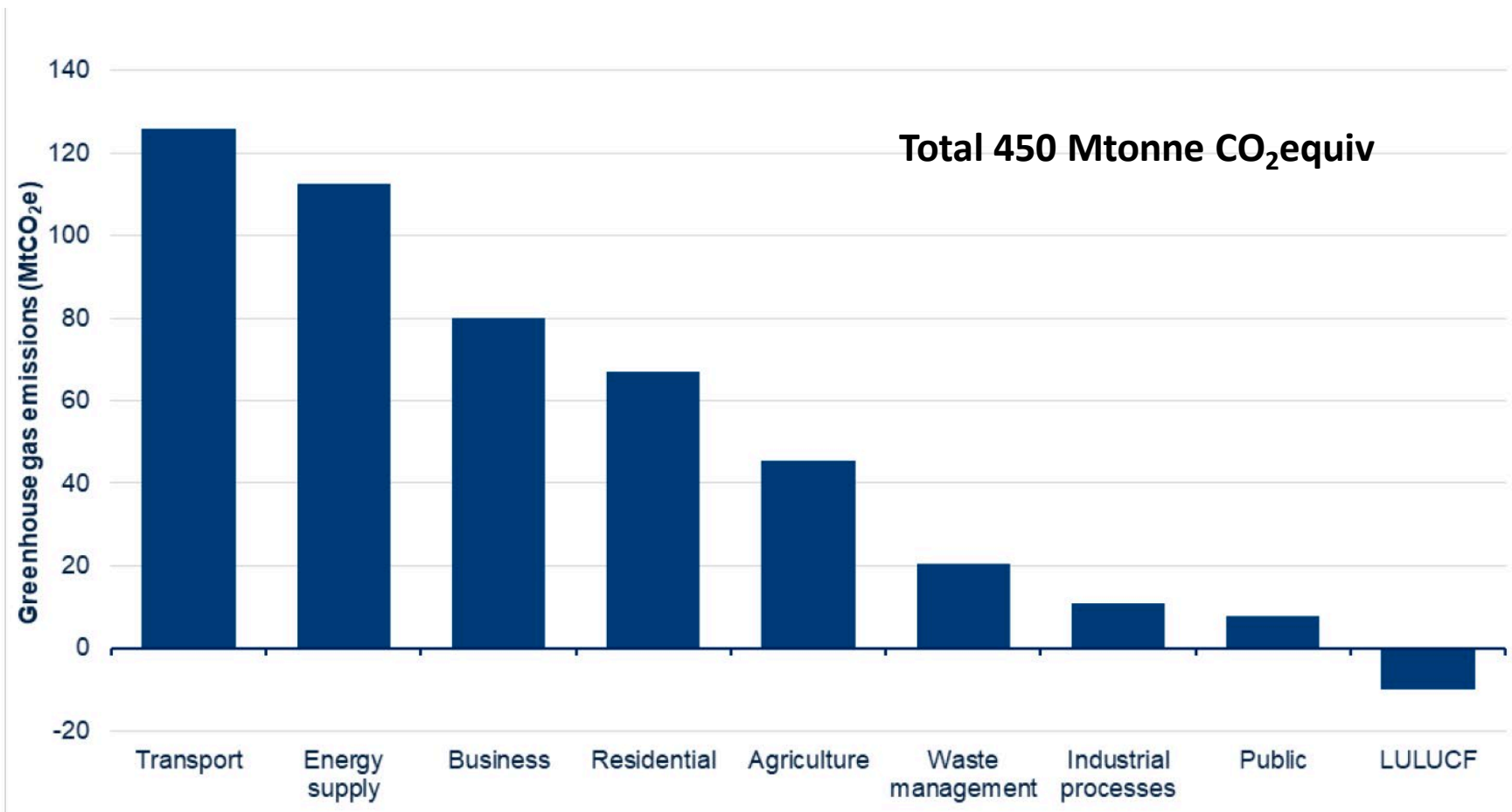


The background of the slide is a composite image of Earth from space. The lower half shows the Earth's surface with blue oceans and white clouds. The upper half shows the dark blue/black sky of space, filled with numerous stars. A large, detailed image of the Moon is positioned in the upper right quadrant, appearing to rise over the horizon of the Earth.

The wise use of hydrogen in the UK

Tom Baxter, FIChemE



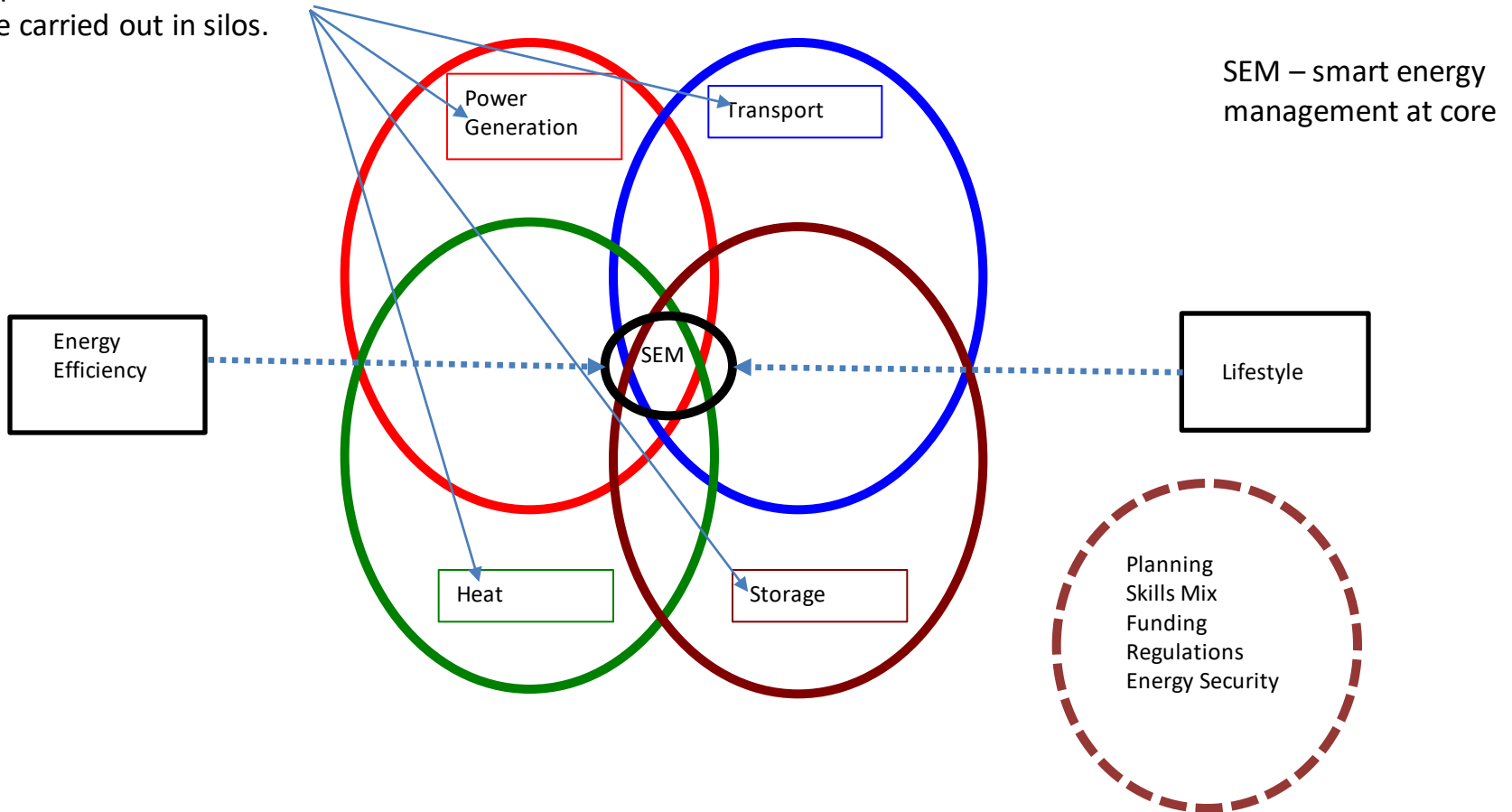
UK CO₂ Emissions 2018

1. A more 'circular' energy system, with energy efficiency at its core.
2. A greater direct electrification of end-use sectors.
3. Use of renewable and low-carbon fuels, including hydrogen, for end-use applications where direct heating or electrification are not feasible.

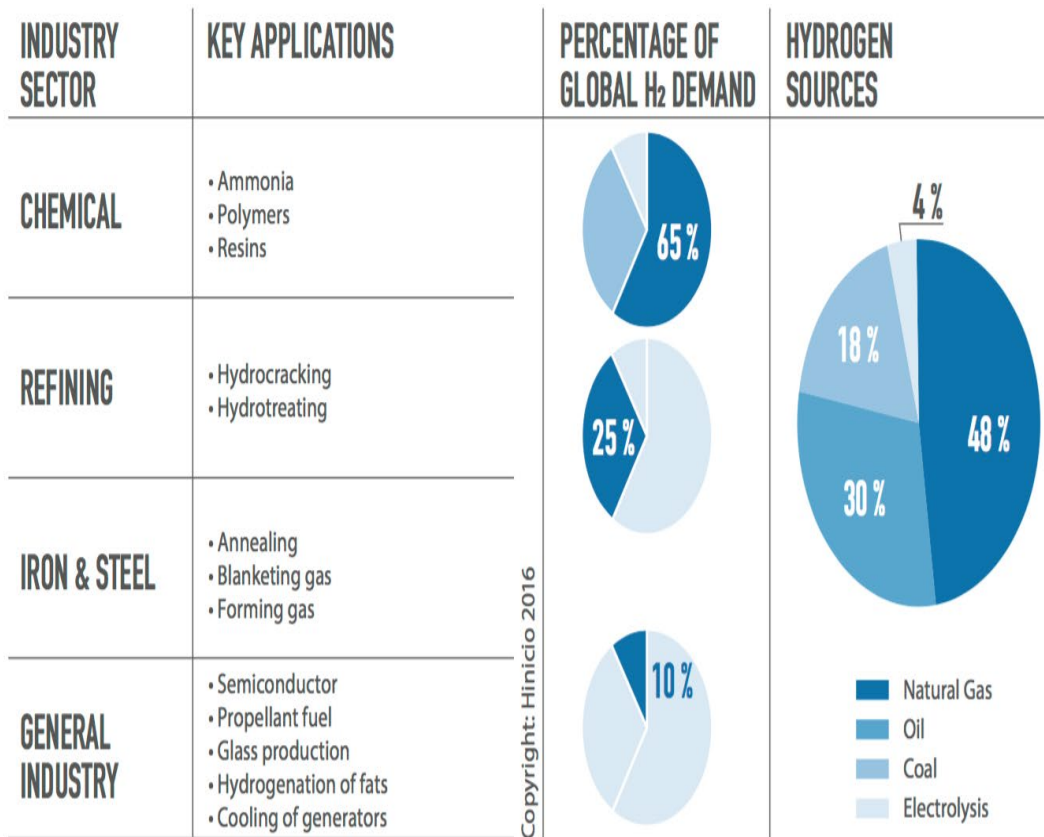
“Deliver against net zero on a trajectory in line with the Paris Agreement, decreasing UK emissions by at least 68% by 2030 as set out in our Nationally Determined Contribution, 78% by 2035 compared to 1990 levels in line with our Sixth Carbon Budget.”

EU Strategy and UK's GHG commitment

Option selection can't
be carried out in silos.



To make evidence based decisions integrated modelling is required



100 Mt/year Almost entirely supplied from fossil fuels, with 6% of global natural gas and 2% of global coal going to hydrogen production.

CO₂ emissions of around 900 MtCO₂ /yr.

More CO₂ equivalent if methane losses are included.

Source: IRENA based on FCH JU (2016).³

Grey Hydrogen – 9 tonnes CO₂/tonne H₂

Current Hydrogen Uses – immediate abatement focus

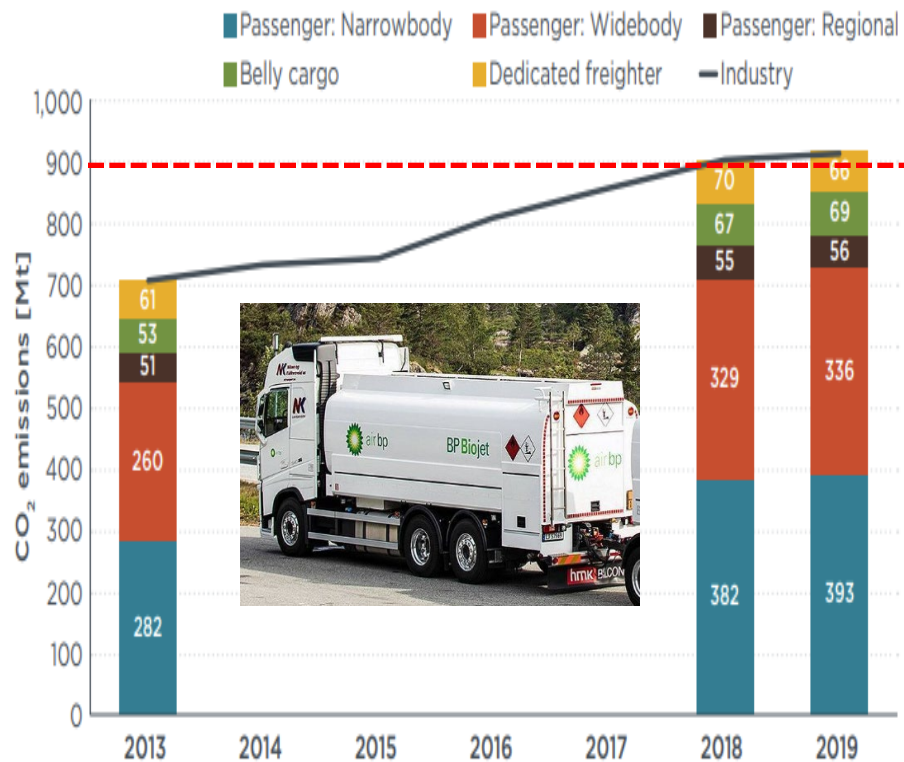
Hydrogen Champion Report

Recommendations to government and industry to accelerate the development of the UK hydrogen economy

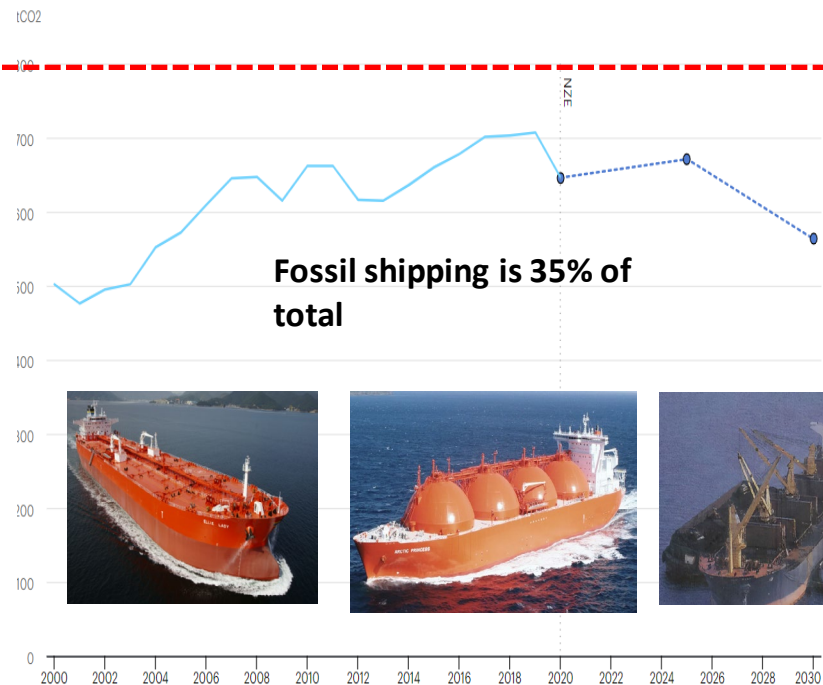
Government recommendation 3: *Drive rapid development of the hydrogen economy by stimulating demand in blending, heating and transport.*

No mention of displacing grey hydrogen

GOVUK's Hydrogen Champion's Report



CO₂ from hydrogen production

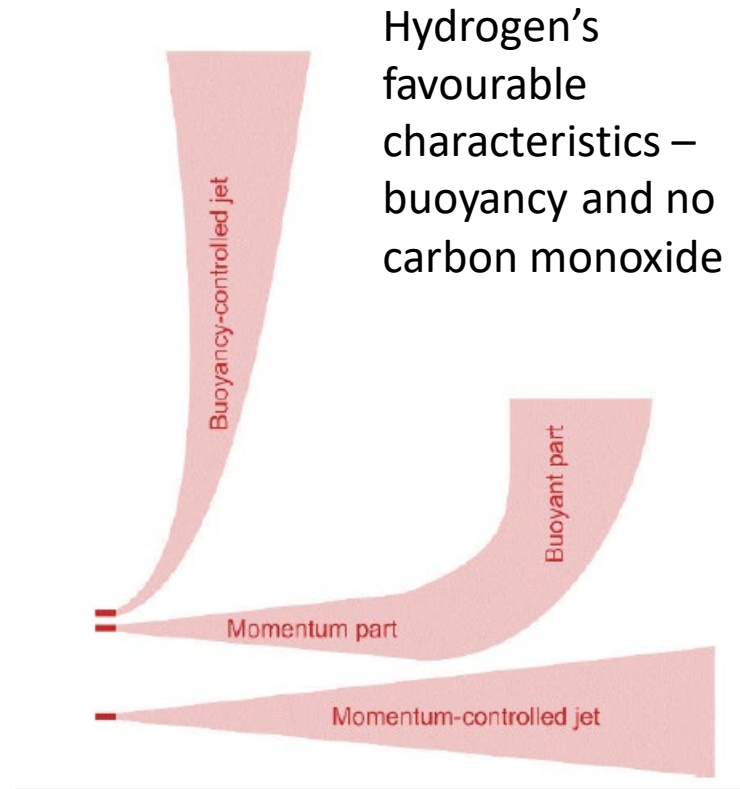


World Aviation and Shipping

Property	Hydrogen	Methane
Boiling Point (DegC)	Minus 253	Minus 161
Flammability Limits (%)	4-75	4.3 – 15
Ignition energy mJ	0.019	0.28
Laminar flame speed (m/s)	2.1	0.4

Heating Value

Hydrogen LHV	120 MJ/kg 10.8 MJ/Sm ³
Methane LHV	50 MJ/kg 35.8 MJ/Sm ³
Liquid Hydrogen	4000-5000 MJ/m ³
Kerosene	35300 MJ/m ³



Hydrogen Properties

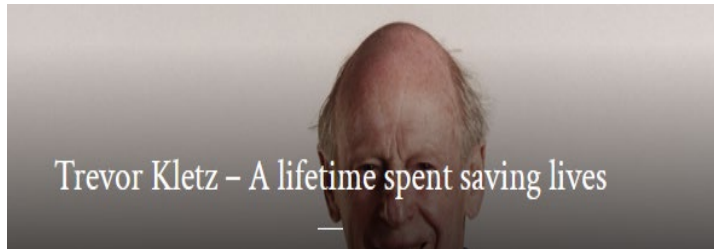
“What you don’t have, can’t leak” was a 1978 article in Chemistry and Industry.



An article that has shaped my thinking for over four decades.

Kletz’s approach to inherent safety are a mainstay for hazardous plant designers.

1. Eliminate the potential for harm;
2. Reduce the severity or scale of the consequences of the hazards;
3. Reduce the likelihoods of the hazard’s occurrence; and
4. Separate or protect people from the hazards.



Hydrogen Home Heating - What you don’t have, can’t leak

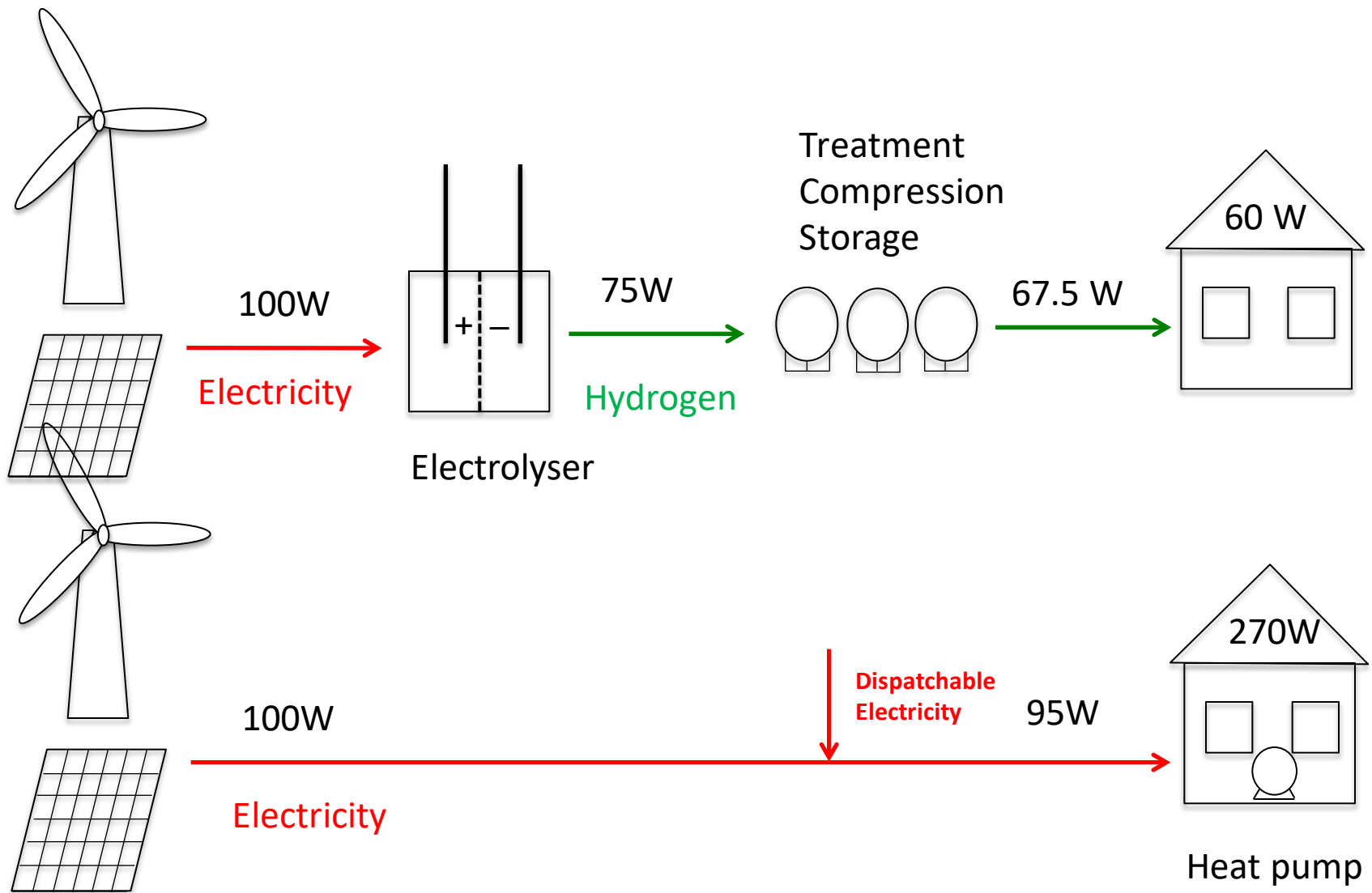
Does the UKGOV's Hy4Heat, domestic hydrogen project overlook the first principle of inherent safety – eliminate?



Hydrogen in a domestic setting presents direct risks from fire and explosion and the generation of NO_x. It also presents an escalation risk should there be a house fire.

Can the domestic hydrogen risk be eliminated? Yes - use electricity or a heat network for domestic heating.

What you don't have, can't leak



Green Hydrogen – Heat Pump – 3-4 x more efficient



'Time to stop the fight' | 32 independent studies slam the widespread use of hydrogen for heating

Expanded study of studies concludes that H₂ heating would be far too expensive and inefficient to compete with heat pumps

From an inherent safety and cost standpoint the evidence does not support hydrogen for household heating

Cost of household hydrogen

bp 2023 “There is only a limited role for hydrogen in buildings”

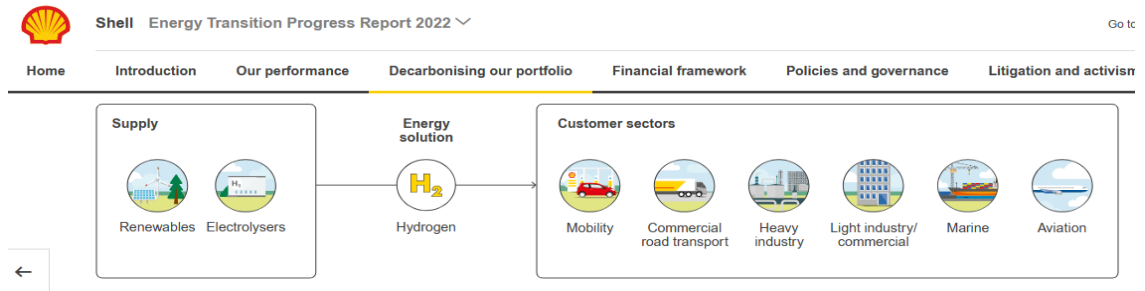
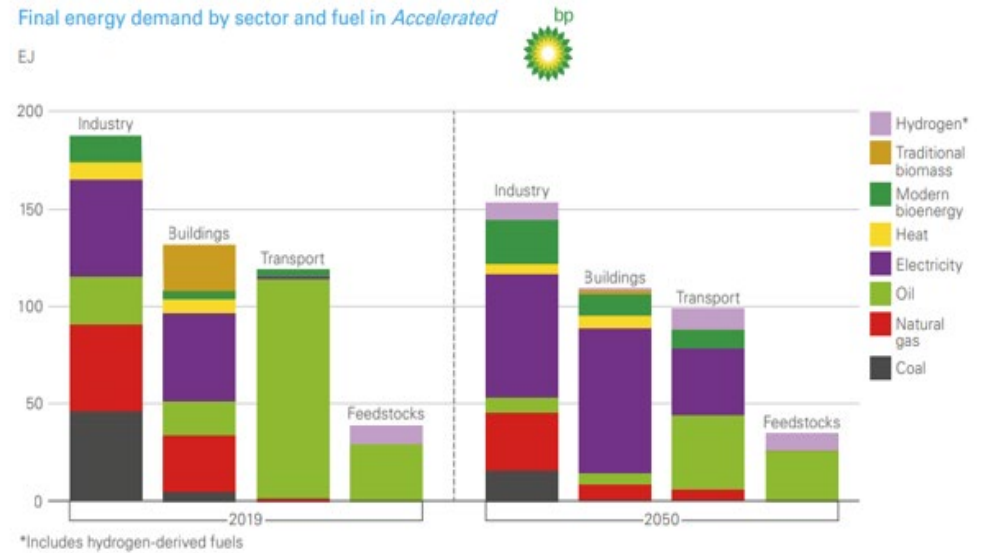


Heating 2017

Heating is another area that is difficult to decarbonise, and currently heating Britain's buildings and hot water is responsible for nearly a fifth of UK greenhouse gas emissions.

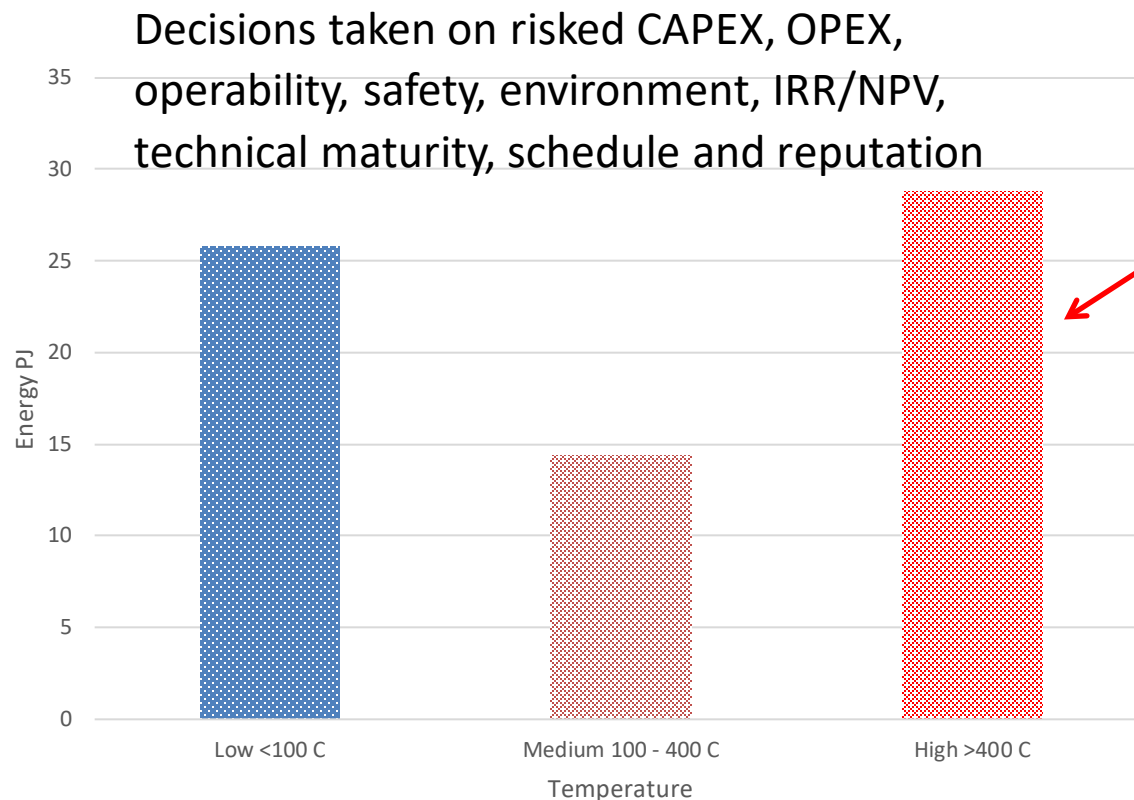
More than 80% of homes in the UK are heated by natural gas, so replacing these fuels with low-carbon alternatives, for instance electricity for heat pumps or hydrogen, is a critical step to reducing the UK's emissions.

The right alternative may differ by consumer preference, region or building type but hydrogen can be stored at high energy density in liquid or gaseous form for long periods of time – particularly important in the UK where energy demand is often greater in winter than in summer – and can also be combusted in boilers for heating. As such, Shell believes that there is a role for hydrogen power to play in the decarbonisation of central heating systems.

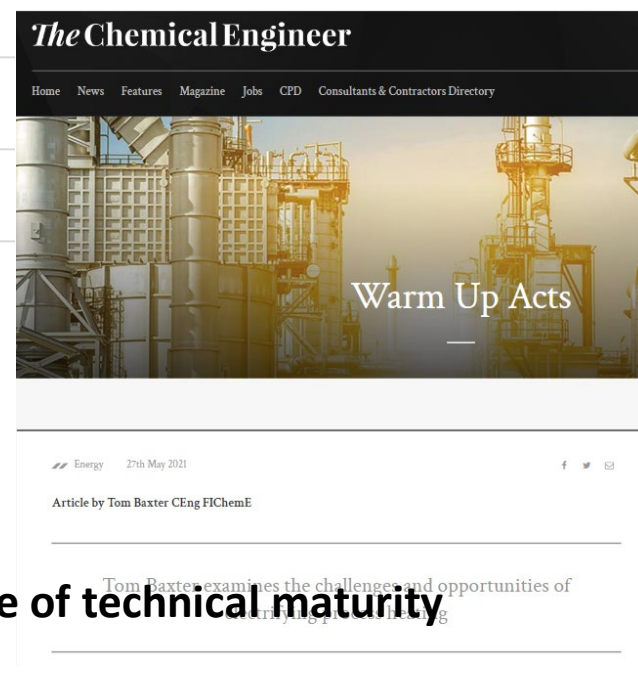


2022

Views of big oil



Hydrogen for high temperature heat and as reducing agent?



New build outcome different from retrofit on existing plant

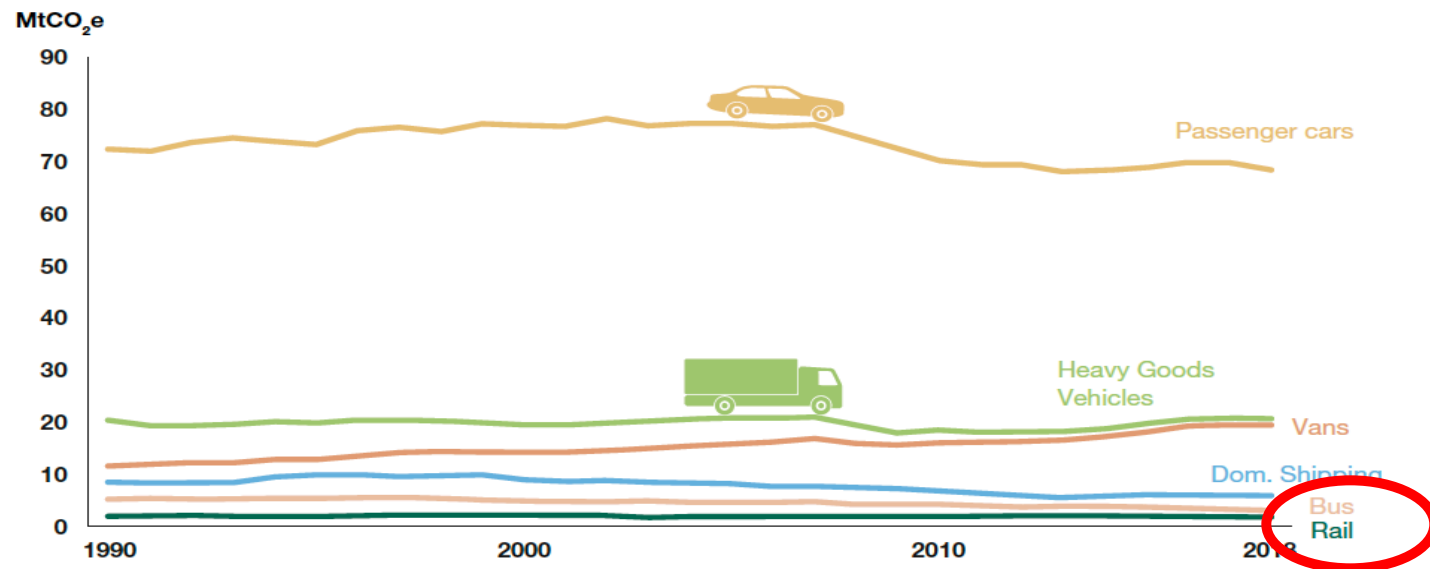
Technical maturity important

Electricity can provide all levels of temperature – an issue of technical maturity

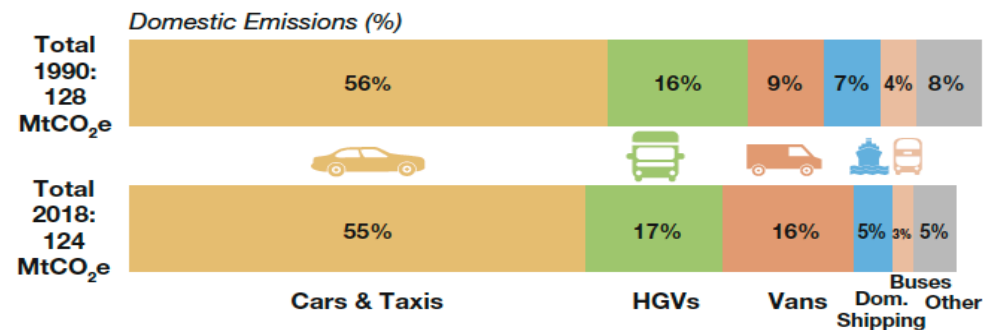
Industrial Heating

Figure 3: UK domestic and international GHG emissions, 2018

UK domestic transport GHG emissions from selected sources, 1990 to 2018

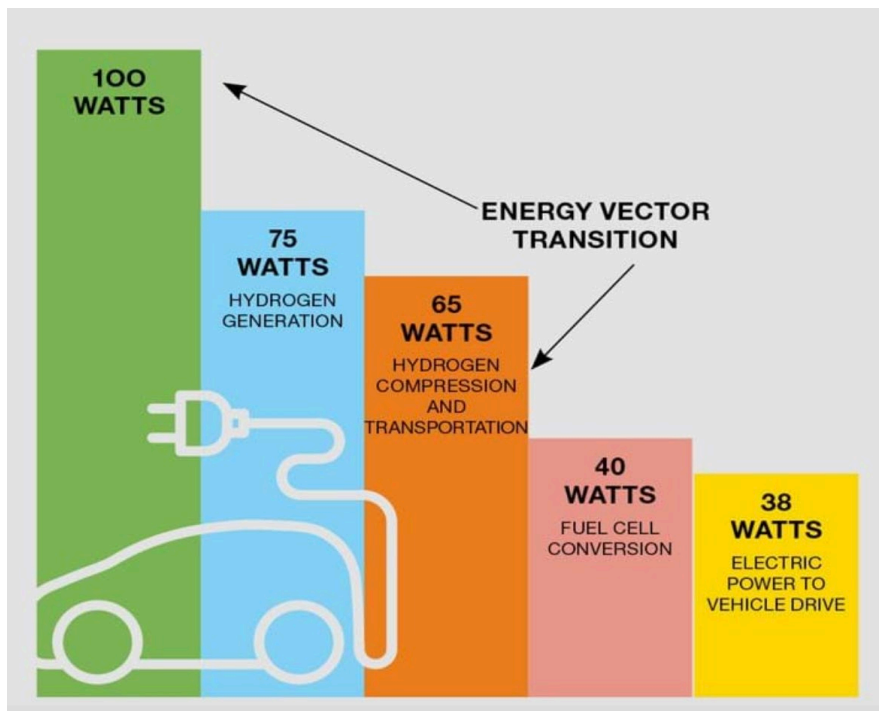


UK Transport GHG emissions by mode, 1990 and 2018

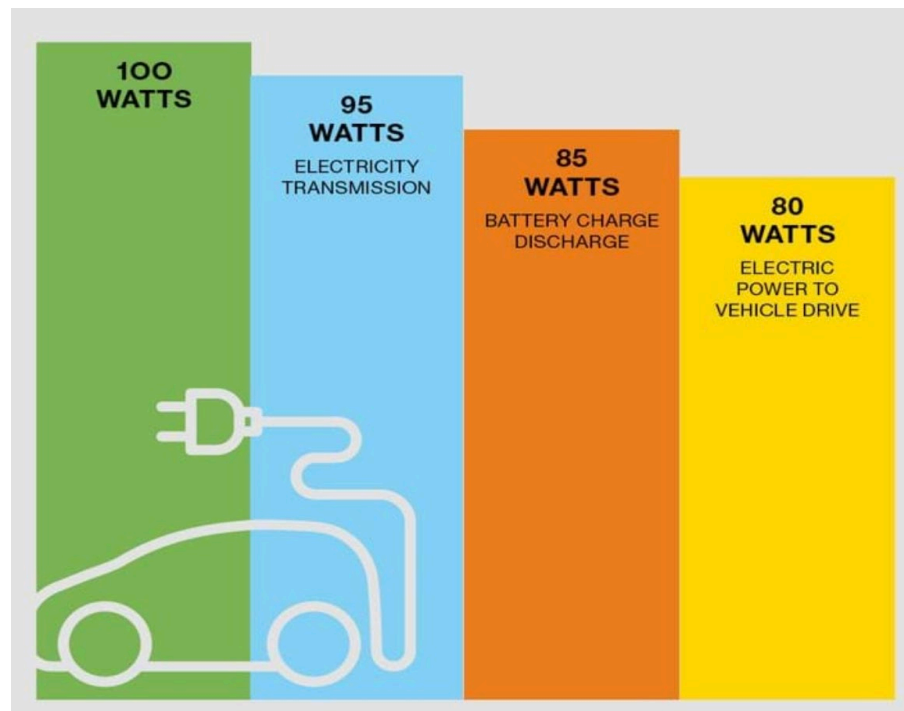


Transport - Passenger car dominated

HFCEV



BEV



BMW – “The overall efficiency in the power to vehicle drive energy chain is therefore only half the level of a BEV.”

BEV twice as efficient as HFCEV

Maybe, You Can Drive My Car

Article by Tom Baxter CEng FICChemE



Figure ES1: Summary of breakdown of overall lifecycle greenhouse gas impacts for Lower Medium Cars for selected powertrain types (Baseline scenario for 2020, 2030 and 2050, Net Zero Power for 2050)

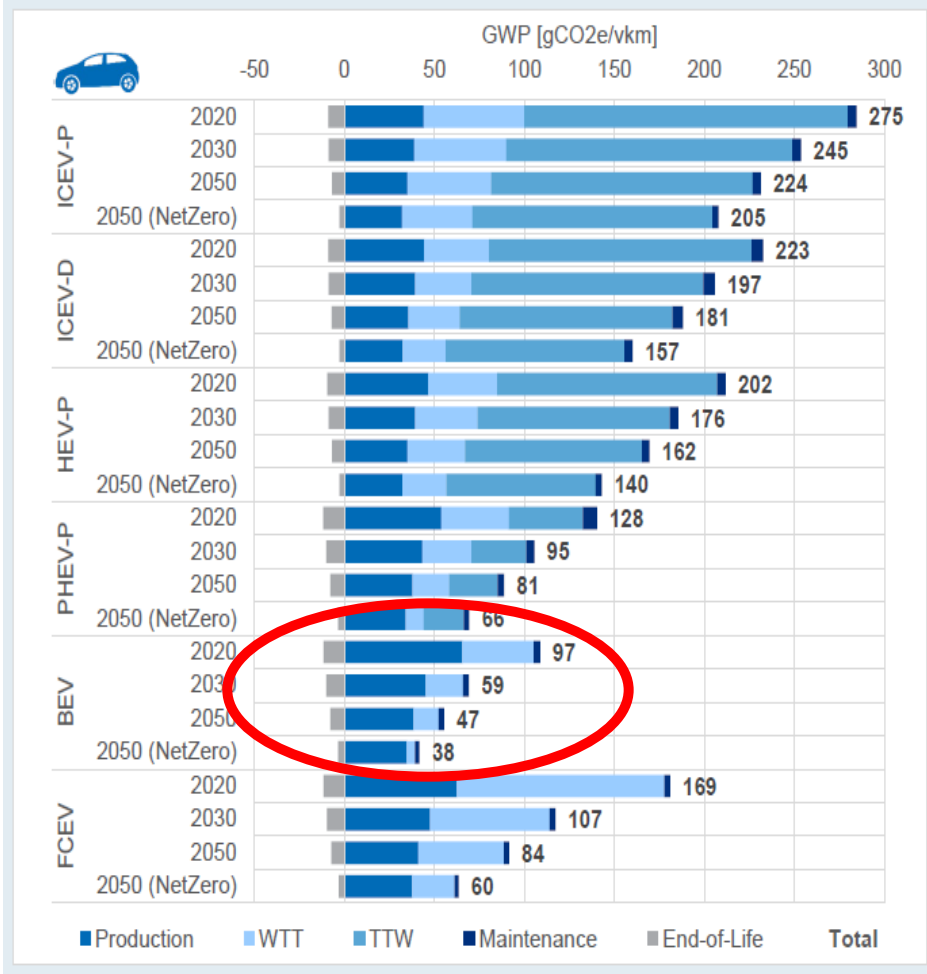
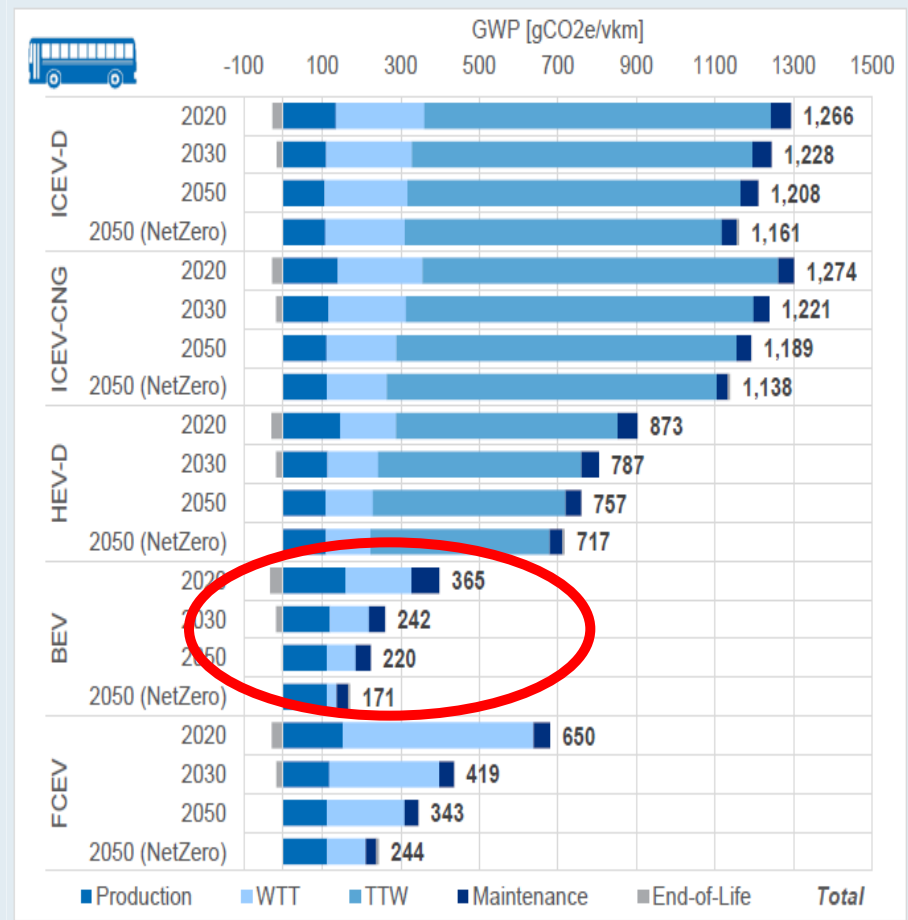


Figure 2.4: Summary of breakdown of overall lifecycle greenhouse gas impacts for urban buses for selected powertrain types (Baseline scenario for 2020, 2030 and 2050, Net Zero Power scenario for 2050)



Battery electric vehicles set to dominate market



Battery electric vs hydrogen

Scania has invested in hydrogen technologies and is currently the only heavy-duty vehicle manufacturer with vehicles in operations with customers. The engineers have gained valuable insights from these early tests and efforts will continue. However, going forward the use of hydrogen for such applications will be limited since three times as much renewable electricity is needed to power a hydrogen truck compared to a battery electric truck. A great deal of energy is namely lost in the production, distribution, and conversion back to electricity.



Scania’s commitment to battery electric vehicles

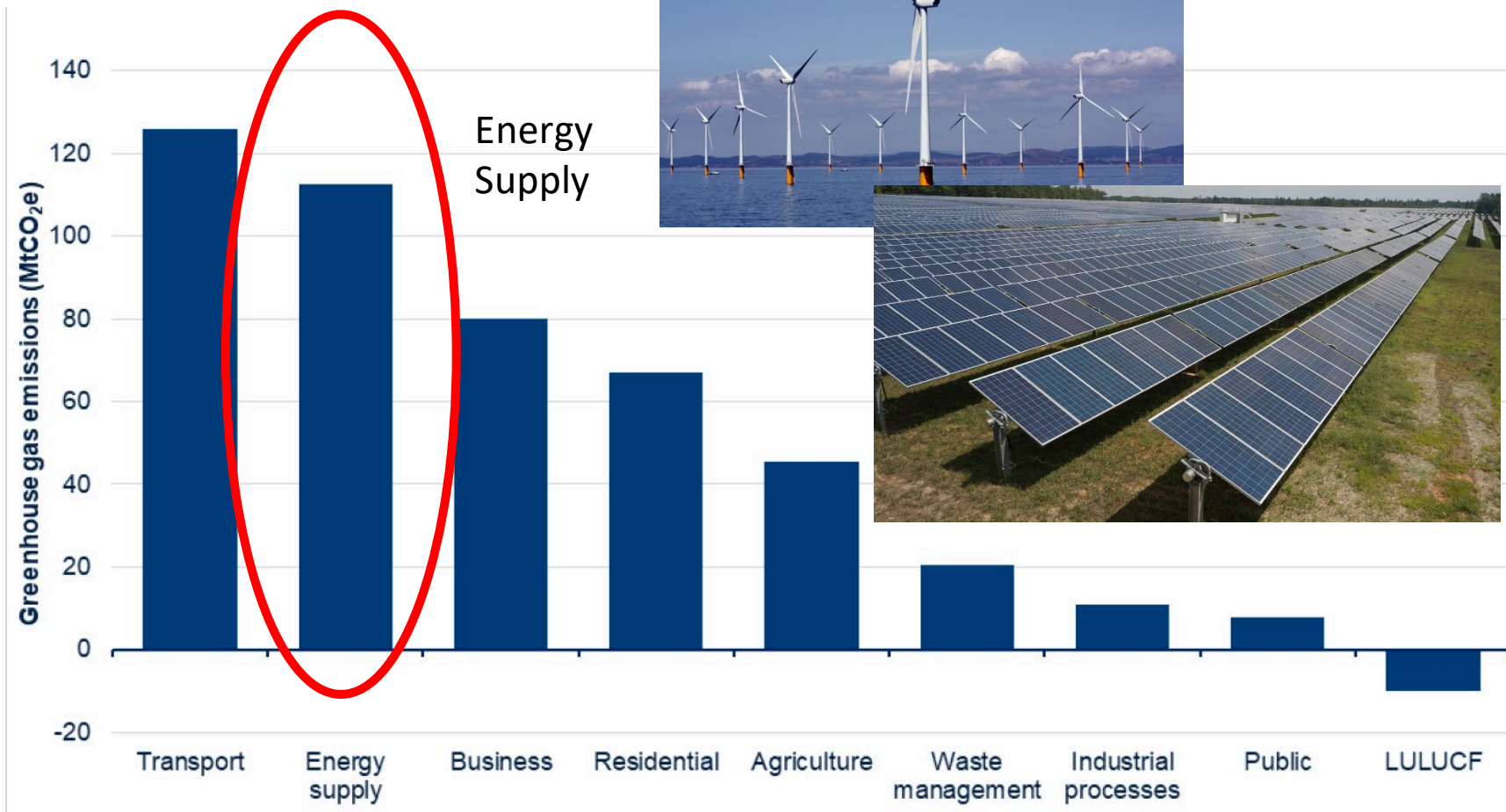
Nikola’s New CEO Says Hydrogen Semis Still Coming This Year As It Recalls Battery Trucks



Hydrogen-Powered Trash Collection Trucks in Glasgow Cancelled: £7 Million Diverted to Electric Vehicles

Hydrogen Heavy Haulage – jury is out

[Scania’s commitment to battery electric vehicles](#)



Energy Supply, Renewable Intermittency and Storage

Gas no CCS – accept short term emissions

Gas with CCS

BECCS

Thermal

Batteries – macro and micro

Hydrogen

Hydrogen derivatives

Hydro

Nuclear

Imports

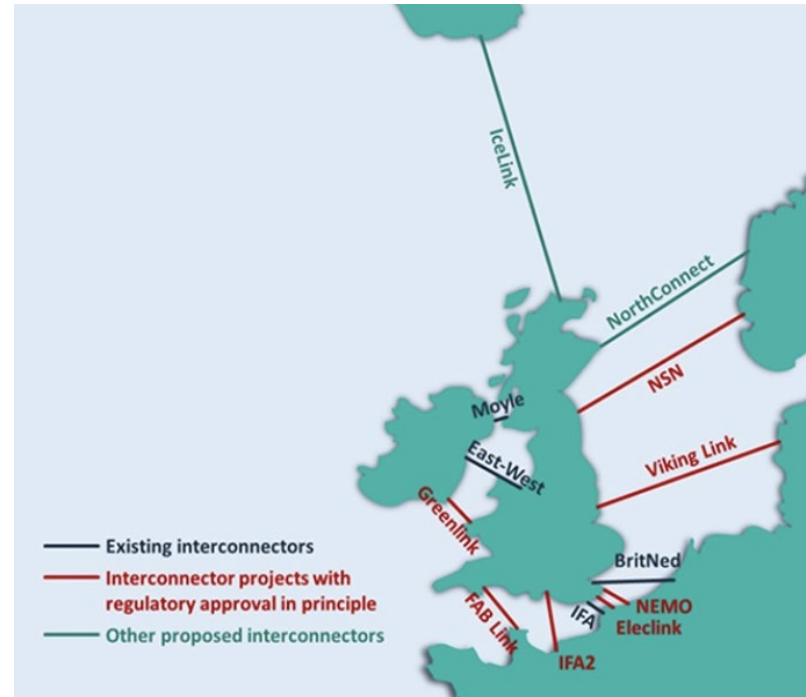
Bio-fuels

Compressed gases

Tidal

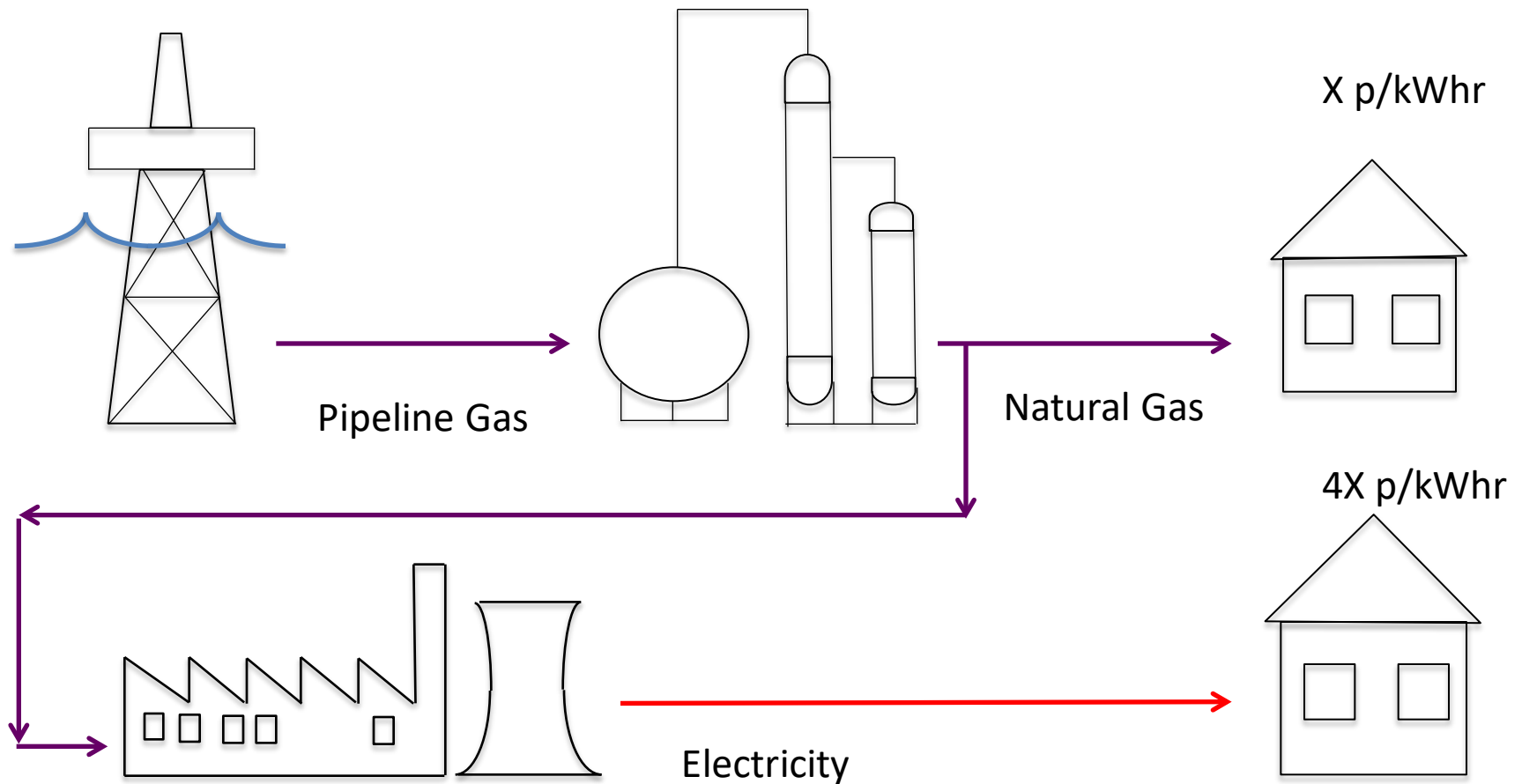
Geothermal

Load shifting



What does statistical modelling say?

What about a beast from the east and no wind?



Current marginal pricing is hindering electrification

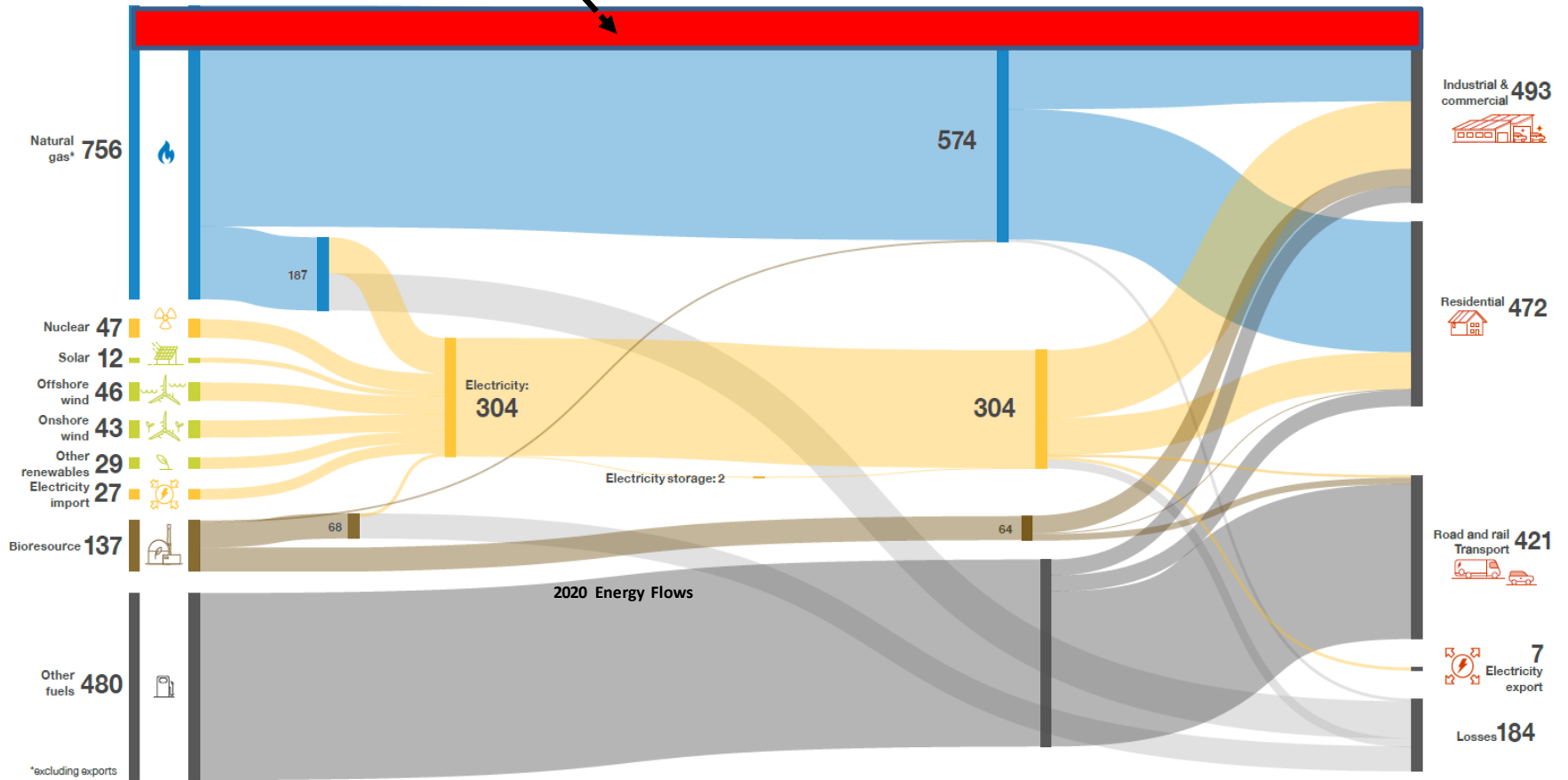
Today's energy supply



Hydrogen will not deliver in the short term – a distraction to what we should be doing now – now is high impact, technology ready options

Aviation and Shipping – ring fence bio-fuels

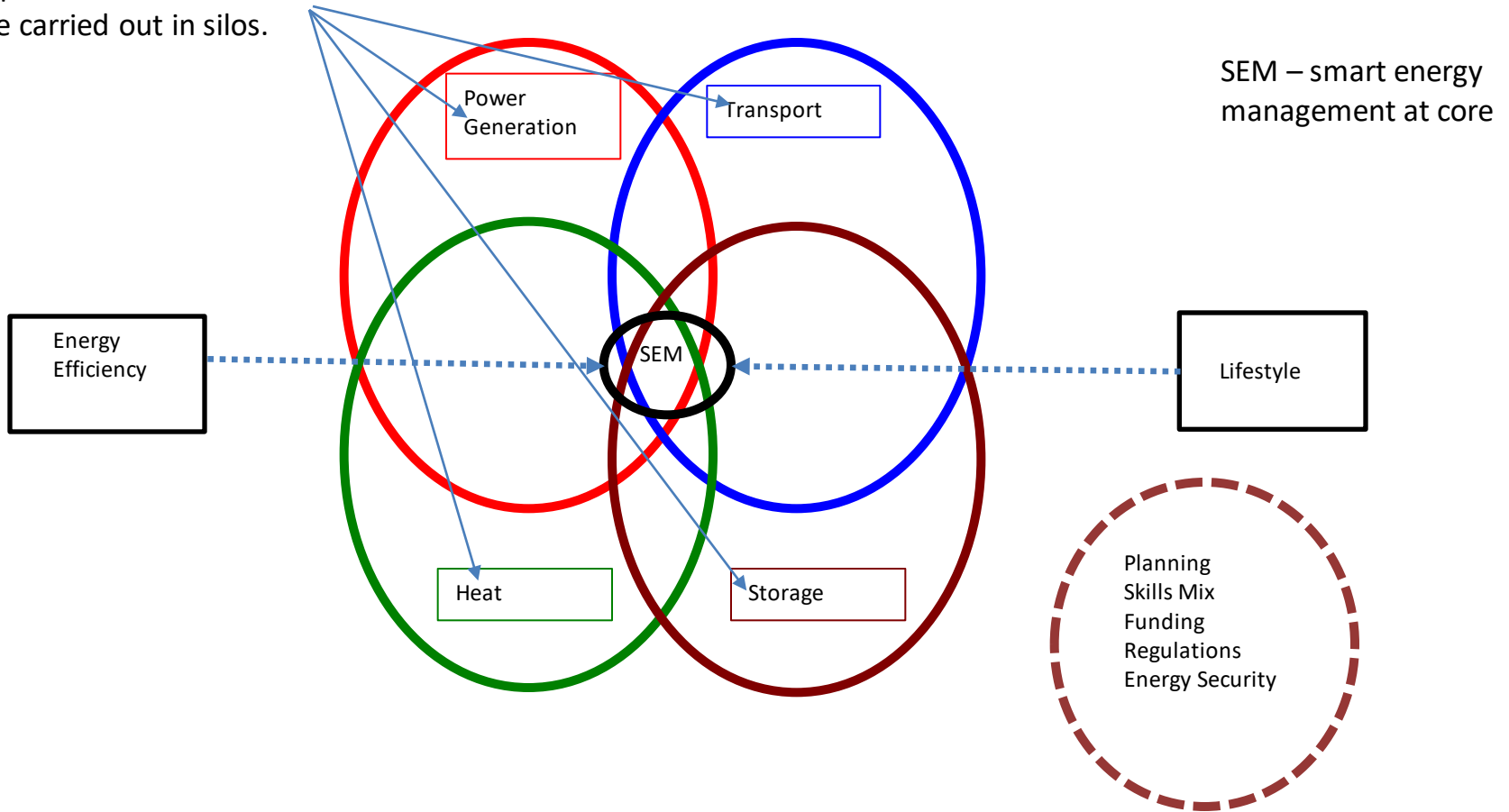
2023 - 2030 Hydrogen 10 GW



Total 1577 TWh

2020 National Grid Energy Flows in TWh per year

Option selection can't be carried out in silos.



Options are being selected without regard to wider system

Displacing grey/brown/black hydrogen should be a priority

Hydrogen has no place in a household

Blending is a very poor use of low carbon hydrogen

Hydrogen will have a role in some industrial heating applications and as a reducing agent

Surface transport will move to electrification

Marine and aviation – jury is out, ring fence bio-fuels

Hydrogen and its derivatives may have a role for seasonal storage

Hydrogen will not deliver in the vital short term – a distraction to what we should be doing now – now is high impact, technology ready options

Hydrogen is good for big business not the consumer

Conclusions