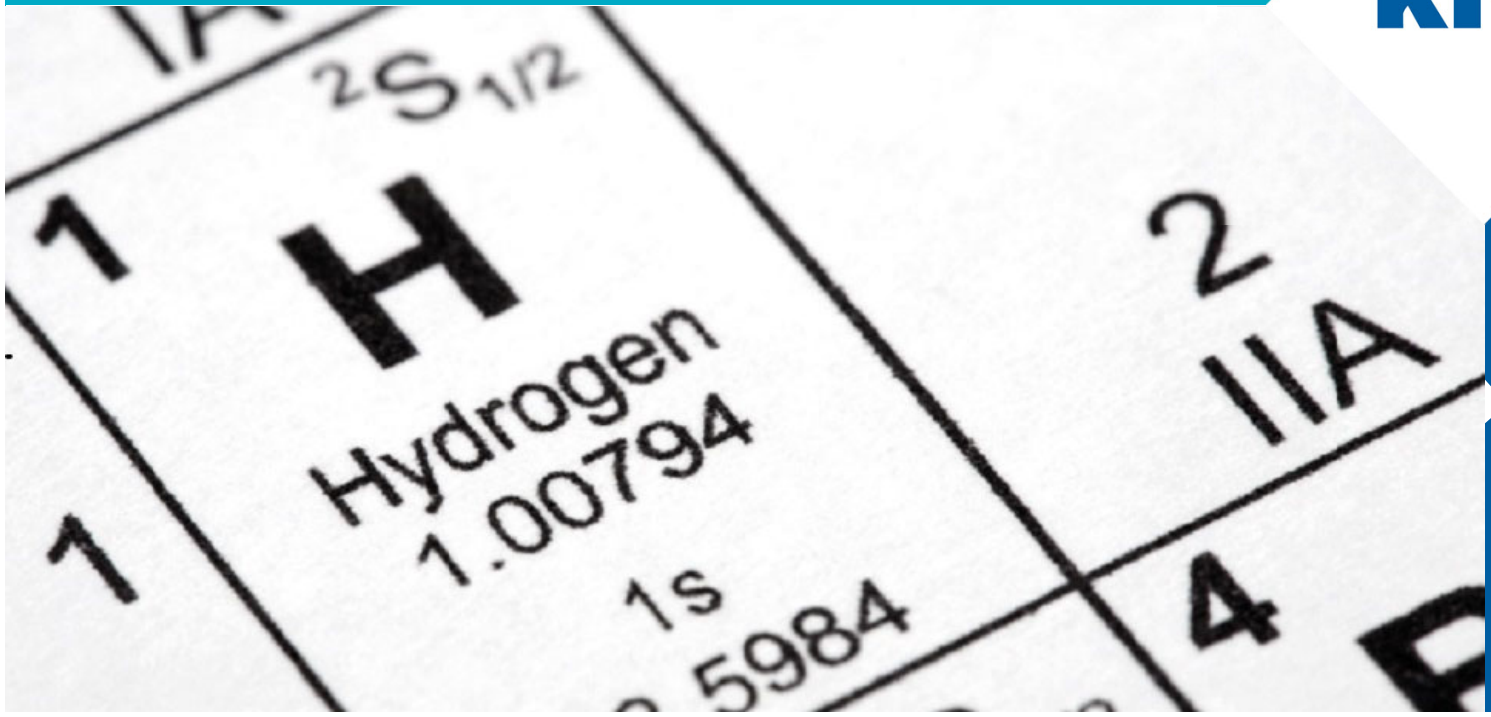
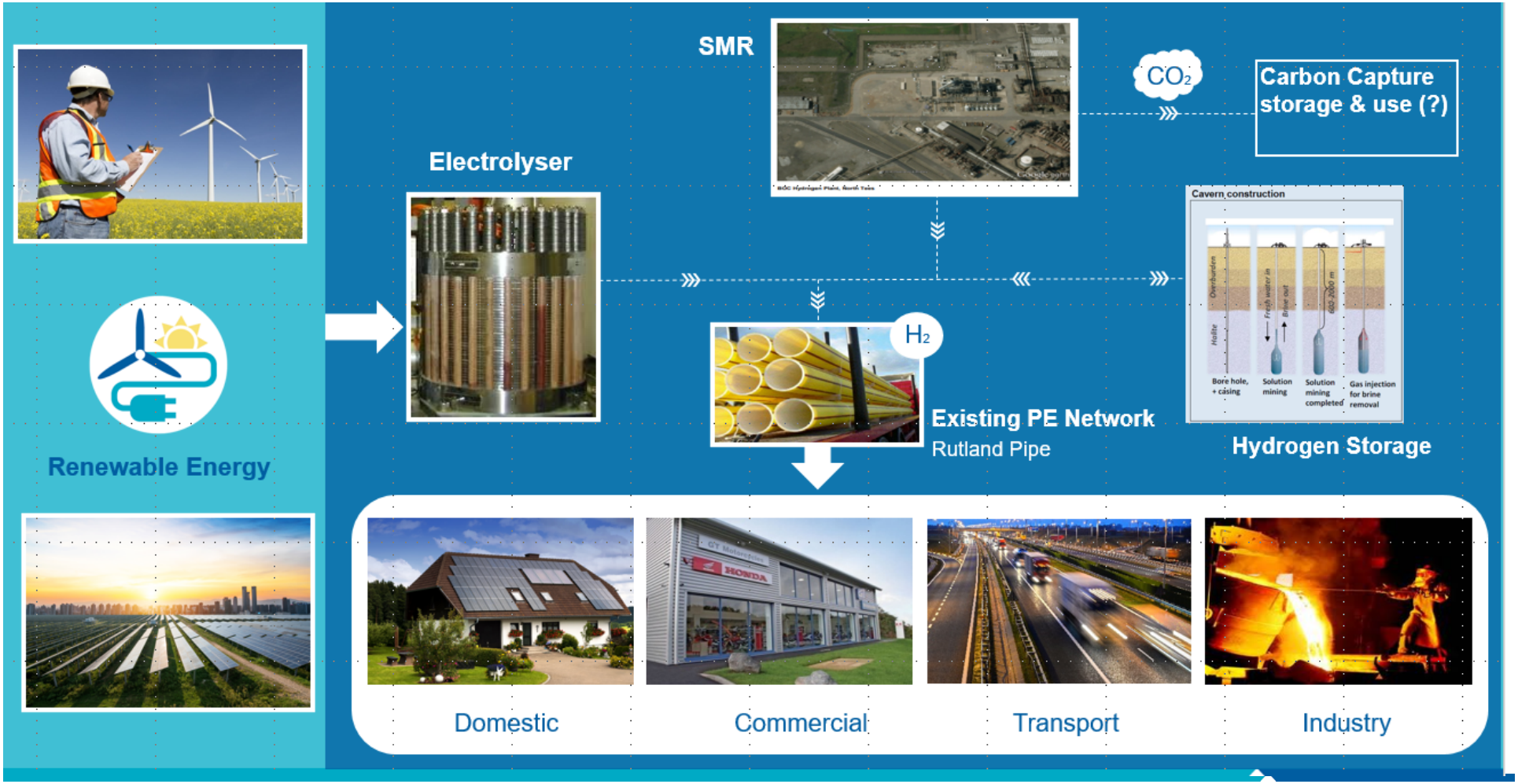
Hydrogen: Cost, Storage & Transportation

Mark Crowther



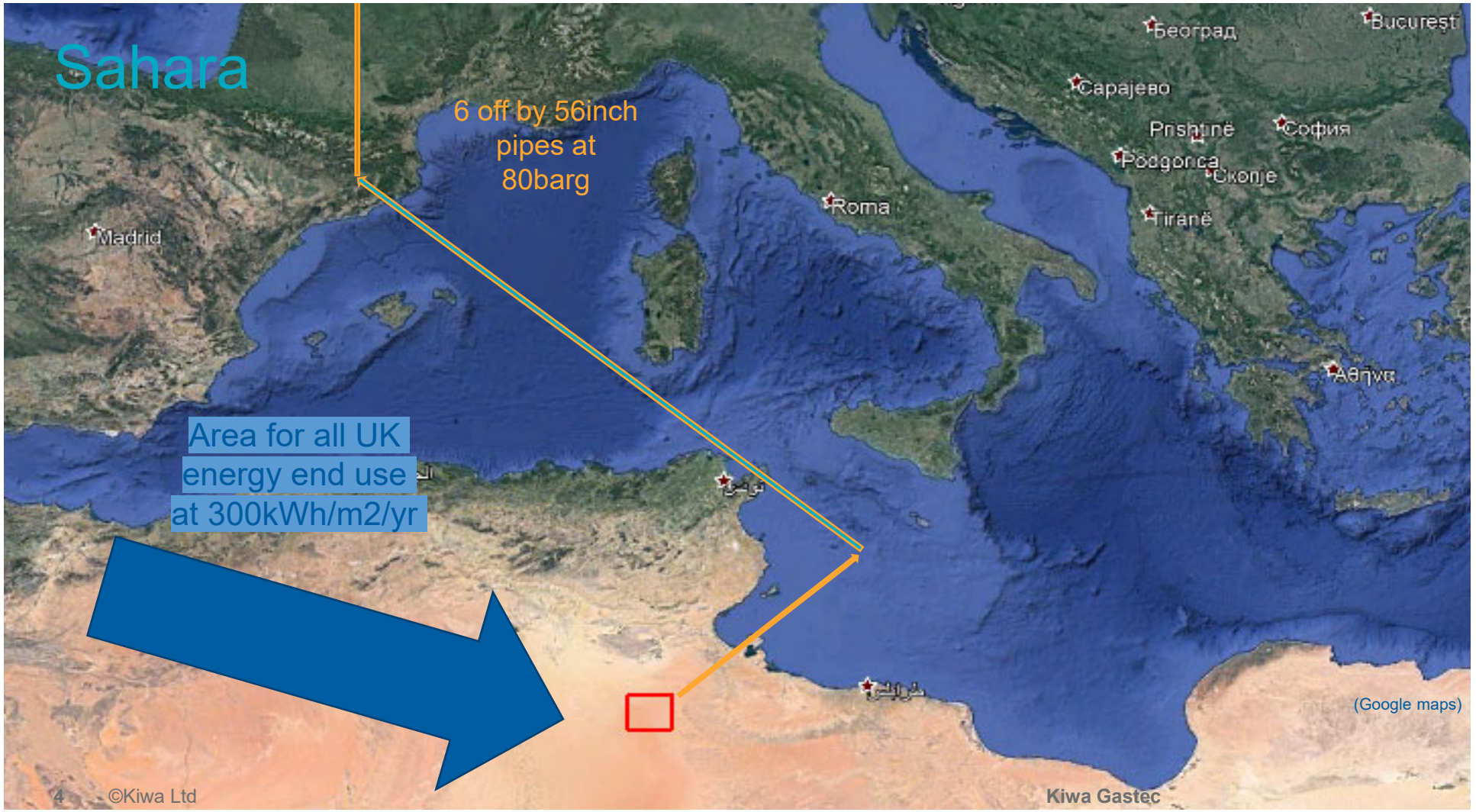
Kiwa Gastec

Trust
Quality
Progress


SMR
CO_2
Carbon Capture storage & use (?)
Electrolyser
H_2
Existing PE Network
Rutland Pipe
Cavern construction
Overburden
Halite
Fresh water in
Brine out
600-2000 m
Bore hole, + casing
Solution mining
Solution mining completed
Gas injection for brine removal
Hydrogen Storage
Renewable Energy
Domestic
Commercial
Transport
Industry

Assertions

- The world is not short of potential renewable energy.
  6,200 km2 of Sahara desert would produce all UK final energy needs (1/2 of an Australian sheep farm!)
- The world does require an energy vector.
  Reliable, modestly priced to move this energy from point of production/capture and transfer to consumer when required.
- Historically, storage has enabled transparent markets.
  The separation of production from use improves the efficiency of both.
- Ideally, the vector should not be poisonous, or of short life.
- Ideally, no greenhouse gas emissions (e.g. CO_2) at point of use.
- Probably unrealistic to think low carbon energy can ever be cheaper than some fossil fuels e.g. oil or gas in Saudi or parts of Russia.
- BUT de-carbonisation should be as cost effective as possible.


Sahara
6 off by 56inch pipes at 80barg
Area for all UK energy end use at 300kWh/m2/yr
Madrid
Roma
Београд
Bucureşti
Сарајево
Priština
София
Podgorica
Skonje
Tiranë
Αθήνα
(Google maps)

Hydrogen

Hydrogen is not a solution looking for a problem, but a solution to very real and complex issues, the principal one being: **UK inter-seasonal variation in energy demand.**

Figure 2

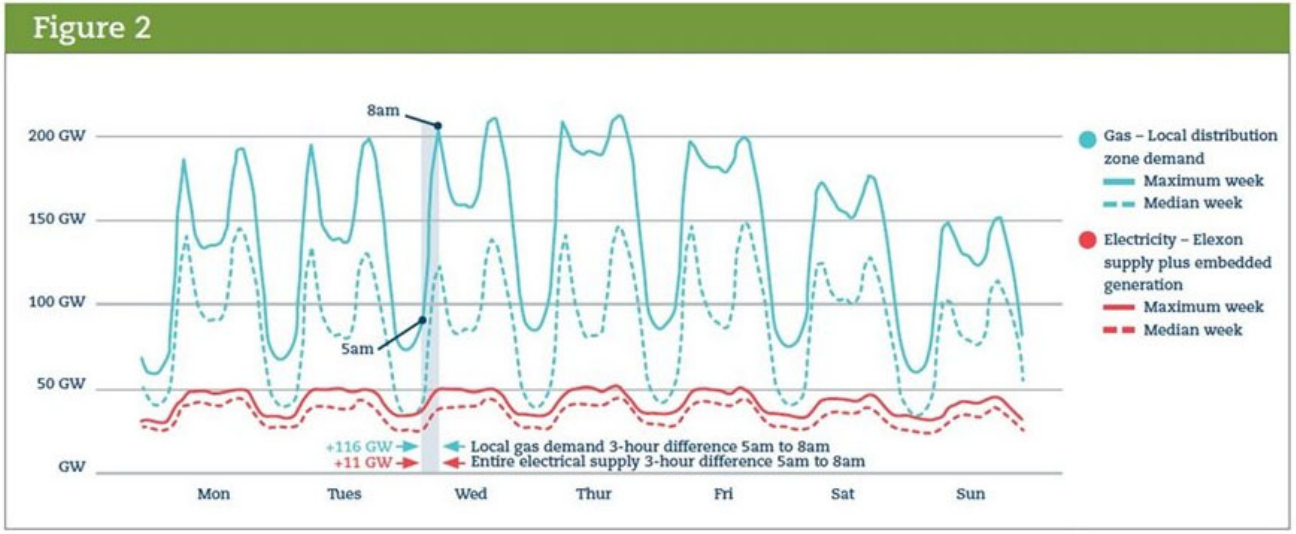


Figure 2: Britain's local gas demand and electrical system supply - maximum and median demand weeks. The week dating 22nd to 28th January is the week most representative of median weekly demand for the 2017–2018 heating season. The week dating 26th February to 5th March represents the maximum demand week of the 2017–2018 heating season.

These figures exclude future energy for transport and industry that will be required

Ref UKERC

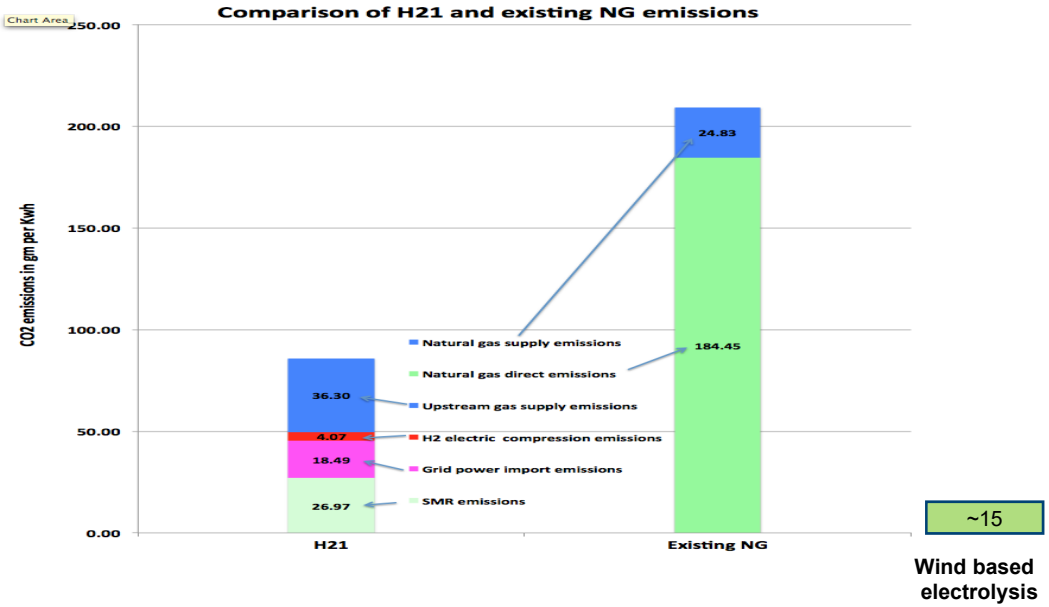
Hypothesis of this presentation

- **Hydrogen to replace Natural Gas in the existing plastic low pressure distribution systems (some ~2barg, but principally 25-70 millibarg). !**
- As required, these would be inter-connected with a new high pressure national/international hydrogen transmission system at 85bar.

- GB has changed gas quality before:
  - Town Gas 50%v/v Hydrogen to Natural Gas
  - 1968-1977: 44million gas appliances in 13m homes at £630/house (2020 money)
- Natural Gas to Hydrogen
  - 2025-? ~44million appliances in 23m homes
- Republic of Ireland changed circa1990 and the IoM as recent as 2010 (£3500/house).

Does it really save carbon emissions?

Components of Scope 3 carbon footprint of Natural Gas, SMR, hydrogen and wind turbine hydrogen END TO END WHOLE SYSTEM.



Yes, whilst enabling householders to keep their much-loved combi boiler!

Is it cheap to convey and store?

- Yes - it will be a bit more expensive than NG, but a lot less than electricity expressed as per MW or MWh.

PIPELINE TRANSPORT	MW	Dist km	Project cost	£/MW km	Ref GaC from public data	Ratio to av: gas
S Wales NTS	24000	316	£700m	£92	Milford Haven to Stroud	
Nord Stream	68000	1222	£8800m	£106	Vyborg , Greifswold	
Brit Ned	1000	240	£540m	£2250	Sub-sea HVDC	1:23
Scotland wind	2700	220	£350m	£589	Beauly-Denny, Scotland	1:6
Carlisle to Sellafield to Heysham HV	3400	190	£2800m	£4325	Planning application through National Park	1:47
Spittal to Blackhillock	190	320	£970m	£2526	As built – mixed line	1:26

Wobbe Index
H2 45.8 MJ/m3
Methane 50.4 MJ/m3

INTERSEASONAL STORAGE			Ratio to gas
Salt cavern Large	£/kWh	0.2	
Salt Cavern Small	£/kWh	0.6	
Australian Mega Battery	£/kWh	450	1:750 to 2250

Energy density
Li/S battery 0.5 kWh/kg
H2 39.5 kWh/kg

Is conversion to hydrogen cheap? Zero carbon

For house 10kW peak COP 2.5 House heat pump 4kW(elec)	Wind alone	Nuclear alone	Wind/hydrogen
Hydrogen/electricity Prod facility	£10,000	£27,879	£18,265*
Inter-seasonal storage	NA	NA	£2,000
Hydrogen/electricity trans/dist	£10,000	£10,000	£1,142
Appliance change	£9,000	£9,000	£2,500
TOTAL	£29,000	£46,879	£23,907
Notes	Re-wiring the UK costs are ?? Operation during still periods ?? Effectiveness of insulation ??	Re-wiring the UK costs are ?? High production capital	No re-wiring H2 for ALL sectors Inter-seasonal storage offers continuous demand for wind and lowers peak. Keep their combi boilers

* 12,000kWh/y house using 30% yield wind-turbine/electrolyser at £4000/kW

Why is conversion to hydrogen cheap?

- Avoids re-wiring the UK, whilst uniquely addressing all sectors ie heat, and industry using standard technology and opens the door to hydrogen vehicles.
- *Why* is H_2 cheap relative to other options?
  - Hydrogen can be stored. No need for peak generation to meet winter demand. H_2 is a fungible.
  - Because (in the short term) SMR hydrogen is cheap to make, store, transport and burn in the home.
  - Renewable hydrogen can be shipped at low cost from locations where renewables are cheap.
- Plastic pipes and holes in the ground are low cost. As an energy vector H_2 needs much less copper or lithium/rare earth batteries, than electricity.
- Peak (low carbon) electricity generation is expensive.

The cost of de-carbonisation-a different perspective.

Using wind derived hydrogen the UK could de-carbonise its housing stock for about £23,000 per household eg the cost of (for example) a new SUV.

Wind/solar derived H_2 will eliminate the on-going costs of imported oil and gas

Just build and maintain. The energy source is free.

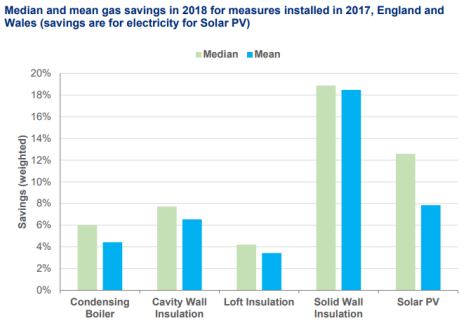
Sweat the wind/solar assets around the year to make hydrogen for Dec-Mar

Is it safe?

- UK gas industry fire & explosion, whole supply chain. Typically 1 death per year.
- UK struck by lightning and killed by cows. Typically 3-5 deaths per year.
- UK road accidents . About 1800 deaths per year.
- H2 eliminates all risk of CO poisoning and death
- During the transition (1968-'77) Town Gas (50% H_2) to Nat Gas. No change in accident rate for fires & explosions.
- On conversion to hydrogen excess flow valves will be fitted to cut-off large leaks.
- A conversion to hydrogen will have no meaningful effect on the accident rate.

Is it convenient for end consumers?

- 80% of householders neither have the skills nor money to carry out any significant decarbonisation (ref WWU).
- Substantial energy saving is a challenge; they are often small values <10%



- People love combi boilers – no tank and limitless hot water; H_2 boilers also offer improved local air quality.
- The conversion from Nat Gas to Hydrogen (i.e. 100% point of use de-carbonisation) should take from 9am one day to noon the next. Costs (at the time) will be borne by the GDNO and H2 suppliers.
- Probably hydrogen's USP. No upfront consumer cost and no hassle for people in a busy world.

Is it a politically acceptable message?

- HMG will arrange the complete decarbonisation of your property with minimal hassle (giving you a new boiler, cooker or gas fire) at no upfront cost.
- This is the same operation as was carried out in the UK in the 1960/70's & more recently in other countries. Initially this will reduce carbon emissions by about 2/3 when the hydrogen is made from Natural Gas.
- You can keep your combi boiler. You can heat your property as and when you want.
- Emissions will fall further as green hydrogen is increasingly imported from windy/ desert areas, until almost complete decarbonisation is achieved.
- The hydrogen can be used to heat your house, commerce, refresh industry and enable you to refuel your vehicle at the local filling station.

Discussion

Thank you.

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