

26th April
2021

The Hydrogen Economy, a real energy prospect or flimflam?

Dr. Michael C. Clarke

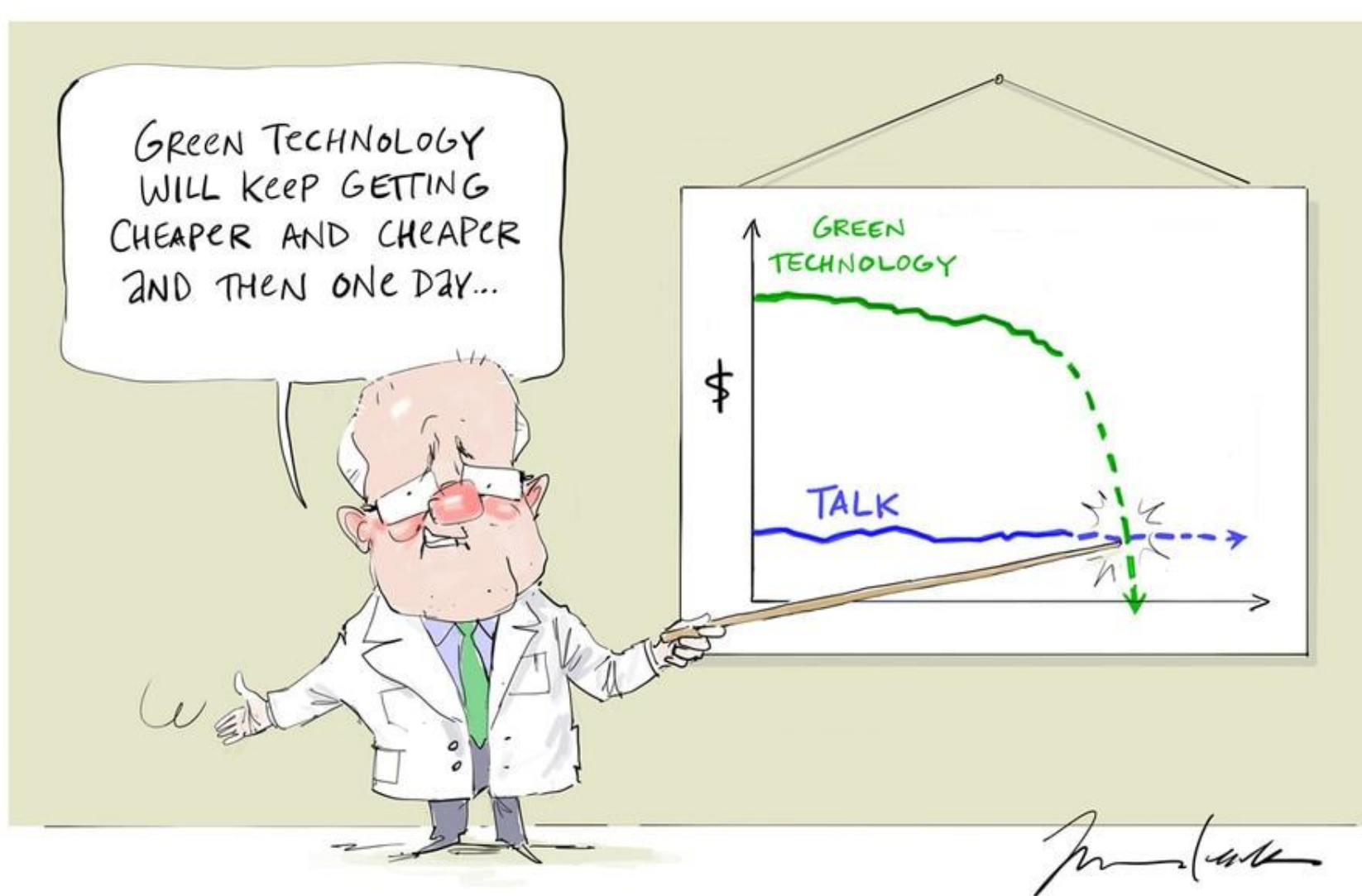
CPEng, FIEAust, APEC Engineer, IntPE(Aus), FAusIMM, MPESA, RPEQ (Mining & Chemical)

Infrastructure Development & Resource Management Engineer

The Term 'Hydrogen Economy' from whom, when & where did it come?

- Crabtree, Dresselhouse & Buchannan, 2004, Physics Today
- Hydrogen from non-fossil fuel resources,
- Leading to Renewable Energy society,
- Truly cleaner production,
- Produce a 'safe and abundant' transport fuel,
- Emissions are carbon free (perhaps),
- A possible Carbon Capture Sequestration transitory stage, and
- A bright future for us all.

The hydrogen hub funding, which increases the government's support for the emerging industry to more than \$850m, could be set up at sites identified in seven states and territories, including the Pilbara, Gladstone, La Trobe Valley, Hunter Valley, Eyre Peninsula, Darwin and Bell Bay.



Johannes Leak, The Australian, 20th April 2021

An introduction to the Combustion of H₂ with O₂

- Little George who played with a dangerous toy; a large balloon filled with hydrogen & oxygen
- Hilaire Belloc,

$2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$ Plus a Big Bang



What on earth is Hydrogen Economy?

F.I.I.K.

It is an envisioned use of hydrogen for heating, transport, powering and lighting,

The raw fuel (hydrogen) will be sourced from renewable sources that will NOT produce or require carbon, and

It may be summarised in the formula: $2\text{H}_2 + \text{O}_2 \leftrightarrow 2\text{H}_2\text{O}$.

Proponents point to the World's vast amount of water to prove the sanity of their 'Hydrogen Economy science'.

The Hydrogen Economy; the Science???

- The Economy of a World without carbon in the energy equation,
 - Note: There is NO carbon $2\text{H}_2 + \text{O}_2 \leftrightarrow 2\text{H}_2\text{O}$,
- $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$ is an exothermic reaction, it gives off heat,
- $2\text{H}_2\text{O} \rightarrow 2\text{H}_2 + \text{O}_2$ is an endothermic reaction that requires heat,
- The use of hydrogen in a gaseous (and possibly a liquid form) or in a compounded form (e.g. ammonia NH_3 or hydrazine N_2H_4),
- For the final embodiment of the Hydrogen Economy is that all facets will involve green energy (including hydro), with the use of all fossil fuels and nuclear energy being excluded (they will have become not required for the new economy).

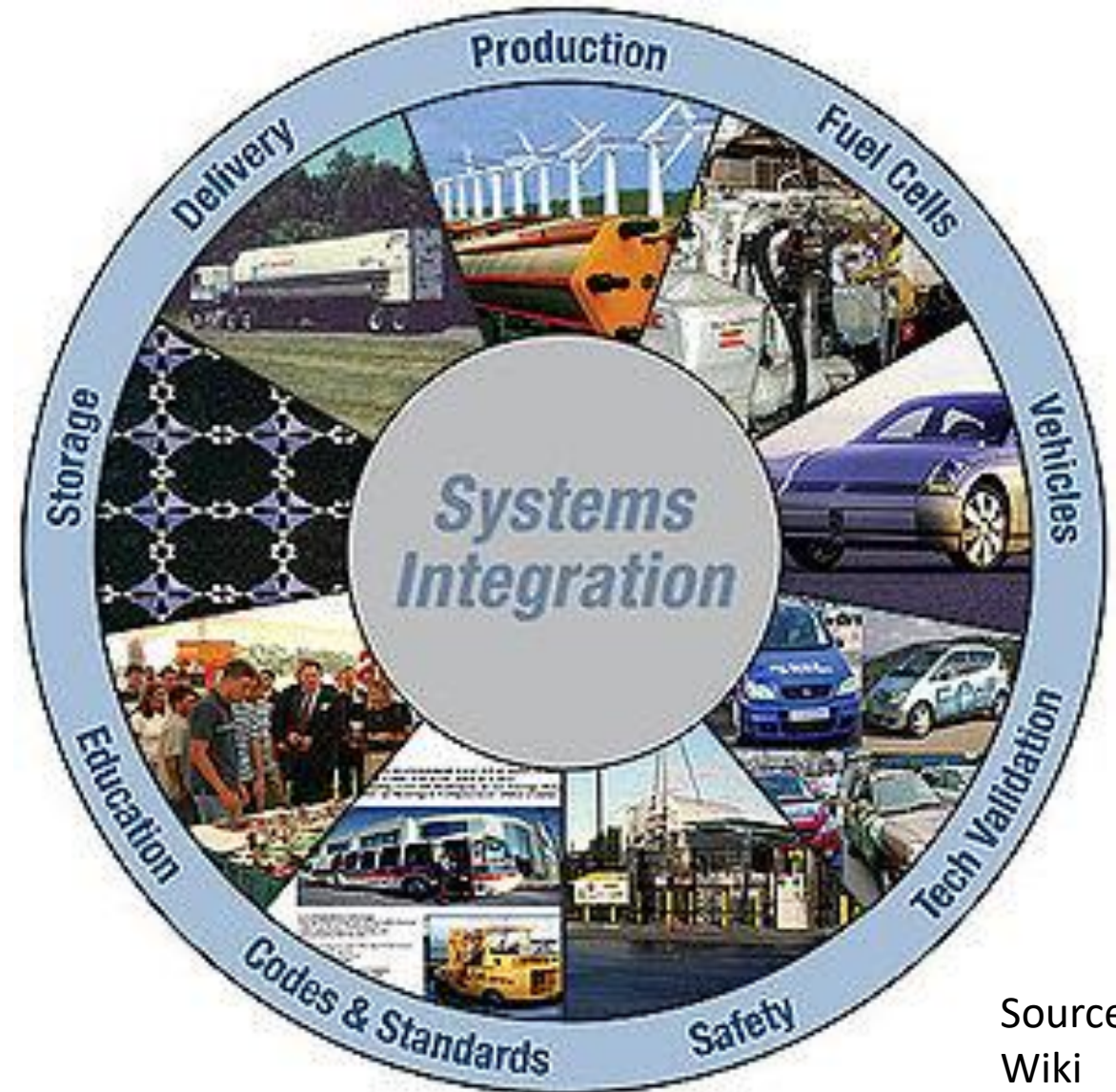
The Proponents View of the way to the Hydrogen Economy

Will the components shown in the figure really Integrate?

Is Hydrogen Production truly uninterrupted from Green sources?

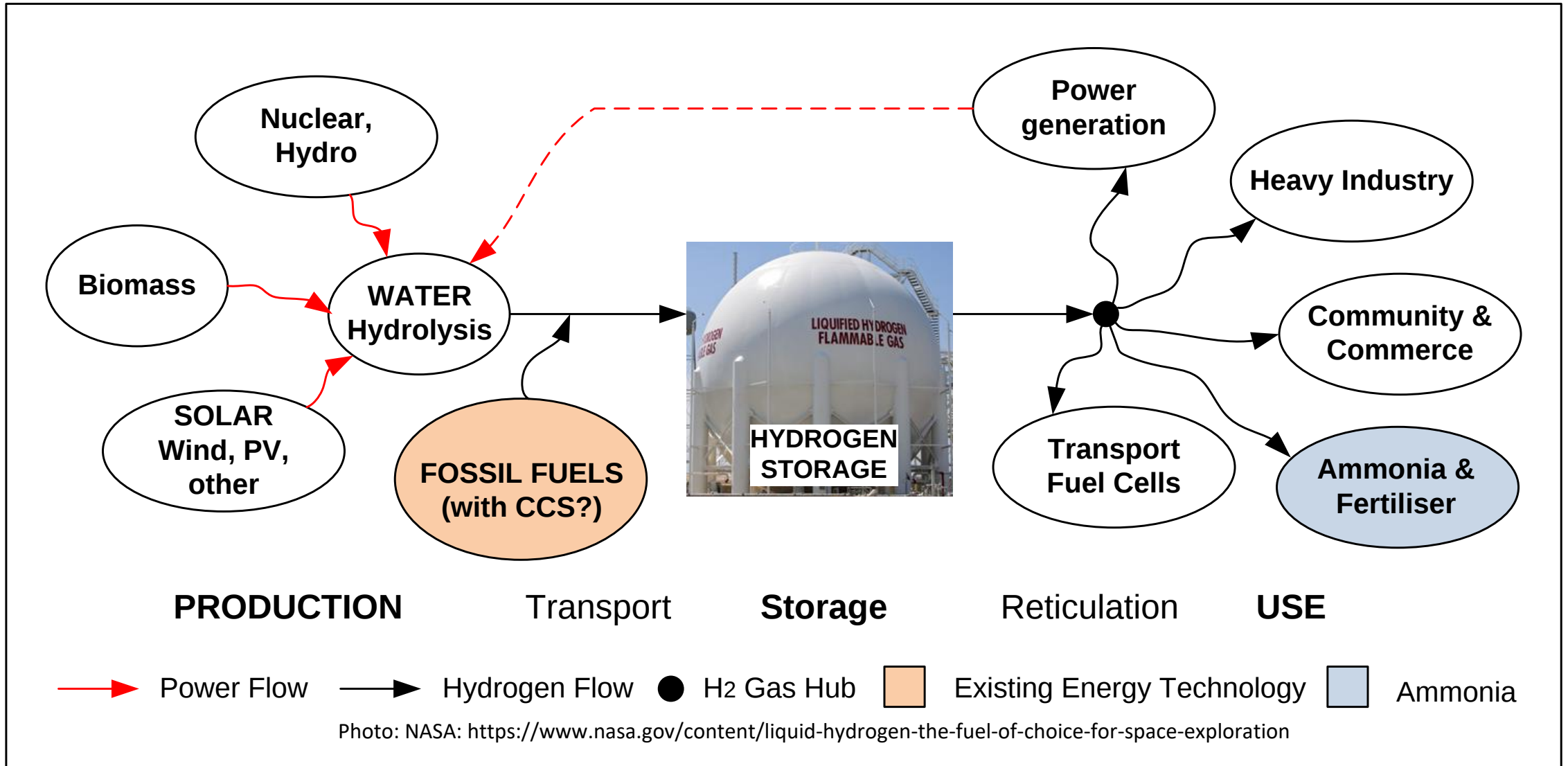
Can storage make hydrogen (energy) supply more secure?

Can Hydrogen be a transport fuel?



Source
Wiki

A Grand View of the Hydrogen Economy

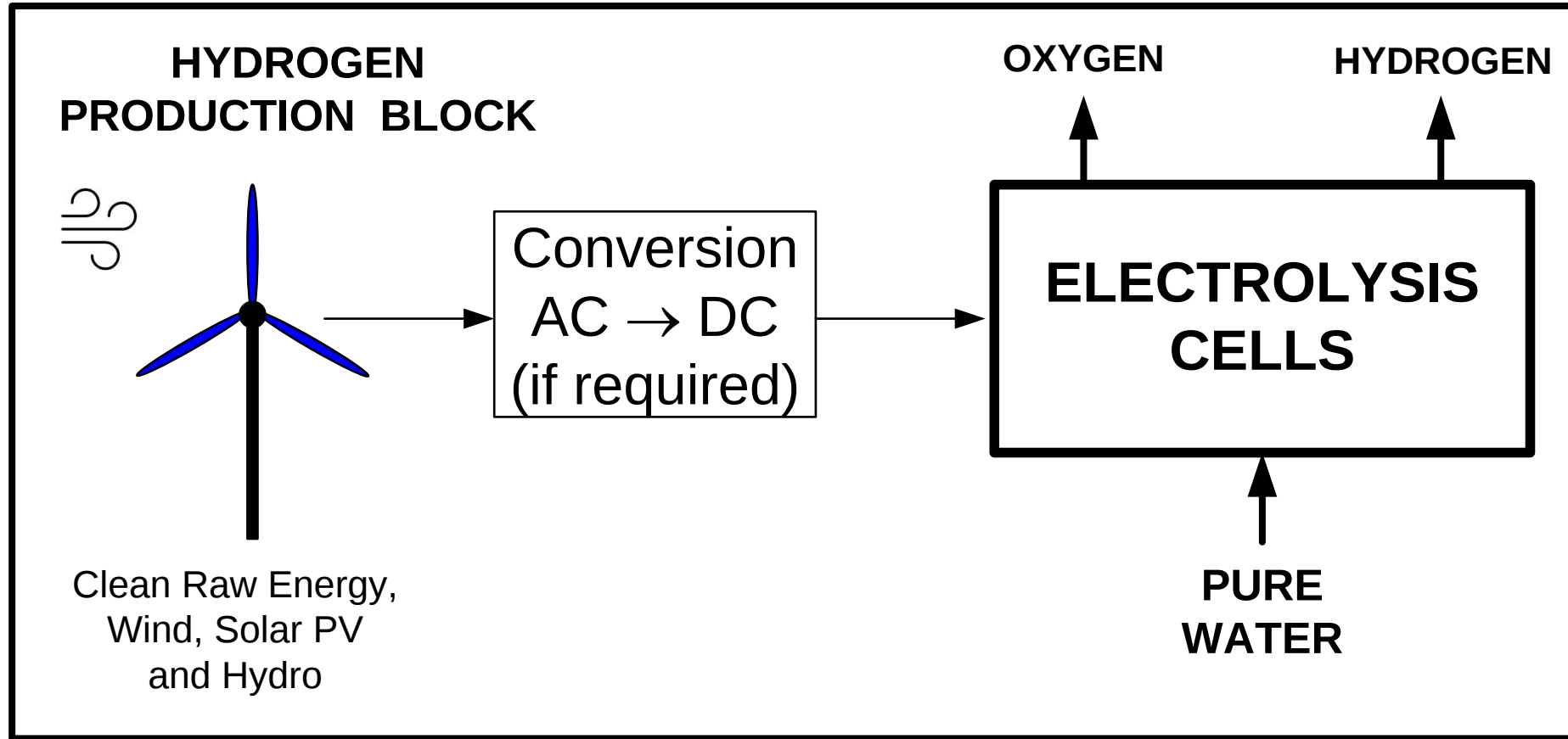


Green Hydrogen Versus Blue Hydrogen

- Green Hydrogen, produced from purely green energy sources; if carbon is required, it must come from biomass, but 'low and behold', we have;
- Blue Hydrogen, hydrogen that can come from fossil fuel sources so long as all the CO₂ is sequestered;
- Is carbon sequestration on the scale required for Blue Hydrogen to be a reality in the new Hydrogen Economy possible?

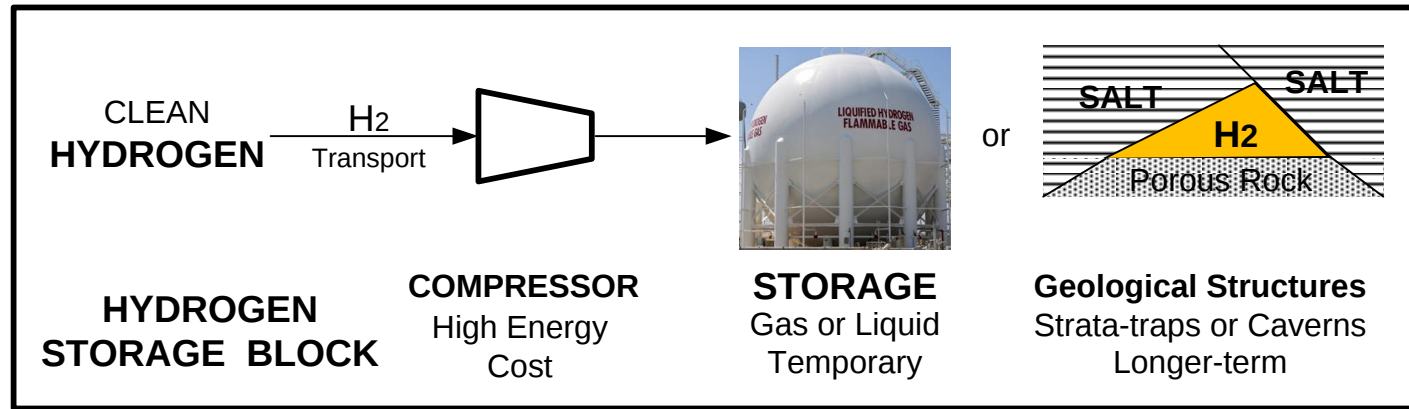
But how about NATURAL HYDROGEN from mother Earth.

A Pruned View of the Green Generation Side



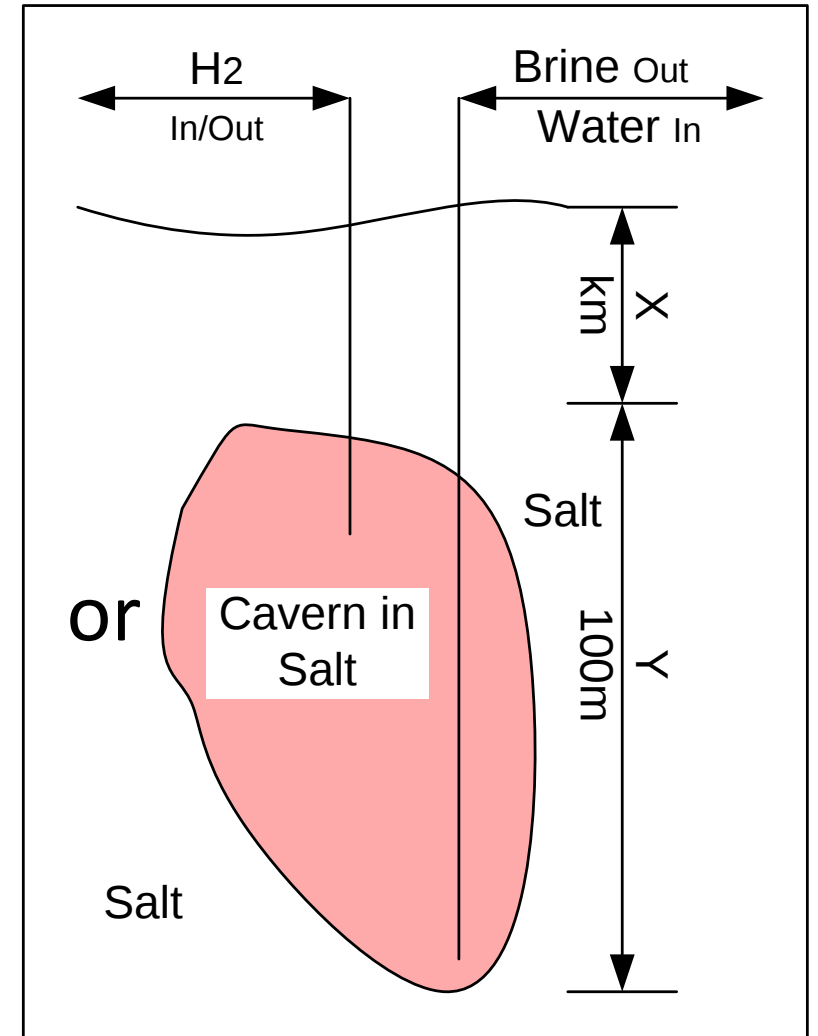
For the purist all raw energy coming into the HE will be GREEN - RENEWABLE

Pruned View 3 and a Brine Cavern

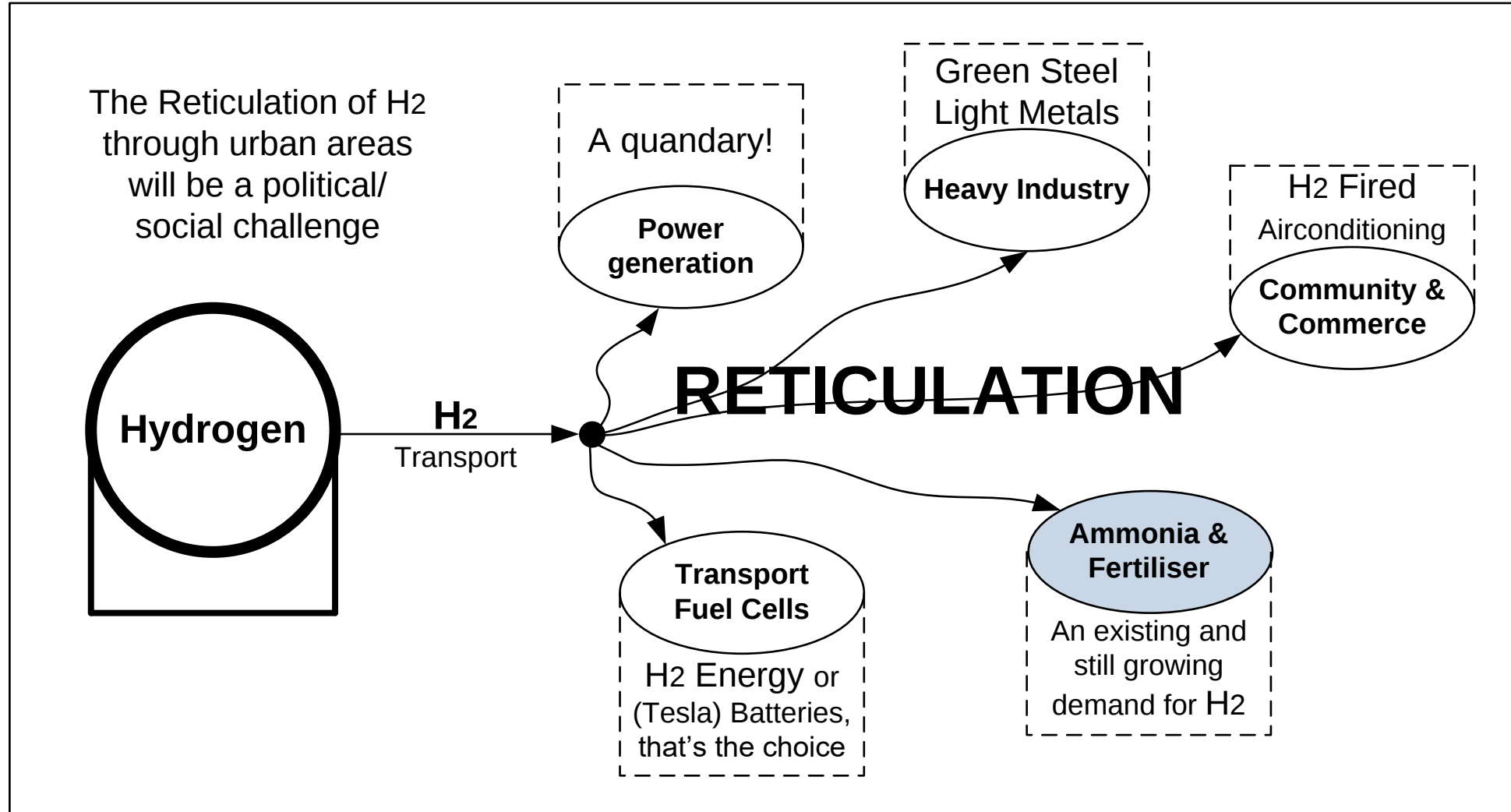


The Hydrogen Economy will require vast storages for Hydrogen.

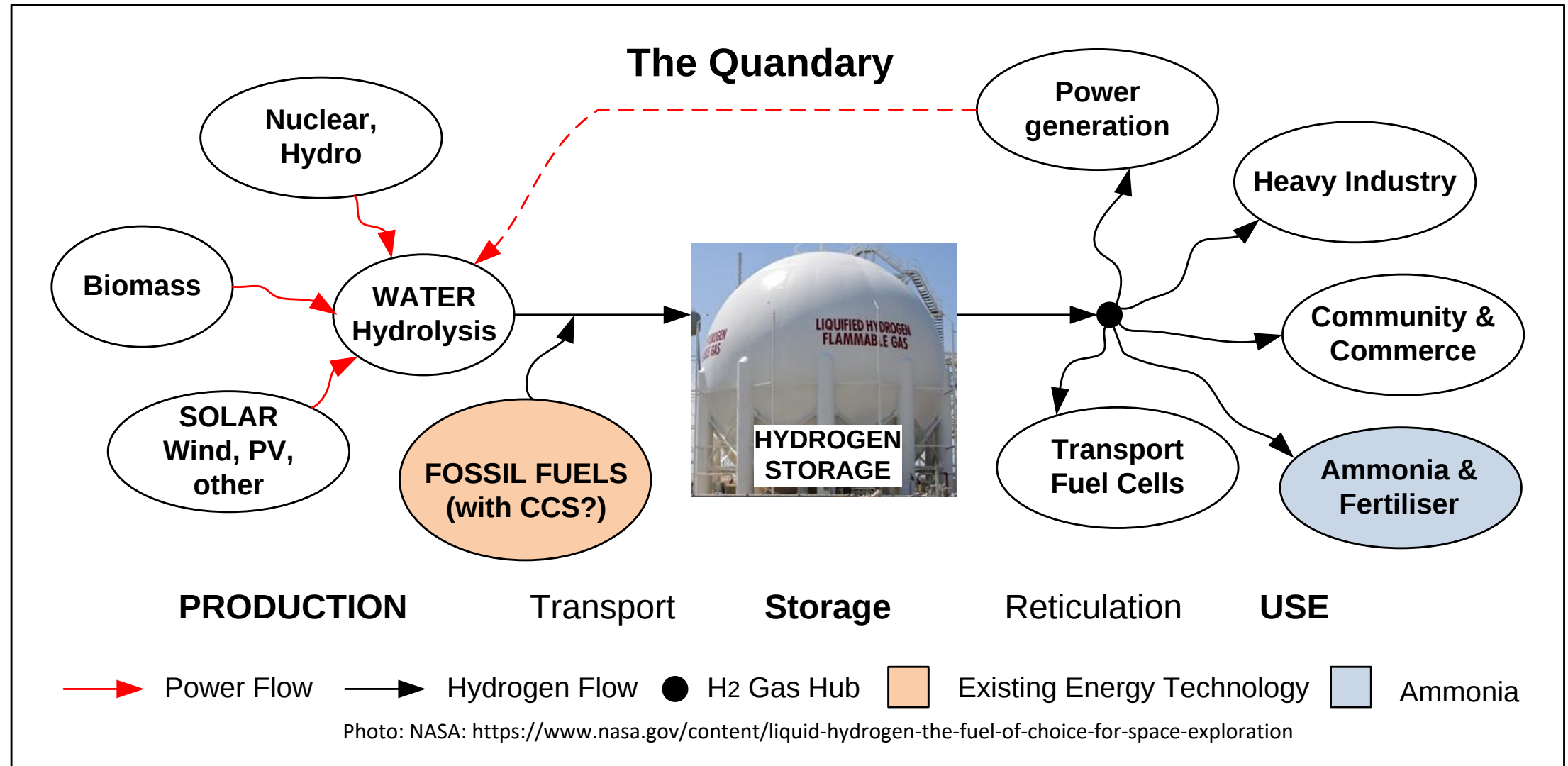
If the main source of hydrogen is intermittent renewables, the storage of sufficient hydrogen to cover shortfalls will be crucial.



Pruned View post production and storage.



The Electricity Quandary & H₂ for NOW

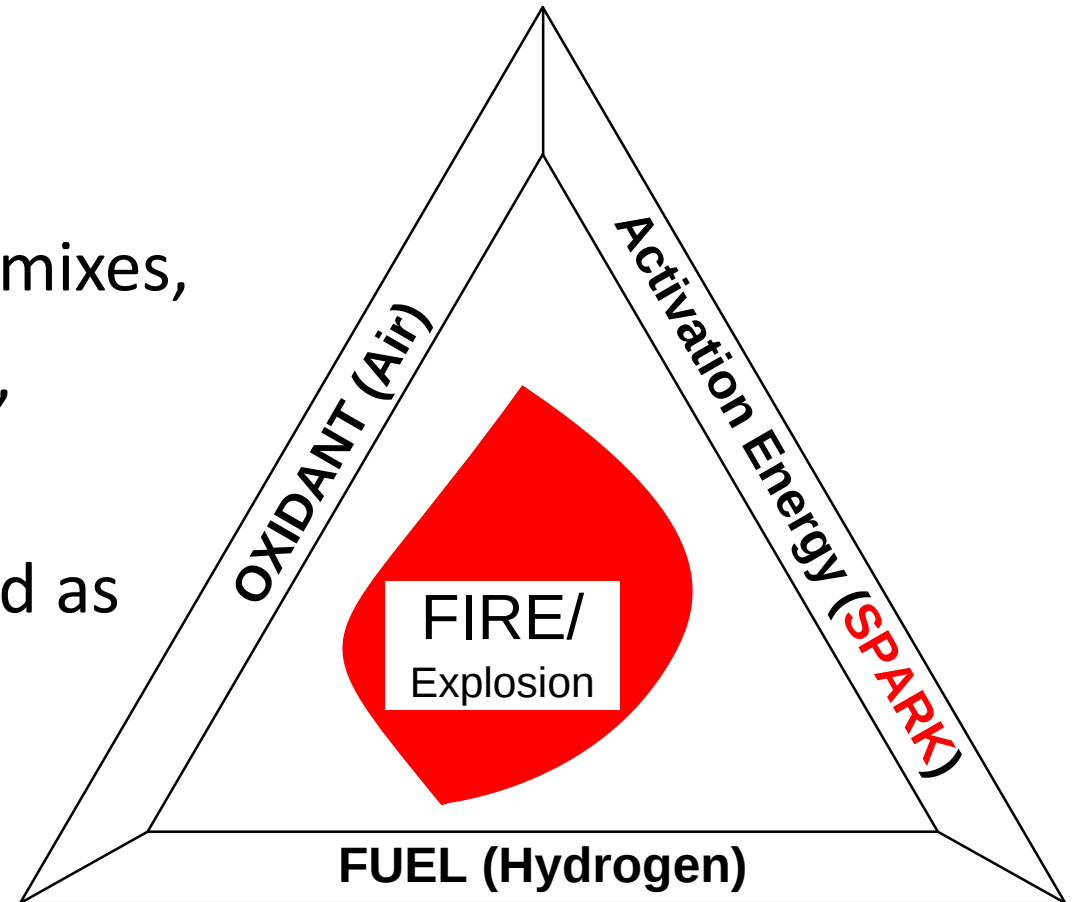


Summarising the Hydrogen Economy from a Green Perspective

- Hydrogen is presently sourced primarily from methane (natural gas) with the co-production of carbon dioxide; THIS HAS TO STOP! (-The Greens say)
 - $\text{CH}_4 + 3\text{H}_2\text{O (steam)} \rightarrow \text{CO} + 3\text{H}_2$ – Steam Reforming
 - $\text{CO} + \text{H}_2\text{O (more steam)} \rightarrow \text{CO}_2 + \text{H}_2$ – Water Shift
 - $\text{CH}_4 + 2\text{H}_2\text{O (lots of steam)} \rightarrow \text{CO}_2 + 4\text{H}_2$ – Combined Reaction,
- Hydrogen produced from methane is used in oil refineries to produce gasoline and diesel from crude oil, and in ammonia production, but
- The good GREEN news; HOWEVER, for the HE we will not need hydrogen for petroleum production since gasoline and diesel will cease to be major energy inputs.

Hydrogen Safety 1

- The Fire (Explosion) triangle:
- Wide explosive limits for air/hydrogen mixes,
- LEL 4% and UEL 74% (methane 5/15%),
- Very low activation energy ≈ 0.02 mJ,
- The Activation Energy could be supplied as static electricity, and
- Released pressurised hydrogen will always ignite hydrogen.



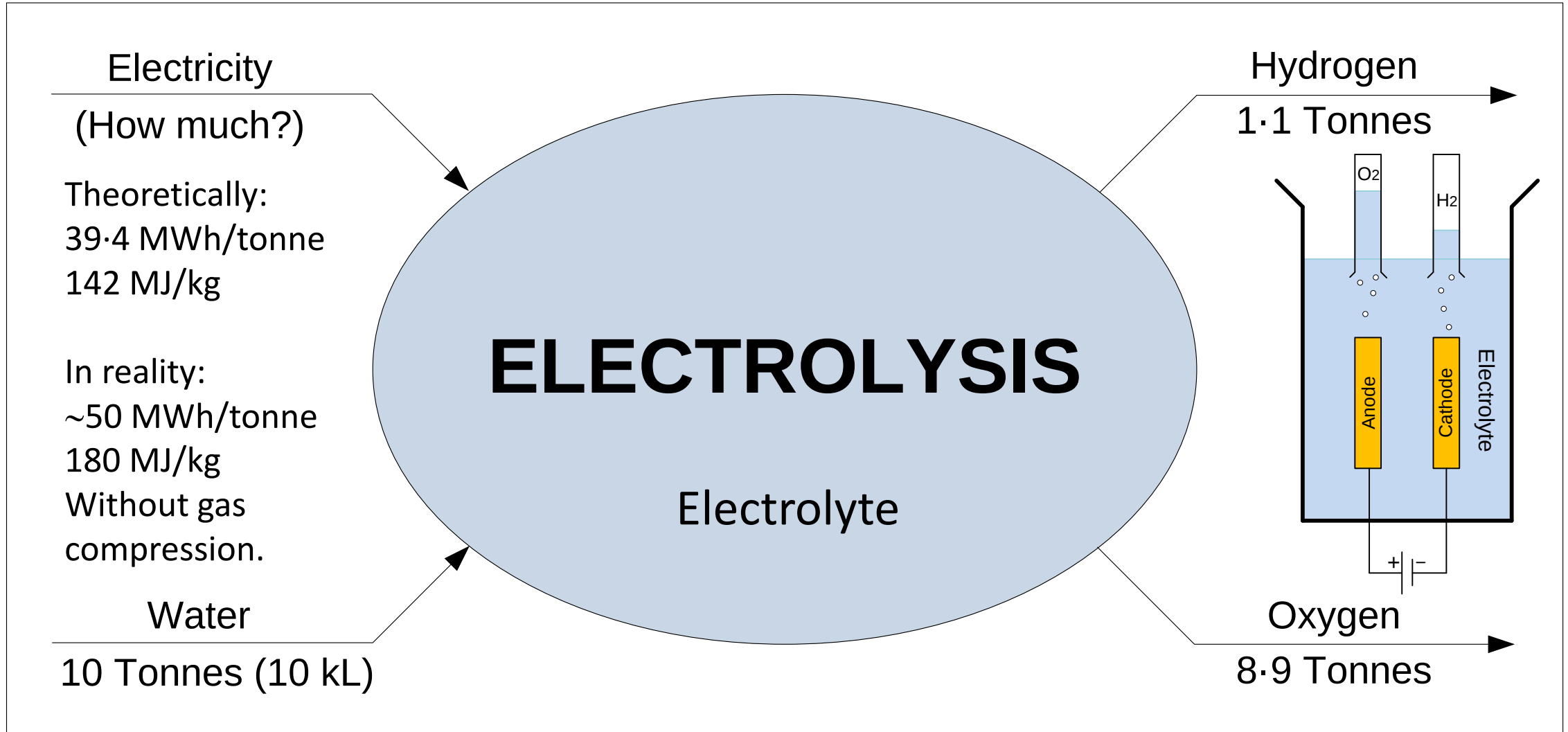
Hydrogen Safety 2 (Not much interest to Little Henry!)

- Hydrogen can migrate through steel and other confining materials causing an increase in brittleness,
- Hydrogen becomes a liquid at minus 20·28K (Helium at 4·2K and Methane 111·6K),
- LH₂ is a cryogenic fluid that requires care in handling,
- Hydrogen has no odour and is difficult to odorise,
- Hydrogen burns with a clear, near invisible flame,
- Mixtures of H₂ and air (or O₂) are detonatable, and
- Leaks are difficult to detect.

Liquid Hydrogen (LH₂), its promise and its butts

- LH₂ is seen by the Hydrogen Economy apostles (such as Tim Flannery) as the replacement for LNG (or LPG) and reticulated NG (and all things carbon),
- It is NOT!
- For every 100 tonnes of H₂ thirty tonnes sent to liquefaction 30 tonnes will be used up in the process of liquefaction (plus more energy will be lost in regasification),
- A liquid at 20K requires special cryogenic handling,
- It is not possible to put LH₂ into transport, reticulation and storage designed for LNG without major upgrading (or replacement) of infrastructure, and
- Very few direct LHG to LH₂ swapping options/uses are realistic.

An Introduction to Water Electrolysis



Other ways of producing hydrogen, besides electrolysis & steam reforming

- Cracking Methane, $\text{CH}_4 \rightarrow \text{C}_{(\text{Solid})} + 2\text{H}_2$ (This reaction demands a high energy input)
 - The use of catalysts (e.g. molten tin), plus heat to crack methane,
 - The real value will likely be in the carbon; but what allotropes?
 - Vertical retorts are still going through RD&D,
- Synthetic Photocatalysis, $2\text{H}_2\text{O} \xrightarrow{h\nu} \text{O}_2 + 2\text{H}_2$ $h\nu$ **Photonic Radiation**
 - This reaction has low energy efficiency in converting water ~18%,
 - The photosynthetic cells still require development & demonstration, and
 - It may be applicable for primarily oxygen production.

BJORN LOMBORG

The Australian, March 6, 2021



- BL: Across the world, politicians are going out of their way to promise fantastically expensive climate policies.
- BL: Most rich countries now promise to go carbon neutral by mid-century.
- BL: We are incessantly being told that renewables are ever cheaper and a Green New Deal will make us richer.
- BL: Yet, this facile argument is belied by reality. Solar panels in some places make cheaper electricity at noon, but at night the cost is infinite.
- BL: The UN Climate Panel found that of 128 analysed climate policies all made us poorer.
- BL: we should spend tens of billions to innovate the price of green energy below fossil fuels.
- MC: These billions should not be spent on most of the Hydrogen Economy.

MIKE CLARKE

Home Office, March/April, 2021



- The overall concept of Hydrogen Economy is severely faulted,
- Its failure is partially based on deep misunderstandings of hydrogen (gas and liquid) and an oversimplification of its similarity to methane/LNG,
- The concept that it can replace methane, in terms of availability and use is faulted,
- Extracting it from water is energy intensive – it is strongly ENDOTHERMIC,
- Hydrogen is relatively expensive, the cheapest source is CH₄ has carbon management challenges (specifically making carbon capture & sequestration a real possibility),
- The non carbon sources of Hydrogen are limited (so much for HE being pure green),
- Money for RD&D in creating innovative options for clean energy, inclusive of clean fossil fuel energy, are required, and
- The Acquiescence to the Hydrogen Economy is totally irresponsible.

Technologies for a Secure Clean Energy Future

- Nuclear Energy from both large grid reactors (>600 MWe) and small to medium modular reactors, to provide grid security and demand following capability respectively; nuclear energy is required for even a partial Hydrogen Economy.
- Excess (off-demand) capacity from large reactors could be directed towards hydrogen production, delivery and storage,
- Cracking methane, could provide carbon for construction and fabrication and hydrogen for multiple uses,
- The large scale development of water electrolysis could produce oxygen for sanitation, thus,
- Looking for and developing co-production (e.g. solid carbon and hydrogen) could provide opportunities for real economic development.

Thanks:

May the Hydrogen Economy remain a dream,

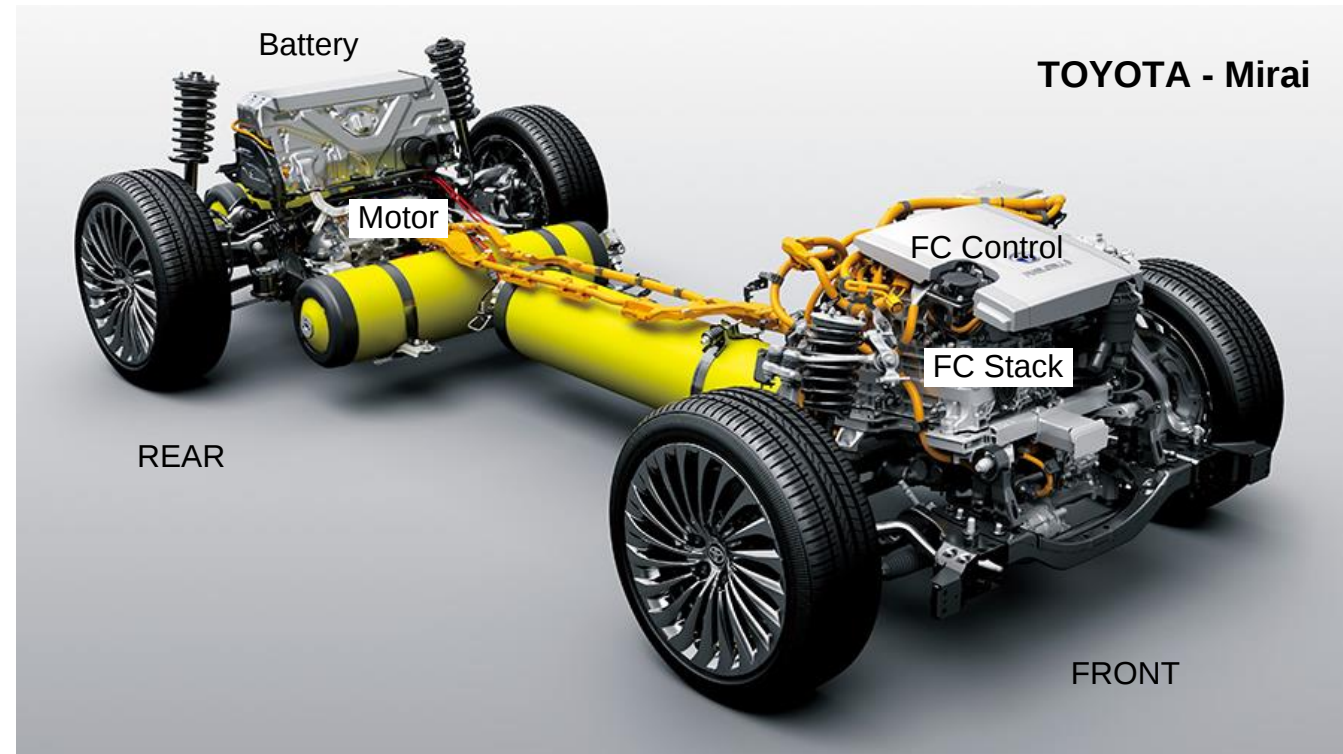
with its

bits of fact, a few possibilities but lots of

FLIMFLAM

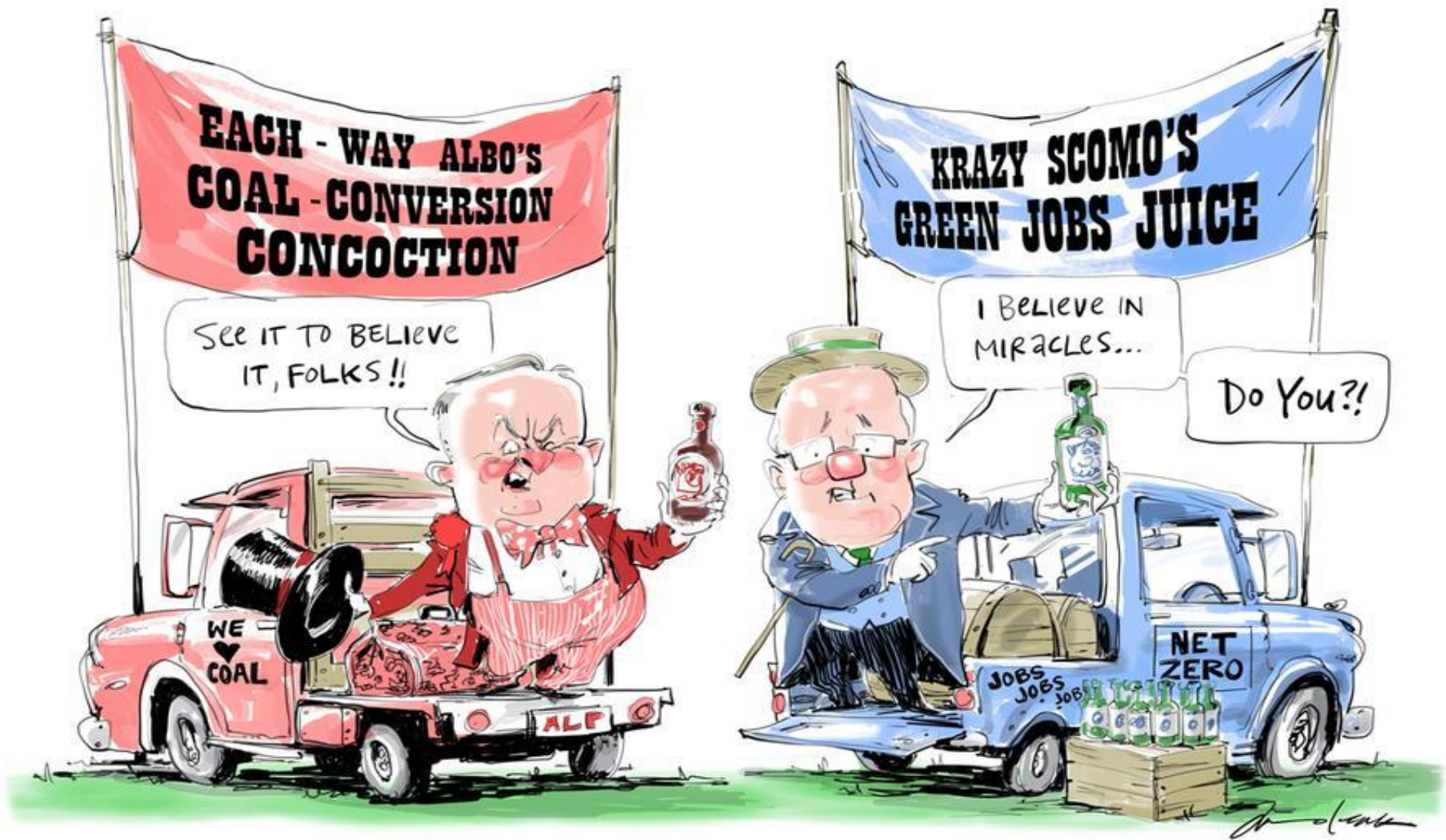
Addendum: Hydrogen versus Battery Cars

- Musk/Tesla with his Lithium Ion Batteries or
- Toyota's (and other's) with Hydrogen/Fuel-cell systems, with
- Recuperative energy by way of a motor/generator,
- Three hydrogen tanks holding 5.6 kg of H₂ (compressed gas),
- Fuel eq 142 L H₂ gas @ 70MPa,
- BUT!



The Battery Car (EV) beats the Hybrid FC/Bat.

- The Hybrid is a beautiful piece of Advanced Engineering, BUT
- It requires a parallel fuel supply to the existing electric grid,
- A 'hydrogen grid' will be expensive to build, maintain and have significant hazards,
- The Hybrid Vehicle has two highly flammable substances (H_2 and Li) in close proximity to electrics,
- The H_2 fuel tanks will have a limited useful before materials recycling; (H_2) permeates containing materials causes failure, and
- The overall complexity of the Hydrogen Vehicle is expensive.



Johannes Leak, The Australian, 22nd April 2021

A Water Electrolysis Cell

