Nuclear and Hydrogen – is it not rocket science?

As long-term investors in infrastructure that drives the decarbonisation of economies, we take a technology agnostic approach, developing infrastructure that directly or indirectly reduces greenhouse gas emissions (GHG), and delivers an attractive risk-return profile.

The investment community regularly asks us whether we are planning to invest in nuclear energy, or in green hydrogen. Hydrogen has taken up much of the attention over the past few years, but nuclear energy has recently become the centre of energy debate in Australia.

We have no desire to participate in political debate, however it is important that we articulate clearly what we invest in, what we don't invest in, and why.

Green hydrogen and nuclear technologies both have the potential to contribute to the energy transition. Neither of these technologies is likely to present an investible opportunity with an acceptable risk return profile over the next 20 years. The technologies are vastly different, but the fundamentals are the same – advanced engineering is extremely expensive.

We like to (dad) joke that we already invest in nuclear energy – nuclear fusion no less; because the sun creates the irradiance for our solar plant and the wind driving our turbines.

NUCLEAR (FISSION)

Safety is the most common public objection to nuclear energy. The reasons for this are evident; Fukushima, Chernobyl, Three Mile Island. The counterfactual is France, for example, which has operated a nuclear industry safely for over 60 years. 62% of France's electricity is produced by nuclear generation[1].

Nuclear energy can be made safe, but therein lies the problem. The consequences of nuclear plant failure are catastrophic. To reduce the risk of failure to an acceptable level, a nuclear plant must be engineered for an extremely high level of redundancy to ensure failsafe operations.

Other technologies fail too, of course; the Callide C coal plant in Queensland, BESS fires in Victoria and Queensland, and turbine gearbox fires. The consequences of failures in these technologies are contained and are lower risk to life and limb.

It comes down to cost, and how controllable those costs are. In building wind and solar I would consider a 20% cost overrun to be unacceptable.

Consider then a recent nuclear plant - Hinkley Point C in the UK, being built by Electricity de France (EdF). The 3,200 MW reactor will cost about $87 billion[2]. That is a 250% cost blow-out, and the project is already 6 years late. France's own latest reactor, the 1,650 MW Flamanville 3 unit – also built by EdF – is expected to come online late 2024[3]. That is 12 years late and at $21 billion[4], 400% over budget.

We have no nuclear industry in Australia, no expertise, and no experience with the technology. We will need to build this highly specialised industry from first principles. If EdF, having built and operated 56 reactors over 60 years, can't control time and cost on a modern reactor how will we build an industry from scratch and achieve this in 10 years, while controlling costs? Of course it can be done but 20 years to first electrons would be more realistic in our view.

Some perspectives on construction cost then,

	$/MW Capex
Hinkley Point	$27,187,000
Flamanville	$12,727,000
Onshore wind Australia estimated average	$3,200,000
Solar Australia estimated average	$1,900,000

[1]World Nuclear Association
[2]GBP32 billion estimate by EdF, the constuction
[3]Le Monde, 19 January 2024
[4]EUR 13.2b. Source: World Nuclear News, 8 May 2024

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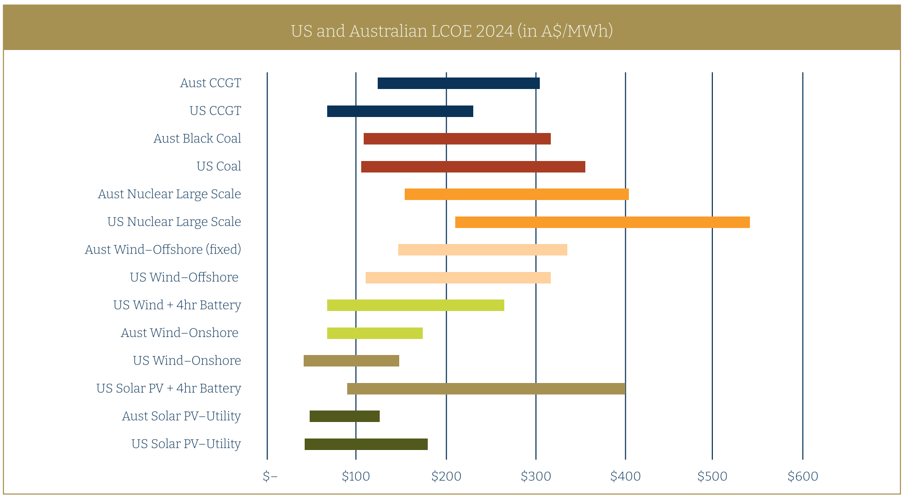
Nuclear requires fuel while wind and solar don't. Nuclear can run at a near 100% net capacity factor (NCF), while wind is about 40% and solar about 25%. For these reasons simple cost per MW capex is of limited value.

This is where the levelized cost of energy (LCOE) metric comes into play. Based on comprehensive analysis by Lazard and the CSIRO, the cost of an electron produced by nuclear energy is >3x the cost of an electron produced by solar, and 2.5x the cost of a wind electron. Even after accounting for the storage required to firm their intermittency, wind and solar are substantially cheaper than nuclear energy. Why would we not replace our coal fleet with the lowest cost energy source?

If we wait for nuclear and don't build wind solar and storage as soon as possible, the retirement of coal plants will become more problematic.

In this situation gas becomes the logical technology to fill the gap. We estimate that we would need ~20 GW gas to come in ahead of nuclear in this scenario. We simply don't have gas reserves available to power a fleet of that size, meaning we would need to import LNG. This of course ignores the fact that gas emits about half a tonne CO_2 per MWh, and is more expensive than solar and storage.



HYDROGEN

Hydrogen has been promoted as a replacement for fossil fuels for 50 years;

The oil shocks of the 1970s led to research into hydrogen technologies but they never went far. In the 1980s the Soviet Union even flew a hydrogen-powered passenger jet—the maiden flight lasted just 21 minutes.[5]

So why hasn't it taken off? For Hydrogen to be widely available to replace gas, coal and oil it needs to be transportable over long distances, just like LNG is today. However liquifying, transporting and re-gassifying hydrogen requires engineering to a far higher standard than LNG. To become liquid, hydrogen must be cooled to -253o C, only 20o C above absolute zero.

Some context here; The temperature in interstellar space is about -260o C. Absolute zero, the point at which atoms stop moving, and weird science[6] occurs is -273o C.

Of course, we can produce liquid hydrogen – it is used as a rocket propellant. But rocket science and industrial scale liquefaction and transport of hydrogen are very different matters. At such low temperatures materials become extremely brittle, and as smallest atom it takes some effort to contain hydrogen and maintain it below its -253o C boiling point. All of this comes to advanced engineering and economics.

[5]*The Economist*, 9 October 2021
[6]At extremely low temperatures exotic states of matter appear, such as superfluids that have no friction and viscosity and so climb out of their containers; superconductors, which have zero electrical resistance, and Bose-Einstein condensates, where atoms act totally in unison and never collide.

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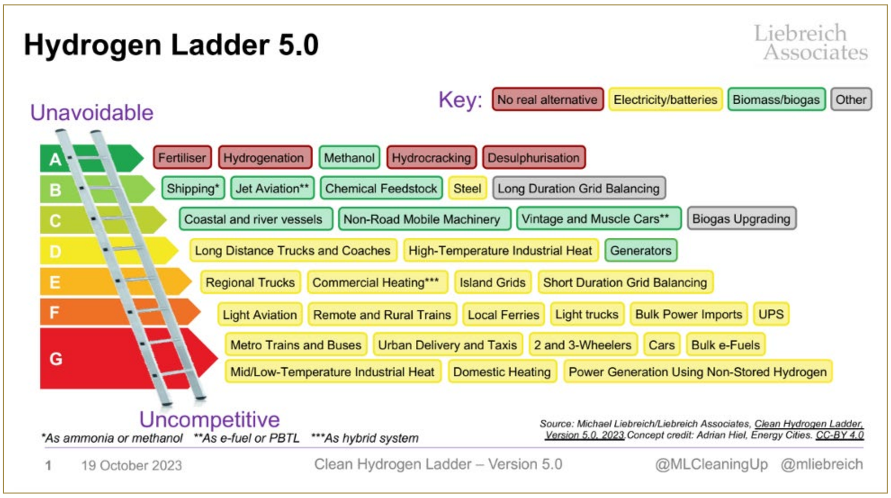
Producing, liquifying, transporting, storing and re-gasifying hydrogen is extremely expensive due to the engineering involved. In addition, there is the issue of round-trip efficiency, meaning the amount of energy put in versus the amount of energy yielded. Seaborn green liquid hydrogen for energy generation will have a round-trip efficiency of ~20% with today's technology. Why? Creating green hydrogen uses a lot of electricity (and water), then 30-40% of that hydrogen is consumed cooling the Hydrogen to -2530C, then there is a high rate of boil-off[7] during storage and transport.

If you are losing 80% of your energy in the process, the electricity created at the end will be very expensive. In other words, new technologies must bring costs down a long way before hydrogen makes sense as a technology for electricity production. Michael Liebreich's "Hydrogen ladder[8]" puts this into sharp perspective. Note that electricity production from hydrogen is on the very bottom rung, and that doesn't even include the cost of liquification and transport.



There are other more efficient ways of creating and transporting hydrogen – as an ammonia molecule (NH4) for example. Liquid ammonia has been used as a fuel since the early 19th century. It can be readily transported and used in that form, or it can be "cracked" to produce hydrogen. We think this is a more likely pathway to an international hydrogen industry.

IN CONCLUSION

In summary achieving net zero will require a mix of generation and storage technologies. Nuclear and hydrogen may play a part in that transition, but we are of the view that it will be peripheral until technologies mature, and costs are reduced substantially.

Stephen Panizza is a founding Partner of Federation.

[7]Boil-off is a process of regasification when hydrogen heats up during storage and transport. LNG also has boil off but hydrogen boil off is far higher due to the lower storage temperature.
[8]See https://www.liebreich.com/
[9]https://www.chem4us.be/liquid-ammonia-a-green-fuel-for-the-transport-sector/#:~:text=During%20the%20Second%20World%20War,engines%2C%20especially%20for%20military%thesenew20purposes.

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