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The Hydrogen Complex

A 60/40 economy

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Towards a 60/40 economy: Hydrogen's net-zero contribution

This is the first in our three-part series looking at hydrogen as an energy vector in a net-zero future.

Here, we look at both the potential and limitations of the molecule, as well as its different production methods.

It's the simplest element in the periodic table, and the most abundant in the universe – little wonder hydrogen has excited the imagination of scientists and energy innovators for so long. But a down-to-earth analysis reveals there is nothing simple about it. It rarely occurs in its simple gaseous form on our blue planet and, as a result, integrating hydrogen as a major component of earth's energy systems is a task of astonishing complexity.

And yet, we believe that to achieve net-zero, hydrogen must be a critical energy vector. Indeed, some predict hydrogen could account for as much as 40% of our future energy needs.

Before we look at the challenges that must be confronted to achieve this, it is necessary to acknowledge the other 60%: electricity. Electrification will always be more efficient and therefore the better choice – where it is viable – given that the production of hydrogen requires requires energy, whether from renewable electricity, or other sources, such as coal or gas (hydrogen isn't an energy source, it's an energy carrier.) Therefore, on a level-playing field, for most use-cases, electrification wins.

On top of that, the playing field is not level. Electrification is already incumbent with the infrastructure largely in place for its delivery. The challenge hydrogen faces is therefore not just one of efficiency, but also of co-ordination in rolling-out and scaling-up the required infrastructure. Both the complexity of this challenge, and the rewards of solving it, are difficult to overstate.

In the meantime, there are a whole host of existing hydrogen-users that need to migrate to less polluting versions of the carrier. Just greening this existing demand – from industries as diverse as petrochemicals, refining, ammonia and steel-production – is a major undertaking.

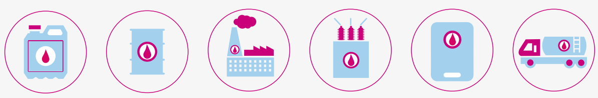
Like nothing else, hydrogen has the potential to solve the truly 'hard-to-abate' cases of the energy transition. These include heavy duty transport, shipping, aviation, as well as processes requiring high-temperature direct heat, e.g. furnaces. Electrification, with all its advancement, is not currently a contender. Hydrogen generation and distribution may be difficult and expensive, but so are the decarbonisation challenges that we need it to tackle.

Why hydrogen?

While its logistical problems are manifold, in its essential properties, hydrogen is the Rolls Royce of all clean fuels.

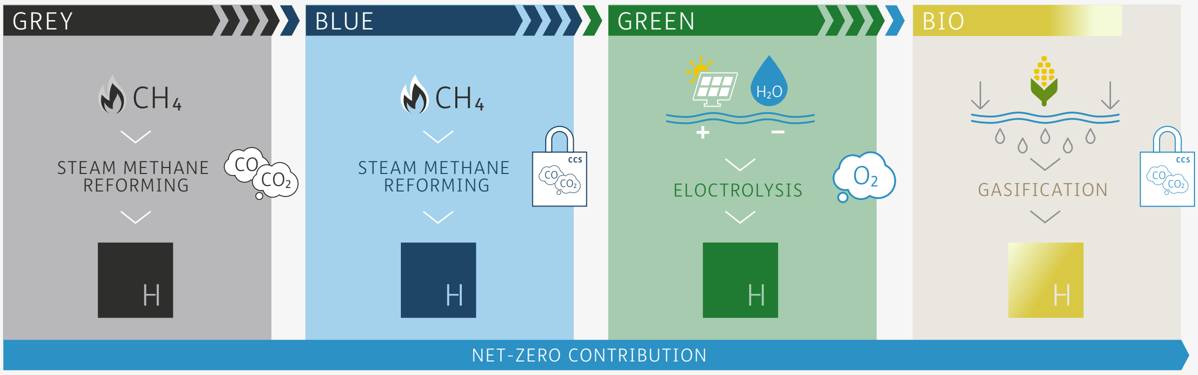
- It is a zero-carbon energy carrier (it doesn't produce CO_2 when it is burned).
- It is the lightest element in the universe, so it has an extremely high (gravimetric) energy density (it is literally rocket fuel).
- It can be stored for weeks or months, and has the potential to be transported over long distances. That means hydrogen could become the future medium for transporting renewable power around the globe.

So far, so good.
But not all hydrogen is created equal...



Hydrogen has the potential to solve the truly 'hard cases' of the energy transition.

Fig 1) Major production process



Source: Baringa Partners

Hydrogen in techni-colour

Producing hydrogen requires energy, because on earth, most hydrogen atoms have gone and attached themselves to other things, like oxygen to create water (the word "hydrogen" means water-generator.) There are different ways to crack it into a simpler shape, which vary significantly in their sustainability credentials, and industry, over time, has assigned each one a colour.

For instance purple or pink hydrogen is created with nuclear energy; brown hydrogen uses thermal coal; and there's even a turquoise hydrogen which is converted from natural gas using methane pyrolysis, a novel technique that yields solid carbon but is unproven at scale.

But the colours that matter are grey, blue and green.

Grey hydrogen is by far the most common form, about 95% of hydrogen today is made by steam methane reforming.

Blue hydrogen is produced through the same process, but most of the carbon emissions are captured and stored.

Green hydrogen is the use of renewable power to electrolyse water to release hydrogen.

Blue is significantly better than grey, but green is the holy grail, given that it provides a zero-emissions form of fuel.

Bio hydrogen

However, there is a fourth method for producing hydrogen that we consider very promising using biological feedstocks and our models have shown the gasification of biomass to show the most promise. The process has great potential, it works at scale, and it produces very low, or even negative, emissions given that growing the bio-material extracts carbon from the atmosphere, while most of the carbon released in the production process can be captured.

We have not added this to the rainbow of hydrogen colours. Instead, we just call it bio-hydrogen, and it is represented in Fig 1, in the final column (ok, we've painted it gold, because that's what you find at the end of a rainbow!)

Ultimately, the colours will fade as the key differentiator will be the carbon footprint of hydrogen purchased, and this will improve iteratively, and in a context-specific manner. Finally, it's important to note that every process, no matter how brightly coloured, will generate some green house gas emissions from a lifecycle assessment perspective. But the opportunity for CO_2 reduction promised by these techniques is encouraging indeed.

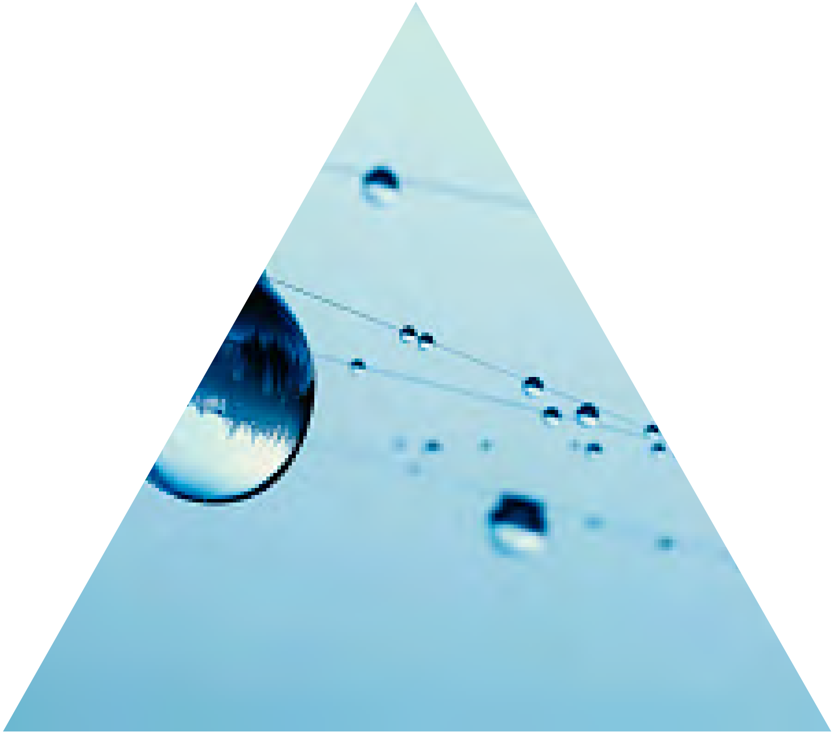
Fig 2) Hydrogen's brightening outlook

PROCESS	INPUTS		KG CO_2/KG H_2*
Reforming	Gas		9
Gasification	Coal		19
Reforming + CCUS	Gas		1–4
Gasification + CCUS	Coal		2
Methane pyrolysis	Gas		Solid carbon
Gasification + CCUS	Biomass		Negative
ALK	Nuclear	Renewables	0
PEM			
SOEC			

Thermo-Chemical Electro-Chemical

*Process emissions only

In the second part in our series, we will assess the increase in clean hydrogen production required to substitute grey hydrogen and some options to overcome local production capacity constraints.



Baringa Partners

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