Will blue hydrogen lock us into fossil fuels forever?

Jan Rosenow[1] and Richard Lowes[1]

1: Regulatory Assistance Project, Brussels, Belgium

Pre-print version of article published in *One Earth*. Please quote as following:

Rosenow, J., Lowes, R. (2021): Will blue hydrogen lock us into fossil fuels forever? One Earth 4(11), pp. 1527-1529

Introduction

Blue hydrogen – once an unfamiliar term to most, is at the centre of the energy and climate debate. It involves making hydrogen from fossil fuels and capturing and storing the associated carbon emissions as part of efforts to meet net zero climate targets. Promises have been made by the fossil fuel industry suggesting blue hydrogen can replace oil and gas in industry, buildings and transport while avoiding harmful greenhouse gas (GHG) emissions. Blue hydrogen would involve capturing and storing the fossil fuel emissions that contribute to climate change preventing them from reaching the atmosphere. Partly in response to these claims and demands for policy support from the industry, more than 20 national governments and the European Union have released hydrogen strategies. In this commentary we consider blue hydrogen and ask how credible is it as a scalable low carbon fuel?

Is history repeating itself?

Hydrogen appears to be currently peaking on a 'hype-cycle',[1] i.e. the current expectations are inflated way beyond its likely impact. Business interests and media representation tend to drive these expectations. A previous hydrogen hype-cycle between 2002 and 2009, primarily based on the use of hydrogen in transport, led to little development.[2]

There are many different types of hydrogen: Black hydrogen generated from coal, brown hydrogen from lignite, grey hydrogen from fossil gas, green hydrogen from renewable electricity via electrolysis, pink hydrogen electrolysis powered by nuclear energy, turquoise hydrogen from a process called methane pyrolysis, and finally blue hydrogen produced mainly from natural gas using a process called steam reforming. Only green, pink and turquoise hydrogen can be truly zero carbon with black, grey and brown hydrogen being more carbon intensive than fossil fuels. Blue hydrogen relies on capturing the carbon emissions associated with its production and storing them. Without carbon capture and storage (CCS), the emissions from blue hydrogen would also be higher than those of fossil gas because of the additional energy required to drive the process of hydrogen production and the carbon capture process.

Clearly, the fossil fuel industry has a vested interest in maintaining its existing business model, and its strong support for blue hydrogen is primarily driven by self-preservation rather than climate protection concerns. We have seen this before: when the coal industry came under pressure to reduce emissions it promised clean coal.[3] Significant policy support was subsequently offered, and clean coal attracted a lot of attention from policymakers.

After years of pilot projects and substantial public investment in coal power plants with CCS, only a single commercially operating facility remains – one 115 megawatt unit of the Boundary Dam Power Station in Saskatchewan, Canada (Figure 1). Its primary purpose is to provide a low-cost source of carbon dioxide, to the Weyburn Oil Field, for enhanced oil recovery.[4] In the U.S., after $163 million in public subsidies awarded through the American Recovery and Reinvestment Act, the last commercially operating coal power plant with CCS, Petra Nova, was retired in 2021.[5]

The European Union spent €587 million to support the development of clean coal. Today, the European Commission's website states that 'even with supportive EU regulations and co-funding opportunities provided […] carbon capture and storage has failed to develop at the expected rate.'[6]

It is notable that most current CCS facilities support fossil gas processing, and the majority are using the captured emissions for enhanced oil recovery.[7] After 30 years of public support and multiple pilot projects, CCS has little to show.[8] CCS has not developed as expected and the CCS that does exist now is mainly supporting increasing fossil fuel extraction.

This cautionary tale offers some important lessons for blue hydrogen. Claims by the fossil fuel industry that capturing emissions is feasible and can be done fast need to be carefully examined. There is also a risk of locking in new fossil fuel infrastructure. New coal power plants were approved under the condition that they had to be 'CCS-ready', requiring operators to prove that CCS could be retrofitted under the right conditions. They may have been ready, but it never happened. The main reason: capturing emissions from coal power plants proved to be an energy-intensive and costly process.

Similar arguments are made in support of new gas infrastructure. It has been suggested that the controversial Nord Stream 2 gas pipeline could at some point transport hydrogen from Russia to Europe.[9] Of course it would take many years until significant amounts of hydrogen could be available, and this is by no means guaranteed. In the meantime, the new pipeline (if constructed) would continue to supply fossil gas for many years to come.

Of course, the past is not necessarily a good predictor of the future. Perhaps blue hydrogen will develop in line with expectations, perhaps not. Higher carbon prices could make investments more attractive, and in Europe carbon prices have lately exceeded €60 per tonne of carbon dioxide. But if we can learn anything from the history of clean coal, then it is this: great expectations and promises by the fossil fuel industry and governments do not necessarily guarantee delivery of fossil-based, low-carbon. Betting on successfully capturing carbon again seems a risky strategy. Critical thinking and evidence-based decision-making resistant to magical thinking should be applied across the energy system, including in the case of blue hydrogen.

Even if delivery follows expectations, there remains the question of how effective blue hydrogen will be in reducing emissions.

Blue hydrogen's second problem: residual emissions

Just days before the UK government launched its hydrogen strategy in August 2021, new research by Howarth and Jacobson[10] issued a stark warning against the use of blue hydrogen, claiming that leakage of methane and the energy intensity of the process of capturing carbon emissions resulted in higher emissions than burning fossil gas.

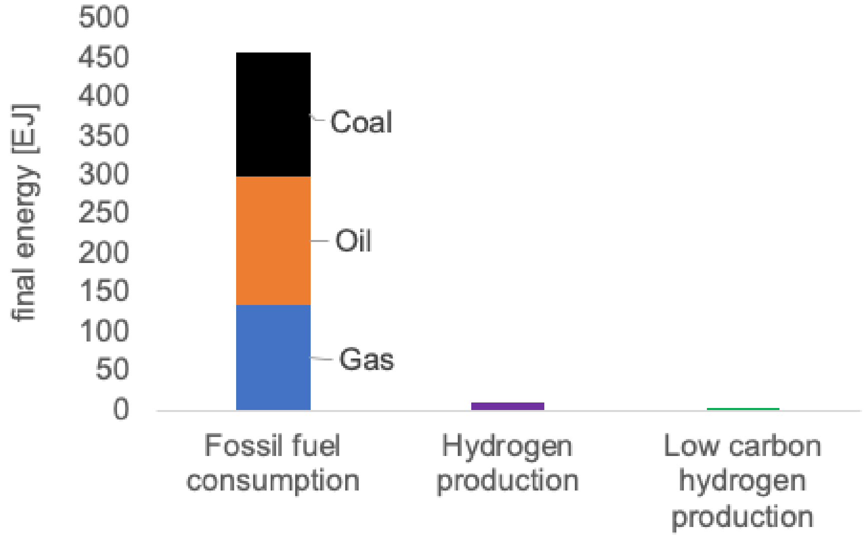
In a heated public debate questioning Howarth and Jacobson's conclusions, several independent experts spoke out against the assumptions made in the paper. They claimed that, if regulated properly and if using the best available technology, more than 90% of the carbon emissions from fossil gas could be captured. Howarth and Jacobson, they said, had made unrealistic assumptions, ignoring advances in capture technology.

What the Howarth and Jacobson paper showed is this: if leakage rates of blue hydrogen are high and the capture rate of emissions is low, the overall emissions of blue hydrogen can exceed those from burning fossil gas and coal. This is partly due to the additional energy required to run the capture process. Even with low leakage and high capture rates there remain residual emissions. The UK's Committee on Climate Change, believes residual emissions could be between 15-40%.[11]

The unavoidable residual emissions mean that even though blue hydrogen might achieve significant carbon reductions compared to existing fossil fuel use, it will still contribute to GHG emissions. Blue hydrogen will therefore likely never be an ultra-low or zero-carbon technology. At best, blue hydrogen is a stop-gap measure on the route to fully low-carbon technologies. At worst, it has the potential to foreclose the deployment of genuinely lower-carbon alternatives, of which there are many.

Separating fact from fiction

Claims that oil and gas could be replaced with hydrogen like-for-like are highly questionable. In 2020, 458 EJ of oil, gas and coal were consumed globally. In comparison, just 10 EJ of hydrogen were produced.[12] Furthermore, less than 0.7% of current hydrogen production is from renewables or from fossil fuel plants equipped with CCS;[13] and most existing facilities with carbon capture do not achieve high enough capture rates. Data from existing carbon capture facilities shows a mean capture efficiency of 78.8% meaning more than 20% of the carbon emissions reach the atmosphere.[10]



Replacing so-called grey and black hydrogen produced from fossil fuels without carbon capture with low- or zero-carbon hydrogen should be the priority. There are applications where there are few alternatives to using hydrogen: a good example is fertiliser production. There are applications such as high-temperature processes in heavy industry, shipping, aviation and dispatchable power generation where hydrogen could play an important role. Together, these applications currently contribute more than two thirds of global energy-related carbon emissions.[12]

However, suggestions that cars and heating systems will run on blue hydrogen are misleading, and most if not all independent analysis does not see a future for hydrogen in those applications, at least not at scale.[14] There are more economical and efficient solutions available that offer full rather than partial decarbonisation, such as heat pumps and electric vehicles. Because of the ability to directly use renewable electricity via a heat pump or a battery, the efficiency is much higher than when producing and combusting hydrogen.

Hydrogen policy

The obvious question that arises for policymakers and regulators is what to do when faced with demands from gas network operators and gas heating system manufacturers to support blue hydrogen? In Europe, the main gas industry business association Eurogas has campaigned for this for many years.

Prioritise green hydrogen over blue

Net zero or zero emission climate targets require near full decarbonisation of all sectors. Because blue hydrogen is never zero carbon, its widespread use would potentially compromise society's ability to sufficiently mitigate GHG emissions. Therefore, green hydrogen should be prioritised over blue while ensuring that green hydrogen is truly green and based on renewable electricity. This is reflected in the European Union's hydrogen strategy, but others, such as that published by the U.K. government, are agnostic about blue and green hydrogen.

Support blue hydrogen only under strict conditions

If policymakers want to ensure that blue hydrogen delivers the expected emissions reductions it will be important to have sound regulation in place. Emissions performance standards are a vehicle to discuss minimum requirements for blue hydrogen production, but robust estimates of leakage and capture rates are required to estimate the carbon emission impacts. If monitoring and verification are weak, there is a risk of underperformance even with ambitious standards. Governments have started developing emissions performance standards: for example, the U.K. has launched a public consultation on a low-carbon hydrogen standard. It remains to be seen how stringent and effectively regulated such standards will be.

Identify sensible and inappropriate use cases for hydrogen

If policymakers want to ensure low transition costs, they need to carefully examine existing evidence both where hydrogen makes the most sense and where other lower-cost options are available. There have been several attempts to rank end-uses of hydrogen, ranging from the hydrogen merit order by the Potsdam Institute for Climate Impact Research[14] to Michael Liebreich's hydrogen ladder.[15] While such attempts to identify sensible and inappropriate use-cases for hydrogen differ, they also have similarities and can provide insight and confidence to government officials responsible for carbon goals.

Don't delay tried and tested solutions

Most projections for future hydrogen production do not foresee large quantities of hydrogen, whether blue or green, at least until the 2030s. Much of it will need to replace existing grey hydrogen or be directed to hard-to-decarbonise end-uses, such as industry or possibly aviation. Policymakers should support technologies that can be readily deployed today to reduce emissions over the next 10 to 15 years. In the transport sector this includes electric vehicles. Buildings can be decarbonised today through energy efficiency coupled with electrification and district heating using renewable energy. Analysis by the International Energy Agency suggests that these are the key technologies for decarbonisation in these sectors over the next three decades.[12]

With energy system decarbonization needed at an already challenging rate, any delay puts global climate goals at risk. At best, blue hydrogen offers a partial decarbonization solution to some niche energy demand sectors. At worst, blue hydrogen represents a colossal waste of money and time and risks distracting from the clear value of energy efficiency, systemic electrification and the development of naturally low carbon green hydrogen. Clearly the risk of lock-in associated with blue hydrogen is significant and while this lock-in is unlikely to last in perpetuity, it could lead to climate mitigation delay. Policymakers should ensure that any hydrogen strategies support hydrogen only where it clearly has systemic value and if it comes from truly sustainable sources.

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