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White hydrogen: geological curiosity or game changer?

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Spoiler: no game changer
There is a lot of interest in white hydrogen today, i.e. hydrogen that occurs naturally in the subsurface. Wouldn't it be great if one could exploit it in a similar way to natural gas? Hydrogen that escapes to the earth's surface is found in many places. However, hydrogen-accumulations in the subsurface, in permeable reservoirs, are extremely rare. There are two plausible reasons for this: hydrogen both escapes easily and is converted easily. White hydrogen will therefore not become a "game changer". Local production may take place on a limited scale, in the few places where hydrogen has previously been found by serendipity.

Zusammenfassung
Heutzutage besteht grosses Interesse an weissem Wasserstoff, also Wasserstoff der natürlicherweise im Untergrund vorkommt. Wie gut wäre es, wenn man es auf ähnliche Weise wie Erdgas gewinnen könnte. Wasserstoff, der an die Erdoberfläche entweicht, findet sich vielerorts. Wasserstoffansammlungen im Untergrund, in durchlässigen Reservoirs, sind jedoch äusserst selten. Dafür gibt es zwei plausible Gründe: Wasserstoff entweicht leicht und er lässt sich leicht umwandeln. Weisser Wasserstoff wird daher kein "Game Changer" sein. Die lokale Produktion kann in begrenztem Umfang an den wenigen Orten stattfinden, an denen zuvor zufällig Wasserstoff gefunden wurde.

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1 The topic

Hydrogen will be part of our future, clean energy system. After all, the combustion of hydrogen, unlike the combustion of natural gas, is not accompanied by the emission of CO_2. Hydrogen will be applied where certain of its characteristics, such as its relative ease to transport and store and its relatively high energy density per kg, give it decisive advantages over renewable electricity. It is still unclear for which exact applications that will be the case, as that will largely depend on the future cost of hydrogen. It is obvious though that 'hard-to-abate' industrial processes will belong to this.

Currently, about 100 megatons of hydrogen are produced annually (equivalent to 3% of the world's energy needs). In 2050, production could be five times larger. Now, this is almost exclusively grey hydrogen, made by splitting methane with steam. The production of green hydrogen, made by splitting water via electrolysis (where the electricity comes from renewable sources), has hardly started. Unfortunately, the current ways to produce hydrogen also result in a lot of CO_2 (grey hydrogen) or it costs a lot of energy and is relatively expensive (green hydrogen). Blue hydrogen (where the CO_2 released during the production of grey hydrogen is collected and stored in the subsurface) is in between, both in terms of CO_2-emissions and costs.

Hence the interest in white (naturally in the subsurface occurring) hydrogen. How wonderful it would be if one could exploit it in a similar way as natural gas. It would promote hydrogen from an energy carrier to a primary energy source. And it is being claimed to be affordable too! For the last ten years, therefore, in parallel with the budding energy transition, the potential for white hydrogen has been enthusiastically investigated by research institutions and speculative new-ventures companies. In the last year, this was accompanied by a deluge of articles in the media. Those articles often emphasise the amount of white hydrogen generated in the earth and the potentially low production costs.

This article makes a number of critical comments. First, a brief overview of underground hydrogen systems is given; how hydrogen is formed in the earth, how it moves and how it could be preserved. Where is hydrogen found, either trapped in the subsurface or escaping from the surface? What kind of work is being done to get a better understanding of the hydrogen system and what has taken place in exploration for hydrogen? Next, an estimate is made of the potential of white, natural hydrogen and whether there is any chance that this can ever be produced in meaningful volumes on a global scale. Spoiler: that doesn't seem to be the case.

2 A lot of hydrogen is produced in the subsurface

There are a number of ways in which white hydrogen is formed. An important one seems to be the reaction between ferroid rock and water. For example, the reaction between olivine and water leads to the formation of serpentinite and hydrogen. Such reactions take place in a number of tectonic settings. In the case of mid-oceanic ridges, where new oceanic plate material is produced, it concerns the serpentinisation of olivine. Often this hydrogen escapes through hydrothermal vents or is consumed by microbes in the vicinity of these vents (something that has been widely studied because of its relevance to the creation of early life on Earth).

This serpentinisation with the accompanying generation of white hydrogen is also known from several ophiolites (old oceanic plate material obducted onto continents), such as the eternal fire of Chimaera in the Turkish Tekirova ophiolite zone where approximately 5,000 kilograms of methane-hydrogen mix per square kilometre per day comes out of the ground, in the Bulqizë chromite mine in Albania, the Semail ophiolite in Oman and the southern Pyrenees. Another important location of white hydrogen is in cratonic settings (eg. Mali and South and West Australia) where old, iron-rich formations (including the so called Banded Iron Formations) are oxidised.

White hydrogen can also be related to fossil fuels, either as a late product (high temperature), after oil, gas and/or coal have been formed, or as adsorbed molecules in organic matter, in particular coal (e.g. in Lorraine, France). Urban gas, in some European cities used until the 1960's, formed by heating coal, also contained hydrogen in addition to methane.

Another possibly significant source of natural hydrogen may be the degassing of geologically very old ('primordial') hydrogen, from a few hundred kilometres deep in the earth. Finally, there is radiolysis, in which water molecules are split as a result of natural radioactivity. This could take place e.g. in uranium-rich granites.

So unlike methane, which is almost exclusively formed from the conversion of organic matter, there are many processes that create white hydrogen. The U.S. Geological Survey calculated a global annual hydrogen flux from the earth's surface of 23 megatons (with a large uncertainty). The main message here is that the formation of hydrogen is not a limiting factor for the potential of natural hydrogen. Even if only a small fraction of all the produced hydrogen would be preserved and would be recoverable this would suffice to provide all the necessary hydrogen for a long time.

While the formation of hydrogen takes place in different ways and in different settings than that of methane, it migrates in similar ways, either in gas form (where the relatively low density is important), or dissolved in formation water. And like methane, hydrogen can encounter impermeable layers under which it, like methane, could be trapped. One of the differences with methane, however, is that hydrogen escapes much more easily due to the smaller dimensions of the hydrogen molecule. On the positive side, helium, with a similar molecular size, can be trapped under salt. *In general terms, the critical factor for the potential of white hydrogen is not its formation but the trapping and preservation in the subsurface.* Compared to methane, hydrogen is at a disadvantage in two ways: it escapes much more easily (which might not be a showstopper in the case of an excellent top seal) and it reacts much more easily. Reactions can take place in a biotic way, by microbes, or abiotically (with carbon it forms methane, with oxygen it forms water, etc.).

3 In many places, white hydrogen escapes to the surface; accumulations are found in very few places.

The vents at mid-oceanic ridges contain hydrogen. However, mining these, at a depth of generally several kilometres below sealevel, is commercially not feasible. Fortunately, much better insight has evolved in the past decade also into the distribution of onshore hydrogen vents and seep. 'Fairy circles' (oval-shaped structures with anomalous vegetation, attributed to escaping gases including hydrogen) with a diameter of a few tens of metres to a few kilometres, are recognised in more and more places on earth. But here too, commercial production, given the diffuse escape from the earth's surface, does not seem like a real option.

Research into the potential of hydrogen focusses therefore on underground accumulations and here a problem emerges: these accumulations have hardly been discovered so far. The few who have been found, often decades ago and by serendipity, are widely publicised. We mention the best known below.

In 1987, a water well in Mali, produced hydrogen from shallow depths. Since 2011, this well has produced hydrogen for a number of years for local electricity production and a number of additional wells have been drilled in which hydrogen was also found. Production was small-scale; with a flow rate of 1,500 cubic metres per day, this corresponds to only 3 barrels of oil-equivalent per day in terms of energy.

South of the Pyrenees, the exploration company Helios-Aragon wants to drill the Monzon-2 well in 2024. This is in the vicinity of the Monzon-1 well wich already in 1963 encountered high concentrations of white hydrogen at a depth of 3,600 metres under a salt layer. The company is talking about 1 megatonne to 10 megatonnes of recoverable hydrogen.

A similar appraisal program is carried out in the Yorke Peninsula in South Australia (the Gawler craton). Here, Gold Hydrogen drilled the Ramsay-1 and Ramsay-2 wells in 2023, in proximity to the Ramsay Oil Bore-1 and the American Beach-1 wells, where highconcen trations of hydrogen were found about 100 years ago. The focus in 2024 is on gaining a better understanding of the size of the field and the scope for limited development on a local scale. However, it is not excluded that an eventual development will focus on the helium that has also been found here.

In Kansas and Nebraska, o.a. HyTerra and Natural Hydrogen Energy are investigating the potential for hydrogen extraction in an area around the subsurface Nemaha Ridge where hydrogen was found in oil- and gaswells in the 1980's. In a first well, drilled in

2019 (Hoarty-NE3), hydrogen was found, but it is unclear how much commercial potential there is. Apparently, the results were insufficiently promising for immediate follow-on funding. In 2023, a flow test was carried out with money from a new partner, but the results are as yet not publically available.

In Northeast-France, hydrogen has been found in low-permeable coal layers. The gas, at a depth of several hundred metres to about 1 kilometre, is mainly methane with 12%-15% hydrogen. Because the concentration of hydrogen increases with depth, much higher concentrations are expected to be found at greater depths (one even speculates about a concentration of 90% at 3 kilometres depth). However, the potential to produce large-scale hydrogen from this is viewed with necessary scepticism. Production at a small depth of several hundred metres might well be possible with methods such as those used for coalbed methane extraction. This would require large amounts of wells and the processing of large quantities of co-produced water. Production at greater depths would, given the low permeability, require large-scale stimulation by fracking. For methane, such production at these kinds of depths in coal layers has never been realised.

In-situ combustion of fossil fuels also results in hydrogen ('syn-gas') which could theoretically be extracted from production wells. Problems with such underground combustion are the cost and operational complexities (for example, controlling the underground combustion front). Apart from these technical problems, shale gas (methane) from low-permeable sandstones is a commercially much more attractive proposition.

4 Research and exploration have been initiated to a limited extent

A limited number of research institutes have been working for some time to get a better understanding of the different white hydrogen systems. A well-known example is the project at the University of Pau in France led by Isabelle Moretti, supported by energy company Engie. Those who want a good overview can consider watching her AAPG Distinguished Lecture on white hydrogen. The USGS (US Geological Survey) also executes a research programme. In addition, there are a number of relatively small startups that focus on appraising existing hydrogen finds. We already mentioned Gold Hydrogen in Australia, Hydroma in Mali, Helios- Aragon in Spain and Hyterra in the USA. All these relatively small companies focus on evaluating existing hydrogen discoveries. Those discoveries were in all cases the result of serendipity, finding hydrogen by chance. These companies are not looking for new occurrences.

'There is even talk of "enhanced" white hydrogen production: water could be injected into iron-rich formations, after which the formed white hydrogen could be extracted.' A test is planned in Oman. The big problem here is the required permeability, which is often lacking and is very difficult to create. So far, the major oil and gas producers have been reluctant to support research, and none of them have decided to launch an exploration campaign and drill wells.

5 The potential for white hydrogen production is small

Many arguments have been put forward to explain why no large hydrogen-accumulations have been found: "white hydrogen is mainly associated with geological areas where the oil and gas industry is little active"; "people were not looking for it"; "no measuring equipment was used in the oil gas-water wells that could detect hydrogen", "the large oil and gas producers are very conservative", etc. However, there is probably a much simpler reason why hardly any hydrogen accumulations have been found: they are simply extremely rare.

As mentioned above, there are two aspects which put hydrogen at a disadvantage with respect to methane: hydrogen escapes more easily and hydrogen is converted more easily (either by reactions with rocks and underground liquids, or by microbes). In terms of migration and diffusion: many places have been found where hydrogen escapes from the soil. As for preservation, virtually no significant accumulations have been found in the subsurface: the breakdown by microbes is under some circumstances, such as the storage of hydrogen in empty gas fields, already an issue on a human time scale, let alone on a geological time scale.

Hydrogen, compared to methane, is more difficult to capture under a caprock. However, excellent caprocks such as salt could theoretically trap hydrogen accumulations. The helium molecule has a similar size to the hydrogen molecule and there are plenty of examples of helium in gas- accumulations under salt (not as much as natural gas fields, but helium is generated in much smaller quantities).

Why then is hardly any hydrogen found under salt? It is true that mudlogging units will normally overlook it, but the CNL tool (Composite Neutron Log), which is routinely used over reservoir intervals, and more advanced liquid sampling, should have seen hydrogen. In addition: there are thousands, if not tens of thousands of gas fields where salt forms the top seal and even if hydrogen had been missed during the exploration phase, it cannot be overlooked at a test or during the production phase. We conclude that it simply is not there. The ease with which hydrogen migrates to the earth's surface and the great speed at which hydrogen in the surface reacts with microbes, carbon and oxygen are plausible reasons for this. In the words of Chris Ballentine during a lecture at the University of Oxford: 'The microbes were there first'.

All this does not mean that there will be no small-scale production of hydrogen in a number of locations. But this will mainly happen in places where hydrogen has already been found accidentally in wells that originally set out to find oil, gas or water. It is possible that a number of seeps (natural leakages on the surface) can also be operated for local use. Searching for new hydrogen accumulations is hardly pursued at the moment because there is simply no commercially attractive exploration method. It's like looking for a needle in a haystack. If one finds one, it is a cheap needle. But that doesn't mean that looking for a needle in a haystack is an at tractive business model.

A better understanding of the hydrogen system could perhaps lead to a greater chance of finding seeps and smaller occurrences at relatively shallow depth. But the scope for large white hydrogen accumulations, with all the oil and gas wells already drilled to prospects or fields under excellent top seals, seems almost nil. Happy to be proven wrong and with that thought in mind we welcome further research.

6 The media about white hydrogen

In fact, in the last ten years, not much has changed in terms of geology in the knowledge about hydrogen systems in the subsurface. Between 2015 and 2020, with the start of the energy transition, many of the major oil and gas companies looked at the potential of white hydrogen. And they have made a similar evaluation as in this article.

These oil and gas companies are not risk averse. They are willing to spend large amounts of money on risky exploration campaigns, provided that the potential profits justify the risks. And that is not the case for white hydrogen, not then and not now.

What has changed is the attention of the media. That exploded in 2023. There is no geological breakthrough that justifies this though, but rather the irrational hope of a clean, primary energy source ('wouldn't it be great if this worked?') and a certain herd mentality of journalists: as soon as a critical mass of articles on a subject has appeared, a snowball effect frequently arises.

For earth scientists working on this topic, this is a challenge. It's encouraging when research close to one's heart attracts press coverage. It becomes uncomfortable if these articles start to play a role in obtaining funding for research or for exploration. It becomes very uncomfortable when expectations are raised that in all likelihood can never be met.

Sources

1. Waterstof: quo vadis? | Energeia
2. Global Hydrogen Review 2023 – Analysis - IEA
3. Global Hydrogen Review 2021 – Analysis - IEA
4. Natural hydrogen in the energy transition: Fundamentals, promise, and enigmas - ScienceDirect
5. Massive release of natural hydrogen from a geological seep (Chimaera, Turkey): Gas advection as a proxy of subsurface gas migration and pressurised accumulations - ScienceDirect
6. UNDERSTANDING THE POTENTIAL FOR GEOLOGIC HYDROGEN RESOURCES (energy.gov)
7. Discovery of a large accumulation of natural hydrogen in Bourakebougou (Mali) - ScienceDirect
8. How we chanced upon what may be the world's largest white hydrogen deposit (theconversation.com)
9. Natural Hydrogen Exposed! Interview with Geoscientist Arnout Everts - Green Hydrogen News (energynews.biz)
10. Subsurface technologies for hydrogen production from fossil fuel resources: A review and techno-economic analysis - ScienceDirect
11. Isabelle Moretti - The Natural H2 Exploration Started: Why, Where and by Who? (aapg.org)
12. The Potential for Geologic Hydrogen for Next-Generation Energy | U.S. Geological Survey (usgs.gov)
13. https://www.omanobserver.om/article/1149480/business/energy/us-firm-gets-grant-to-study-omans-geologic-hydrogen-potential
14. https://publications.tno.nl/publication/34637695/1RqPrg/TNO-2020-R12005.pdf
15. https://pubs.geoscienceworld.org/pg/article/28/2/petgeo2021-029/610750/The-principles-of-helium-exploration
16. Gold natural hydrogen .. Pipeline or pipedream? | 7 June 2022 (youtube.com)

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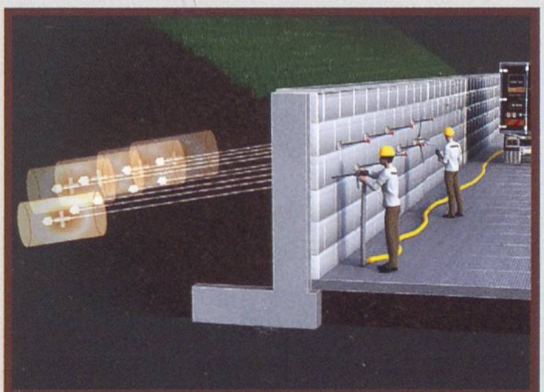

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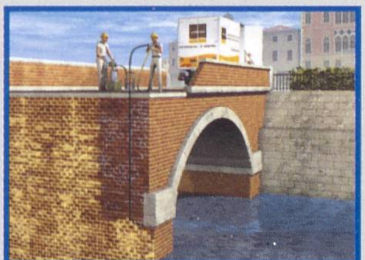

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