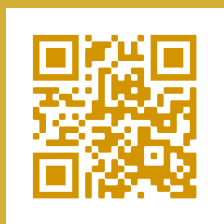


GOLDRUSH: NATURAL HYDROGEN

A New High Potential in the Energy Mix

White Paper I



EN

EATING SHARKS

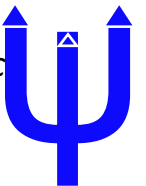
Fine Climate Consulting

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GOLDRUSH: NATURAL HYDROGEN

Bill Gates invests in natural Hydrogen Startup

July 2023: Koloma, a Denver-based natural hydrogen startup, is backed by Bill Gates, his Breakthrough Energy Ventures and other partners with \$91 million. The four-member executive team has deep expertise in earth sciences, geology and drilling. The company has filed 16 patents for the discovery and extraction of natural hydrogen.



GOLDRUSH: NATURAL HYDROGEN

A new High Potential in the Energy Mix

There is talk of a gold rush in natural hydrogen. At least since Bill Gates invested a sum of \$91 million in a secretive hydrogen startup in Denver. But geoscientists and industry specialists have been noticing a trend for some time. The world's top experts are working to understand it. Why is the zero-emission, low-cost hydrogen option only now getting more attention? The reason is simple: you can't find what you're not looking for.

The famous eternal fires of Mount Chimaera in the Olympos Valley are an open display of the source's potential. But there is plenty of scientific evidence for the existence of natural hydrogen around the world, some of it dating back a hundred years. Natural hydrogen, also known as geological, white, golden, or native hydrogen, has simply been overlooked. The focus was on oil and gas, the fossil fuels.

With the realization of their climate-damaging effects and the implementation of the Paris Climate Agreement, renewable energies have come to the fore. Research into natural hydrogen is also supported by some energy producers of oil and gas. They have the drilling knowledge, and their equipment can be reused to extract hydrogen. Politics, of course, plays an overriding role in terms of geopolitics, government models, legal and funding instruments.

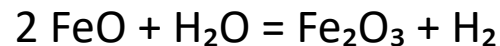


GOLDRUSH: NATURAL HYDROGEN

It is very attractiveWhat is It?

Natural hydrogen is an energy source, not a vector. It is continuously produced in the Earth's interior by several chemical reactions. The most important are oxidation of ferrous minerals, radiolysis of water, maturation of organic matter and outgassing from the Earth's mantle. The most promising, because it is the most efficient, is the production of natural hydrogen by the interaction of iron-rich rocks or minerals with water.

In what are known as redox reactions, the ferrous iron rusts and captures oxygen from the water, releasing hydrogen. One corresponding chemical equation is:



The world's best geoscience experts recommend that the exploration strategy for natural hydrogen should focus on areas where ferrous iron and/or natural radioactivity is present and can react with water.

Chemist and entrepreneur Viacheslav Zgonnik (Natural hydrogen energy LLC) has already registered 465 geo-references of natural hydrogen occurrences, which are fairly evenly distributed around the world. There are several potential sources with different volumes. Technology maturity using the Technology Readiness Level (TRL) methodology is estimated to be on a par with that of green hydrogen. One regional-scale prototype with several bore-holes in Mali.



NATURAL HYDROGEN IN TURKEY

The eternal Flames

Hydrogen is believed to be the source of the Olympic fire. The perpetual gas fires of Mount Chimaera near Antalya (also Yanartaş or Burning Stones) are a famous feature of the ancient Olympos Valley. It was a site for Hephaistos, the god of fire. The flames are alive since 2500 years. They are subject to seasonal variations, being more vigorous in the winter months. The hydrogen concentration is between 7.5% and 11.3%.



NATURAL HYDROGEN IN GERMANY

Milestones from Politics and Research

There are two milestones regarding the importance of natural hydrogen in Germany. The first concerns Germany's hydrogen plans. Recently, the Federal Cabinet announced the continuation and further development of the national hydrogen strategy in Germany. Natural hydrogen is mentioned together with green, blue, turquoise and orange hydrogen as a clean hydrogen option. The electrolysis capacity planned for 2030 has been doubled

from 5GW to at least 10GW. The second is HyAfrica, a collaboration between international universities, the Fraunhofer Institute for Energy Economics and Energy System Technology IEE and the Leibniz Institute for Applied Geophysics LIAG to research natural hydrogen for local use in rural African communities. The premise is that "natural hydrogen – also known as white hydrogen – is a primary and clean energy source that is continuously generated by

geochemical reactions in geological formations. However, the methods for exploring and using natural hydrogen are poorly defined and there are few regulatory measures in place for this in the countries where the project is being carried out." The project, which was launched in 2022 and investigate deposits in Morocco, Mozambique, South Africa and Togo, will run for three years and is funded by the EU to the tune of €1 million.





NATURAL HYDROGEN IN MALI

12 Years of Community Power Supply

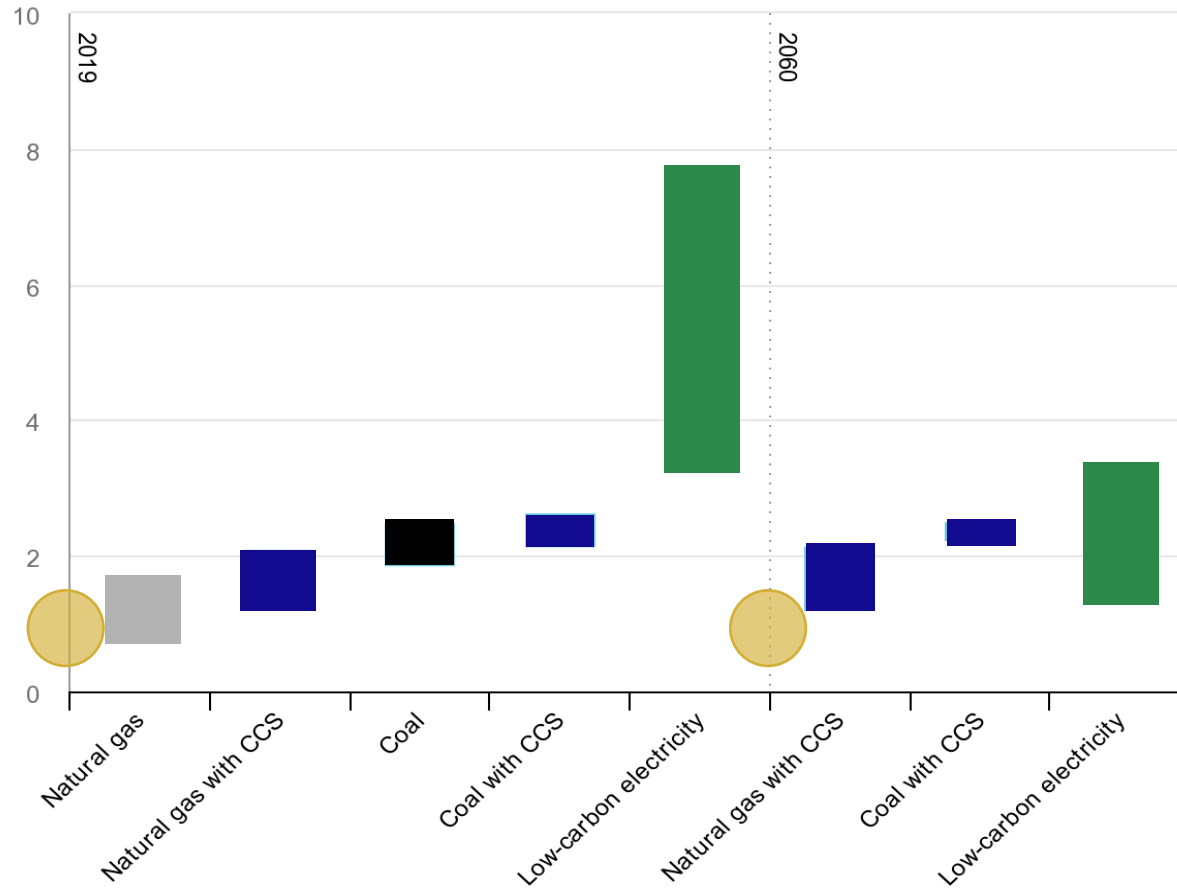
The Bourakébougou natural hydrogen field is already famous in the geoscientific world, and now also in the press. It has been supplying the community with electricity for 12 years now. Gas chromatographic analysis has shown that the gas consists mainly of natural H_2 (98%) associated with nitrogen and methane (1% each). The main source of Bourakébougou's hydrogen is thought to be the oxidation of iron-rich rocks reacting with water (redox reaction).

Source: Omar Maïga et al.



NATURAL HYDROGEN ADVANTAGES

The global average levelized Cost of Hydrogen (LCOH)



The global average levelized cost of hydrogen production (LCOH/ kg H₂) by energy source and technology, 2019 and 2060, estimated by the IEA, shows trends in the development of the different sources. Natural hydrogen was not included. The golden dots represent the cost of Mali production (2019) and the projected cost of Monzon production (2060) in the Aragon region in Spain. They range from approx. 0.5 to 1.2 USD, according to the producers.

NATURAL HYDROGEN IN SPAIN

The Monzon Field, Aragon

The company Helios Aragon is currently developing the commercial production of natural hydrogen and helium in northern Spain. Drilling is expected to start in 2024, depending on the legal situation. The oil and gas experts expect large hydrogen deposits to be exploited in the next 20-30 years. The company states that the break-even cost of hydrogen supply from the €300-800 million project is around €0.5/kg. Natural H₂ does not require storage.



NATURAL HYDROGEN ADVANTAGES

1. Cheap 2. Clean 3. High social Acceptance

		Resource, not a vector		Volume: 10 years PDOP, 1PDOP= ~ 2 trillion USD	
1 Cheap	3 High social acceptance	5 Renewable hydrogen: Possibly replenishing	6 Substance: Technology demand 14	Lean: Re-use equipment 9	
2 Clean, very low carbon emissions	4 Value architecture of helium, geothermal energy and brines = low costs.	7 24/7 production, Dunkelflaute compensation	8 Fast growing 11	Many occurrences 13	
	4 Helium tracker.		12 Disruptive potential	10 Community attention	15 High



NATURAL HYDROGEN AT ASX

HyTerra at Australian Securities Exchange

HyTerra is a Hydrogen company to be listed on the ASX (ASX:HYT) with a focus on pioneering the exploration and production of natural hydrogen. It is working in a joint development with Natural Hydrogen Energy LLC in the United States to develop the exploration and production of this hydrogen (and helium). The Nehama Ridge in Kansas is considered the preferred and most promising site for this. The company relies on the sighting of geophysical data.

Source: HyTerra



NATURAL HYDROGEN ADVANTAGES

Wrap-Up: What are the Benefits of this Resource?

The combination of low cost and low to zero emissions is the clear advantage of natural hydrogen. This results in a high level of social acceptance, an underestimated factor. On the other hand, social resistance is to be expected with all more expensive technologies. The term "emission-free" refers to the resource itself, which is a clean and, above all, lean direct energy source. All the additional processes required to manufacture proper energy

vectors produce greenhouse gases. With natural H₂, systems can continue to operate without additional on-site storage. It can be produced almost around the clock and used as an energy source to bridge periods of Dunkelflaute. It is highly productive. The more productive the project, the more the embodied carbon decreases. A Stanford study shows this. Land use, water consumption and additional resources are also not critical compared to blue or

green hydrogen. The producers for natural hydrogen are the same as for oil and gas. There are certain characteristics to consider for natural H₂. But for them, however, production is likely a routine process, whereas all other technologies are subject to far greater risks. Oxford Energy Network experts estimate the potential volume in 2022 to be 10 years of Present Day Oil Production (PDOP). One PDOP is worth \$2 trillion.

NATURAL HYDROGEN IN ICELAND

Geothermal Energy and Hydrogen

Iceland has a unique geological landscape; its hot springs are world-famous and have been used for centuries. Geothermal energy provides 65% of the energy supply and hydropower 20%. As a result, the country is a world leader in the field of renewable energy. Geothermal power plants in Iceland emit a total of ~ 1.2 kt H_2 per year. At an estimated price of $\text{€}2/\text{Kg}$, the hydrogen emitted has a value of $\text{€}2.3$ M/yr.



NATURAL HYDROGEN CHALLENGES

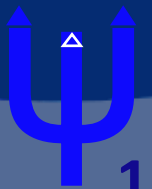
The geological Clock

The geological Clock: a projection of the Earth's 4.5 Gigaannum (Ga) history onto a clock. Megaannum = one million years (Ma) and Gigaannum = one billion years (Ga) ago. Hydrogen research and exploration is based on a highly complex system of geoscience and planetary science, physics and chemistry.

1 Ga

Proterozoic

2 Ga



NATURAL HYDROGEN SOUTH AUSTRALIA

Gold Hydrogen on the Yorke Peninsula

Gold Hydrogen is another ASX-listed company (ASX:GHY) specializing in natural hydrogen. Recent soil sampling has detected 90% pure hydrogen on the Yorke Peninsula in South Australia, where the company has secured rights. Airborne geophysical surveys have recently been carried out. Only lately has active drilling been conducted, and helium has been discovered alongside natural hydrogen. Further drilling is planned.



NATURAL HYDROGEN CHALLENGES

1. Highly diffusive 2. Microbes 3. Scalability questionable

<p>1 Highly diffusive and mobile H₂</p>	<p>2 Microbial problem</p>	<p>5 Lack of systematic studies</p>	<p>6 High system complexity</p>	
<p>3 Scalability questionable</p>	<p>4 Geological pattern</p>	<p>7 Possibly local, decentralised production</p>	<p>9 Legislation</p>	<p>10 Image problem</p>
		<p>8 Unstructured; mid- and downstream challenge</p>		<p>11 Wait & See</p>



NATURAL HYDROGEN IN THE USA

Natural Hydrogen Energy in Kansas

Natural Hydrogen Energy, which operates at Nemaha Ridge in Kansas, USA. It is one of the pioneers in the industry. Founder and CEO Viacheslav Zgonnik holds a PhD in chemistry and has conducted extensive research on natural hydrogen. The company is a joint development partner of HyTerra, a listed company (ASX:HYT) in Australia.



NATURAL HYDROGEN CHALLENGES

Wrap-up: Looking at the big Picture

Hydrogen is highly reactive, mobile and difficult to capture. It is also lost in the flow from deep to shallow. A study of a Brazilian reservoir estimated the loss at 50% after seven years of drilling, assuming microbiological methanogenesis. Natural hydrogen is converted into methane. Geoscientists favour several theories for its formation, such as ferrous iron redox reaction or radiolysis. But more systematic studies are still needed. Drilling and further

monitoring could also clarify whether the sources are local or scalable deposits. Natural H₂ research looks at the big picture. It thinks in terms of geological and planetary timescales, i.e. eons. On a practical level, researchers might consider temperature differences or rainfall, for example, as well as the amount of continental crust, gravity and tides. It is precisely these circumstances that confuse us. We prefer to rely on supposedly plannable projects, such as

the production of hydrogen by electrolysis. The classification of geopolitical conflicts is relevant to all forms of energy production and supply, including natural hydrogen. Energy producers are taking a wait-and-see approach and are already supporting international research projects, some of them in-house. Because hydrogen has been widely overlooked, the system is unstructured, and more understanding is needed.



NATURAL HYDROGEN IN LORRAINE, FRANCE

Exploration and Research

In northern France, the energy company FDE has discovered large deposits of natural hydrogen in one of its former wells in Carboniferous formations. It is thought to have a concentration of 98% at a depth of 3000 metres. The University of Lorraine is providing research support for the project. Further measurements are pending, and the legal permit covers an area of more than 2000 km².

NATURAL HYDROGEN CONCLUSION

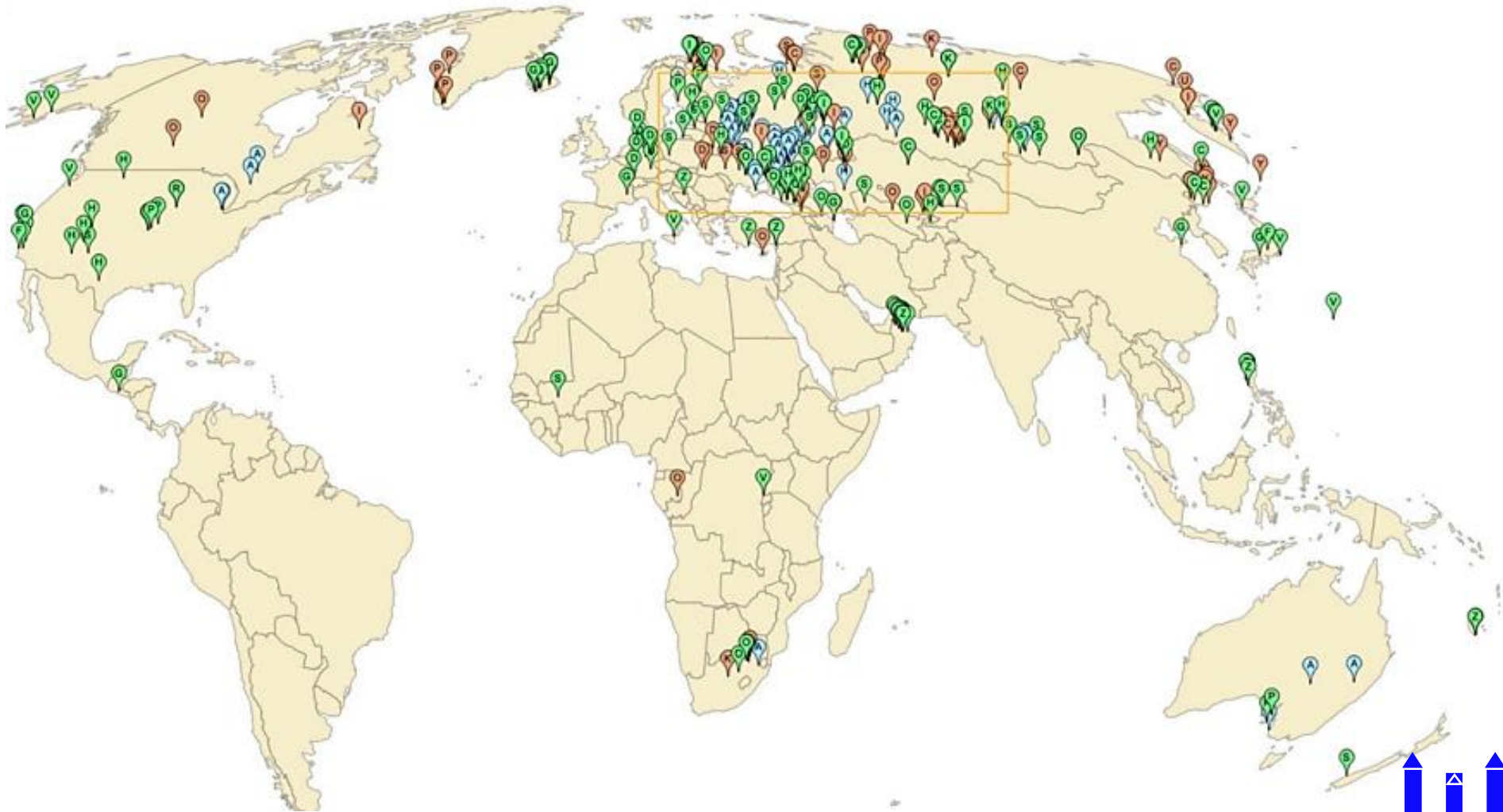
The cheap, clean & lean hydrogen market challenger.

Natural hydrogen has been overlooked as a cheap and emission-free energy source, despite up to 100 years of scientific evidence from some 465 geo-points around the world, from Oman to Canada. You don't find what you don't look for. While the benefits are clear and compelling, cogeneration with helium is particularly worth highlighting. Helium is also a scarce and valuable resource, used in high technology applications such as MRI scanners or cooling

semiconducting magnets. For quantum mechanics researchers, it is important for the property of superfluidity. Natural hydrogen is a helium tracker. So, the mixture with which natural hydrogen occurs is valuable in many cases. In terms of greenhouse gas emissions, price and efficiency, it compares favourably with other hydrogen products and energy sources. The main drawback are the properties of the hydrogen molecule

itself: it is highly reactive, mobile, and difficult to capture. Added to this is the high system complexity of the research field, from earth and planetary sciences to physics and chemistry. This makes it seem almost superhuman and difficult to grasp. But the positive characteristics and the network of experts are convincing, and the international interest in this energy source is high, to mention Bill Gates again in conclusion.

NATURAL HYDROGEN AROUND THE WORLD



Source: Viacheslav Zgonnik

RECOMMENDED ACTIONS

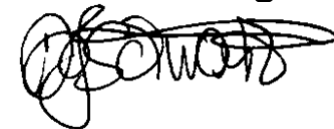
1. Research 2. Follow-up 3. Legal situation

Current developments, from the effects of the climate crisis, the pandemic, the war in Ukraine, to energy-intensive cutting-edge technology such as artificial intelligence, show the huge demand for cheap and emission-free energy. Especially from industry, as the IEA reported in May 2023, based on global oil consumption. The use of natural hydrogen is of great importance for consumers and for all representatives of politics, business and civil

society. Firstly, I recommend supporting scientific research to enable further systematic studies of natural hydrogen and its gaseous mixtures. Second, the development and results of the current and future drilling projects in Mali, Australia, Europe and the USA mentioned here should be followed with great interest and monitored. Thirdly, the review and adaptation of the legal situation in favour of the production of natural hydrogen.

This first guide is intended to help you – and to keep you ahead of the game, I am happy to support you with strategic concepts. I invite you to contact me at any time!

With kind regards



Dag Juvel Schwarz

Founder & CEO of Eating Sharks
Fine Climate Consulting
Engineer, Technology and Knowledge
Manager

A close-up, macro photograph of numerous water bubbles of various sizes, some large and some tiny, rising through clear water. The lighting creates bright highlights and soft shadows on the bubbles, giving them a three-dimensional appearance. The overall color palette is a range of blues and greens, from deep teal to light, almost white, highlights.

NATURAL HYDROGEN

In Times of Dunkelflaute

Plans to expand renewable energy and the clean hydrogen economy are in the spotlight worldwide. Germany's national hydrogen strategy recently doubled the share of planned energy production from green hydrogen. From an efficiency and risk perspective, every form of energy production is both affected by and responsible for the consequences of the climate crisis. Even in times of Dunkelflaute emission-free and cheap support must be available. Natural hydrogen could fill this gap.



NATURAL HYDROGEN APPENDIX

The Hydrogen Colours

Natural Hydrogen

Natural (also white, gold or geological) hydrogen from the Earth's interior is cheap, the use emission-free.

Orange Hydrogen I + II

Generation of natural hydrogen by stimulation of underground rocks with water (I). Or of H₂ from waste (II).

Red/Pink Hydrogen

Red hydrogen is produced by electrolysis using nuclear energy. Energy-intensive, use emission-free.

Turquoise Hydrogen

Hydrogen is produced from natural gas by methane pyrolysis. The separated carbon is stored. Use emission-free.

Blue Hydrogen

Previously grey hydrogen, carbon dioxide CO₂ is stored (CCS), use emission-free.

Green Hydrogen

Electrolysis of water from renewable energy produces emission-free but still expensive hydrogen.

Grey Hydrogen*

Steam methane reforming, SMR, of natural gas. CO₂ - emissions, climate-damaging. *95% of current production

Brown Hydrogen*

Coal gasification from lignite by heating & steaming. CO₂ - emissions, climate-damaging. *95% of current production

Black Hydrogen*

Coal gasification from hard coal by heating & steaming. CO₂ - emissions, climate-damaging. *95% of current production



NATURAL HYDROGEN APPENDIX

Metrics for Climate Technology

The various terms are preceded by an intensive scientific debate. For example, the “Greenhouse Gas Intensity” indicator means the sum of all greenhouse gas emissions generated by a system over the entire value-added lifecycle. It includes the extraction of raw materials, production and manufacturing, processing and assembly, sales and packaging, transport, maintenance and repair, storage and warehousing, and final disposal.

The GHG intensity is used to mathematically estimate initial risks and trends in greenhouse gas emissions. Stanford University has researched GHG intensity including embodied carbon precisely for one hydrogen product, here for natural hydrogen. There is also the “Green Premium”, which estimates the additional costs we have to spend on clean technologies compared to emission intensive technology. The production of green hydrogen, for

example, is still significantly more expensive than grey hydrogen from natural gas. However, fossil sources are not in line with the Paris climate goals and the achievement of Net Zero. Selecting the most efficient climate technology based on measuring and comparison is therefore important. There are emission-free resources (e.g. natural hydrogen). The whole life cycle should be assessed for the carbon footprint.



ABOUT EATING SHARKS AND ME

From Engineering & IT to Fine Climate Technology

It all started around the corner from LEGO in Denmark with an engineering internship at Brandtex, a top fashion manufacturer. I then managed IT projects, moved to startup legend myToys, and later led major national policy projects such as *Equal Pay Day*. My passion for sustainability was my calling to research the leanest, cleanest and cheapest hydrogen option: Natural Hydrogen. I am very committed to combining this energy source with my digital skills. Creating solutions that benefit people and the climate while also doing good business!

Throughout this journey, I have never shied away from discomfort or difficult challenges to grow and to be innovative — 'eating the sharks' so to speak! It's personal as well as professional. I still speak Danish, and that time will always be close to my heart — just like LEGO around the corner from where it all began!

My experience over the past few years has given me invaluable insight into both technology management and sustainable energy. It is incredibly fulfilling to be able to combine my passions — and make a positive impact on our planet through practical solutions.

If you are interested in my full CV, please send me a short email. Or have a look at the short LinkedIn extract.