EATING SHARKS

FINE CLIMATE CONSULTING

GOLDRUSH: NATURAL HYDROGEN

A NEW HIGH POTENTIAL IN THE ENERGY MIX?

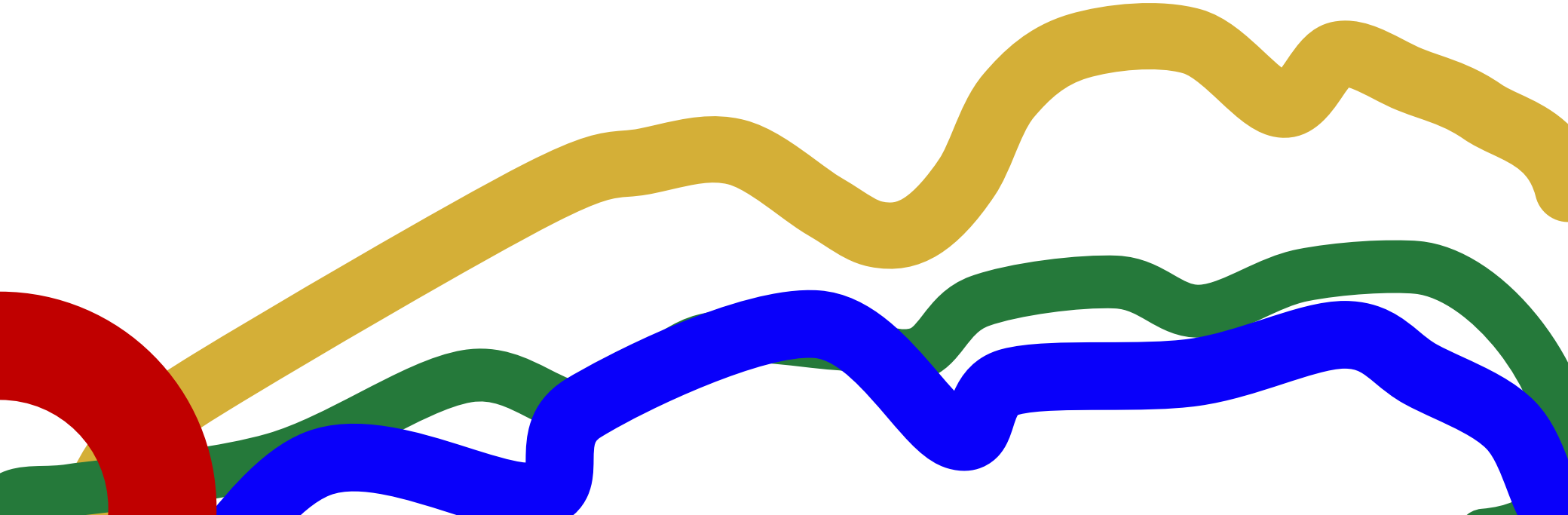


TABLE OF CONTENT

GOLDRUSH: NATURAL HYDROGEN

Bill Gates invests in natural Hydrogen Startup

Koloma, a Denver-based natural hydrogen start-up, was backed by Bill Gates, his Breakthrough Energy Ventures and other partners to the tune of 91 million dollars in 2023. In 2025, the total private investment volume amounts to 246 million dollars according to Pitchbook.

Source: Photo Wikimedia, WEF, Severin Nowacki, CC BY-SA 2.0 ; Pitchbook; Forbes

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 the impressive sum of 91 million dollars in a secretive hydrogen start-up from Denver back in 2023. 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? Experts think that 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 used to extract hydrogen. Politics, of course, plays an overriding role in terms of geopolitics, government models, legal and funding instruments.

Source: Viacheslav Zgonnik

GOLDRUSH: NATURAL HYDROGEN

It is very attractive …….What 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. Science considers the production of natural H_2 through the interaction of iron-containing rocks or minerals with water to be the most promising.

In what are known as redox reactions, the ferrous iron rusts and captures oxygen from the water, releasing hydrogen. 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. Hydrogen pioneer and chemist Viacheslav Zgonnik has compiled a catalogue of georeferences for natural hydrogen occurrences, which are fairly evenly distributed around the world. There are several potential sources with different estimated volumes.

The group of experts at the International Energy Agency (IEA) considers the technology readiness level (TRL) to be level five. Bourakébougou, Mali, is the only functioning production site with several wells to date.

Source: Eric Gaucher et al, earth2 Initiative, IEA Global Hydrogen Review 2024

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 for 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%.

Source: Photo Wikimedia, Chimaera, William Neuheisel, CC BY 2.0 License; Viacheslav Zgonnik

NATURAL HYDROGEN IN GERMANY

Milestones from Politics and Research

There are two milestones regarding the importance of natural hydrogen in Germany. The first concerns the German hydrogen plans. Geogenic hydrogen is mentioned in a marginal way in the national hydrogen strategy of the traffic light coalition - and only about its global potential. As Germany had well-known, historically significant iron ore deposits, I strongly recommend national research. The second milestone 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. How-ever, 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.

Source: Germany The Federal Government, Germany Federal Ministry for Economic Affairs and Climate Action, Fraunhofer-Institut für Energiewirtschaft und Energiesystemtechnik

NATURAL HYDROGEN IN MALI

12 Years of Community Power Supply

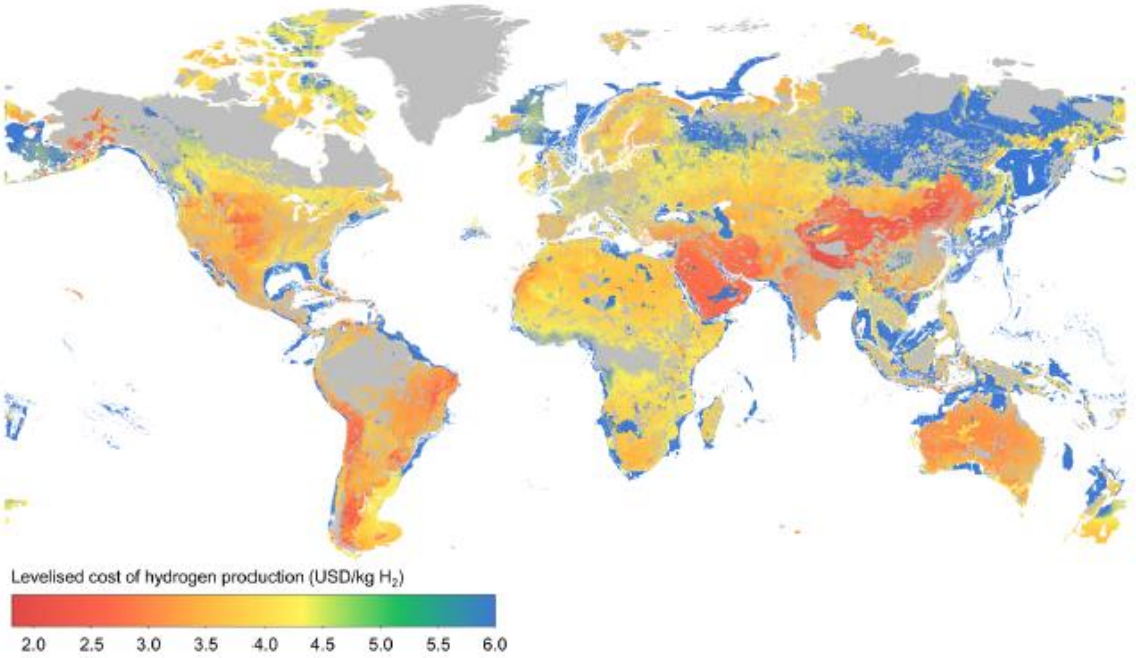
The Bourakébougou natural hydrogen field is already famous in the geoscientific world, and now also in the press. It has been supplying the community with electricity for 12 years now. Gas chromatographic analysis has shown that the gas consists mainly of natural H_2 (98%) associated with nitrogen and 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 Maiga et al.

ADVANTAGES NATURAL HYDROGEN

The Costs

Figure 3.13 Hydrogen production cost from hybrid solar PV and onshore wind, and from offshore wind in the Net Zero Emissions by 2050 Scenario, 2030



According to manufacturers, the production costs for geological hydrogen are between USD 0.5 and USD 1.2. In its Global Hydrogen Review 2024, the IEA provides a detailed report on the current cost and production status of the different hydrogen variants. Here, geological hydrogen is compared with the green variant, as this takes up the lion's share of the public coverage and scientific and financial focus.

Source: Hydroma Mali, Helios Aragon Spain; IEA Global Hydrogen Review 2024, CC BY 4.0, Forschungszentrum Jülich

NATURAL HYDROGEN IN SPAIN

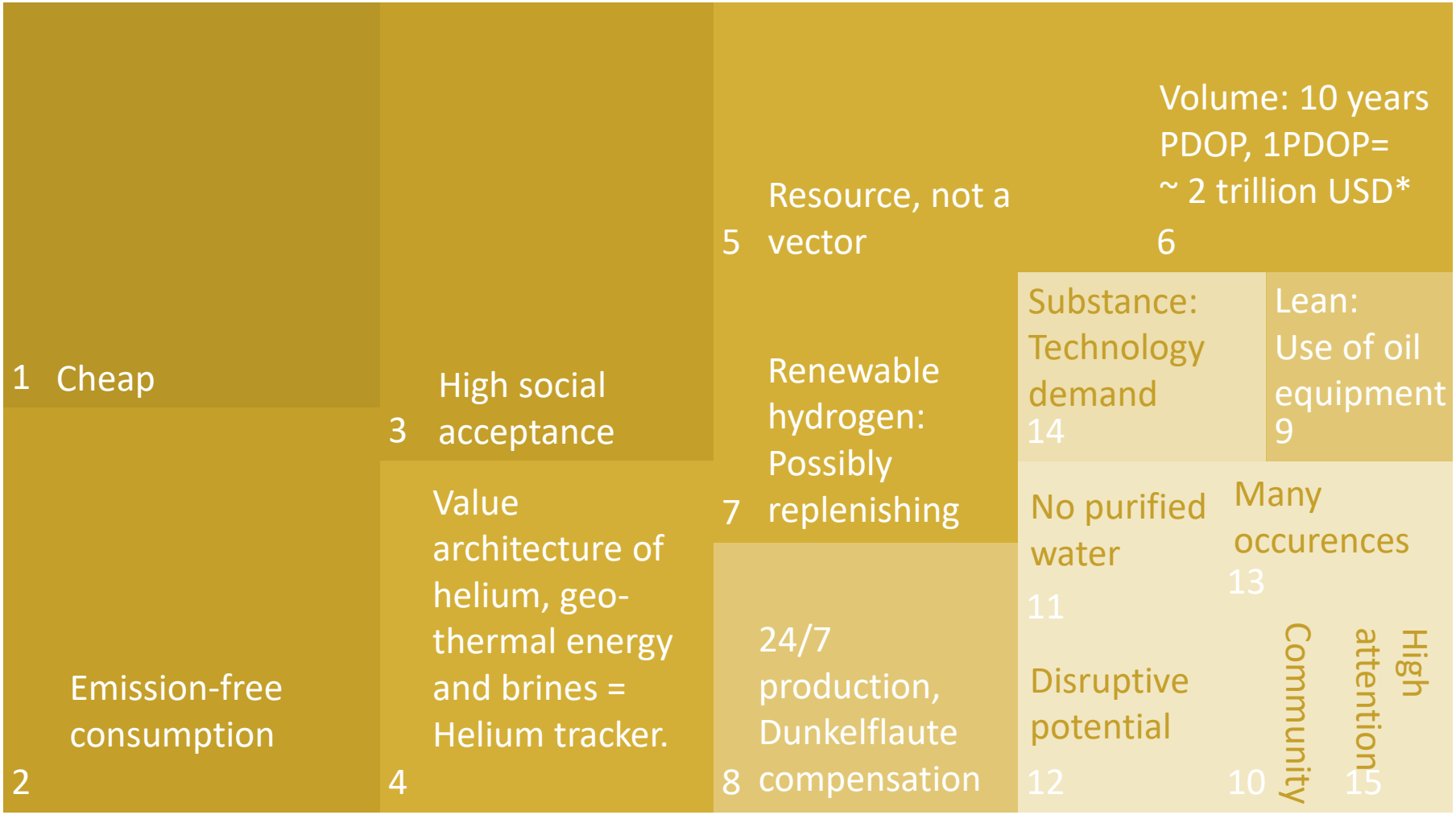
The Monzon Field, Aragon

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.

Source: Photo Wikimedia, Pyrenees in Aragon, Simo Räsänen, CC BY-SA 4.0; Helios Aragon

NATURAL HYDROGEN ADVANTAGES

1. Cheap 2. Clean 3. High social Acceptance



Source: *Oxford Energy Network; Natural hydrogen producers, Eric Gaucher et al

NATURAL HYDROGEN AT ASX

HyTerra at Australian Securities Exchange

HyTerra is a publicly listed company focused on natural hydrogen (ASX:HYT). The company focuses on geophysical exploration.

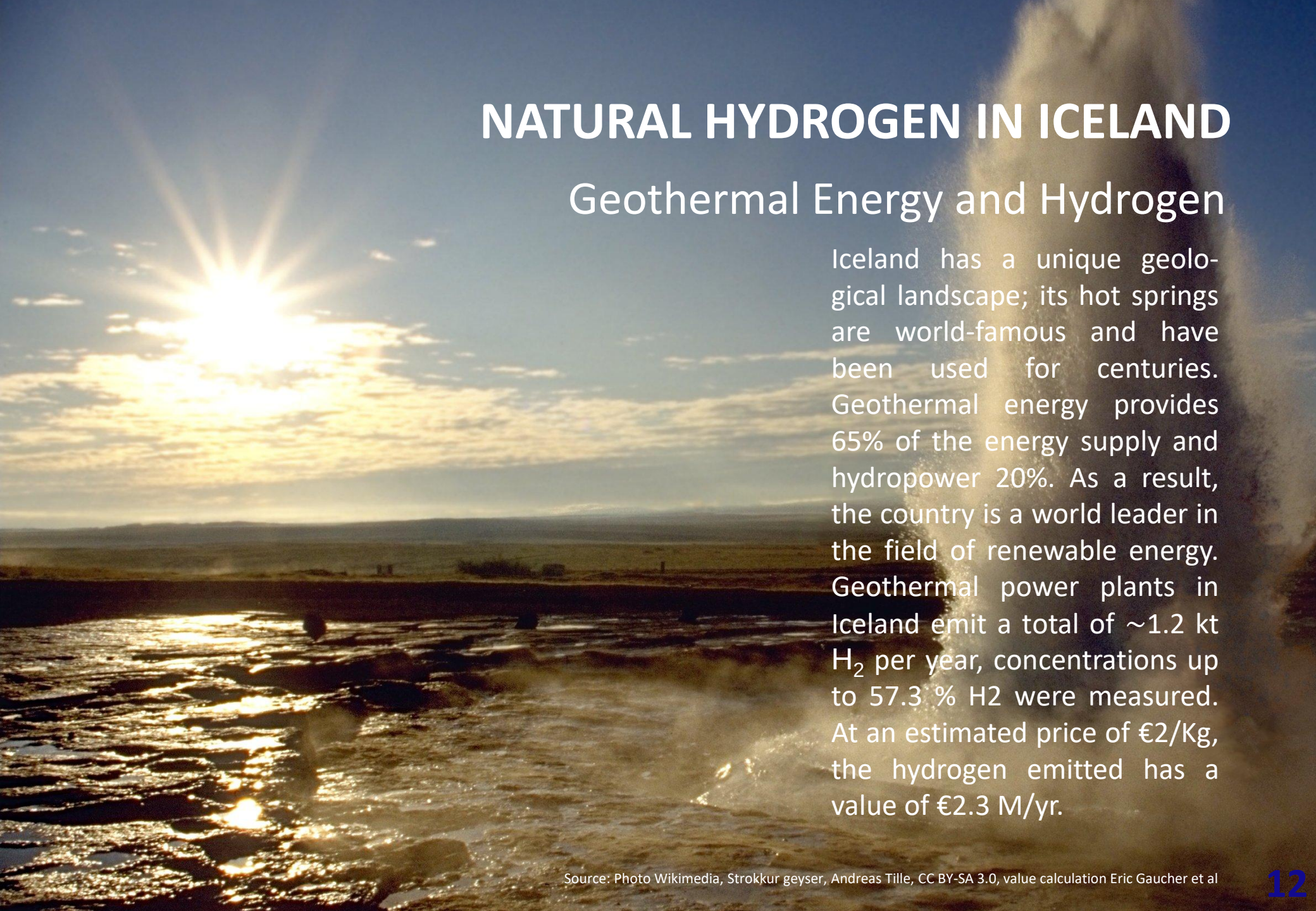
Source: HyTerra

NATURAL HYDROGEN ADVANTAGES

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

The combination of low cost and low to zero emissions is the advantage of natural hydrogen. This results in a high level of social acceptance. On the other hand, social resistance is to be expected with all more expensive technologies. The term emission-free refers to the resource itself; depending on the gas mix, it is a clean and above all primary energy source. All the additional processes required to manufacture proper energy vectors produce greenhouse gases. With natural H_2, 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. The more productive the project, the more the embodied carbon decreases according to a Stanford study. Land use, water consumption and additional resources are also not critical compared to blue or green hydrogen. Oil and gas producers can efficiently explore and extract natural hydrogen based on existing geological expertise and equipment. 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.

Source: IEA Hydrogen TCP Task 49, Oxford Energy Network; Department of Energy Science & Engineering, Stanford University



NATURAL HYDROGEN IN ICELAND

Geothermal Energy and Hydrogen

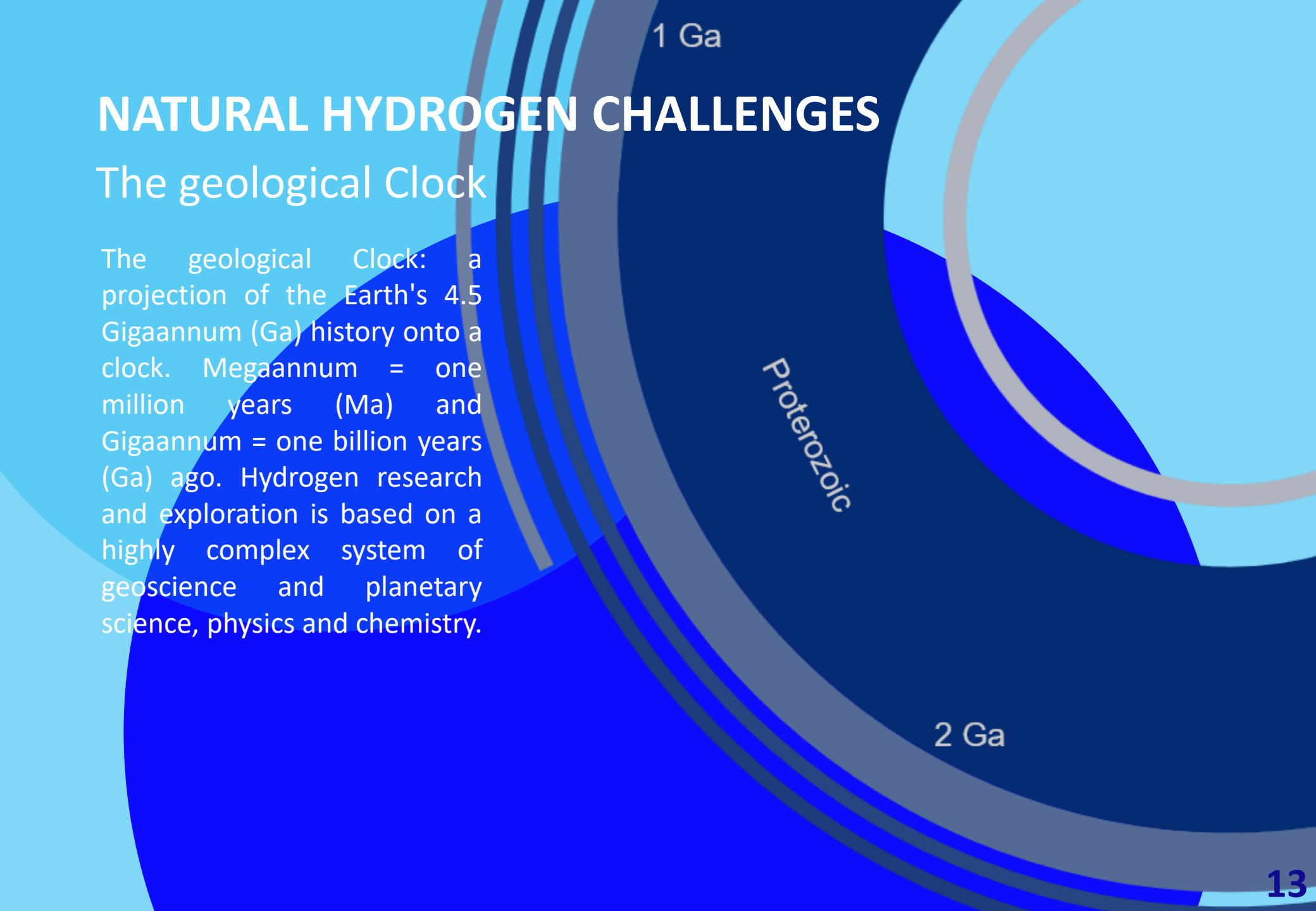
Iceland has a unique geological landscape; its hot springs are world-famous and have been used for centuries. Geothermal energy provides 65% of the energy supply and hydropower 20%. As a result, the country is a world leader in the field of renewable energy. Geothermal power plants in Iceland emit a total of ~1.2 kt H_2 per year, concentrations up to 57.3 % H2 were measured. At an estimated price of €2/Kg, the hydrogen emitted has a value of €2.3 M/yr.

Source: Photo Wikimedia, Strokkur geyser, Andreas Tille, CC BY-SA 3.0, value calculation Eric Gaucher et al

NATURAL HYDROGEN CHALLENGES

The geological Clock

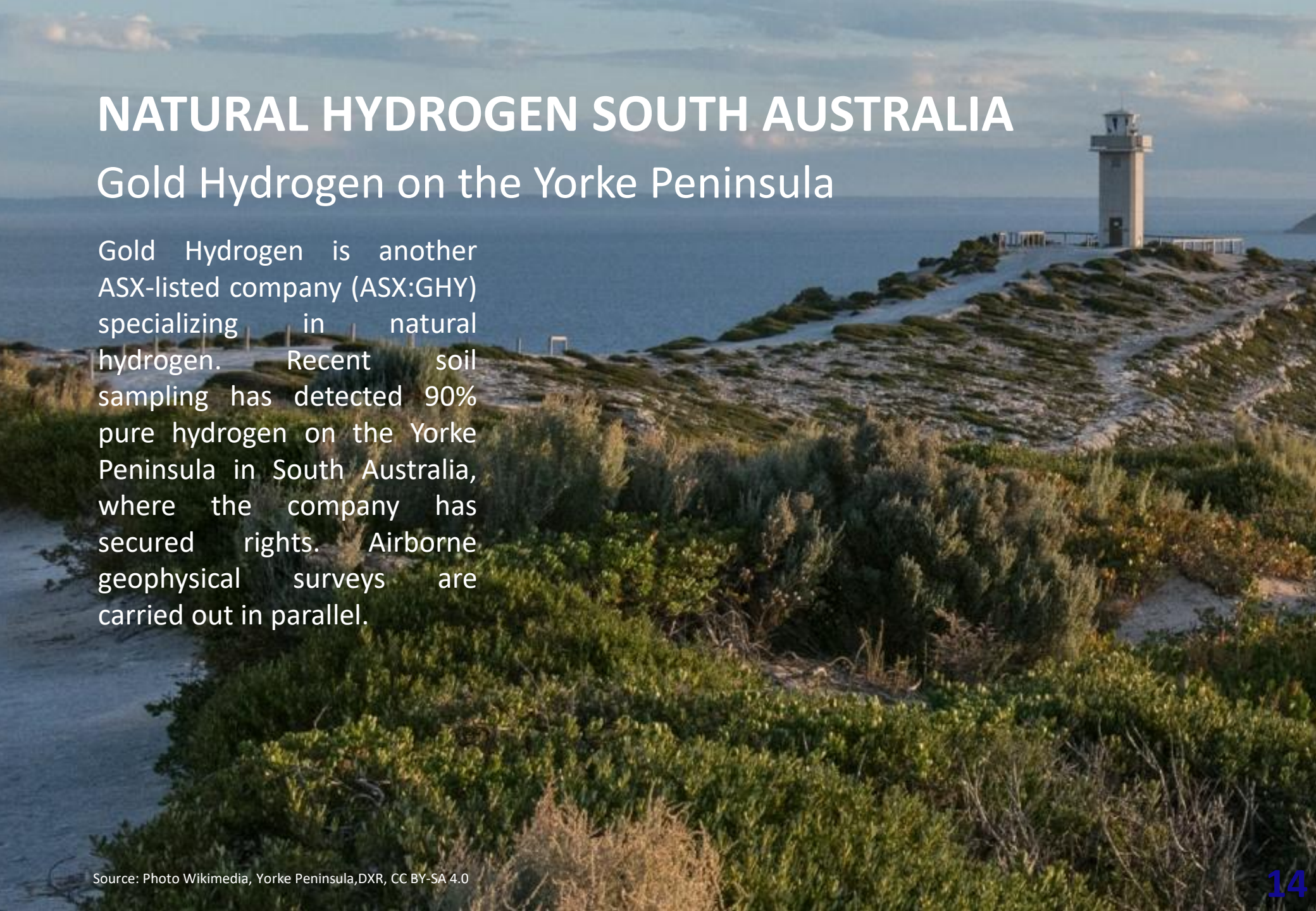
The geological Clock: a projection of the Earth's 4.5 Gigaannum (Ga) history onto a clock. Megaannum = one million years (Ma) and Gigaannum = one billion years (Ga) ago. Hydrogen research and exploration is based on a highly complex system of geoscience and planetary science, physics and chemistry.



NATURAL HYDROGEN SOUTH AUSTRALIA

Gold Hydrogen on the Yorke Peninsula

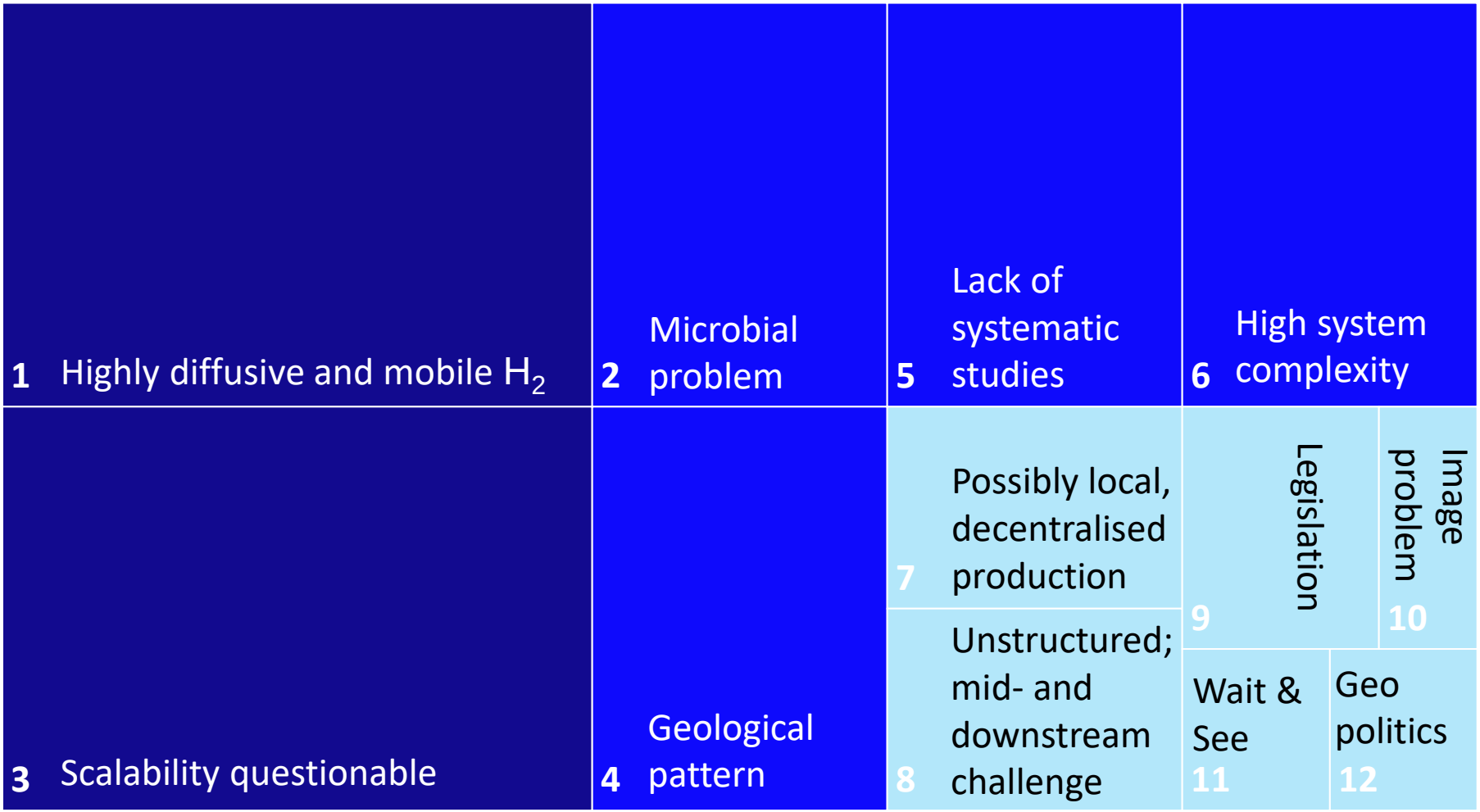
Gold Hydrogen is another ASX-listed company (ASX:GHY) specializing in natural hydrogen. Recent soil sampling has detected 90% pure hydrogen on the Yorke Peninsula in South Australia, where the company has secured rights. Airborne geophysical surveys are carried out in parallel.



Source: Photo Wikimedia, Yorke Peninsula,DXR, CC BY-SA 4.0

NATURAL HYDROGEN CHALLENGES

1. Highly diffusive 2. Microbes 3. Scalability questionable



Source: Oxford Energy Network

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.

Source: L'Université de Lorraine; Bloomberg

NATURAL HYDROGEN CHALLENGES

Wrap-up: Looking at the big Picture

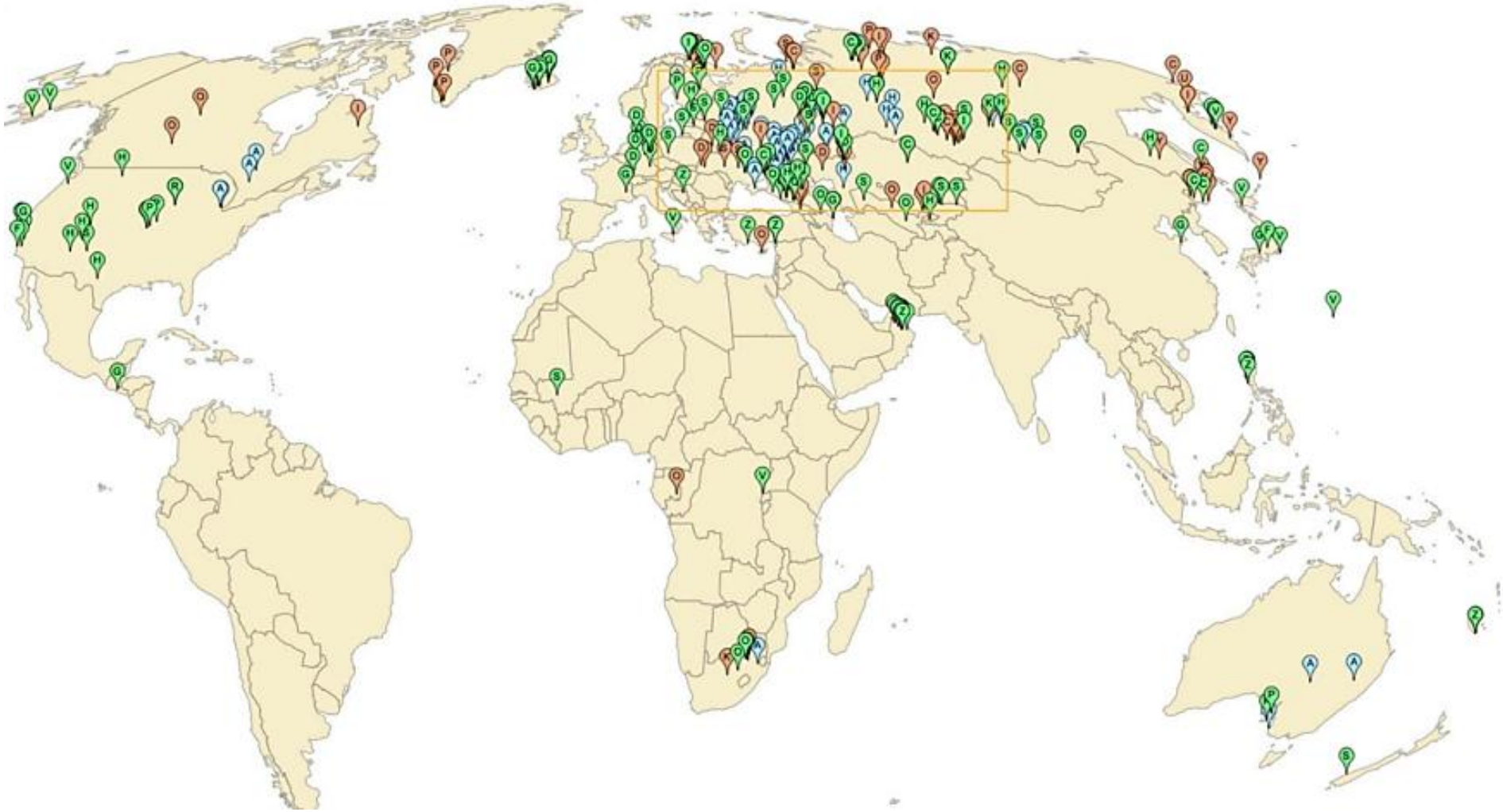
Hydrogen is highly reactive, mobile and difficult to capture. It is also lost in the flow from deep to shallow. A study of a Brazilian reservoir estimated the loss at 50% after seven years of drilling, assuming microbiological methanogenesis. Natural hydrogen is converted into methane. Geoscientists 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 H_2 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 CONCLUSIO

$NatH_2$ is a market challenger. Helium included.

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 inter-national interest in this energy source is high, to mention Bill Gates again in conclusion.

NATURAL HYDROGEN AROUND THE WORLD



Source: Viacheslav Zgonnik

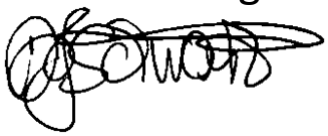
RECOMMENDED ACTIONS

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, 2025

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	Turquoise Hydrogen	Grey Hydrogen*
Natural (also white, gold or geological) hydrogen from the Earth's interior is cheap, the use emission-free.	Hydrogen is produced from natural gas by methane pyrolysis. The separated carbon is stored. Use emission-free.	Steam methane reforming, SMR, of natural gas. CO_2 -emissions, climate-damaging. *95% of current production
Orange Hydrogen I + II	**Blue Hydrogen**	**Brown Hydrogen***
Generation of natural hydrogen by stimulation of underground rocks with water (I). Or of H_2 from waste (II).	Previously grey hydrogen, carbon dioxide CO_2 is stored (CCS), use emission-free.	Coal gasification from lignite by heating & steaming. CO_2 -emissions, climate-damaging. *95% of current production
Red/Pink Hydrogen	**Green Hydrogen**	**Black Hydrogen***
Red hydrogen is produced by electrolysis using nuclear energy. Energy-intensive, use emission-free.	Electrolysis of water from renewable energy produces emission-free but still expensive hydrogen.	Coal gasification from hard coal by heating & steaming. CO_2 -emissions, climate-damaging. *95% of current production

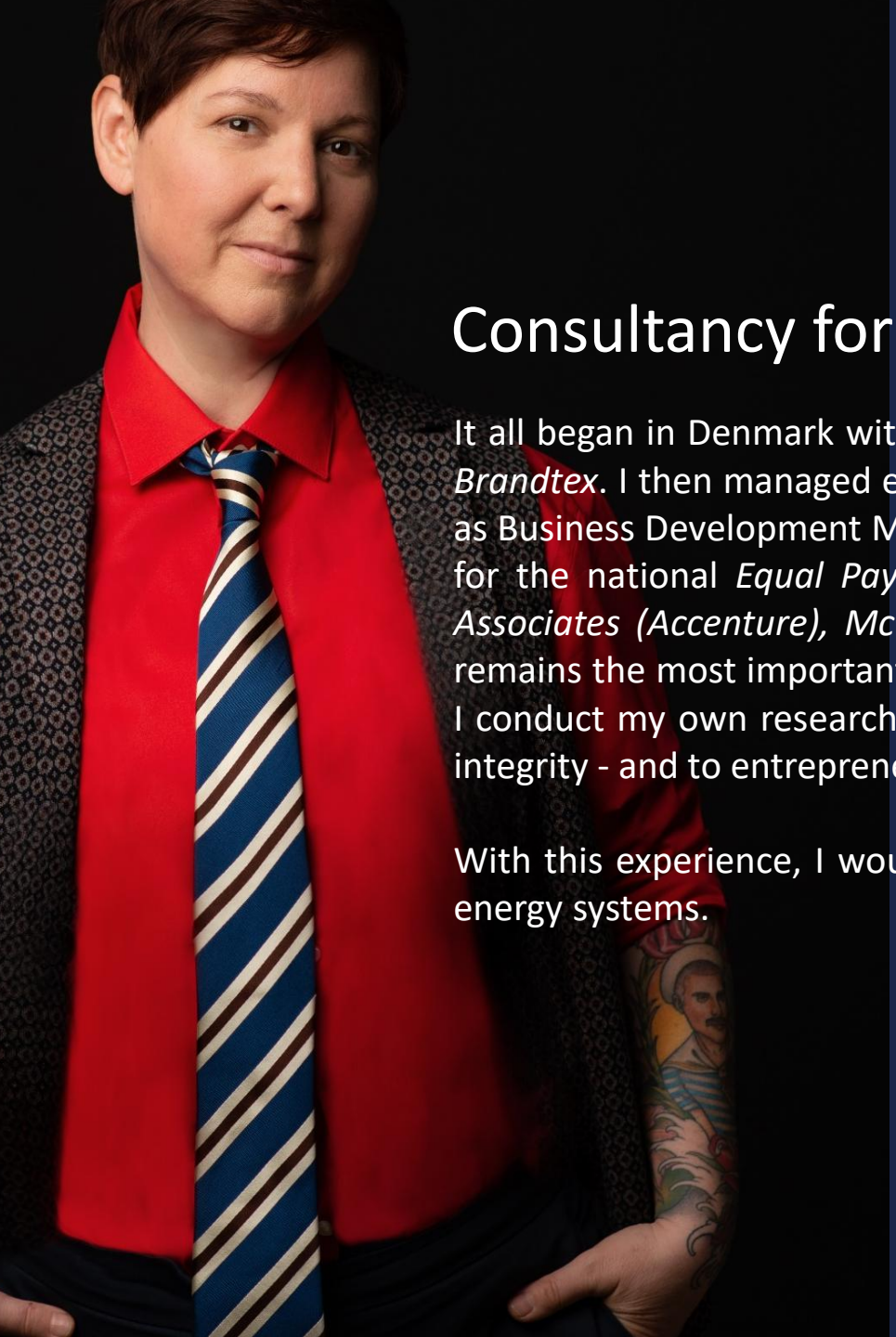
NATURAL HYDROGEN APPENDIX

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 must 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.

Source: Breakthrough Energy, The Green Premium; Department of Energy Science & Engineering, Stanford University



ABOUT *EATING SHARKS*

Consultancy for intelligent local Energy Systems

It all began in Denmark with an engineering internship at the textile manufacturer *Brandtex*. I then managed exciting IT projects and built up the Scandinavian market as Business Development Manager at the start-up legend *myToys*. I was responsible for the national *Equal Pay Day* and worked with consultants from *Kurt Salmon Associates (Accenture), McKinsey* and *E&Y*. Securing affordable and clean energy remains the most important issue - whether for civil society, companies, or politics. I conduct my own research and am committed to scientific neutrality, quality, and integrity - and to entrepreneurial vision with a sure instinct.

With this experience, I would like to offer you the best advice for intelligent local energy systems.

FüE BSFZ - 2025 -

The BSFZ seal stands for entrepreneurial innovation expertise