# Beneath Our Feet Lies the Future: Why Geologic Hydrogen Deserves the Spotlight

By Caroline Kaitano and Thokozani Majozi

### The Evolution of Hydrogen

Hydrogen has long been touted as the fuel of the future. It is energy-dense, emits only water when used, and could help decarbonize stubborn sectors like cement, steel, and aviation. But how we produce hydrogen matters.

For nearly 250 years, hydrogen has captured human imagination, sparking waves of excitement, innovation, and occasional disappointment. First identified in 1776 by British scientist Henry Cavendish, who demonstrated that burning hydrogen produced only water, this simple element seemed almost magical. By 1788, Antoine Lavoisier had named it "hydrogen", meaning "water-former" in Greek, thus setting the stage for centuries of scientific fascination.

The 19th century fueled further dreams. In 1800, William Nicholson and Anthony Carlisle discovered electrolysis, splitting water into hydrogen and oxygen using electricity. By 1838, the fuel cell effect of hydrogen was revealed: it could generate both electricity and clean water. Influenced by the hydrogen craze of the time, the French novelist and playwright, Jules Verne, predicted in his 1874 novel, *The Mysterious Island*, that hydrogen would one day fuel the world.

In the 20th century, the promise moved closer to reality. The German engineer Rudolf Erren adapted combustion engines to run on hydrogen mixtures in the 1920s. Hydrogen-powered airships, most notably the *Hindenburg*, whose tragic explosion in 1937, though later attributed not to hydrogen itself, but to its flammable exterior coating, deeply shook public trust in the safety of hydrogen.

Nevertheless, the potential of hydrogen remained undeniable. During the Space Race, NASA's Apollo missions relied heavily on liquid hydrogen to fuel rockets and power onboard systems. In the 1950s and 1960s, practical fuel cells were developed, notably the "Bacon Cell," which later helped sustain astronauts during lunar missions.

The 1970s oil crisis reignited hydrogen dreams. Amid skyrocketing petroleum prices and supply shocks, scientists and policymakers began seriously envisioning a "hydrogen economy." Electrochemist John O'M. Bockris coined the term, proposing solar-powered hydrogen systems to free the world from fossil fuels. Research and momentum accelerated with the founding of the International Association for Hydrogen Energy (1974) and national initiatives like the Federal Hydrogen R&D Program by the U.S. Department of Energy.

Yet once again, excitement cooled. As oil prices stabilized and fossil fuels remained cheap and convenient, hydrogen struggled to compete economically. Infrastructure was expensive, technology was immature, and governments shifted focus back to conventional energy sources.

Still, advances quietly continued. In the 1980s and 1990s, hydrogen-fueled experimental vehicles, submarines, and even aircraft were developed. Automakers like Daimler-Benz introduced hydrogen-powered cars. Iceland boldly declared plans to build the first hydrogen economy by 2030. Major oil companies like Shell and Royal Dutch/Shell invested in hydrogen divisions.

In the early 2000s, President George W. Bush announced a \$1.2 billion hydrogen initiative, hoping that children born that year might one day drive hydrogen-powered cars. Research funding surged. Fuel cell vehicles and hydrogen buses appeared in pilot programs across the globe.

Yet, once again, hydrogen enthusiasm faltered. Battery-electric vehicles advanced more quickly. Fossil fuels remained cheap. Infrastructure challenges loomed large. Hydrogen was seen as promising but perpetually "ten years away" from mass adoption.

So, with so many instances of shattered hopes, what is behind the hydrogen craze this time? The answer is simple: today, the stakes and the opportunities are far greater than ever before.

Unlike previous hydrogen waves of excitement and promise, which were often driven by technological curiosity or short-term economic shocks, today's hydrogen renaissance is

fueled by the urgent reality of the climate crisis. Compared to earlier surges, the world is now in a far stronger position scientifically, with a deeper understanding of the properties of hydrogen and the technological tools needed to harness them effectively. Its unique strengths, which are clean emissions, high gravimetric density and versatility across sectors, make it indispensable for decarbonizing industries that renewable electricity alone cannot easily reach, such as steelmaking, shipping, aviation, and heavy-duty transport. In particular, green hydrogen, produced through renewable-powered electrolysis, offers a vital means of storing excess renewable energy, balancing power grids, and enabling a complete and sustainable energy transition.

In South Africa, this global momentum has been embraced through the Hydrogen Society Roadmap, launched in 2021. Recognizing its rich endowment of sun, wind, and platinum group metals, South Africa aims to become a global leader in green hydrogen production, driving industrialization, job creation, and energy resilience. The Hydrogen Society Roadmap is a national policy in South Africa aimed at directing the advancement and implementation of hydrogen technologies and infrastructure to establish a hydrogen-based economy. Its objective is to include hydrogen across several industries, foster economic development, and support South Africa's climate objectives. The plan, created by the Department of Science and Innovation alongside several partners, establishes national objectives, prioritizes sectors, and delineates a comprehensive policy framework for the hydrogen economy.

And yet, even as the world races to manufacture hydrogen synthetically, a quieter revolution is underway, one that could fundamentally change the hydrogen landscape.

Beneath our very feet lies geologic hydrogen, a naturally occurring, renewable source of hydrogen formed by geological processes over millions of years. Unlike green hydrogen, geologic hydrogen does not require vast amounts of water or expensive electrolysis infrastructure. It could offer a faster, cheaper, and more decentralized path to clean hydrogen, especially for countries with limited resources but abundant geological formations.

As we look toward a hydrogen-powered future, it is time not only to reach for the technologies of tomorrow, but also to unlock the hidden gifts of the Earth itself.

#### The Many Colours of Hydrogen

Hydrogen is an invisible gas. So, despite its colourful descriptions, there is no visible difference between the different types of hydrogen.

Currently, most of the produced hydrogen falls into the category of grey hydrogen. This refers to hydrogen produced from fossil fuels, typically through steam methane reforming of natural gas. While the production of grey hydrogen is inexpensive and well-established, it releases large amounts of carbon dioxide during production, making it highly polluting. Blue hydrogen also originates from fossil fuels but with one key difference: its production incorporates carbon capture and storage (CCS) to trap and store the CO<sub>2</sub> produced. Nonetheless, it continues to depend on hydrocarbons and poses concerns about methane leaks and the long-term security of carbon storage.

Turquoise is classified based on its production via methane pyrolysis, a thermal process that splits methane into hydrogen and solid carbon. This technique eliminates CO<sub>2</sub> emissions during manufacture and generates valuable solid carbon byproducts. Nonetheless, akin to blue hydrogen, it remains reliant on natural gas as a fuel and necessitates sustainable energy inputs to achieve genuine low-carbon status.

Purple hydrogen, also referred to as pink hydrogen, is generated via the electrolysis of water utilizing nuclear energy as the power source. It offers the zero-carbon advantages of green hydrogen, yet it has distinct challenges, such as elevated expenses, nuclear waste disposal, and societal opposition to nuclear facilities. Green hydrogen, frequently seen as the benchmark, is produced by electrolyzing water utilizing electricity derived from sustainable sources such as solar or wind energy. It is environmentally sustainable and adheres to netzero objectives. However, it is expensive, reliant on extensive infrastructure, and demands significant water resources, between 9 and 18 litres of freshwater per kilogram of hydrogen produced, creating difficulties in areas with limited water availability [1].

This is where geologic hydrogen, also known as gold hydrogen, changes the game.

# A Fuel Formed by Nature

Unlike its synthetic cousins, geologic hydrogen is a natural byproduct of geochemical reactions within the Earth's crust. Water interacting with certain rocks, natural radioactive decay, and even deep-earth degassing through faults and fractures can all release hydrogen over long time periods. These underground processes do not just create hydrogen; they may replenish it, making it a potentially renewable and sustainable source.

And while it may sound theoretical, the proof is already here. In Mali, a natural hydrogen seep has powered an entire village for years. In France, geologists recently discovered a reservoir that could fuel the country for decades. Across Africa, Australia, the United States, Russia, and Brazil, early signs point to vast untapped potential.

# The Infrastructure Advantage

One of the most promising traits of geologic hydrogen is that it does not require a technological leap. The tools developed by the oil and gas industry, i.e. seismic imaging, well drilling and reservoir modelling, are ready-made for hydrogen exploration. Former oil wells, once thought empty or unviable, could even be repurposed. This is an open invitation for fossil-fuel-reliant economies to pivot without starting from scratch. The caveat, however, is that hydrogen is unique in many ways from other gases. Foremost among its idiosyncracies is that it is the smallest molecule, which makes it very difficult to handle. This has always presented significant storage and transportation challenges.

And the possibilities do not stop at hydrogen. Some reservoirs also contain helium, a rare gas essential to medicine and electronics. Others may enable on-site hydrogen-powered desalination, fuel cell power generation, or ammonia production, effectively turning geological formations into decentralized clean energy hubs.

# The Numbers Make Sense

Geologic hydrogen is not just compelling. It is competitive. While green hydrogen is currently estimated at a cost of USD 3-6/kg (R55-R112/kg) [2], early estimates suggest geologic hydrogen could be produced for as little as USD 0.5-1.0/ kg (R9 to R20/kg) [3]. At these price points, hydrogen becomes a serious contender not just for rich nations but also for the Global South, where affordability has long been a barrier to clean energy.

In addition to its low water footprint, you have a fuel that is particularly suited for arid, infrastructure-poor regions, including many parts of Africa.

# Africa's Time to Lead

Africa has a unique opportunity to lead the geologic hydrogen revolution. The continent is rich in the kinds of rock formations that produce hydrogen. Countries like Namibia and South Africa are already drawing early exploration interest. But the opportunity goes far beyond geology.

A young, rapidly growing population and rising energy demand make Africa the ideal testing ground for new hydrogen technologies. Geologic hydrogen could electrify rural areas, power local industries, and reduce dependence on costly fuel imports. It could even allow African nations to shift from exporting raw materials to exporting value-added clean fuels.

But we must act now. That means investing in research, developing policy frameworks, training scientists and engineers, and creating public-private partnerships to de-risk early projects. Most of all, it means including local communities in the conversation and ensuring that the benefits of this new energy boom are shared widely and fairly.

### The Role of Academia and Policy

Research institutions and universities have a central role to play. Hydrogen geochemistry, process systems engineering, and reservoir mapping need to become core parts of academic programs, especially in countries with geologic potential. Regional collaboration is key. African universities, policymakers, and private companies must work together to shape a hydrogen strategy that aligns with both climate action and economic justice.

Governments, too, must step up funding surveys, build regulatory systems, and encourage responsible development. The mistakes of past resource booms, in which wealth left the continent and communities were left behind, must not be repeated.

### A Second Chance at a First Impression

Geologic hydrogen may not be flashy. It does not shimmer like solar panels or spin like wind turbines. But it could be the dark horse of the energy transition, i.e. humble, powerful, and already here. It could also prove to be the black swan we desperately need to change the energy game for good.

We have a rare opportunity to get it right from the beginning: to create an energy system that is not only clean but also inclusive, affordable, and grounded in nature. This is not just another chapter in the hydrogen story, it is a chance to write a new kind of energy future.

But we must move quickly. Because what lies beneath us may very well shape what is ahead.

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