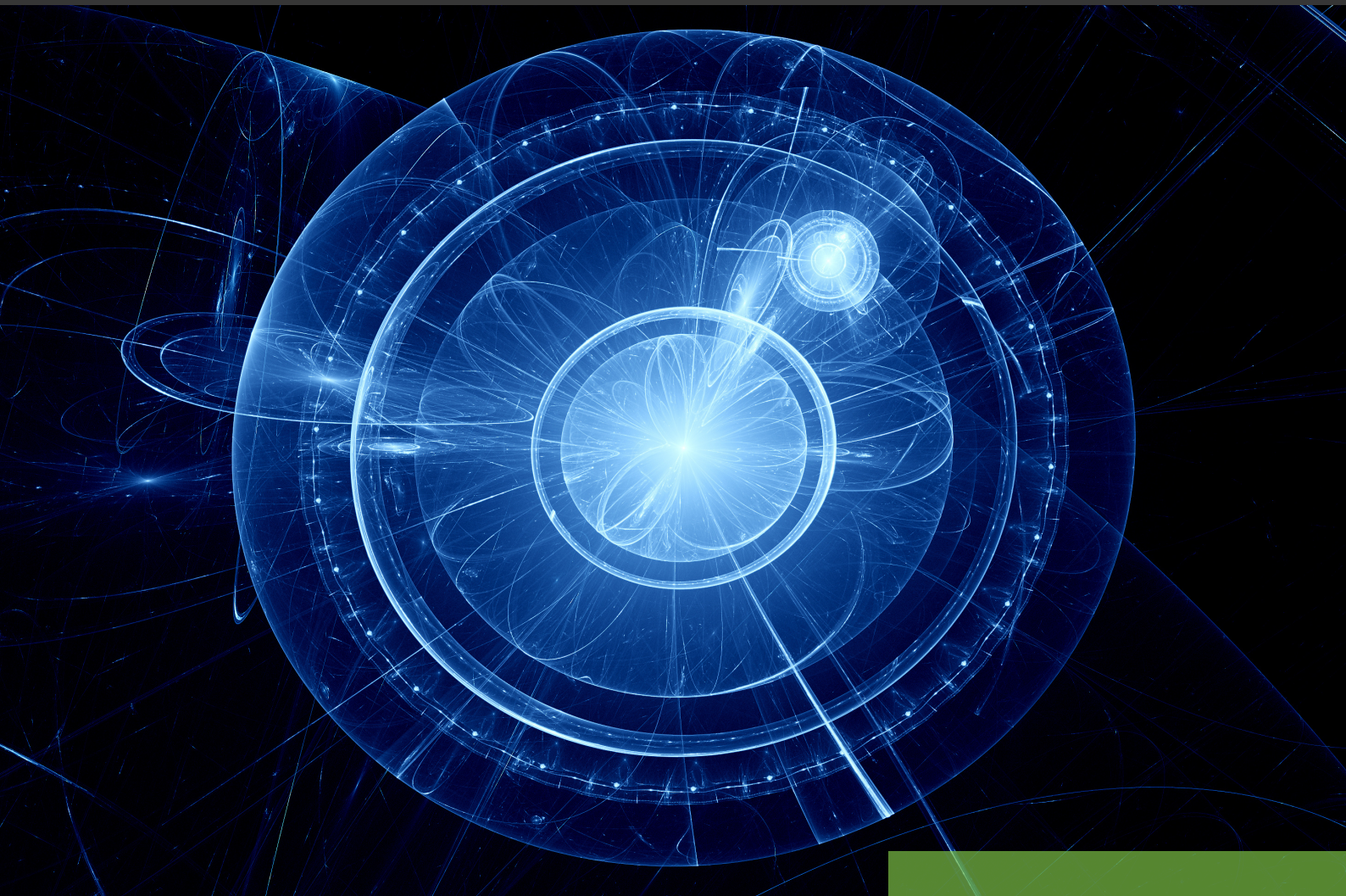

50 SHADES OF HYDROGEN

FROM GREY INDUSTRIAL BUILDING BLOCK
TO COLORFUL AGENT FOR CHANGE IN THE
GLOBAL ENERGY TRANSITION



INTRODUCTION

For several decades, hydrogen has played an essential role in the global economy. In agriculture, via ammonia, hydrogen is a fundamental building block for the manufacture of nitrogen-based fertilizers, which are the source of around 40% of the protein feeding the global population.^[1]

In the petrochemical industry, hydrogen is used to remove sulfur in oil refining and ‘upgrading’ heavy grades of crude oil to more valuable lighter grades.

In the bulk chemicals and polymer industries, hydrogen is used to produce methanol, which is then used to produce acetic acid (vinegar), vinyl acetate (for cinematic film and wood glue), formaldehyde, melamine, and fabric anti-crease treatments.

In the semiconductor industry,^[2] hydrogen is used as a cover and heat transfer gas during the annealing of silicon, as a carrier gas for thin film deposition, and to remove oxygen as semiconductor layers are formed (epitaxy).

At present, about 55% of the hydrogen produced worldwide is used for ammonia synthesis, 25% in refineries, and about 10% for methanol production. The other applications worldwide account for only about 10% of global hydrogen production.^[3] Almost all of this hydrogen is currently produced by steam methane reforming of natural gas.^[4]

This status quo looks set to change as hydrogen, and its derivatives ammonia and synthetic fuels, are called upon to play their part in the low-carbon global energy transition.

[1] <https://ourworldindata.org/fertilizers>.

[2] https://www.linde-gas.com/en/images/Expanding%20Use%20of%20Hydrogen%20in%20the%20Electronics%20Industry%20Gasworld%20November%202016_tcm17-418683.pdf.

[3] <https://hydrogeneurope.eu/hydrogen-industry>.

[4] <https://www.mdpi.com/2073-4344/10/8/858/pdf>



SHADES OF HYDROGEN

Similarly to how you may select a normal or a 'green' electricity tariff depending on how it is generated, a color-coding to convey the environmental sustainability of the generation of hydrogen is also taking shape, but it is a little more complex.



- **GRAY HYDROGEN**

is generated from fossil fuel-derived energy, and CO₂ is emitted to the atmosphere. Typically, natural gas is converted using steam into hydrogen and CO₂ ('steam reforming' and 'water-gas shift'). Approximately 9kg of CO₂ is emitted to produce one kg of hydrogen from methane.^[5]

- **BLACK AND BROWN HYDROGEN**

are both forms of gray hydrogen but specifically denote that they originate from coal or lignite, respectively. The old 'town gas' supplies were essentially black or brown hydrogen supplies. Approximately 20kg of CO₂ is emitted to produce 1kg of hydrogen from coal.^[6]

- **BLUE HYDROGEN**

is generated from fossil fuels, but the CO₂ is separated and is either used as an industrial feedstock or is sent for long-term geological storage, so it is not emitted into the atmosphere.

- **TURQUOISE HYDROGEN**

is generated by the pyrolysis of natural gas. The fuel's carbon content does not oxidize in the process, so it becomes available as solid carbon as an additional product of the process.^[7]

- **PINK HYDROGEN**

is generated through electrolysis powered by nuclear energy.

- **PURPLE HYDROGEN**

usually refers^[8] to the many other ways of generating hydrogen using nuclear energy.^[9] However, this may be about to change since a purple - colored bacterium has been found to be able to generate hydrogen and protein from wastewater using infrared light.^[10]

- **WHITE HYDROGEN**

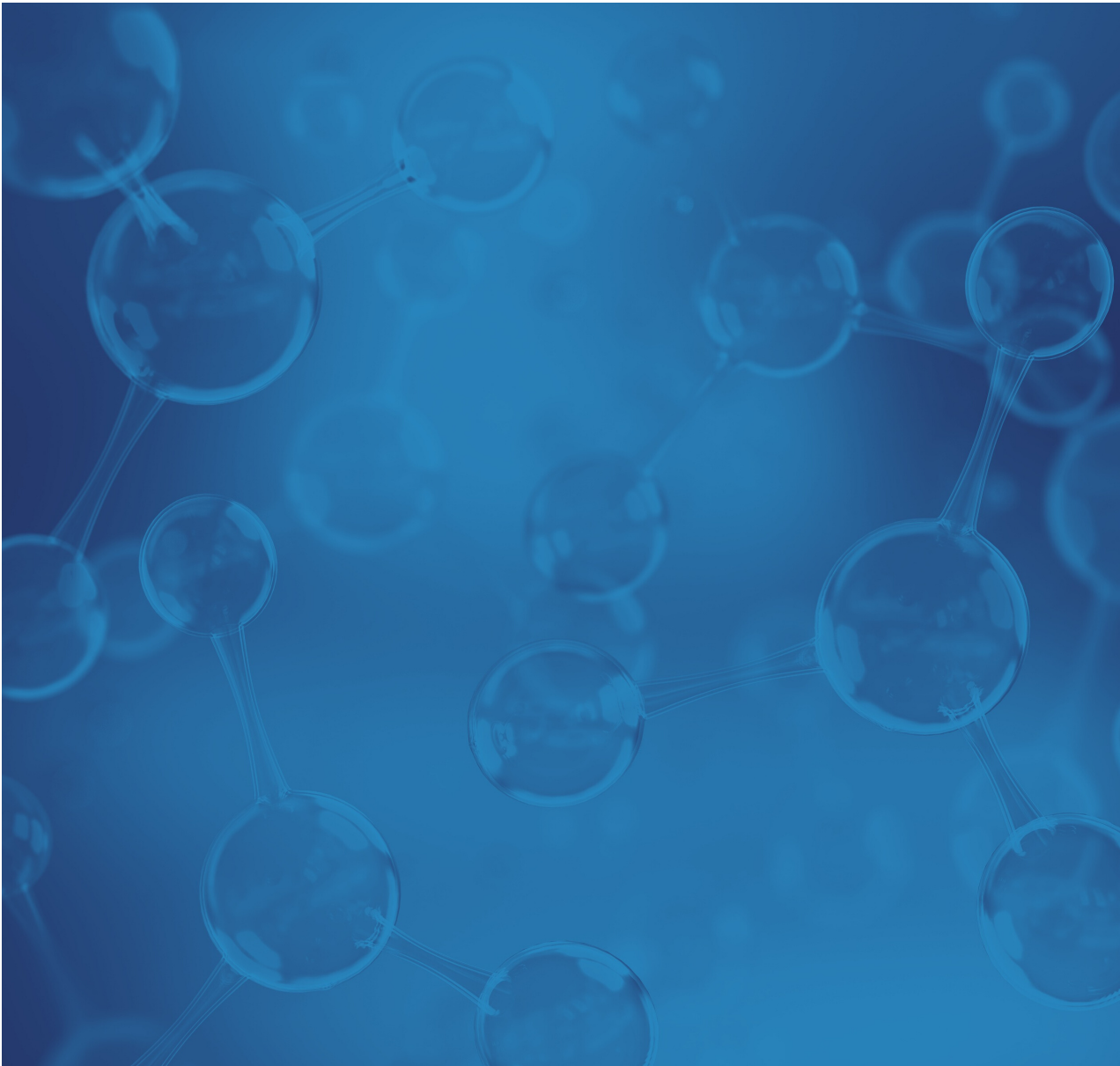
is naturally occurring geological hydrogen.^[11] Exploratory drilling is currently underway in the USA.^[12]

- **GREEN HYDROGEN**

is generated using exclusively renewably sourced energy, so no CO₂ is produced in the generation process. Typically, this is done by the electrolysis of water using renewable derived electricity.

CHOOSE YOUR COLOR AND JOIN THE ENERGY REVOLUTION!

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- [11] <https://www.enapter.com/hydrogen-clearing-up-the-colours>
- [12] <http://www.nh2e.com/>



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