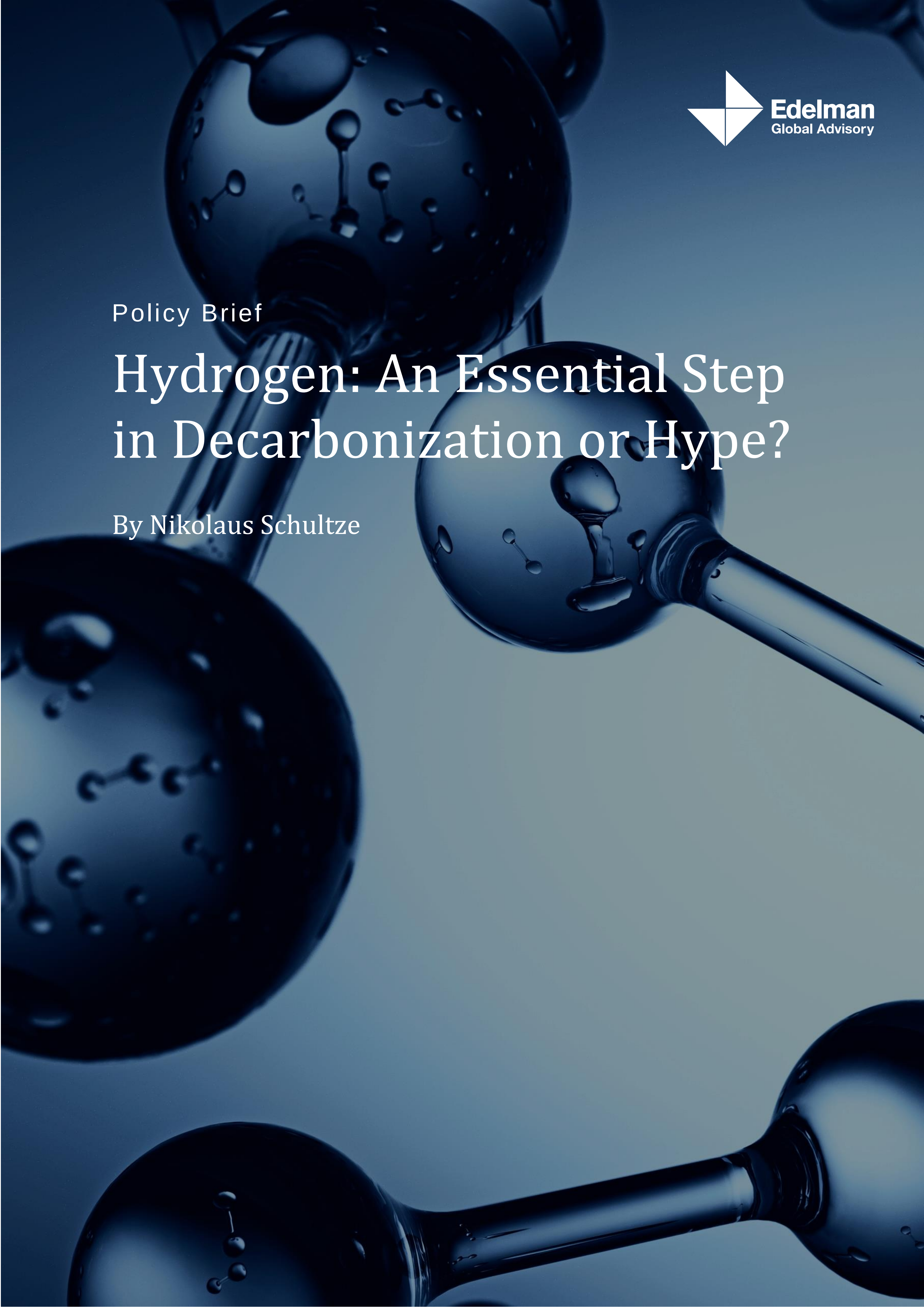

Edelman
Global Advisory

Policy Brief

Hydrogen: An Essential Step in Decarbonization or Hype?

By Nikolaus Schultze

Hydrogen is being widely discussed as a key solution towards reaching the goals of the Paris Agreement — through its use in the decarbonization of industrial processes and transportation, as well as its potential in renewable energy storage. But these discussions need to be put into perspective as not all hydrogen is equal and it does not make economic sense to deploy hydrogen in all possible applications.

According to the International Energy Agency (IEA), global hydrogen production in 2020 amounted to 90 million tons — of which less than 0.1% could be considered "green." In contrast, current production levels of hydrogen generate the equivalent of 900 million tons CO2e emissions per year. Nonetheless, the IEA expects the demand for hydrogen to grow sixfold by 2050, nearly all of it from low carbon sources. According to the Hydrogen Council, a hydrogen industry association, USD 300 billion is expected to be deployed through public and private sources over the next decade.

Clearly, the environmental and economic implications of hydrogen are significant. This policy brief provides an overview of hydrogen: its production methods, different classifications, key uses, economic viability, and recent policy support.

Hydrogen Production Methods and Their Feedstocks

Different methods have been developed to produce hydrogen at scale. The feedstocks used in the process are associated with different carbon footprints.

a. Steam methane reforming (SMR)

SMR is the most common process, accounting for around 75% of global hydrogen production. This process is very energy (and carbon) intensive, as it uses natural gas as feedstock — reacting with steam under high temperature and pressure — releasing 9-10kg CO_2e per kg of hydrogen produced.

b. Coal gasification

Accounts for 23% of global hydrogen supply. It is the most carbon intensive method, releasing around 19kg of CO_2e per kg of hydrogen produced.

c. Electrolysis

Accounts for 2% of global supply. Splitting water into hydrogen and oxygen through electrolysis is highly energy intensive. Its carbon footprint depends on the energy source used in the process, ranging from 14kg of CO_2e per kg of hydrogen using the average European energy mix to zero when using only renewable energy sources.

Classification of Hydrogen Types

As a result of processes, feedstock used, and carbon footprint, a hydrogen classification system has emerged. This classification is important as it leads to different types of support schemes being deployed.

Despite the hype, hydrogen is still only contributing towards decarbonization of energy, transport, and chemicals production systems in a rather limited number of instances. The vast majority of hydrogen is still produced from fossil fuels, generating substantial annual emissions of CO_2e — the equivalent of the combined emissions of Indonesia and the UK.

a. "Grey" hydrogen

Hydrogen produced from fossil fuels — natural gas (SMR) or coal (gasification) — without capturing released emissions.

b. "Blue" hydrogen

Hydrogen produced from natural gas (SMR) associated with carbon capture and storage (CCS) — could sequester 95% of generated emissions. The economic viability of "blue" hydrogen is therefore directly linked to both the price for natural gas, which has shown strong variations over the past year, and to the level of capital investments required to operationalize CCS.

c. "Green" hydrogen

Producing hydrogen using renewable energy sources has a zero carbon footprint since the energy used in the electrolysis process would itself be zero carbon. The efficiency of this process, however, is questionable as there is an estimated 30% energy loss in the electrolysis process and further inefficiencies along the process. High costs (and intermittency) of renewable energy may further constrain this route, and some argue that the energy deployed in electrolysis would be better deployed in electrification instead.

d. "Red" (sometimes pink) hydrogen

Nuclear power could provide the steady supply of decarbonized electrons needed for hydrogen produced under the SMR process. Some countries, including France, are making the case for hydrogen produced through (excess) supply of low carbon nuclear energy.

Current and Future Uses of Low Carbon Hydrogen

From an economic and climate perspective it would only make sense to deploy more "green" hydrogen in those sectors where there is no alternative to electrification — and where renewable energy could be accessed at competitive rates.

a. Areas where hydrogen is already being used

Focusing on those areas where hydrogen is already used and where infrastructure for its use exists improves the economic viability of "green" hydrogen. This is the case of *refineries*, which today account for more than half of pure hydrogen demand and where switching from "grey" to "green" hydrogen would be possible. *Chemical companies* — which already generate hydrogen — as a by-product of some manufacturing processes — would be well placed to switch from "grey" to "green" as the basic infrastructure to use hydrogen would already be available.

b. Industrial applications in hard-to-abate sectors which require extreme heat

Steel

To make steel, iron is extracted from its ore in blast furnaces at temperatures of up to 1,200C using coke — a carbon rich form of coal. This leads to high emissions of CO_2e in the process — reflected in steel accounting for up to 9% of all direct emissions generated from the use of fossil fuels. By using large electrolysis plants — green hydrogen can be pumped into a reactor, powering a *direct reduction process* to produce a solid intermediate product — *direct reduced iron* (DRI) that can be directly used in a furnace to produce "green" steel.

Cement

Cement accounts for 8% of all global emissions. The thermal combustion process of limestone to produce cement generates about 60% of the sector's GHG emissions — and no replacement technology is available. Low carbon types of cement could possibly be developed using CCS associated with the use of "green" or "pink/red" hydrogen in the process.

c. Shipping…and ammonia

The International Maritime Organization (IMO) seeks to reduce the carbon intensity of international shipping by at least 40% by 2030. Due to low volumetric energy density — it is difficult to use hydrogen as an energy carrier in transportation. This can be overcome by adding nitrogen to produce pure ammonia[1], which could power fuel cells to be used in long haul shipping combustion engines.

d. Power storage

Hydrogen could be used to store excess energy — produced from renewable energy. Under certain conditions it could supply base-load power — thereby overcoming the inherent intermittency of renewable energy sources. The *power-to-gas-to-power* process is, however, still constrained by large efficiency losses — up to 60% of efficiency losses.

Ammonia could also be directly used for storage purposes as well as a dual fuel in fossil fuel plants. Efficiency is much higher under the ammonia form since there is no need to crack ammonia back to hydrogen again.

e. Conventional use of ammonia

Ammonia is widely used as a synthetic fertilizer as well as for refrigeration. Use of conventionally produced ammonia could be switched to "green" or "pink/red" ammonia produced from low emissions energy sources.

Economics of Low Carbon Hydrogen

The cost of energy represents 50% of total cost under electrolysis — twice as much as under SMR. The economic viability of green hydrogen is therefore highly dependent on the cost of producing renewable energy electrons.

a. Capacity constraints to generate low carbon hydrogen

Use of "green" hydrogen at scale is constrained by infrastructure and the volumes of renewable energy required to produce it. Just replacing the "grey hydrogen" in refining and chemicals production *[see 4.a above]* with "green hydrogen" would require 143% of all wind and solar energy installed globally to date[2]. If ammonia for shipping was pursued — this would require 300% of China's current renewables output. If all the globally used hydrogen was to be "green" — then it would require the entire renewable energy generation of the EU. The "green hydrogen" supply chain is further limited by lack of capacity to produce the large electrolysers necessary to split water into hydrogen and oxygen.

b. Cost drivers in "green hydrogen" production

1. Capital expenditure — e.g., the cost of the electrolyser
2. Electrolyser conversion efficiency
3. Renewable energy costs
4. Asset utilisation rates
5. Regulatory environment

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[1] under the current Haber-Bosch process
[2] Source: Michael Liebreich Associates

Public Support for the Green Hydrogen Supply Chain

Even under rising CO_2 prices the transition from “grey” hydrogen to “green” hydrogen would be too lengthy. With rising natural gas prices, using “blue” hydrogen as a transition technology was made less attractive under rising natural gas prices. Without public interventions “green” hydrogen will remain too expensive to compete with other technologies.

More than 30 countries published hydrogen support plans involving support packages of more than USD70bn to reduce production costs.

a. United States

Through the *Inflation Reduction Act* (IRA) hydrogen production (including “blue” hydrogen) is being massively supported. This includes tax shields of up to 3 USD per produced Kg of hydrogen, which would approximately reduce the cost of producing hydrogen by half. Making it the most attractive destination for future investment in this sector.

b. European Union

Under the revised *fit-for-55* climate package — the European Commission is targeting the production of 20m tonnes of low carbon hydrogen (10m domestically produced and 10m through imports from countries with access to cheap renewable sources). Contrary to the US, the EU does not consider “blue” hydrogen under its support instruments. On “green” hydrogen, the Commission approved *Hy2Tech* as an *“Important Project of Common European Interest (IPCEI)”* to support industrial size deployment of the “green” hydrogen technology supply chain. It will include up to EUR5.4bn in direct subsidies. The European Commission further announced the establishment of a *Hydrogen Bank* with the aim of overcoming market failures in manufacturing electrolysers, scaling up hydrogen production capabilities, fostering new demand for renewable and low-carbon hydrogen and developing dedicated hydrogen infrastructure.

c. China

Accounts for 1/3 of worldwide hydrogen production — but is 2/3 reliant on coal-based energy. The deployment of “green” hydrogen is supported via concessional credits, tax credits, green credit lines as well as incentives via the national emissions trading system. China aims at producing one million hydrogen fueled vehicles and 1,000 refueling stations by 2030.

Conclusions

Hydrogen could be used in hard-to-abate sectors if it significantly leads to lower emissions — taking into account the energy deployed to produce hydrogen in the first place. Hydrogen based power plants could function as back-up to intermittent renewable energy production, providing *residual load*. Deploying the necessary infrastructure (production, transport and storage) will, however, require public funding in the foreseeable future.