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THINK

POLICY BRIEF

PROMOTING CARBON-NEUTRAL HYDROGEN THROUGH UNFCCC AND NATIONAL-LEVEL POLICIES

Task Force 2

CLIMATE CHANGE AND ENVIRONMENT

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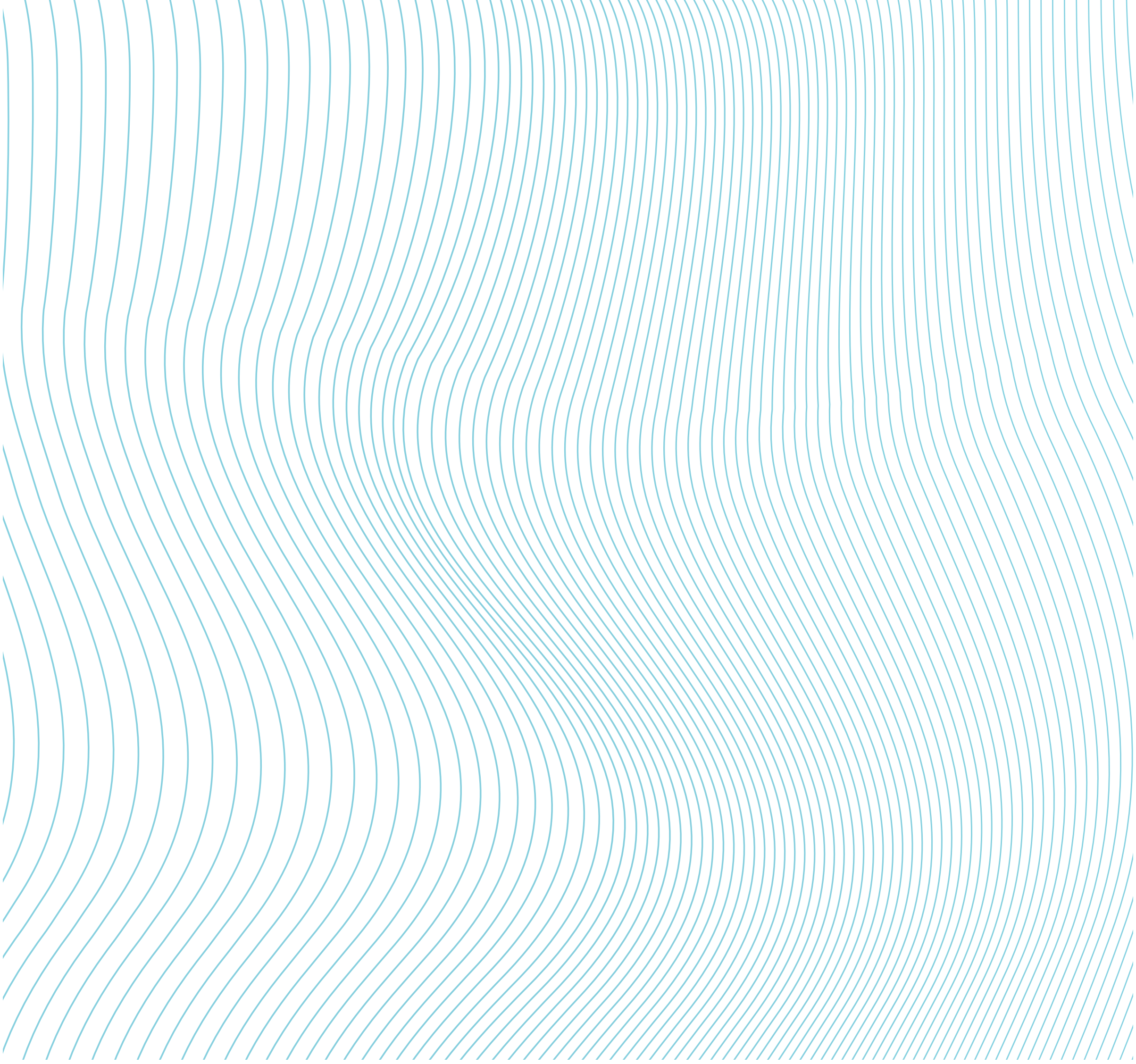

موجز السياسة

تعزيز الهيدروجين محايد الكربون من خلال اتفاقية الأمم المتحدة الإطارية بشأن التغير المناخي (UNFCCC) والسياسات على المستوى الوطني

فريق العمل الثاني

تغير المناخ والبيئة

المؤلفون

أكسل مايكلوا، سونيا بوتسينغيفر، رومان ديار، عدنان شهاب الدين، ريتشارد فوريست، كلود مانديل، أنطوان روستاند

ABSTRACT

Hydrogen can play an important role in a widespread transition to societies that emit low levels of greenhouse gases. However, “green” hydrogen—from renewable energy—and “blue” hydrogen—from fossil fuels with carbon capture and storage—still face significant cost gaps compared to “brown” hydrogen. We propose a dedicated institution that allows the Group of Twenty (G20) to coordinate national policy responses to support green and blue hydrogen applications, including support for “lighthouse” activities through, for example, bilateral collaboration under Article 6.2 of the Paris Agreement. This would accelerate the ramp-up of the global hydrogen market. The G20 countries should assess and introduce policy instruments that support quick transformation to green hydrogen economies. Moreover, we propose a G20 program to develop baseline and monitoring methodologies for generating emission credits under the market mechanisms of the Paris Agreement.

يمكن للهيدروجين أن يلعب دورًا مهمًّا في التحول واسع النطاق إلى مجتمعات منخفضة انبعاثات الغازات الدفيئة. غير أن الهيدروجين "الأخضر" من الطاقة المتجددة والهيدروجين "الأزرق" من الوقود الأحفوري، مع حبس الكربون وتخزينه؛ لا يزالان يواجهان فجوات كبيرة في التكلفة مقارنة بالهيدروجين "البني". ونقترح إنشاء مؤسسة متخصصة تسمح لمجموعة العشرين بتنسيق استجابات السياسة الوطنية لدعم استخدامات الهيدروجين الأخضر والأزرق، بما في ذلك دعم أنشطة "الإرشاد"، على سبيل المثال، من خلال التعاون الثنائي. وينبغي لدول مجموعة العشرين تقييم أدوات السياسة التي تدعم التحول السريع لاقتصاد الهيدروجين الأخضر وتبنّيها. علاوة على ذلك، نقترح وضع برنامج لمجموعة العشرين لتطوير منهجيات خط الأساس والمراقبة لتوليد أرصدة للانبعاثات بموجب آليات السوق في اتفاقية باريس.

CHALLENGE

While significant progress has been made in reducing the emissions intensity of the electricity generation sector, the mitigation of greenhouse gas (GHG) emissions by other sectors, particularly transport and heavy industry, is facing significant challenges. Achieving the ambitious targets of the Paris Agreement requires an accelerated transition of these sectors to zero-carbon fuels. Moreover, for fossil fuel exporters to accept a stringent global response to the climate change threat, they need a new business model that is consistent with climate change mitigation (Michaelowa and Butzengeiger 2019). This business model can be built on hydrogen—an intermediate energy carrier that can easily be stored, shipped, and exported, by partially using existing gas infrastructure. Additionally, energy structures in consumer countries must be adjusted to facilitate the transition to green hydrogen economies. The Group of Twenty (G20) can play an important role in facilitating policy action in both hydrogen producing and consuming countries by creating a coordinating entity, implementing hydrogen lighthouse projects, and developing internationally accepted standards.

Hydrogen can be produced through intermittent renewables such as solar and wind, in which significant potential exists for key fossil fuel exporters ("green" hydrogen). Alternatively, it can be produced by using hydrocarbons as feedstock ("brown" hydrogen) and then sequestering the carbon geologically ("blue" hydrogen), involving carbon capture and storage (CCS).

Together, blue and green hydrogen can provide a powerful alternative to existing energy sources. However, the cost of green hydrogen is still three to ten times higher than that of brown hydrogen, while the cost of blue hydrogen is, on average, twice that of brown hydrogen. This cost gap must be eliminated to enable the replacement of GHG-emitting fossil fuels with a zero- or low-carbon energy carrier (on a life-cycle basis) and accelerate the transition of fossil fuel exporters to exporters of renewable energy in the form of green hydrogen.

However, closing the cost gap requires a coordinated, integrated policy response that harnesses instruments under the United Nations Framework Convention on Climate Change (UNFCCC) as well as dedicated national policy instruments that generate demand for green and, potentially, blue hydrogen. Such instruments must be designed to allow for the rapid development of hydrogen infrastructure, along with its ecosystem of applications and end-users. One must consider that several G20 countries such as Germany and other countries of the European Union, clearly aim to limit hydrogen use to green hydrogen (Dezem and Parkin 2020). By contrast, countries such as the UK and the Netherlands aim to actively work with blue hydrogen as an intermediary solution (Gasunie and TenneT 2019).

PROPOSAL

The International Energy Agency's (IEA's) landmark report on hydrogen, "The Future of Hydrogen: Seizing Today's Opportunities" (IEA 2019) provides a comprehensive overview of the current status of hydrogen production, transport, storage, and economic perspectives. Given the vast low-cost hydrocarbon reserves in oil and gas producing countries, blue hydrogen can significantly contribute to global energy systems. Combining current brown hydrogen production capacity with CCS can quickly create a large quantity of blue hydrogen. Thus, it boosts the development of the value chain and new applications, while providing time and space for green hydrogen deployment. The G20 brings together the key countries that could generate demand for green and blue hydrogen through dedicated policy instruments. For example, Japan aims to become a hydrogen-based society, while the European Union (EU) member states are implementing the "European Green Deal."

The G20 countries have the technological capacity to upscale hydrogen technology. Moreover, the G20 can support efforts to agree on policy instruments under the UNFCCC, given its important role in various regional negotiation groups. Fossil fuel producing countries will find opportunities to export a cleaner energy carrier from their vast low-cost hydrocarbon reserves and from renewable sources in the long term. Meanwhile, energy importing countries will drastically reduce their GHG emissions as they accelerate the deployment of green, and other renewable, sources. Thus, the G20 is an appropriate forum to spur the development of an integrated multi-level set of policy initiatives that enables the generation of revenue for activities that produce green and blue hydrogen.

Proposal I

G20 countries should coordinate the rapid ramp-up of a new global hydrogen market

To achieve the desired rapid ramp-up of a global hydrogen market, international cooperation is fundamental, both in terms of political initiatives and standardizing technicalities.

This coordinative role can be assumed by either a new or an existing institution, for example, the IEA or the International Energy Forum (IEF), which can credibly represent the interests of all relevant actors: fossil fuel exporting countries, future hydrogen importing countries, and renewable energy producers. If a new institution is created, an International Hydrogen Economy Initiative (IHEI) can be established to serve as a policy coordination tool between hydrogen importers and exporters. Such an institution could develop its own dedicated niche, like the International Renewable Energy Agency (IRENA) did in the context of renewable energy.

Initially, the institution/IHEI could focus on accelerating interactions between the Gulf region—and other potential suppliers such as Australia (see Bruce et al. 2018), Canada, Russia, and the USA—and Japan and the EU, who are likely to become key hydrogen importers in the next decade based on their self-defined energy policy targets. This could be achieved by supporting the development of long-term blue and green hydrogen delivery contracts that are linked to joint investment in the infrastructure needed to generate and transport the hydrogen. As the EU has announced a significant strengthening of its nationally determined contribution (NDC) under the Paris Agreement and following the EU Commission's "New Green Deal," the role of hydrogen in achieving the EU's mitigation target is becoming more important. The institution/IHEI could become a direct component of Saudi Arabia's G20 presidency year strategy.

The institution/IHEI should coordinate research and development on green and blue hydrogen and initiate new demonstration projects, which will be critical in advancing technologies to reduce production costs. In addition, it should define standards for the different hydrogen types and qualities, for example, maximum emissions for green and blue hydrogen (eventually differentiated into sub-categories such as "A-quality" and "B-quality"), considering the specific upstream emission profiles and long-term permanence. The set of standards should also include monitoring, reporting, and verification (MRV) requirements and safety standards for production, transportation[1], and storage.

The institution/IHEI could also study the design of national-level instruments that incentivize the production of green and blue hydrogen and test policies in its member states. This design should assess the extent to which policies should incentivize both producers and end-consumers to switch to green/blue hydrogen. An initial set of possible policies could be:

1. green hydrogen "feed-in" tariffs (i.e., price premiums for green hydrogen similar to renewable feed-in tariffs),

2. governmental subsidies covering the price differential between classical fuels and green/blue hydrogen, or

3. tax reduction for hydrogen types that stay below certain emission limits (e.g., 2 kg CO_2/kgH_2).

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[1] Including international marine transportation.

In addition, further efforts are required to enable the commercial transport and storage of hydrogen, lowering costs, and ensuring safety in all stages of the process. Hence, forward-looking policies should cover the entire supply chain; this would also help to address competitiveness issues, as lowering the cost of all elements of the supply chain will prevent competitive distortions.

Moreover, the institution/IHEI could develop a blueprint to provide long-term policy support for hydrogen. Any international coordination efforts should ensure that national sovereignty of all G20 member states Is respected, and that all international policies are non-discriminatory.

Proposal II

G20 countries are best positioned to develop "lighthouse" bilateral initiatives under the cooperative approaches of Article 6.2 of the Paris Agreement

Such initiatives could build on the activities undertaken by Japan in the context of the Joint Crediting Mechanism (JCM) for bilateral collaboration on greenhouse gas mitigation. Japan and Saudi Arabia are already collaborating under the JCM and, thus, would be ideal candidates for the first activity, which could be mobilized before 2025 and highlighted at COP 27 of the UNFCCC, to be held in 2022.

Other major economies, like several EU member states, have declared their interest in making use of bilateral agreements under the UNFCCC. Therefore, this might be an excellent opportunity to rethink and renew the economic collaboration between oil-exporting countries and Europe under a new, low-carbon umbrella, for even closer economic partnerships. The same applies to countries in other regions, such as China, India, Brazil, Indonesia, Mexico, and South Africa.

Numerous countries around the world (including Eastern European and North African countries) are already considering the ramp-up of their green hydrogen production. Therefore, we see a window of opportunity over the next 1–2 years for first-movers to initiate new, long-term economic partnerships.

Proposal III

G20 countries should coordinate a hydrogen program to develop baseline and monitoring methodologies for generating emission credits under international market mechanisms

To enable the generation of emission credits, baseline and monitoring methodologies for the use of green and blue hydrogen are required, in the context of the Paris Agreement's Article 6.2 and 6.4 mechanisms. Key G20 countries should develop and use such methodologies in the context of Article 6.2 pilots (Greiner et al. 2019) and then submit them to the Supervisory Body of Article 6.4 under the UNFCCC. Such methodologies are necessary to enable the generation of carbon credits and associated revenues. It should be noted that the bottom-up nature of Article 6.2 allows G20 countries with different circumstances to experiment with innovative approaches that could be more difficult to gain consensus on under Article 6.4, which is subject to international rules. Methodologies should reflect both direct emissions (scope 1, e.g., CO_2 emissions from reforming) and indirect emissions from the power sector (scope 2, e.g., CO_2 emissions from power production related to electrolysis). In addition, uncertainties around the permanence of stored carbon must be reflected, similar to how it was done in the context of CCS/EOR activities under the Clean Development Mechanism (CDM) of the Kyoto Protocol.

Experience from the CDM indicates that the development of internationally approved methodologies takes 2–3 years (including development, international review, revisions, and approval). Therefore, the process should be initiated with sufficient lead time. The development of methodologies provides a public good to any country, including those outside of the G20 and, thus, helps to prevent imbalances regarding competitiveness.

Key Recommendations

1. G20 countries should establish international coordination for a rapid ramp-up of the new global hydrogen market.

2. G20 countries are best positioned to develop “lighthouse” bilateral initiatives under the cooperative approaches of Article 6.2 of the Paris Agreement.

3. G20 countries should coordinate a program for the development of baseline and monitoring methodologies for generating emission credits under international market mechanisms.

REFERENCES

Bruce, Sam, Max Temminghoff, Jenny Hayward, Elizabeth Schmidt, Christopher Munnings, Doug Palfreyman, and Patrick Hartley. 2018. “National Hydrogen Roadmap: Pathways to an Economically Sustainable Hydrogen Industry in Australia.” CSIRO. Last modified August 23, 2018. https://www.csiro.au/~/media/Do-Business/Files/Futures/18-00314_EN_NationalHydrogenRoadmap_WEB_180823.pdf?la=en&hash=36839EEC2DE1BC38DC738F5AAE7B40895F3E15F4

Dezem, Vanessa, and Brian Parkin. 2020. “Germany Sees No Role for Natural Gas in Draft Plan for Hydrogen.” Bloomberg Green. Last modified March 5, 2020. https://www.bloomberg.com/news/articles/2020-03-05/germany-sees-no-role-for-natural-gas-in-draft-plan-for-hydrogen-k7ev6f5t?utm_source=CP+Daily&utm_campaign=bad90770a7-CPdaily06032020&utm_medium=email&utm_term=0_a9d8834f72-bad90770a7-36104189

Gasunie and TenneT. 2019. “Infrastructure Outlook 2050.” TenneT. Last modified February 14, 2019. https://www.tennet.eu/fileadmin/user_upload/Company/News/Dutch/2019/Infrastructure_Outlook_2050_appendices_190214.pdf

Greiner, Sandra, Thiago Chagas, Nicole Krämer, Axel Michaelowa, Da rio Brescia, and Stephan Hoch. 2019. “Moving towards Next Generation Carbon Markets – Observations from Article 6 Pilots.” Climate Focus and Perspectives. Last modified June 2019. https://www.climatefocus.com/publications/moving-towards-next-generation-carbon-markets-%E2%80%93-observations-article-6-pilots

IEA (International Energy Agency). 2019. “The Future of Hydrogen: Seizing Today’s Opportunities – Executive Summary and Recommendations.” Last modified June 2019. https://iea.blob.core.windows.net/assets/8ab96d80-f2a5-4714-8eb5-7d3c157599a4/English-Future-Hydrogen-ES.pdf

IRENA. 2020. “Global Renewables Outlook: Energy Transformation 2050.” IRENA. Last modified April 2020. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Apr/IRENA_Global_Renewables_Outlook_2020.pdf

Kearney Energy Transition Institute. 2020. “Hydrogen Applications and Business models.” Last modified July 2020. https://www.kearney.com/documents/17779499/18269679/Hydrogen+applications+and+business+models_single_page.pdf/c72700b3-e66a-6338-82bb-46ca8031e86d?t=1594994670696

Michaelowa, Axel, and Sonja Butzengeiger. 2019. “Breakthrough of Hydrogen Technologies until 2030: Chances and Risks for Gulf Countries, International Policy Implications.” EDA Insight, Emirates Diplomatic Academy, Abu Dhabi. Last modified September 2019. https://eda.ac.ae/docs/default-source/Publications/eda-insight_hydrogen-economy_en_final.pdf?sfvrsn=2

APPENDIX A

Overview of brown, green, and blue hydrogen technologies

Both green and blue hydrogen avoid “downstream emissions,” that is, GHG emissions at the point of utilization, and enable the improvement of air quality, particularly at the consumption point in populated areas (e.g., transportation). They differ regarding upstream emission profiles. In the case of blue hydrogen, GHG emissions occur from CCS (energy consumption required for the capture and storage of carbon) and the residual risk that the storage may not be permanent (referred to as “seepage”). In the case of green hydrogen, one needs to ensure that electrolyzers are operated only with green electricity. If electrolyzers are driven with grid electricity, which typically includes a mix of fuels, including fossil fuels, the resulting hydrogen is no longer 100% green. Green hydrogen infrastructure can also provide grid stabilization services (peak management and frequency stabilization).

Brown hydrogen

Brown hydrogen results from the transformation of fossil fuels—either natural gas, oil, or coal. It involves several possible processes, in which technologies extract the hydrogen molecules from the hydrocarbon molecules, along with their carbon content in the form of CO_2 gas. The most common processes are Steam Methane Reforming (SMR), coal gasification, and autothermal reforming. The quantity of CO_2 emitted varies with the hydrocarbon used and the transformation process but generally reaches between 10 to 20 kg CO_2/kgH_2.

Blue hydrogen

Blue hydrogen results from the combination of a brown hydrogen source with CCS, for which multiple technologies are available. Within the energy value chain, CCS applied in hydrogen production is considered as “pre-combustion capture,” where carbon is removed from fossil fuel to create hydrogen. Following onsite capture, carbon can be transported through pipelines or ships and later stored in underground geological storage (e.g., depleted oil and gas fields). The carbon can also be used for further processes, such as chemical feedstock (e.g., for methanol or liquid fuels synthesis), enhanced oil recovery (EOR), or agriculture. It should be noted that in the “use” cases, emissions are not completely avoided but reduced by different degrees.

CCS can be deployed at different stages of the end-to-end production and purification process. Several technologies are available, such as amine capture and membrane separation. Although blue hydrogen technologies are mature, they are not yet deployed on an industrial scale. The quantity of CO_2 emitted from blue hydrogen-related operations is estimated to be between 1 to 5 kg CO_2/kgH_2.

Green hydrogen

Green hydrogen mostly relies on electrolysis technologies, involving an electrochemical reaction, whereby electrical energy allows a water molecule to be split to produce hydrogen and dioxygen. Assuming that carbon-free power sources are used in the production process (e.g., renewable sources), there are limited CO_2 emissions associated with green hydrogen production.

Three main electrolysis technologies are available: alkaline electrolysis (AE), proton exchange membrane (PEM), and solid oxide electrolysis cell (SOEC). AE is a proven technology that has already been deployed at a large scale by the chlorine production industry. PM has been deployed in various countries, while SOEC is still at early stage. Green hydrogen generates lifecycle emissions of 1–2 kg CO_2/kgH_2.

APPENDIX B

Comparison between the production costs of brown, green, and blue hydrogen
Both green and blue hydrogen costs are expected to decline and close the gap with brown sources by 2030, as shown in Figure B1. Thereafter, green sources are projected to become more competitive than blue sources by around 2050 (Figure B2).

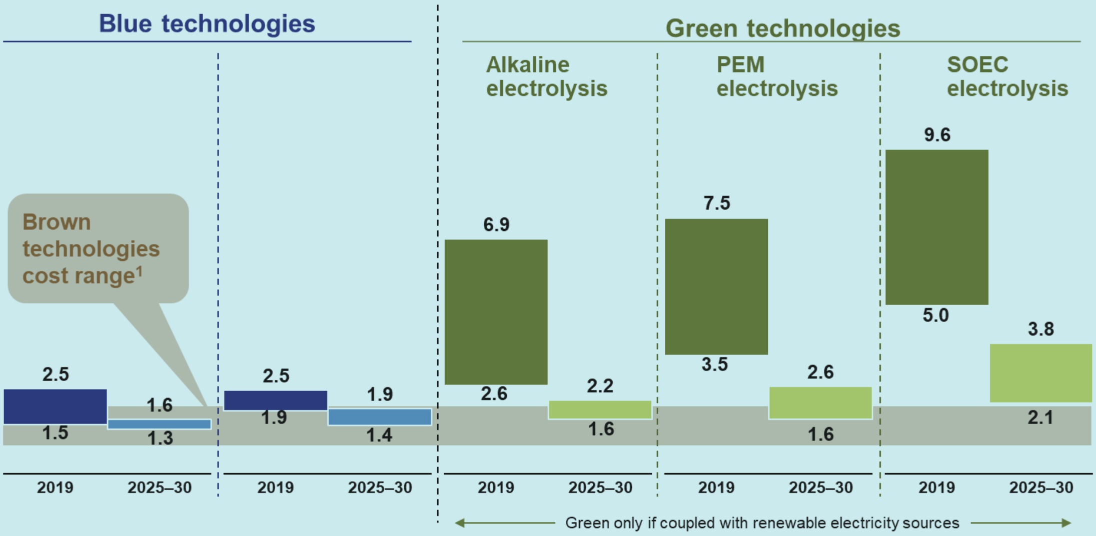


Figure B1: **LCOH evolution (USD/kg, min–max)**

Notes: **Ranges are indicative. LCOH highly depends on fossil fuel prices, electricity prices, and asset utilization.**

Source: **Kearney Energy Transition Institute (2020).**

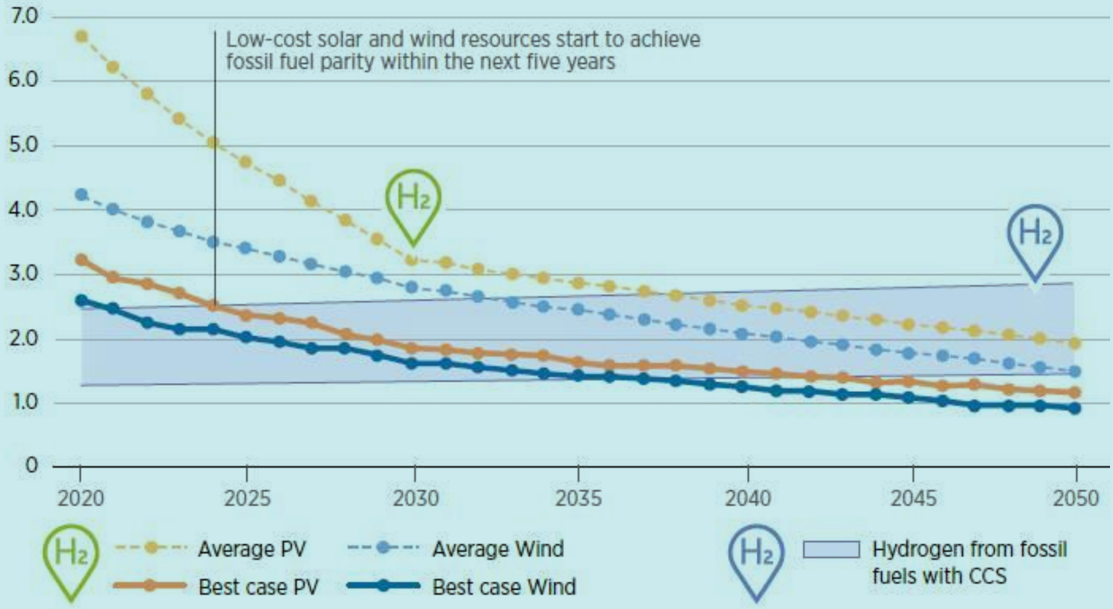


Figure B2: **Levelized cost of hydrogen (USD per kg H_2)**

Notes: Electrolyzer costs: USD 770 per kW (2020), USD 540 per kW (2030), USD 435 per kW (2040), and USD 370 per kW (2050). CO_2 prices: USD 50 per ton (2030), USD 100 per ton (2040), and USD 200 per ton (2050).

Source: **IRENA (2020)**

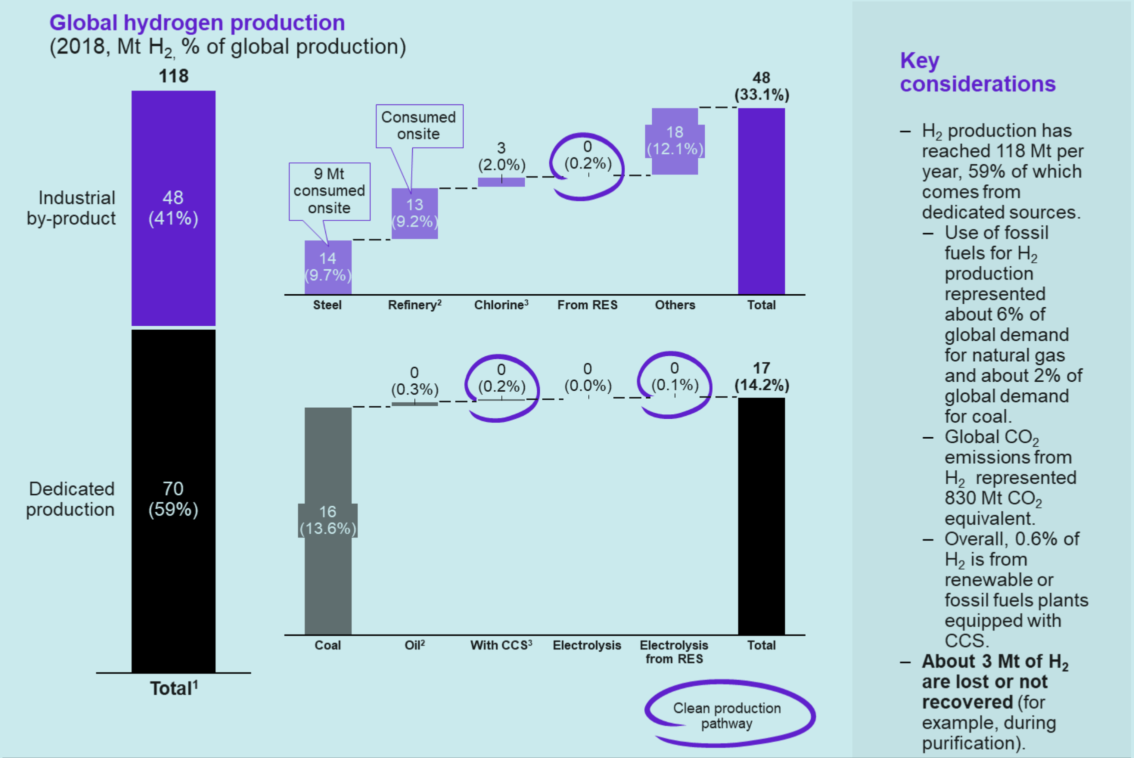
APPENDIX C

	Advantages	**Disadvantages**
Blue hydrogen	• Low unit cost (USD per kg of H_2) • Potentially high production capacity in the short term • Leverage of existing infrastructure (natural gas storage and transport network) • Smooth transition for the fossil fuel industry	• Requirements of carbon capture and storage capacities • Possible public acceptance issues
Green hydrogen	• Storage of excess renewable power output • Possibility of distributed generation of H_2 (e.g., electrolysis plants in remote locations) • Support the development of local economies and ecosystems • No management of CO_2 storage	High unit cost (USD per kg of H_2) • Limited global production capacity in the short term • Access to permanent green electricity sources (i.e., that are decarbonized and allow a load factor of ~90%)

APPENDIX D

Current global hydrogen production

Approximately 118 Mt of hydrogen were produced in 2018, mainly from fossil fuels (see Figure D1).



Key considerations

- H_2 production has reached 118 Mt per year, 59% of which comes from dedicated sources.
  - Use of fossil fuels for H_2 production represented about 6% of global demand for natural gas and about 2% of global demand for coal.
  - Global CO_2 emissions from H_2 represented 830 Mt CO_2 equivalent.
  - Overall, 0.6% of H_2 is from renewable or fossil fuels plants equipped with CCS.
- **About 3 Mt of H_2 are lost or not recovered** (for example, during purification).

Figure D1: **Global hydrogen production (2018, Mt H_2, % of global production)**

Notes:

1 Mtoe = 0.35 Mt H_2

2 35% of refinery H_2 needs come as a by-product.

3 World chlorine production: about 100 Mt per year – ratio of 1/35 tH_2/tCl_2

Source: **IEA (2019); Kearney Energy Transition Institute (2020).**

APPENDIX E

Projection of global hydrogen demand in 2050

Hydrogen demand could reach approximately 540 Mt per year by 2050 (see Figure E1).

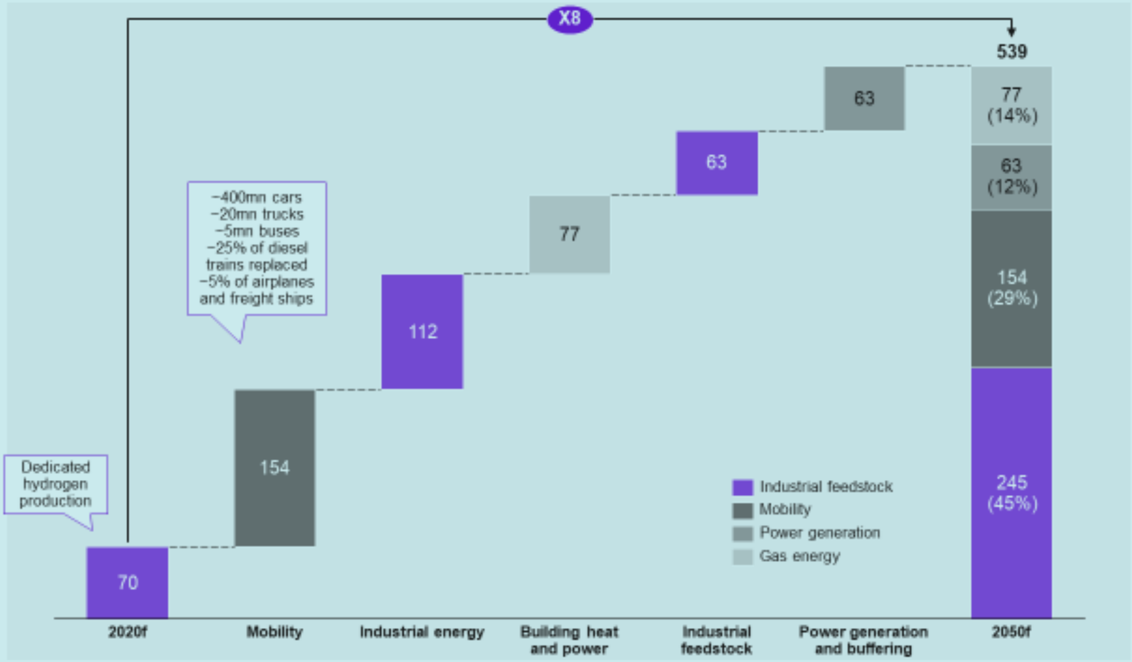


Figure E1: **Possible hydrogen consumption by 2050 (pure hydrogen, MtH_2)**

Source: **Kearney Energy Transition Institute (2020).**

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