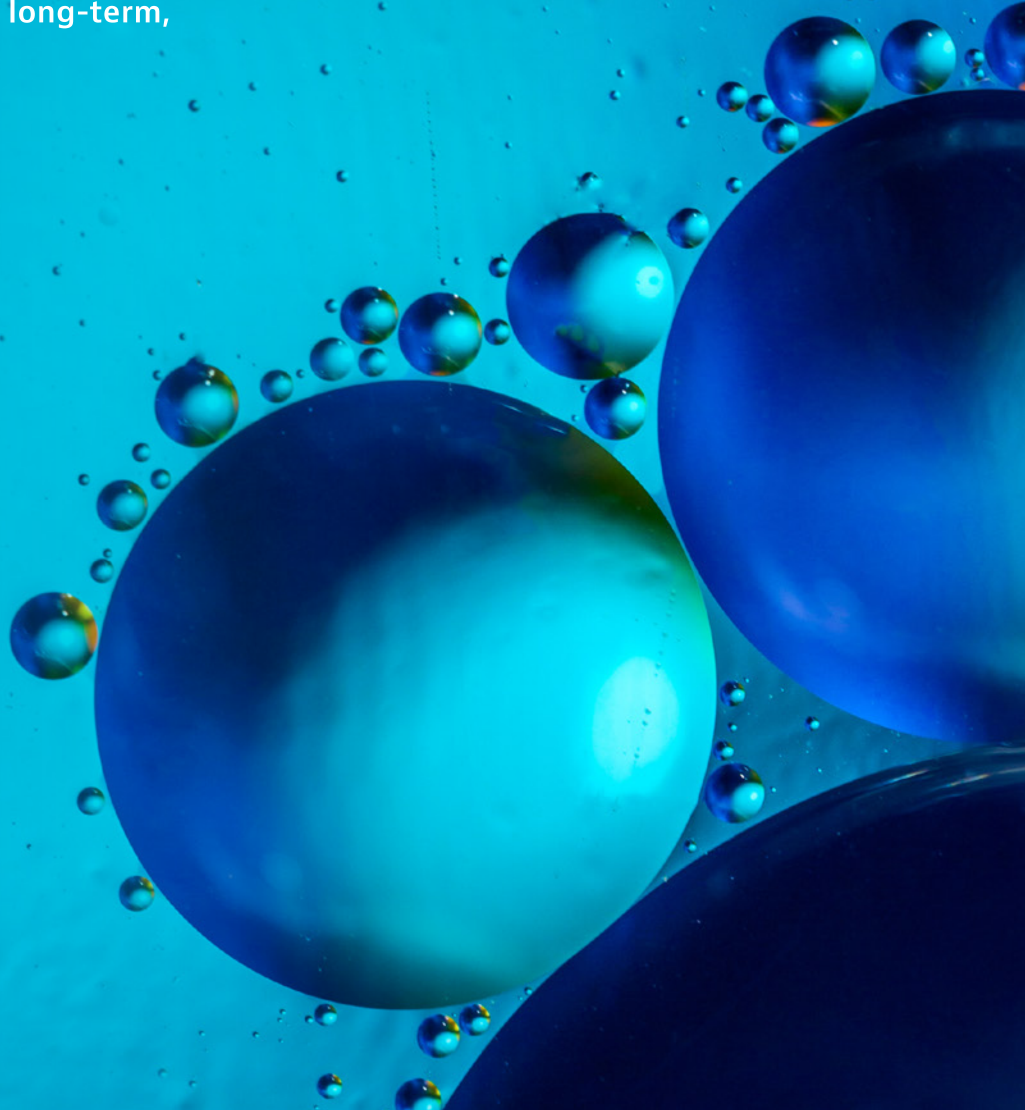
Baker McKenzie.

SHAPING TOMORROW'S GLOBAL HYDROGEN MARKET

VIA DE-RISKED INVESTMENTS

Why being the first mover on the decarbonized energy market can bring huge, long-term, benefits if done right



In order to deal with the climate emergency, the European Union is on the road to decarbonization. Many other countries around the world are also taking action. These countries are rapidly concluding that a successful decarbonization path cannot solely rely on renewable electricity and that a zero-carbon hydrogen solution will be needed. Growing the hydrogen market will also be necessary to lower costs, to increase the power system's flexibility and to decarbonize many industries. Therefore, governments have started supporting the growth of the low-carbon hydrogen market, just as they did for renewables. By wisely making use of government support and policies, smart first-movers will be able to reap the benefits of de-risked investments and shape the future of the global hydrogen market.

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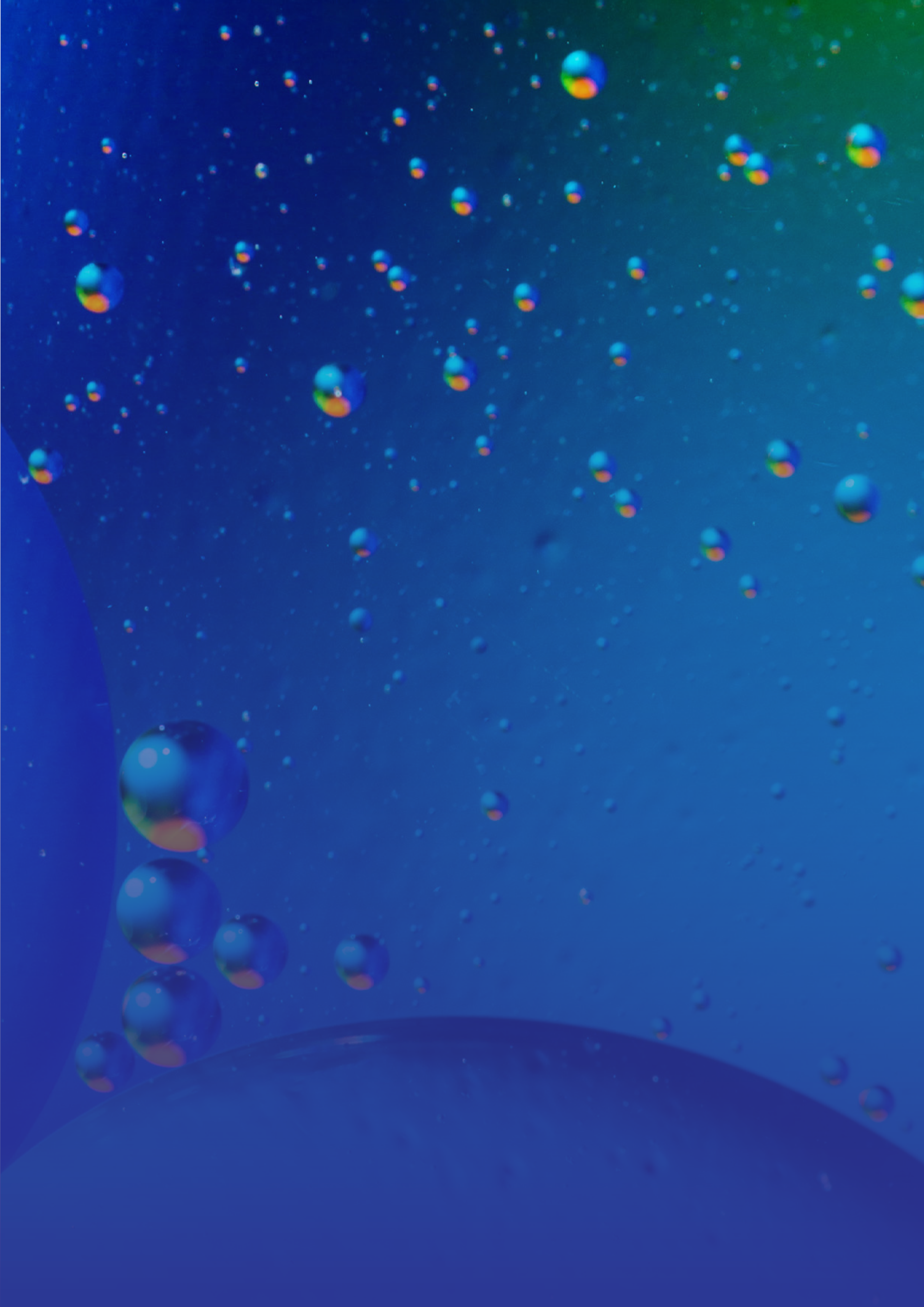

Introduction

The world is starting to fully face the climate emergency. After signing the Paris Agreement in 2016, proclaiming their intention to limit global warming to well below 2°C above pre-industrial levels, the 195 signatory countries now have to act on their commitments. In parallel, more and more businesses are committing to play their role, and citizens and shareholders increasingly demand that companies assume responsibility for their impact on climate change. This attitude is now beginning to feed through into finance and capital markets, as we see governments and the European Union (EU) adopting regulations on 'sustainable' finance. Acting on this commitment represents a major challenge; decarbonizing an entire energy system is far from simple.

According to the Intergovernmental Panel on Climate Change (IPCC), if we wish to keep global warming to well below 2°C above pre-industrial levels, which will already cause major drawbacks for future generations, globally the world will need to cut CO_2 emissions by 25% by 2030 and be net zero by 2070.[1] Whichever way one looks at this, the world will accept either a climate emergency, or it has to decarbonize, and the richer countries will have to bear the heaviest burden for it.

Within just a few decades, all our energy needs, electricity, industry, transport, buildings and agriculture, will have to come from carbon-free sources. This will require huge changes in little more than a single generation, and will need innovative solutions, technologies and policies. For example, in order to meet its climate objectives and follow the recommendations of the IPCC,[2] the EU is committed to transform its electricity, transport, buildings and industrial sectors in order to render them completely, or almost completely, carbon neutral by 2050. This is a 'Third Industrial Revolution', and the hydrogen economy will be an integral part of it, and much sooner than many think today.

Hydrogen will play a crucial role in making this fundamental change to our energy systems. It can – and will – constitute a key part of the solution to climate change. Indeed, renewable and nuclear electricity alone will never be able to provide all our energy needs, and hydrogen will need to play a crucial complementary role.

Despite regulatory challenges, legal complexity and the current lack of incentives to invest in decarbonized hydrogen without government support, there already exist important opportunities for businesses to reap first-mover advantages and to shape the future of the hydrogen economy. Indeed, although decarbonized hydrogen projects are currently expensive and investment risks are high, closing the gap between cost and revenue is possible by making smart use of government support in the form of public funding and public-private partnerships.

A few years ago, many believed that offshore wind would never be a competitive energy source. In a little more than a decade, however, costs have descended to the point that some bids in Europe are at or below current electricity costs. The companies that had the courage and foresight to invest are now reaping the rewards.

It is a very simple equation: if the world acts to prevent the climate emergency becoming a catastrophic reality for the next generations, the global hydrogen economy of the future will be massive. There will be no deep decarbonization without decarbonized molecules. What is not yet clear is which companies will lead this revolution.

1. IPCC report on Global Warming of 1.5°C at https://www.ipcc.ch/sr15/

2. The Intergovernmental Panel on Climate Change (IPCC) is an intergovernmental body of the United Nations that is dedicated to providing the world with an objective, scientific view of climate change.

To Combat Climate Change, Hydrogen is Essential

Hydrogen is an energy vector.

Hydrogen is not an energy source but a *chemical energy carrier,* also known as an *energy vector.*

As a vector, it is used to convert, store, and then release energy. It can be produced, among other ways, using water and electricity or natural gas (see *Box 1*). When used, hydrogen does not produce greenhouse gases, particulates, SO_x or ground-level ozone. If used in a fuel cell, it emits nothing but water.

Hydrogen can also be combined with other chemical elements to produce what are referred to as "hydrogen-based fuels", such as synthetic methane, ammonia, synthetic liquid fuels and methanol. These can be easier to handle than pure hydrogen and can be used as feedstock in industry.

As always, there are efficiency losses when converting from one energy form to another. For example, converting electricity into hydrogen, shipping, storing and converting it back using a fuel cell can entail a 70% loss of the original energy content.[3] This means that hydrogen is usually more expensive than the electricity or the natural gas used to produce it. Nonetheless, hydrogen can obviously be used with high efficiency in many applications and can be produced without CO_2, making it economically interesting when emissions are valued.

Box 1. Hydrogen at a glance

Colors are often used to refer to different types of hydrogen according to how it was produced, in the following way.

Green	Produced from water by electrolysis, using renewable electricity (e.g., solar, wind). Nuclear electricity can also be used in this manner to produce hydrogen, and this is referred to as 'yellow hydrogen'.	Mostly pilot projects.
Blue	Produced by steam methane reforming **with** carbon capture, utilization and storage (CCUS), using natural gas or biomass (thus with very low or no CO_2 emissions).	Numerous demonstration size plants exist and are in development. The technology is proven but needs to be scaled to industrial size.
Gray	Produced by steam methane reforming **without** CCUS, using natural gas. Gray hydrogen produces a lot of CO_2.	Most of the current production.

This report discusses the economic opportunities in developing low-carbon hydrogen production and application. We therefore focus mostly on blue and green hydrogen production. Of course, from the point of view of applications, hydrogen of all "colors" are the same and can be used in identical ways.

3. International Energy Agency. (2019, June). ***The Future of Hydrogen***. p. 33. Retrieved from https://webstore.iea.org/the-future-of-hydrogen

A decarbonization path based solely on electricity is too expensive and impracticable.

There is a growing consensus among academia, industry and political leaders that a decarbonization path based (quasi-)exclusively on electricity networks (an 'electricity only' model) is unrealistic and would be too expensive. Deep decarbonization will require hydrogen to satisfy current industrial demand; 'no molecules, no deep decarbonization'.

Substantial amounts of hydrogen are already used today in industrial and chemical processes. Although this is mostly still gray hydrogen today, it will progressively become green or blue. Moreover, for many applications, such as energy-intensive industry or heavy-duty and maritime transport, relying on electricity is simply not technically viable, and is unlikely to become so. Besides, it would be difficult, if not impossible, to build enough overhead electricity lines to meet electricity demand under an 'electricity only' model, whereas hydrogen can simply rely on the existing gas network with some modifications.

From a financial point of view, a 'hybrid' electricity-hydrogen model will be far cheaper than an 'electricity only' model, to the extent that adopting the former would save the EU hundreds of billions of euros per year according to recent studies.[4] Furthermore, for many applications that can technically use electricity, hydrogen is still expected to be the cheaper alternative.

Lastly, hydrogen will be vital to complement and balance intermittent renewable energy sources, providing a flexible electricity balancing service,[5] especially when pumped hydro-storage is not possible. In the EU, for instance, ambitious renewable energy targets have been agreed, with the objective that, by 2030, 32% of the entire EU's energy demand and more than 50% of its electricity demand will come from renewable sources. Such an increasing level of intermittent generation on the electricity grid requires greater level of balancing services and hydrogen will have to play an important role here. Hydrogen can also be expected to play an important role in long-term and seasonal electricity storage, required by high shares of intermittent renewables.

The mathematics are therefore simple. Either the world fails to deal with the climate emergency or it progressively decarbonizes and the low and zero-carbon hydrogen market becomes a huge engine of growth.

4. Figures vary, but sources are in favor of a hybrid electricity-low carbon gas decarbonization path, at least for the EU. A Navigant study (2019) (https://www.gasforclimate2050.eu/files/files/Navigant_Gas_for_Climate_The_optimal_role_for_gas_in_a_net_zero_emissions_energy_system_March_2019.pdf) puts the savings of the hybrid path at EUR 217 billion per annum for the EU. Frontier Economics (2017) (https://www.frontier-economics.com/media/2260/der-wert-der-gasinfrastruktur.pdf) puts it at EUR 12 billion per annum for Germany only. The dena Study Integrated Energy Transition (2018) (https://www.dena.de/en/topics-projects/projects/energy-systems/dena-study-integrated-energy-transition/) arrives at EUR 600 billion per annum for the EU and the Eurogas Scenario Study with PRIMES (2018) (https://eurogas.org/website/wp-content/uploads/2018/05/Eurogas_infographic_20180502b.pdf) at EUR 335 billion per annum.

5. Investment in smart power solutions, and in particular energy storage, has been on the rise for the past few years. This was explored in depth in our 2018 survey report: *The Smart Power Revolution: Opportunities and Challenges* available at https://www.bakermckenzie.com/en/insight/publications/2018/04/smart-power-revolution

Governments are Supporting the Decarbonized Hydrogen Industry

Governments will support hydrogen as they did with renewables to drive down costs.

Since the widespread production of decarbonized hydrogen is crucial to achieve a successful energy transition, governments committed to dealing with the climate emergency and realize the potential economic benefit of leading the future global hydrogen economy and are supporting the development of the clean-hydrogen market. This trend is growing rapidly.

Government intervention has already underpinned the development of several clean energy technologies into major new industries since the beginning of the millennium. Renewable electricity production technologies were first backed by direct government support, including funds and mandatory targets. Now, investment comes mostly from the private sector, to the tune of USD 124 billion per year.[6] The parallels between hydrogen today and solar panels and wind turbines at the beginning of the century are obvious: green and blue hydrogen are relatively expensive fuels (at least compared to gray hydrogen), produced by often still immature technologies and with low levels of demand. However, this was also the case with renewables and this experience can be relied on to provide today's investors with the knowledge that governments are capable of making the green and blue hydrogen market grow.

The support for hydrogen has already begun and is working.

Many governments are already supporting the growth of hydrogen using innovation funds, mandatory targets and public-private partnerships, and this support is already showing results.

- **Hydrogen transportation is starting to become a reality.** Around 11,200 hydrogen-powered cars and 20,000 hydrogen forklift trucks are already in use globally and can rely on 381 hydrogen refueling stations (from 80 in 2015).
- **Fuel cells are developing and improving.** Costs have more than halved in the last five years and are at around 3% of their 2005 level. At the same time, fuel cell durability can extend up to 10,000 hours, and some stationary fuel cells running 80,000 hours have been reported.
- **CCUS demonstration projects are expanding.** Since 2000, nine CCUS hydrogen production facilities have been in operation. Many refineries have already installed CCUS facilities for hydrogen production, both in the US and the EU. This increased interest for CCUS, and in some areas public opposition to the idea of storing CO_2 on land has led some academics to argue that methane pyrolysis[7] could be the most cost-effective, low-carbon hydrogen production technology.[8]

6. International Energy Agency (IEA). (2019, June). ***The Future of Hydrogen***. p. 25. Retrieved from https://webstore.iea.org/the-future-of-hydrogen

7. Pyrolysis involves the decomposition of natural gas into solid, black (i.e., pure) carbon and hydrogen. It relies on high temperatures produced thermally or catalytically in a non-oxidative environment.

8. Information in this bullet point and the above two bullet points have been sourced from International Energy Agency. (2019, June). ***The Future of Hydrogen***. p. 25-27. Retrieved from https://webstore.iea.org/the-future-of-hydrogen

In fact, there has been a surge in low-carbon and decarbonized hydrogen production for energy and climate purposes in recent years, as is shown on *Figure 1*.

These trends will continue. Indeed, other hydrogen-related low-hanging fruits, such as (industry and building) heat from hydrogen or blending hydrogen into the natural gas network to reduce emissions, keep garnering more policy attention. In fact, many countries have adopted (or have committed to do so shortly) hydrogen-specific strategies. See the Appendix for a global summary of key legal, regulatory and policy developments regarding hydrogen.

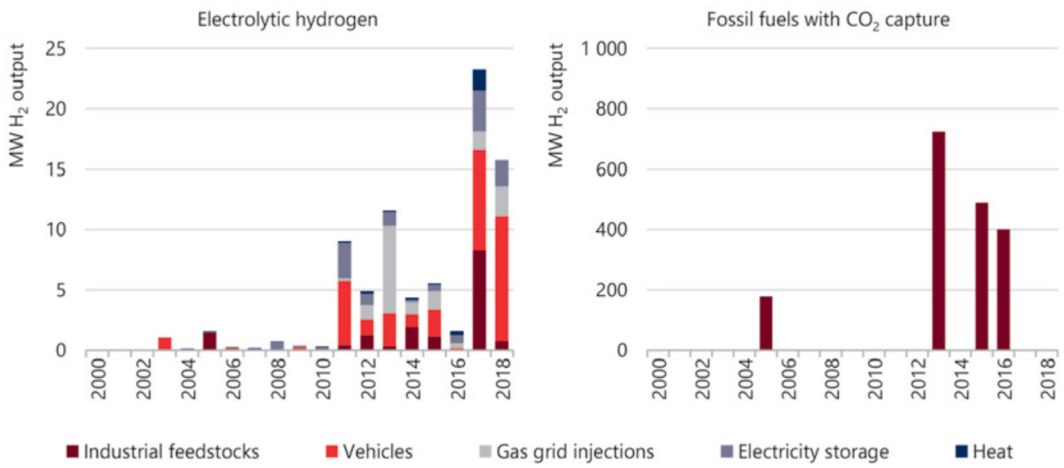

Figure 1. ***Capacity of new projects for hydrogen production for energy and climate purposes, by technology and start date.*** Source: IEA (2019), ***The Future of Hydrogen.*** p. 26. All rights reserved.

Future Hydrogen Markets Will Include Industrial Users, Transport, Buildings and Power Generation

The current hydrogen market is already big and growing.

The industrial use of hydrogen is already a major global business, with a total demand of around 115 million metric tons in 2018[9] (60% for 'pure' hydrogen and 40% for hydrogen-based fuels). In financial terms, this represents about USD 135.5 billion.[10]

Today, industrial applications for hydrogen are dominated by the use of hydrogen as a chemical agent in oil refining and fertilizer production. According to the IEA, the current top four industrial uses are "oil refining (33%), ammonia production (27%), methanol production (11%) and steel production via the direct reduction of iron ore (3%)".[11]

As can be seen on *Figure 2,* demand for hydrogen has grown by more than 300%[12] since 1975 and continues to rise globally. By 2023, industrial demand for hydrogen is expected to grow to USD 199.1 billion.[13]

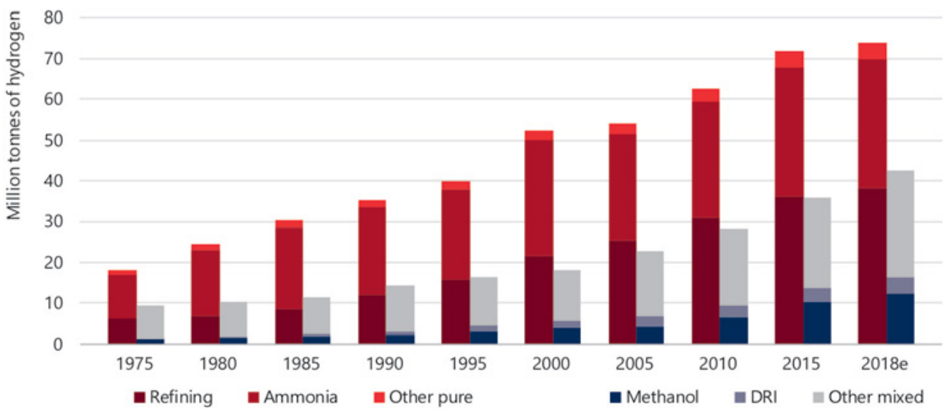

Figure 2. ***Global annual demand for hydrogen since 1975.*** Source: IEA (2019), ***The Future of Hydrogen.*** p. 18.

9. International Energy Agency. (2019, June). ***The Future of Hydrogen***. p. 18. Retrieved from https://webstore.iea.org/the-future-of-hydrogen

10. The Market Research Future's (2020) ***Hydrogen Generation Market Research Report: Global Forecast till 2023*** (https://www.marketresearchfuture.com/reports/hydrogen-generation-market-7026) research projects the expected growth of the hydrogen market between 2018 to 2023.

11. International Energy Agency. (2019, June). ***The Future of Hydrogen***. p. 89. Retrieved from https://webstore.iea.org/the-future-of-hydrogen

12. International Energy Agency. (2019, June). ***The Future of Hydrogen***. p. 17. Retrieved from https://webstore.iea.org/the-future-of-hydrogen

13. In chapter 4 of Market Research Future's (2020) ***Hydrogen Generation Market Research Report: Global Forecast till 2023*** (https://www.marketresearchfuture.com/reports/hydrogen-generation-market-7026), research shows that the demand to decarbonize energy use, and a shifting trend towards cleaner energy, will drive demand for hydrogen.

Today, virtually all of this hydrogen is supplied using fossil fuels without carbon capture, utilization and storage (CCUS) and this production represents about 6% of the current global natural gas demand.[14]

One of the challenges of the future will be decarbonizing hydrogen production. This will entail using (i) renewable (and nuclear) electricity to produce green hydrogen and (ii) natural gas combined with CO_2 storage or conversion into solid carbon to produce blue hydrogen. Both of these production methods for decarbonized hydrogen are expected to play a major role in meeting the world's future energy needs. Nonetheless, blue hydrogen could have the advantage in the near term. Indeed, *Figure 3*, summarizing hydrogen's value chain from production to applications, shows clearly that a large part of today's industrial applications could be decarbonized with minimal disruption to supply chains, merely by increasing the cost efficiency of blue hydrogen production methods. Since using CCUS is already the cheapest low-carbon hydrogen production method, government support could quickly make this into reality. In this way, the rise in demand for hydrogen could very soon be met using CCUS-based hydrogen production.

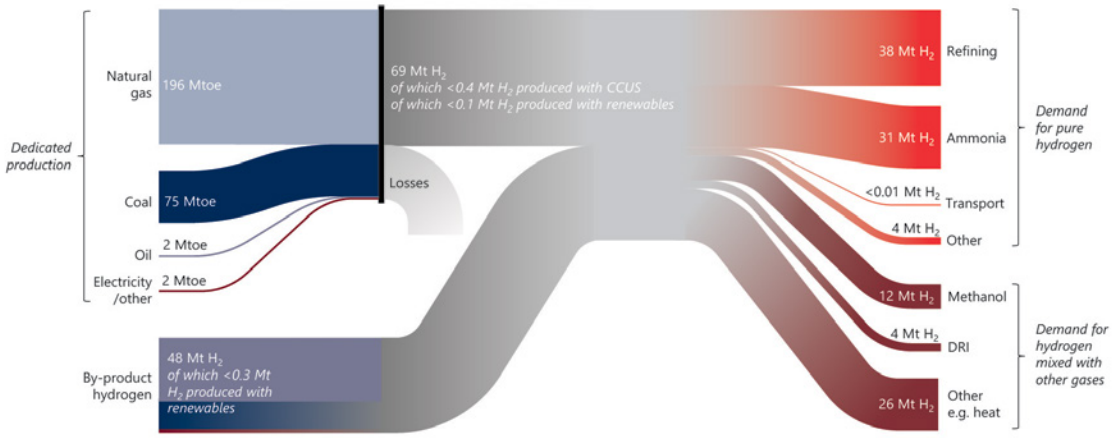

Figure 3. ***Today's hydrogen value chains.*** Source: IEA (2019), ***The Future of Hydrogen.*** p. 32.

14. International Energy Agency. (2019, June). *The Future of Hydrogen*. p. 17, 37-38. Retrieved from https://webstore.iea.org/the-future-of-hydrogen

With new applications, the low-carbon hydrogen market size could reach USD 25 billion by 2030 and grow even further long-term.

Hydrogen also holds long-term promise in many sectors beyond existing industrial applications, including transport, heating buildings, replacing fossil fuels in energy-intensive industries and power generation. *Table 1* below presents a brief explanation of why hydrogen would be useful for these applications.

Table 1. Future applications for hydrogen
Road transport is a notoriously hard industry to decarbonize. Hydrogen fuel cell electric vehicles (FCEVs) drastically reduce air pollution, since they have zero tailpipe emissions and can be CO_2 free. For personal cars, hydrogen is complementary to other alternatives, like electric vehicles and advanced biofuels; costs will decide the balance between them in the long run. However, heavy-duty transport will probably need to rely on hydrogen since electric batteries do not offer a viable solution.
Maritime and air transports are industries for which hydrogen is a leading – albeit still imperfect – option for decarbonization. For shipping, one advantage of these applications is that it can address emissions both at sea and those from port operations, making use of synergies with forklifts and trucks. For aviation, hydrogen-based fuels would require limited changes to design or refueling infrastructure at airports. Long-term, the potential hydrogen demand that this sector could generate is massive, although technical challenges remain. Indeed, for example, the maritime transport sector accounts for around 5% of global oil demand.[15]
Buildings account for about a third of global energy use, mostly for heating.[16] Hydrogen can be an interesting low-carbon contributor for decarbonizing buildings, most notably in the near term by blending hydrogen into existing natural gas networks. It can complement the use of heat pumps, by meeting heating needs during peak cold periods. This would have most impact in apartment blocks and commercial buildings, particularly in dense cities, where conversion of current heating systems to heat pumps is most challenging.
Energy-Intensive Industries, such as steel, aluminum and cement or even refineries, will require hydrogen to fulfill their energy needs in a carbon-neutral way. In these applications, rather than using it in the chemical process itself, hydrogen is used as a feedstock to produce high-temperature heat necessary for, e.g., melting, gasifying, drying or catalyzing chemical reactions. Excluding the chemical and iron and steel sectors, industrial high-temperature heat is currently responsible for more than 3% of global energy-sector CO_2 emissions.[17] Despite the fact that negligible quantities of hydrogen are currently used for this purpose today, the combustion of hydrogen (notably as an alternative to coal and natural gas) offers ways of reducing emissions that are proven at scale.
Power Generation, Balancing and Storage offers many opportunities for hydrogen and hydrogen-based fuels. Near term, ammonia produced from hydrogen could be co-fired in coal-fired power plants to reduce CO_2 emissions. In the next decade, we can expect to see electrolysis plants acting as electricity peak shaving. Hydrogen will also be used for seasonal storage of electricity for countries with high levels of renewable capacity, especially once technology improvements have brought up the conversion efficiency. Underground storage of hydrogen-based fuels such as ammonia, especially in salt caverns, are envisaged and could be one of the most space-efficient long term storage options. Indeed, 150 GWh (the annual electricity consumption of a medium sized city) could be stored using only one 50m × 30m liquid ammonia tank.[18]

15. International Energy Agency. (2019, June). ***The Future of Hydrogen***. p. 138. Retrieved from https://webstore.iea.org/the-future-of-hydrogen

16. International Energy Agency. (2019, June). ***The Future of Hydrogen.*** p. 144. Retrieved from https://webstore.iea.org/the-future-of-hydrogen

17. International Energy Agency. (2019, June). ***The Future of Hydrogen***. p. 117. Retrieved from https://webstore.iea.org/the-future-of-hydrogen

18. ***The Future of Hydrogen*** by International Energy Agency. (2019, June). p. 158-159 shares more information about how storing the same amount of electricity with batteries would require around 1,150 times the largest lithium-ion battery currently available anywhere in the world. Retrieved from https://webstore.iea.org/the-future-of-hydrogen

Since the level of maturity of hydrogen technology, and the commitment to taking concrete action to deal with the climate varies, we can expect this industry to grow at different speeds across the globe. Additionally, the level of competition between hydrogen and other low-carbon technologies also differs between sectors. Indeed, in some sectors such as aviation, shipping or iron and steel, hydrogen faces few competitors. However, in other areas, such as personal transport, the competition will be more intense. Nonetheless, even taking these factors into account, conservative estimates of the mid-term opportunity for the low-carbon hydrogen market still represents at the very least USD 1 billion by 2030, then growing rapidly towards 2050 and beyond.[19] Given that these estimates are based on current government plans only, the actual market value of low-carbon hydrogen is likely to be significantly higher. If, thanks to future government intervention, even only half of the expected increase in demand for hydrogen above the current levels is covered by decarbonized sources, the low-carbon hydrogen market would, under still conservative assumptions,[20] be worth about USD 25 billion by 2030.

Future long-term prospects are even higher, as can be seen on *Figure 4*.

Type of application	Application	Size of the 2030 opportunity (ktH2/yr)	Long term potential scale
Major hydrogen uses today	Chemicals (ammonia and methanol)	Over 100	High
	Oil refineries and biofuels	Over 100	Medium
	Iron and steel (blending in DRI)	10-100	Low
New hydrogen uses for a clean energy system	Buildings (conversion to 100% hydrogen)	Over 100	High
	Road freight	Over 100	High
	Passenger vehicles	Over 100	Medium
	Buildings (blending in the gas grid)	Over 100	Low
	Iron and steel (conversion to 100% hydrogen)	10-100	High
	Aviation and maritime transport	Under 10	High
	Electricity storage	Under 10	High
	Flexible and back-up power generation	Under 10	Medium
	Industrial high-temperature heat	Under 10	Low

Figure 4. ***Applications for low-carbon hydrogen classified by the theoretical size of the 2030 opportunity and the long-term potential.*** Source: IEA (2019), ***The Future of Hydrogen.*** p. 169. All rights reserved.

19. See Figure 4 and by Baker McKenzie's own calculations. According to a Navigant study (2019) (https://www.gasforclimate2050.eu/files/files/Navigant_Gas_for_Climate_The_optimal_role_for_gas_in_a_net_zero_emissions_energy_system_March_2019.pdf), the optimal energy transition scenario with regard to gas involves, by 2050, around 1,710 TWh of low-carbon hydrogen, the equivalent in energy content to 162 billion cubic meters of natural gas, in the EU alone.

20. Assuming price decrease lower than 20% and a 3% constant growth rate of the hydrogen market, equivalent to the long-term growth rate of the hydrogen market (i.e. since 1975). This assumption is conservative, since the historic growth rate is lower than the actual growth rate of recent years and estimated growth rate until 2023.

Smart First Movers Will Benefit from Hydrogen by Monitoring Energy Policies and De-risking Investments Using Government Support

There are still barriers to hydrogen adoption.

Since hydrogen markets will grow exponentially in the mid- and long-term, companies that invest today in hydrogen will be able to capture this growth, become technology leaders and shape the future of the business. For companies with a large natural gas portfolio, investing in hydrogen energy has the additional benefit of providing a long-term future for their assets, notwithstanding decarbonization efforts.[21]

However, there are still multiple barriers to the widespread development of decarbonized hydrogen and each investment will face challenges in the form of policy, regulatory, economic and financial barriers.

As explained in previous sections, the speed of deployment of hydrogen in coming years is expected to vary between sectors and countries. Of course, these variations come partly from the different level of maturity or adoption of the technology required for decarbonized hydrogen development, either globally or in specific regions. However, the details of different governments' strategy will greatly affect what opportunities can effectively be taken advantage of. Mastering government strategies, regulations and sources of funding will be crucial.

In each region, government strategies as well as regulatory barriers should first be assessed and then monitored.

Governments' climate and economic strategies create good market conditions and are particularly crucial.

The speed of development of the decarbonized hydrogen market will depend quite simply on how quickly governments require the current and future markets for hydrogen to decarbonize. Without government intervention through emission trading schemes, energy taxes or similar obligations on gray hydrogen users today, and on those that will use hydrogen when obliged to decarbonize, there will be no market for green and blue hydrogen. Nonetheless, as we have seen with the wind and solar markets, things can change quickly. Those companies ahead of the curve in factoring government climate strategy into investment decisions are the ones that will lead tomorrow's hydrogen market. The presence of favorable economic conditions for the development of green and blue hydrogen, in a particular region or country, should thus be a precondition for any large-scale investment by first movers.

Outdated hydrogen-related regulations should also be monitored.

Despite government commitments and long-term strategies, regulations can be slow to adapt. In fact, two years ago, our own survey research[22] had already revealed that unfit or outdated regulatory regimes were significant hurdles to smart power advancement, including hydrogen-based storage. Indeed, in our survey, 77% of respondents from the industry said legal and regulatory frameworks are inadequate to address the smart power changes.

21. In fact, there are many very interesting synergies between natural gas and hydrogen, but those are beyond the scope of this article.

22. Baker McKenzie (2018). *The Smart Power Revolution: Opportunities and Challenges*. Retrieved from https://www.bakermckenzie.com/en/insight/publications/2018/04/smart-power-revolution

Some of the barriers identified two years ago by our survey participants are still present today. These include, among others:

- The absence of 'Guarantees of Origin' schemes enabling the distinction between different types of hydrogen based on greenhouse gas emissions associated to their production;
- The unclear legal status of "power-to-hydrogen" plants or storage systems that can prevent such plants from being rewarded according to the actual service rendered to the energy system;
- Unclear, incomplete, or counterproductive industrial emissions or safety regulations;
- Inconsistent or counterproductive funding rules;
- Outdated market rules in the gas or electricity markets; and
- Government discrimination of specific technologies and processes based on irrational concerns.

In some of the countries that are already committed to hydrogen development, these regulatory barriers are in the process of being dismantled, and the EU is expected to make a major push in all these areas over the next few years.

Nonetheless, to ensure a return on their investment, first movers should assess (i) the effect of existing regulatory barriers on any new investment or project, (ii) the likelihood of such barrier disappearing for a particular market and within a particular timeframe, and of course (iii) the availability of public support to de-risk the investment when needed.

Smart movers should use government support to de-risk investment with respect to the cost of low-carbon and decarbonized hydrogen.

On top of a careful evaluation and monitoring of government strategies and existing policies, smart first movers should also rely on direct government support in order to de-risk investment during the early years of this emerging market. To do so, it is important to act in the right areas and in the right markets, where government support is likely to be abundant. To best use available government support, companies should therefore understand (i) which countries provide the most and best focused funding or investment support and (ii) what types of projects governments are likely to support.

Companies contemplating a specific investment in their own region and field of expertise should carry out a thorough analysis of funding and financing opportunities. However, understanding regional and sectoral funding trends as well as expert recommendations can already provide some insight as to government-funding and financing patterns.

Hydrogen-related research and development (R&D) budgets in China, the EU and Australia are on the rise, whereas the US situation remains uncertain.

In 2018, funding for hydrogen-related technology research and pilots increased by 8%, representing more than 50 billion in USD equivalent.[23] In fact, funding has been on the rise since 2015, as can be seen on *Figure 5.* This rise in global R&D funding can be largely attributed to an increase in spending from China, whose budget has about quintupled in only three years, as seen on *Figure 5.*

23. Information was retrieved from page 7 of the first edition (launched May 2019) of the International Energy Agency publication *Energy Technology RD&D Budgets*. The second edition was launched in October 2019 and can be retrieved from https://webstore.iea.org/energy-technology-rdd-budgets-2019-overview

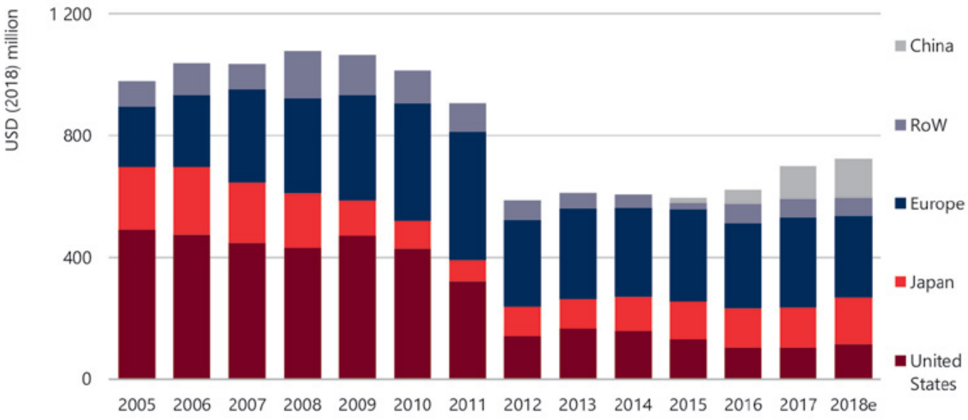

Figure 5. ***Government RD&D budget for hydrogen and fuel cells.*** Source: IEA (2019), ***The Future of Hydrogen.*** p. 20. All rights reserved.

The EU's spending has stayed relatively constant in the last few years. However, in 2021, the EU is expected to institute a long-lasting and more ambitious hydrogen research program as part of its "Horizon Europe", including a new "European Partnership" for hydrogen.[24] This partnership is, in essence, an R&D association specifically dedicated to hydrogen research and whose objective is to address "*Market failure for first movers*".

In addition, as from 2021, a new 'ETS Innovation Fund' will be operational to use an estimated EUR 10 billion, collected from CO_2 allowances under the EU's Emissions Trading System, in order to fund "*demonstration or first-of-a-kind highly innovative projects*". This will include energy-intensive industries, energy storage or CCUS. There is no doubt that the Innovation Fund will grant funding to several hydrogen-related projects. From a company's perspective, this fund will be complementary to Horizon Europe, since it is designed to enable a project to grow from a proof of concept (R&D) phase into a scalable industrial project.

It is thus highly likely that EU R&D spending related to hydrogen will be both better focused and greater in importance in the near future. Furthermore, initiatives in sustainable finance from major institutions mean that ready sources of funds for developing projects will be available. The new climate strategy and energy lending policy by the European Investment Bank[25] which aims, notably, to support "*the production and integration of low-carbon gases (such as hydrogen)*", is one such initiative.

In 2019, Japan adopted a new strategic roadmap for hydrogen making the development of hydrogen technology one of its centerpieces and is working toward decreasing the cost of decarbonized hydrogen production tenfold by 2050.[26] It is thus very likely that its R&D budget will continue to rise, as it has since 2011. The hydrogen economy will also be a centerpiece of Japan's 2020 Olympic Games.

Australia also adopted a National Hydrogen Strategy in 2019[27] which sets a path to build Australia's hydrogen industry. The government plans to accelerate the commercialization of hydrogen, reduce technical uncertainties and build up its domestic supply chains and production capabilities. The Australian Renewable Energy Agency (ARENA) has identified renewable hydrogen as one of its three investment priorities. To date it has committed over AUD 44 million to hydrogen development including early stage R&D and pilot projects.[28] In late 2019, ARENA announced a new funding round

24. European Commission, (2019). ***Inception Impact Assessment***. Ref. Ares (2019)4972390 - 30/07/2019, p. 1. Retrieved from https://ec.europa.eu/info/law/better-regulation/initiatives/ares-2019-4972390_en

25. European Investment Bank (EIB). ***EIB energy lending policy: Supporting the energy transformation*** (final version adopted on by the EIB's Board of Directors on 14 November 2019). Retrieved from https://www.eib.org/attachments/strategies/eib_energy_lending_policy_en.pdf

26. Reuters (2019, September, 25). ***Japan draws support for global hydrogen proposals, including refueling stations.*** Retrieved from https://www.reuters.com/article/us-japan-hydrogen/japan-draws-support-for-global-hydrogen-proposals-including-refueling-stations-idUSKBN1WA19R

27. Commonwealth of Australia (2019, November). ***Australia's National Hydrogen Strategy.*** Retrieved from https://www.industry.gov.au/data-and-publications/australias-national-hydrogen-strategy

28. Australian Renewable Energy Agency. (2019, November, 23). ***ARENA gets cracking on commercial scale hydrogen.*** Retrieved from https://arena.gov.au/news/arena-gets-cracking-on-commercial-scale-hydrogen/

of AUD 70 million to help fast track renewable hydrogen in Australia.[29] The Clean Energy Finance Corporation will also commit AUD 300 million of concessional finance through a new Advancing Hydrogen Fund.[30]

The biggest decrease of hydrogen R&D funding occurred in 2012 in the US, when the Obama administration decided to switch focus from fuel cell to electric vehicle research. However, with the presidential election of 2020 on the horizon, and given the "Green New Deal" platform on which many of the front-runners of the Democratic Primary are running, it seems likely that hydrogen spending will increase unless the Trump administration is granted a second term.

In the past, governments have mostly funded technology development for green hydrogen production and hydrogen transport. As the technology is now mature, projects enabling large-scale demand and standardization should become the focus.

As was already apparent from *Figure 1*, governments have, so far, (i) favored the development of green (as opposed to blue) hydrogen production and (ii) focused on hydrogen-based transportation. In practice, these two efforts are closely connected since 40% of the publicly funded water electrolyzers have been installed to supply hydrogen-fueled buses or cars.[31]

Thanks to these investments, many stakeholders share the opinion that large-scale demand and standardization, rather than further technological progress, are now the key to the widespread adoption of fuel cells, water electrolyzers, and hydrogen refueling. A transition of public funding from technological demonstration projects and R&D into projects enabling large-scale demand and standardization should therefore be expected.

If governments value the recommendation of international experts, they will invest in new hydrogen projects in coastal industrial clusters, transport, gas infrastructure and international trade.

In June 2019, the International Energy Agency (IEA) published a report on the future of hydrogen for the G20 summit hosted in Japan, which represents the most established consensus on the state of hydrogen energy.[32] The IEA identified high-potential business opportunities whose funding would give a boost to the hydrogen market and drive down costs and recommended that government seize the following "near-term opportunities":

- Turning existing industrial ports (e.g., the North Sea in Europe, or the Gulf Coast in North America) into epicenters for scaling up the production and use of clean hydrogen;
- Capitalizing on existing natural gas infrastructure and increase hydrogen demand by implementing an obligation to mix (low-carbon) hydrogen into natural gas (existing infrastructure and equipment can support at least a 10% hydrogen injection);
- Making fuel cell vehicles more competitive for vehicle fleets, freight transports and corridors by ensuring the parallel expansion of infrastructure for hydrogen supply, vehicle refueling and vehicle manufacturing (e.g., by focusing on a few key cost-efficient vehicle types to support);
- Stimulating the creation of international hydrogen trade (e.g., by aligning national hydrogen strategies and standard or supporting hydrogen import-export infrastructure).

One can expect that many governments' strategy will be reviewed in the near future, largely in a direction inspired by the IEA's recommendations.

29. Australian Renewable Energy Agency. (2019, November, 23). ***ARENA gets cracking on commercial scale hydrogen.*** Retrieved from https://arena.gov.au/news/arena-gets-cracking-on-commercial-scale-hydrogen/

30. Minister for Resources and Northern Australia, Minister for Finance and Minister for Energy and Emissions Reduction (2019, November, 23). ***Australia to be a world leader in hydrogen.*** Retrieved from https://www.minister.industry.gov.au/ministers/canavan/media-releases/australia-be-world-leader-hydrogen

31. International Energy Agency. (2019, June). ***The Future of Hydrogen.*** p. 186. Retrieved from https://webstore.iea.org/the-future-of-hydrogen

32. International Energy Agency. (2019, June). ***The Future of Hydrogen.*** Retrieved from https://webstore.iea.org/the-future-of-hydrogen

Appendix

Hydrogen - Key legal, regulatory and policy developments

Jurisdiction	Key legal, regulatory and policy developments
ASIA PACIFIC	
Australia[1]	**December 2018:** The Victorian Hydrogen Investment Program was announced. **May 2019:** The Queensland Hydrogen Industry Strategy (2019-2024) was released. It includes an AUD 15 million industry development fund to support hydrogen projects in Queensland with two funding streams - plant and equipment, and feasibility studies. **July 2019:** The Western Australian Renewable Hydrogen Strategy was released. It sets out the state's potential as a key hydrogen producer and exporter to Asian markets, with support from the establishment of an AUD 10 million Renewable Hydrogen Fund. The Fund will aim to facilitate private sector investment and leverage financial support to the renewable hydrogen industry. **November 2019:** The Victorian government released the Green Hydrogen discussion paper seeking submissions to contribute to the development of a Victorian Green Hydrogen Industry Development Plan. Submissions close on 5 February 2020. **November 2019:** Australia's National Hydrogen Strategy was released identifying 57 joint actions to set a path to build Australia's hydrogen industry accompanied by an AUD 370 million funding package. The Clean Energy Finance Corporation will commit AUD 300 million of concessional finance through a new Advancing Hydrogen Fund and the Australian Renewable Energy Agency (ARENA) will provide AUD 70 million to help fast track renewable hydrogen in Australia. To date ARENA has committed over AUD 44 million to hydrogen development including early stage research and development and pilot projects. The new package takes the government's commitments to the hydrogen industry to over AUD 500 million since 2015.
China[2]	A number of provinces (e.g. Beijing) have developed hydrogen-related policies and some cities (e.g. Wuhan, Datong) are establishing themselves as hydrogen cities through development of the hydrogen industry. **June 2019:** Transition period for the withdrawal of subsidy for new energy vehicles ended. New energy buses and fuel cell vehicles are exempted from the subsidy withdrawal. The savings from the withdrawal are to be used towards hydrogen charging infrastructure and support services. **September 2019:** Publication of key tasks to build national strength in transportation mentioned the need to strengthen construction of facilities such as hydrogen refueling.

1. https://www.premier.vic.gov.au/new-program-to-drive-investment-in-hydrogen-energy/; https://www.dsdmip.qld.gov.au/resources/strategy/queensland-hydrogen-strategy.pdf; http://statements.qld.gov.au/Statement/2019/5/30/queensland-positioned-to-power-the-hydrogen-highway; https://www.dsdmip.qld.gov.au/industry/priority-industries/advanced-manufacturing/hydrogen-industry-development.html; http://www.drd.wa.gov.au/Publications/Documents/wa_renewable_hydrogen_strategy.pdf; https://www.energy.vic.gov.au/renewable-energy/victorian-hydrogen-investment-program; https://s3.ap-southeast-2.amazonaws.com/hdp.au.prod.app.vic-engage.files/4715/7413/9423/VHIP_discussion_paper_FA2_WEB_booklet.pdf; https://www.industry.gov.au/data-and-publications/australias-national-hydrogen-strategy; https://www.minister.industry.gov.au/ministers/canavan/media-releases/australia-be-world-leader-hydrogen; https://arena.gov.au/news/arena-gets-cracking-on-commercial-scale-hydrogen/

2. http://www.beijing.gov.cn/fuwu/lqfw/ztzl/kjcxgjj/wj/xlwj/t1502859.htm; http://www.xinhuanet.com/english/2019-08/04/c_138283135.htm; http://www.xinhuanet.com/english/2018-01/21/c_136913339.htm; http://www.xinhuanet.com/english/2019-08/25/c_138336923.htm; http://jjs.mof.gov.cn/zhengwuxinxi/zhengcefagui/201903/t20190326_3204190.html; http://www.gov.cn/zhengce/2019-09/19/content_5431432.htm; http://english.www.gov.cn/statecouncil/ministries/201909/25/content_WS5d8a9ec4c6d0bcf8c4c13fb6.html

Jurisdiction	Key legal, regulatory and policy developments
India[3]	**November 2019:** In response to criticism by the Supreme Court of India regarding the air pollution problems in New Delhi and northern India, the Solicitor General of India informed the court that the government is making progress, including exploring hydrogen based technology being developed in Japan. The court directed the government to update the court.
Japan[4]	**December 2017:** Basic Hydrogen Strategy released. **July 2018:** Fifth Strategic Energy Plan released. **2019-2020:** In the 2019-2020 budget request for the Ministry of Economy, Trade and Industry as approved by cabinet, JPY 16.3 billion (USD 150 million) was approved to establish a hydrogen supply chain utilizing untapped energy resources and JPY 10 billion (USD 91.7 million) was approved to offer subsidies toward public hydrogen station development for fuel-cell vehicles. **March 2019:** The Renewed Strategic Roadmap for Hydrogen and Fuel Cells (Roadmap) was released to ensure the goals set out in the Basic Hydrogen Strategy and the Fifth Strategic Energy Plan towards a hydrogen-based society are achieved. The Roadmap defined, among other things, new targets on the specification of basic technologies and the breakdown of costs and necessary measures for achieving these goals. **September 2019:** The Strategy for Developing Hydrogen and Fuel-Cell Technologies was released stipulating specific approaches to developing technologies toward the achievement of field-based goals set in the Roadmap.
South Korea[5]	**January 2019:** The government announced its Hydrogen Economy Roadmap and Ulsan's Future Energy Strategy with a primary focus on leading the hydrogen vehicles and fuel cell industry as well as establishing a system for hydrogen production and distribution. **October 2019:** The government announced it is planning to build three hydrogen-powered cities by 2022 with selection of cities to host test areas to be announced by December 2019. Hydrogen will be used in these cities as fuel for cooling, heating, electricity and transportation. **October 2019:** The government announced three key strategies to accelerate the development of its car industry into the future and four specific action plans to achieve these goals. The action plans included seeking to become a leading player in the green car industry which had a specific aim to build a total of 660 hydrogen refueling stations by 2030 and 15,000 electric recharging stations by 2025. Drivers will be able to access a hydrogen station within 20 minutes of any major city or within 75 kilometers from any expressway by 2030. **December 2019:** Further to the October 2019 announcement regarding the plan to build three hydrogen-powered cities, the government announced the three cities will be Ansan, Ulsan and Jeonju/Wanju. Samcheok was also selected to be a city focusing on hydrogen R&D.

3. https://www.theguardian.com/world/2019/nov/13/india-to-use-hydrogen-based-fuel-as-delhi-pollution-continues; http://www.indiaenvironmentportal.org.in/content/466153/order-of-the-supreme-court-regarding-air-pollution-in-delhi-and-adjoining-areas-13112019/; http://www.indiaenvironmentportal.org.in/files/file/air-pollution-north-India-SC_Order_13-Nov-2019.pdf

4. https://www.meti.go.jp/english/press/2017/1226_003.html; https://www.meti.go.jp/english/press/2018/0703_002.html; https://www.meti.go.jp/english/aboutmeti/policy/fy2019/0204.html; https://www.meti.go.jp/english/press/2019/0312_002.html; https://www.meti.go.jp/english/press/2019/0918_001.html

5. http://english1.president.go.kr/briefingspeeches/speeches/110; https://english1.president.go.kr/Media/News/519; http://www.molit.go.kr/USR/NEWS/m_71/dtl.jsp?lcmspage=3&id=95082893; https://www.weforum.org/agenda/2019/11/south-korea-green-energy-hydrogen-future-city-fossil-fuel-renewables/ ; http://www.koreaherald.com/view.php?ud=20191010000806; https://fuelcellsworks.com/news/south-korea-to-create-three-hydrogen-cities-by-2022/; http://english.motie.go.kr/common/download.do?fid=bbs&bbs_cd_n=2&bbs_seq_n=742&file_seq_n=1; https://english1.president.go.kr/BriefingSpeeches/Speeches/677; https://www.rvo.nl/sites/default/files/2020/01/Three-hydrogen-pilot-cities-in-Korea.pdf; https://fuelcellsworks.com/news/korea/korean-govt-announces-its-selection-of-worlds-first-hydrogen-cities/; http://www.molit.go.kr/USR/NEWS/m_71/dtl.jsp?lcmspage=4&id=95083342

Jurisdiction	Key legal, regulatory and policy developments
Hydrogen Energy Supply Chain (HESC) pilot project (2018-2021) - Australia / Japan[6]	This AUD 496 million pilot project involves turning brown coal in the Latrobe Valley, Victoria, Australia into hydrogen gas and then transported to Port of Hastings, Victoria, Australia for liquefaction before shipping in a world-first, purpose-built liquefied hydrogen carrier to Japan for use in fuel cells and power generation. The Pilot Project is the world's largest hydrogen demonstration project. It is delivered by a consortium of Japanese and Australian companies and supported by the Japanese, Australian (AUD 50 million) and Victorian (AUD 50 million) governments. **July 2019:** Construction of the hydrogen liquefaction and loading terminal in Port of Hastings commenced. **November 2019:** Construction of the brown coal gasification plant in Latrobe Valley commenced. **December 2019:** The world's first liquefied hydrogen carrier developed specifically for the HESC pilot project is launched in Japan.
EMEA	
European Union (EU)[7]	**2014 - 2020:** FCH 2 JU (Fuel Cells and Hydrogen 2 Joint Undertaking) was established in 2014 under Horizon 2020 as a continuation of the Fuel Cells and Hydrogen Joint Undertaking first established in 2008. FCH 2 JU is a public private partnership to support research, technological development and demonstration activities in fuel cell and hydrogen energy technologies in Europe. It aims to accelerate commercial deployment of hydrogen-based energy and transport solutions across Europe. The total investment under FCH 2 JU is EUR 1.33 billion. The three members are the European Union (represented by the European Commission), the Industry Grouping "Hydrogen Europe" and the Research Grouping "Hydrogen Europe Research". **September 2018:** The Austrian Presidency of the Council of the EU proposed a Hydrogen Initiative at Linz, Austria. It was signed by the European Commission, a large number of European countries, and a number of provinces, companies and organizations. The signatories aim to maximize the great potentials of sustainable hydrogen technology for the decarbonization of multiple sectors, the energy system and for the long-term energy security of the EU. **November 2018:** The European Commission presented "A Clean Planet for all: A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy," where it calls for a climate-neutral Europe by 2050. Hydrogen pathways are included to achieve a net zero greenhouse gas economy. **June 2019:** First meeting of the Hydrogen Energy Network (HyENet) held. This group of experts from EU member states aims to support national authorities in charge of energy policy to develop on the opportunities offered by hydrogen as an energy carrier. HyENet will act as an informal platform of exchange of information, sharing of good practices, experiences and latest developments as well as joint work on specific issues. **July 2019:** Proposal for a Council Regulation for a European Partnership for Clean Hydrogen under Horizon Europe announced. Horizon Europe is a EUR 100 billion research and innovation program (2021-2027) to succeed Horizon 2020. The proposed partnership is, in essence, an R&D association specifically dedicated to hydrogen research and whose objective is to address "Market failure for first movers". The public consultation period for the proposal concluded in mid November 2019. Commission adoption is planned for first quarter 2020.

6. https://www.premier.vic.gov.au/new-facility-to-propel-victoria-as-hydrogen-leader/; https://hydrogenenergysupplychain.com/; https://www.minister.industry.gov.au/ministers/cash/media-releases/local-jobs-and-new-energy-industry-latrobe-valley

7. https://www.fch.europa.eu/page/who-we-are; https://www.fch.europa.eu/sites/default/files/Press%20Release%20FCH%202%20JU%20final.pdf; https://www.eu2018.at/latest-news/news/09-18-Informal-meeting-of-energy-ministers.html; https://www.eu2018.at/dam/jcr:9b0c0051-2894-4bc6-86ba-ea959dc82c0d/The%20Hydrogen%20Initiative%20(not%20available%20in%20an%20accessible%20format)%20(EN).pdf; https://www.bmnt.gv.at/energie-bergbau/energie/hydrogen-initative.html; https://ec.europa.eu/energy/en/topics/technology-and-innovation/energy-storage/hydrogen; https://ec.europa.eu/clima/policies/strategies/2050_en; https://ec.europa.eu/commission/presscorner/detail/en/IP_18_6543; https://ec.europa.eu/info/horizon-europe-next-research-and-innovation-framework-programme_en; https://ec.europa.eu/info/law/better-regulation/initiatives/ares-2019-4972390/public-consultation_en; https://ec.europa.eu/info/law/better-regulation/initiatives/ares-2019-4972390_en; https://ec.europa.eu/info/law/better-regulation/initiative/11902/publication/5722302/attachment/090166e5c639c381_en

Jurisdiction	Key legal, regulatory and policy developments
Austria[8]	**April 2018:** The government released #mission2030 - Austrian Climate and Energy Strategy, which included boosting infrastructure for hydrogen and a flagship project centered on renewable hydrogen and biomethane. **March 2019:** Development of a hydrogen strategy by the government with industry kicked off.
France[9]	**June 2018:** The government announced its Hydrogen Deployment Plan for Energy Transition. The plan includes EUR 100 million funding and goals relating to decarbonized / "green" hydrogen in industrial applications - 10% by 2023 and 20% to 40% by 2028 - and increasing the number of hydrogen commercial and heavy vehicles and charging stations. **November 2019:** New Energy-Climate law amending the French Energy Code was signed by the French president. Besides setting a target to be carbon-neutral by 2050, the new law also relates to hydrogen, including targets for low carbon and renewable hydrogen to be 20% to 40% of total consumption of hydrogen and industrial hydrogen by 2030.
Germany[10]	**2019:** A national Hydrogen Strategy with an action plan is under development by four federal ministries. It is expected to be released in 2020. A short paper contributing to this development was published in November 2019. **December 2019:** A further 16 winners in the BMVI (Federal Ministry of Transport and Digital Infrastructure) "HyLand - Hydrogen Regions in Germany" initiative was announced: 13 HyExpert regions to receive EUR 300,000 each to create and calculate concrete project ideas for hydrogen concepts and three HyPerformer regions to receive EUR 20 million each to implement existing concepts. The funding is provided by the National Innovation Program Hydrogen and Fuel Cell Technology (NIP2). Nine hydrogen regions were previously announced in September 2019 as winners of the HyStarter competition.
The Netherlands[11]	**June 2018:** A Hydrogen Roadmap for the Netherlands was drawn up by TKI New Gas on behalf of the Dutch Ministry of Economic Affairs and Climate. **June 2019:** The Dutch government presented the new national Climate Agreement which aims to reduce CO_2 emissions in the Netherlands by setting a national reduction goal of 49% by 2030 compared to 1990. The Climate Agreement included a substantial hydrogen development program to accommodate large-scale production and storage of renewable electricity with hydrogen technology. The ambition is to install an electrolysis capacity of 3-4 GW in 2030 and to develop a solid hydrogen infrastructure. The Climate Agreement also aims for zero-emission driving by 2050. To support this aim, the development of hydrogen as a carrier for electric energy will be given a key role in the transition to a sustainable mobility sector, particularly in the heavy transport industry. **October 2019:** The government is in the process of designing an adequate national innovation and support scheme for clean hydrogen under the Climate Agreement. A national hydrogen strategy is being developed.

8. https://www.bmnt.gv.at/service/presse/energie/2018/mission2030-ist-Grundstein-f-r-das-Erreichen-der-Klimaziele-bis-2030.html; https://mission2030.info/; https://mission2030.info/wp-content/uploads/2018/10/Klima-Energiestrategie_en.pdf; https://www.bmnt.gv.at/service/publikationen/umwelt/mission-2030-austrian-climate-and-energy-strategy.html; https://www.bmnt.gv.at/energie-bergbau/energie/Oesterreichische-Wasserstoffstrategie.html; https://fuelcellsworks.com/news/austrian-minister-kostinger-launches-the-development-of-a-hydrogen-strategy/

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Jurisdiction	Key legal, regulatory and policy developments
United Kingdom[12]	**May 2019:** GBP 25 million government investment announced to fund zero-emission transport innovations including to a feasibility study into the potential of hydrogen fuel cell technology as a zero-emission solution for utility and off-road vehicles. **June 2019:** GBP 33 million new government investment through the Advanced Propulsion Centre announced to develop the next generation of low-carbon vehicles, including to a hydrogen-powered engine project. **June 2019:** GBP 26 million funding awarded to nine carbon capture, utilization and storage projects. **August 2019:** Five new Decarbonizing Transport Networks+ announced supported by GBP 5 million of funding from UK Research and Innovation, including one network for hydrogen-fueled transportation. **August 2019:** GBP 390 million government funding announced to help industry cut emissions including a GBP 40 million Hydrogen and Fuel Switching Innovation Fund (which provides funding to two existing government programs, GBP 20 million Hydrogen Supply program and GBP 20 million Industry Fuel Switching competition), a new GBP 100 million competition to enable greater supply of low carbon hydrogen to help business decarbonize and a new GBP 250 million Clean Steel Fund to support the iron and steel industry to transition to a low carbon future, including using hydrogen. **October 2019:** Two competitions (deployment and roadmaps) run by UK Research and Innovation on behalf of the government opened to help the country achieve net zero emissions by 2050 as part of the Industrial Decarbonization challenge. The Industrial Decarbonization challenge will commit GBP 170 million towards deploying technologies like carbon capture and hydrogen networks in industrial clusters, supporting the Industrial Clusters Mission to establish the world's first net zero industrial cluster by 2040.
LATIN AMERICA	
Brazil[13]	**June 2018:** Hosted the 22nd World Hydrogen Energy Conference.
Chile[14]	**October 2018:** 2nd international conference "Green hydrogen for Chile's energy transition" organized by the Promoting Solar Energy Project as part of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU)'s International Climate Initiative (IKI) in cooperation with Chile's Ministry of Energy and Chile's Production Development Corporation (CORFO) was held. **2019 - 2022:** Decarbonization of the Chilean energy sector project commissioned by the German BMU with a EUR 4 million grant includes support for innovative technologies and approaches such as green hydrogen for renewable energy system integration and sector coupling.

12. https://www.gov.uk/government/news/government-awards-25-million-to-fund-zero-emission-transport-innovations; https://www.gov.uk/government/news/new-funding-heralds-uks-leadership-in-low-carbon-automotive-future; https://www.gov.uk/government/news/uks-largest-carbon-capture-project-to-prevent-equivalent-of-22000-cars-emissions-from-polluting-the-atmosphere-from-2021; https://www.ukri.org/news/networks-to-prepare-uk-transport-for-a-low-carbon-future/; https://www.gov.uk/government/news/hydrogen-powered-distillery-to-produce-sustainable-gin; https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/829811/hydrogen-supply-competition-phase-2-itt-guidance-notes.pdf; https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/831024/IFS_Phase_3-Guidance_Notes_Sept_2019.pdf; https://www.ukri.org/news/uk-plans-to-fund-new-technologies-to-decarbonise-industrial-clusters/

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Jurisdiction	Key legal, regulatory and policy developments
NORTH AMERICA	
Canada[15]	**March 2019:** Emissions Reduction Alberta announced funding a three year hydrogen heavy truck project in Alberta. **March 2019:** To support Canada's target to sell 100% zero-emission vehicles (which include hydrogen fuel cell vehicles) by 2040 (with targets of 10% by 2025 and 30% by 2030), federal budget 2019 included CAD 130 million over five years for zero-emission vehicle recharging and refueling infrastructure, CAD 5,000 incentive for zero emission vehicle purchase and full tax write-off for commercial purchase. **July 2019:** Completion of a techno-economic feasibility study for the large-scale centralized production of renewable hydrogen in British Columbia. **September 2019:** The British Columbia Hydrogen Study commissioned by the British Columbia Ministry of Energy, Mines & Petroleum Resources, the BC Bioenergy Network and FortisBC was released. **October 2019:** Natural Resources Canada issued the 2019 Hydrogen Pathways - Enabling a Clean Growth Future for Canadians paper noting 12 potential end use pathways where hydrogen and fuel cell technologies could be deployed and 10 recommended actions to support greater hydrogen and fuel cell use.
United States[16]	**July 2018:** The California Fuel Cell Partnership, an industry-government collaboration, issued a vision report targeting 1 million FCEVs and 1,000 hydrogen fueling stations by 2030. **July 2019:** The U.S. Department of Energy (DOE) announced USD 50 million for new and innovative research of technologies for trucks, off-road vehicles, and the fuels that power them. The projects selected for funding include those relating to hydrogen storage and hydrogen fueling technologies for medium and heavy duty transportation. **August 2019:** The DOE announced approximately USD 40 million in FY2019 funding for 29 projects to advance the H2@Scale concept. The selected projects will advance hydrogen storage and infrastructure technologies and identify innovative concepts for hydrogen production and utilization including grid resiliency. H2@Scale is a DOE initiative that brings together stakeholders to advance affordable hydrogen production, transport, storage, and utilization to increase revenue opportunities in multiple energy sectors. It includes DOE-funded projects and national laboratory-industry co-funded activities to accelerate the early-stage research, development and demonstration of applicable hydrogen technologies. **December 2019:** The DOE announced a Notice of Intent to issue a Funding Opportunity Announcement to advance innovations that will build new markets for H2@Scale.

15. https://www.eralberta.ca/projects/details/alberta-zero-emissions-truck-electrification-collaboration-azetec/; https://www.eralberta.ca/news/stories/eras-best-challenge/; https://budget.gc.ca/2019/docs/plan/chap-02-en.html#Part-2-Affordable-Electricity-Bills-and-a-Clean-Economy; https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-transportation/resource-library/hydrogen-and-fuel-cells-sector-status-and-vehicle-use-canada/21959; https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-transportation/zero-emission-vehicle-infrastructure-program/21876; https://www.h2-view.com/story/hydrogen-essential-in-enabling-bc-to-meet-decarbonization-goals-study-says/; https://www.itm-power.com/news/itm-power-mitsui-chiyoda-and-bc-hydro-in-300mw-power-to-gas-study; https://www2.gov.bc.ca/assets/gov/business/natural-resource-industries/reports/centralised_renewable_hydrogen_production_in_bc_final_report.pdf; https://www2.gov.bc.ca/assets/gov/government/ministries-organizations/zen-bcbn-hydrogen-study-final-v6.pdf; https://www2.gov.bc.ca/gov/content/governments/organizational-structure/ministries-organizations/ministries/energy-mines-and-petroleum-resources/ministry-reports; https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-transportation/resource-library/2019-hydrogen-pathways-enabling-clean-growth-future-canadians/21961

16. https://cafcp.org/sites/default/files/CAFCR.pdf; https://www.energy.gov/articles/department-energy-announces-50-million-commercial-truck-road-vehicle-and-gaseous-fuels-0; https://www.energy.gov/sites/prod/files/2019/07/f65/FY19%20MD-HD%20Truck%20selections%20table_0.pdf; https://www.energy.gov/eere/fuelcells/articles/energy-department-announces-notice-intent-issue-funding-opportunity-0; https://www.energy.gov/sites/prod/files/2019/09/f67/fcto-h2-at-scale-handout-2019.pdf; https://eere-exchange.energy.gov/Default.aspx#Foalde84bbd2f-e759-4a66-979d-bd4f82bdc1e4; https://www.energy.gov/articles/department-energy-announces-40-million-funding-29-projects-advance-h2scale

Jurisdiction	Key legal, regulatory and policy developments
INTERGOVERNMENTAL	
Clean Energy Ministerial (CEM)[17]	**May 2019:** At CEM10 (Vancouver Canada), the Hydrogen Initiative was launched to drive international collaboration on policies, programs and projects to accelerate the commercial deployment of hydrogen and fuel cell technologies across all sectors of the economy. The initial focus areas are hydrogen within current industrial applications, hydrogen technologies in transport and hydrogen in meeting energy needs of communities. The partnership is led by Canada, the United States, Japan, the Netherlands and the European Commission with participation from several other CEM countries.
G20/International Energy Agency (IEA)[18]	**June 2019**: Hydrogen was a central theme for Japan's Presidency of the G20. The G20 Energy ministers agreed to step up efforts to unlock the potential of hydrogen as a clean, reliance and secure source of energy. The IEA published a special report on "The Future of Hydrogen" at the request of Japan, as host of this year's G20. **December 2019:** A Hydrogen side event of the 2019 IEA Ministerial Meeting was held under the theme "Hydrogen: near-term priorities for governments and industry".
Hydrogen Energy Ministerial Meeting[19]	**October 2018:** Japan hosted the 1st Hydrogen Energy Ministerial Meeting with the release of the Tokyo Statement, which consists of four pillars of measures for hydrogen research, development, demonstration, and deployment. **September 2019:** Japan hosted the 2nd Hydrogen Energy Ministerial Meeting with over 30 countries and organizations attending. The Global Action Agenda of a Tokyo Statement was released setting out actions to scale up hydrogen. One aspirational goal is "10 million hydrogen powered systems" and "10 thousand Hydrogen Refueling Stations (HRS)" in 10 years ("Ten, Ten, Ten"). The International Renewable Energy Agency (IRENA) published the report "Hydrogen: A Renewable Energy Perspective" for this meeting.

17. http://www.cleanenergyministerial.org/news-clean-energy-ministerial/countries-launch-new-international-effort-hydrogen-help-achieve; http://www.cleanenergyministerial.org/initiative-clean-energy-ministerial/hydrogen-initiative

18. https://www.g20karuizawa.go.jp/assets/pdf/Communique.pdf?v=190618; https://www.iea.org/hydrogen2019/ ; https://iea.blob.core.windows.net/assets/872dce43-915b-4563-8523-2ae382dbf570/ChairsSummary--HydrogenSideEvent.pdf

19. https://www.meti.go.jp/english/press/2018/1023_007.html; https://www.meti.go.jp/press/2018/10/20181023011/20181023011-5.pdf; https://h2em2019.go.jp/en/; https://h2em2019.go.jp/summary/summary_en.pdf; https://www.irena.org/publications/2019/Sep/Hydrogen-A-renewable-energy-perspective

Baker McKenzie's Hydrogen Team

Baker McKenzie is investing in order to provide a market-leading package of services to companies that wish to invest into hydrogen energy and develop their hydrogen business.

A Truly Global Team

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Suggestions for Further Reading

General information about hydrogen energy, production and consumption:

B. Parkinson, P. Balcombe, J. F. Speirs, A. D. Hawkes and K. Hellgardt (2019). "Levelized cost of CO_2 mitigation from hydrogen production routes" Energy Environ.
Sci., 2019, 12, 19-40.

International Energy Agency (2019, June). The Future of Hydrogen.
https://webstore.iea.org/the-future-of-hydrogen

On the higher cost of a "electricity-only" decarbonization path:

Bothe, David et al. (2017). "Der Wert de Gasinfrastruktur Für die Energiewende in Deutschland".
https://www.frontier-economics.com/media/2260/der-wert-der-gasinfrastruktur.pdf
Site in German.

Bründlinger, Thomas et al. (2018). "dena Study Integrated Energy Transition".
https://www.dena.de/en/topics-projects/projects/energy-systems/dena-study-integrated-energy-transition/

Eurogas (2018). "Eurogas Scenario Study with PRIMES".
https://eurogas.org/website/wp-content/uploads/2018/05/Eurogas_infographic_20180502b.pdf

Terlouw, Wouter et al. (2019). "Gas for Climate".
https://www.gasforclimate2050.eu/files/files/Navigant_Gas_for_Climate_The_optimal_role_for_gas_in_a_net_zero_emissions_energy_system_March_2019.pdf

On hydrogen's role in the power system:

Chehade, Z. et al. (2019), "Review and analysis of demonstration projects on Power-to-X pathways in the world", International Journal of Hydrogen Energy, in press.

Kippers, M. J., J. C. De Laat and R. J. M. Hermkens (2011), "Pilot project on the hydrogen injection in natural gas on island of Ameland in the Netherlands", International Gas Union Research Conference 2011.

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