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Baker Hughes

Hydrogen: Separating hype from reality

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Hydrogen's promise and challenges

Perhaps no element holds more promise for decarbonization than hydrogen. With pressure on both public and private entities to meet ambitious emissions goals, there is a distinct buzz around hydrogen and the accompanying technologies required to develop and deploy the element at scale. It's no wonder that global hydrogen supply from electrolyzers could reach more than 8 metric tons (Mt) by 2030.[1]

The promise of hydrogen lies largely in its natural advantages. Its chemical properties mean it can be used to store and deliver a tremendous amount of energy, acting as both a fuel and a storage system for energy. In short, hydrogen has the potential to serve as an easily accessible, clean source of energy that can meet both the demands of a growing global economy and the demands of international climate ambitions.

The deployment of hydrogen technologies has the potential to transform power generation, abate industrial emissions, and even play a potential role as a consumer fuel. For example, light-duty highway vehicles using hydrogen could result in a 90% reduction in emissions over today's gasoline vehicles. In specialty vehicles, using hydrogen could result in more than a 35% reduction in emissions over current diesel and battery-powered lift trucks.[2] And global hydrogen production capacity is forecast to expand to meet growing demand; estimates suggest production could double over the next decade.[3]

However, while hydrogen could be a crucial piece of the global energy puzzle, several factors will influence how large a role hydrogen will play in the coming energy transition. This starts with how hydrogen is produced.

The colors of the hydrogen rainbow

Hydrogen has been used in the energy sector for over six decades, and it is already a fully realized part of the current energy mix. In fact, hydrogen demand stood at 90 Mt in 2020, making it a significant part of the global energy sector. Much of the current hydrogen market is made up of brown hydrogen, created through coal gasification, and gray hydrogen, generated by steam reforming of natural gas.

While natural gas remains a safe, efficient, and accessible form of energy for hydrogen formation, emissions goals set out by regulators and international climate agreements mean the industry must transition towards alternative ways of creating hydrogen. In the immediate future the market is poised to move towards blue hydrogen, which is formed using hydrocarbons like natural gas but with carbon capture added to the process. The production of green hydrogen, which is formed using renewable energy like solar and wind power, is increasingly positioned to represent a growing share of the hydrogen market as technology develops. Sitting between blue and green is turquoise hydrogen, a novel approach to splitting methane into hydrogen and solid carbon. In this case, natural gas is purely a feedstock for the methane and the whole process is driven by electricity versus combustion. Additionally, the solid carbon output can be used in a variety of industrial applications such as construction, transportation, and agriculture.

The significant existing market for hydrogen also means long-established technologies associated with hydrogen production and utilization will play a key role in the transition to blue, turquoise, and green hydrogen. In fact, Baker Hughes has nearly 60 years of handling hydrogen-rich content across applications, beginning with a reciprocating compressor for hydrogen back in 1962. Now the company has more than 2,000 hydrogen compressors installed globally and is able to cater to all forms of hydrogen — from gray to green.

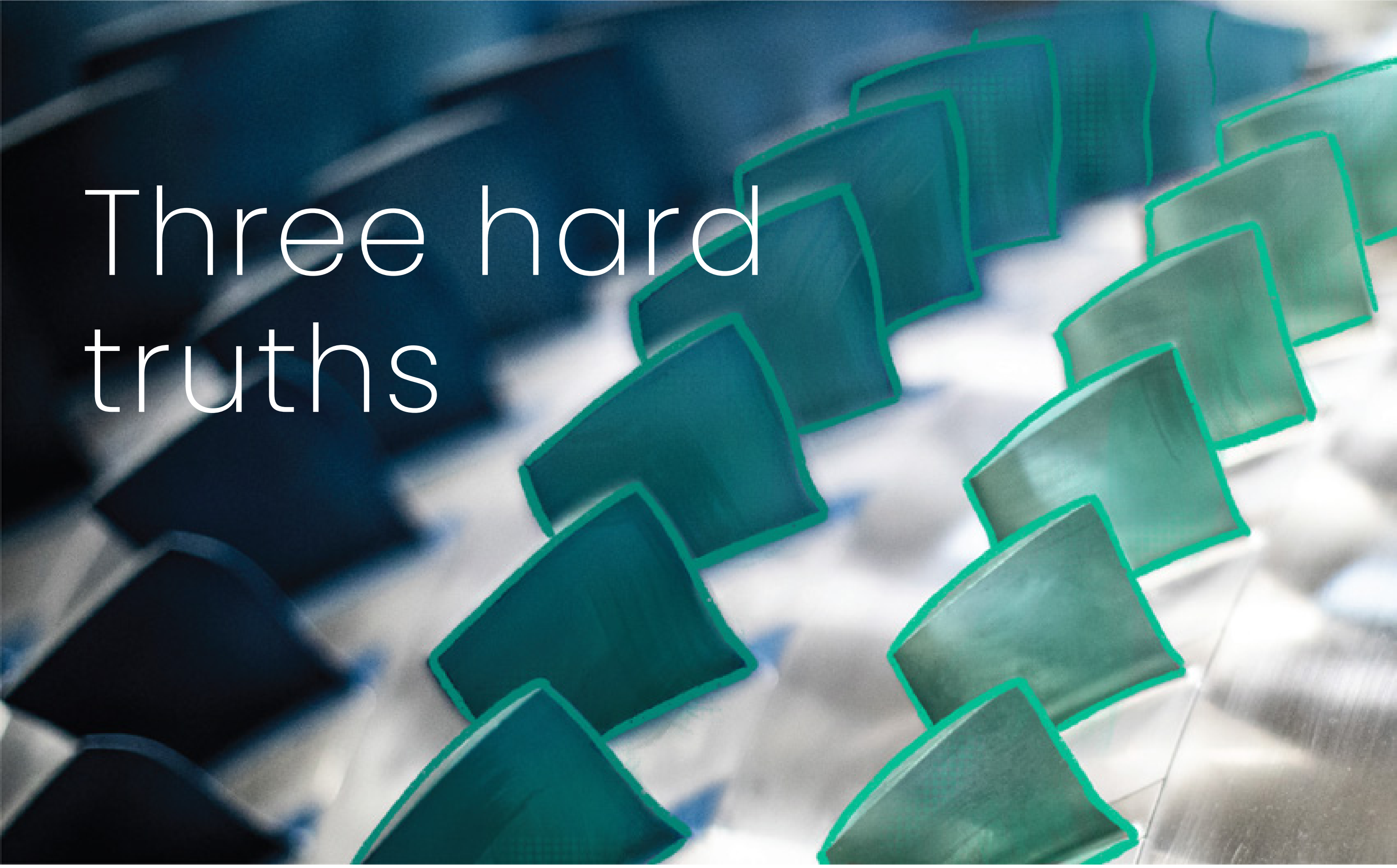
However, even with the benefit of a history of innovation, less carbon-intensive hydrogen production will not scale up overnight. Blue hydrogen is promising in the near-term but is reliant on both the effectiveness and availability of carbon capture technologies (See CCUS Feature Report) and turquoise hydrogen is reliant on continued technological innovation and settling the regulatory classification of the solid carbon output.[19]

Finally, green hydrogen has its own challenges in becoming a true long-term solution. While the production of green hydrogen will, in theory, become more cost competitive as the price of renewable energy continues to fall, in practice green hydrogen systems have yet to be developed at scale to become economically sustainable.

"Blue and turquoise hydrogen provide an interesting opportunity in the short and medium term, however, it will require continued investment in natural gas carbon recovery and also the development of the next generation of turquoise technologies."

Rod Christie
Executive Vice President, Turbomachinery & Process Solutions
Baker Hughes

Three hard truths



The current challenges facing both green and blue hydrogen point to some larger, hard truths that the world must confront before hydrogen assumes a prominent role in the global energy transition.

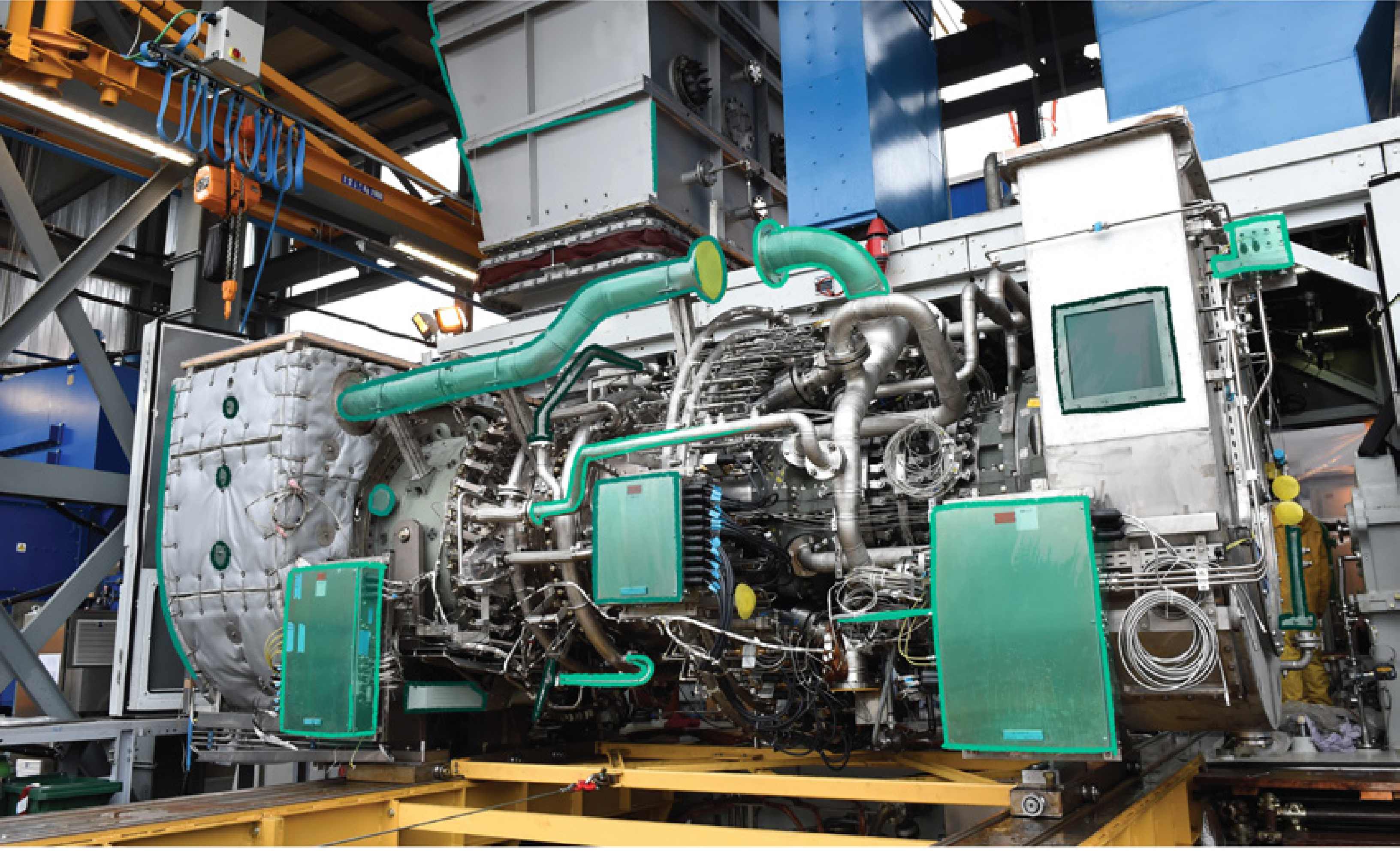
The first is that the cost of green hydrogen production must come down precipitously. According to S&P Global, the cost of producing hydrogen from renewables will need to fall by about 50% by 2030 to make green hydrogen a viable alternative to conventional fuels.[5] Significant investment will be required to bring costs down. Fortunately, both public and private entities appear committed to the task. More than 50 countries have already issued or are preparing a national hydrogen strategy.[6] Many of these strategies are explicitly focused on supporting technology and infrastructure developments designed to reduce the cost of hydrogen. For example, the United States Department of Energy recently announced an "energy earthshot" – a framework to increase investment and tech deployment – aimed at bringing the cost of green hydrogen down to $1 per kilo by 2030.

1st truth

However, the drive to reduce the cost of both green and blue hydrogen is moot if we don't solve for the second hard truth: **A large amount of infrastructure will be needed to allow for the increased utilization of hydrogen.** If hydrogen is produced somewhere other than the point of use, it must be transported. Transporting hydrogen can take several different forms: it can be moved in gaseous form in high-pressure containers, liquefied and transported in insulated containers, or even processed into ammonia for transportation via existing pipelines and distributed networks. In addition, because hydrogen can be volatile, there are significant safety concerns associated with its transportation as well as its use.

One of the most economical forms of transport for pure hydrogen is via pipelines. However, to use existing gas pipeline infrastructure, extensive retrofitting is necessary. Hydrogen requires advanced compression to increase its gaseous density for efficient transport, and its corrosive nature means using advanced materials to prevent metal embrittlement in the existing infrastructure. These differences will require a localized equipment upgrade across the current infrastructure, ranging from pipelines to compressors to gas turbines. Another area of investment will be the development of a usage infrastructure. A network of filling stations will be necessary to use hydrogen as an alternative energy source in the transportation industry. To make hydrogen available across the commercial transportation sector, countries will have to make significant up-front investments to augment what is currently a fledgling network of filling stations. In addition, fueling trucks and trains via large refueling stations will require new tech, such as new compression technology.

2nd truth



Baker Hughes NovaLT™12 gas turbine

We believe, with the right level of investment today, the hydrogen market could gain traction as early as 2025 and make significant contributions to the global energy mix within 10-15 years.

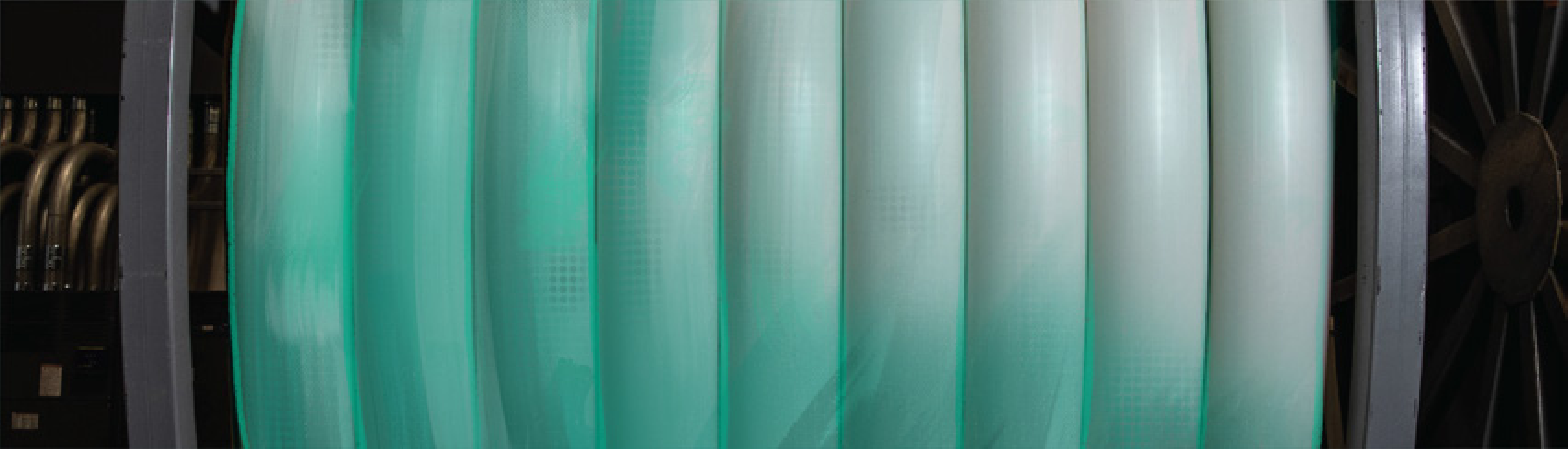
The third hard truth is that hydrogen is not a near-term fix for global greenhouse gas emissions. Over the next decade, hydrogen will play an increasing role in the energy mix, but will still remain a relatively small proportion relative to natural gas.

The largest barriers facing hydrogen are the costs associated with production and the necessity of overhauling existing transportation infrastructure to enable direct consumer applications. We will need a combination of sustained investment, innovative development of applicable technologies, and strategic partnerships right now for hydrogen to fulfill its promise tomorrow. Hydrogen has long been considered "the next big thing," but investment to turn the hype into reality has lagged. We believe that the right type of investment today means the hydrogen market will begin to gain real traction as early as 2025 and make significant contributions to global energy within 10 to 15 years.

3rd truth

Lower costs pave the way for greater adoption

The cost of hydrogen has not only come down rapidly in recent years, but it is also projected to continue dropping. For example, in the European transportation sector, the price of hydrogen is expected to halve from 10 euros/kilo to 5 euros/kilo over 15 years. In other sectors, the price could fall even more significantly over the same period.[17]



Baker Hughes composite flexible pipe

Tackling the hard truths

So, what's necessary to make hydrogen an important part of the emerging energy mix? First, steps need to be taken to confront the largest barrier: cost.

The scale at which green hydrogen is produced and where production occurs play an important role in lowering costs. Creating economies of scale by producing hydrogen near industrial clusters – geographic areas where industries that can utilize hydrogen are co-located – not only provides opportunities for scaling, but also for sharing risk and optimizing demand.

Industrial clusters are already a major part of hydrogen utilization strategy in China and Europe. A good example of the industrial cluster strategy comes from the UK, where the government is setting up industrial hubs as a means of achieving its target of net-zero carbon emissions by 2050. One of the most ambitious is the HyNet Integrated Industrial Hub in Northwest England and North Wales.[7] The project is made up of several different elements, including upgrades to existing facilities as well as the development of new infrastructure. It will eventually incorporate both blue and green hydrogen production, a hydrogen-powered train network, local industrial hydrogen users, hydrogen blending for home and business use, and carbon storage facilities.

But the industrial cluster strategy has limitations in some other parts of the world. For example, areas with less access to water may find it more difficult to use the cluster strategy for hydrogen development because the processes to create net-zero hydrogen require significant amounts of water. This means there are significant parts of the Middle East, North Africa and other regions with scarce water resources where hydrogen production for industrial clusters may prove to be unsuitable.

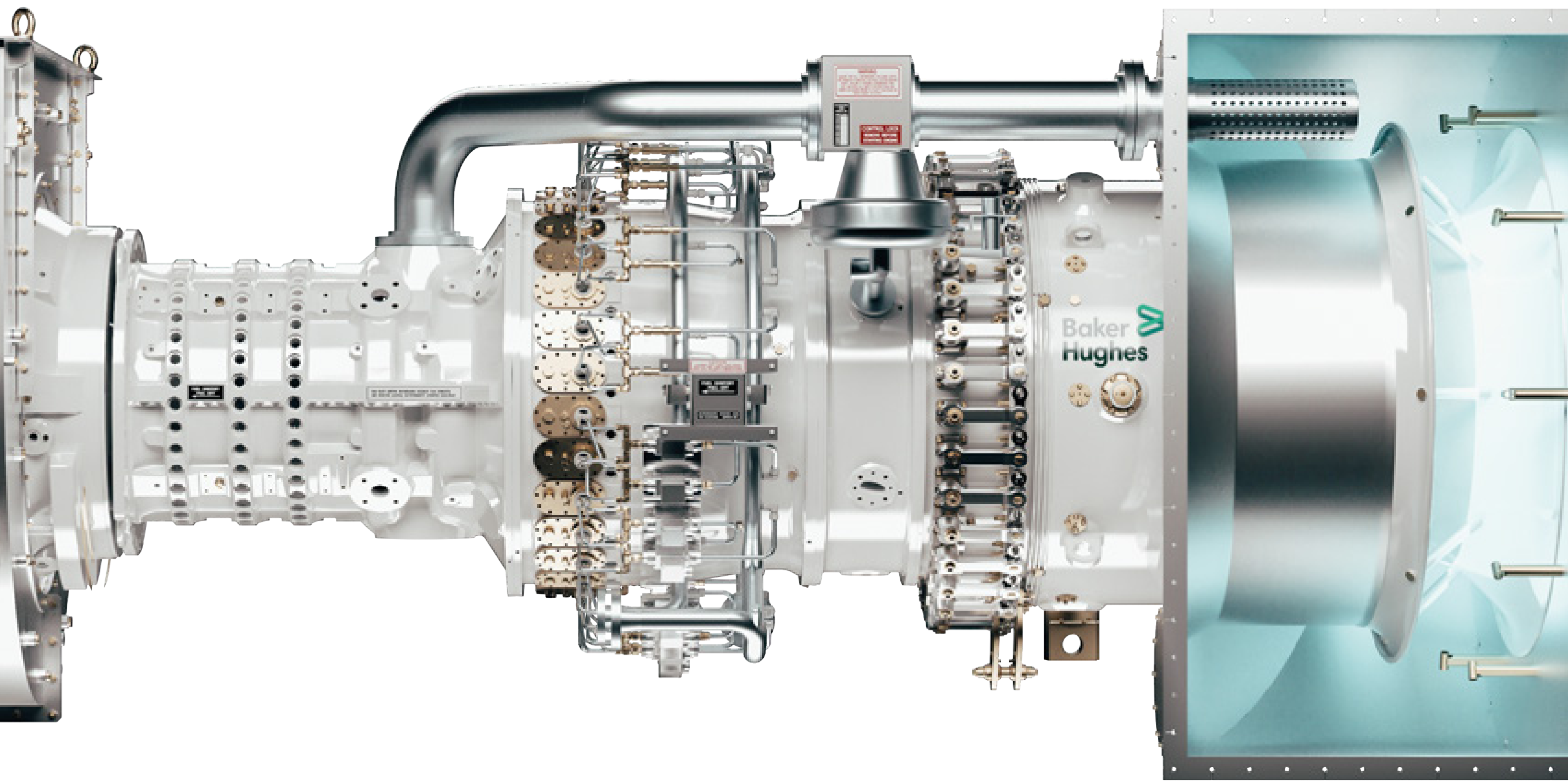
Still, in places with access to both the required natural resources and investment capital, clusters allow for savings by funding large green hydrogen facilities that can be used cooperatively across industries.

At the same time, technological advances also hold potential to reduce the costs in several areas. Improvements in electrolyzer units and better hydrogen-driven turbines will play key roles in reducing the end price of hydrogen. Hydrogen development will also depend on the continuing advancement of material science. Because of its corrosive nature, transporting and storing hydrogen, even for use in industrial clusters, will still come with a significant cost. Innovations in material science, especially new developments in noncorrosive materials made from advanced composites, will help address this issue. Non-metallic advanced composite pipe has several advantages beyond its anticorrosive properties. Lower installation and connection times, reduced installation costs and the elimination of onsite welding all mean that nonmetallic pipe will be key to curtailing costs in hydrogen transport and storage. Non-metallic solutions also have the added benefit of being less carbon intensive.

"The cost of blue and green hydrogen remains a stumbling block, but a combination of technological development and savvy investment inputs will help bring costs down over the next decade."

Raimondo Giavi
Vice President, Hydrogen
Baker Hughes

Historical tech development and hydrogen's future



Baker Hughes NovaLT™12 gas turbine

Fortunately, there is a history in the energy sector of innovations catching up with needs, lowering costs and bringing down barriers to widespread adoption.

Hydrogen fuel cell technology dates to 1839, but the first fuel cells didn't produce enough electricity to be useful. It took until 1959 to develop a hydrogen fuel cell that could power a welding machine. Now not only are fuel cells increasingly efficient, but other developments in hydrogen are making exponential leaps. The first hydrogen turbines were small and operated on a low percentage of hydrogen.

Now Baker Hughes has gas turbines up to 16MW that run on 100% hydrogen.[8]

Recent developments in electrolyzer technology also have the potential for significant gains in efficiency. While there are two primary types of electrolyzers currently on the market – alkaline and proton-exchange membrane (PEM) – there are a number of emerging electrolysis technologies in the development phase such as solid oxide electrolyzer cells (SOEC). Moreover, the existing electrolyzer types have become much more efficient in recent years.

"The pace of technological development across the hydrogen space will be a key part of making hydrogen an important part of the energy transition. But new tech isn't enough. We must incubate existing technologies and accelerate adoption to drive these new developments in the coming years."

Luca Maria Rossi
Vice President, New Frontiers
Baker Hughes

Both technological developments and economies of scale reduced capital costs of hydrogen projects by up to 75% in the past several years.[9]

Such developments are playing a part in driving hydrogen's gains in cost competitiveness. Today, the production of gray hydrogen in parts of the European Union is down to 1.5 euro a kilo, with blue hydrogen around 2 euro a kilo.[10] Further technological advancement in all aspects of production and utilization will be necessary to address costs and incidental methane emissions from blue hydrogen. However, as more research and development dollars go into hydrogen and more tech is deployed, costs and methane emissions will continue to fall. Based on current trajectories, Bloomberg New Energy Finance recently estimated that many parts of the world could deliver green hydrogen at a cost of as low as $2 a kilo by 2030 and $1 a kilo by 2050.

Hydrogen tech development is speeding up

Hydrogen technologies are almost 200 years old, but only in recent decades has hydrogen become practical as a fuel. Now, as the pace of technological developments accelerate, hydrogen is poised to be an important part of the current energy transition.

1800 First electrolyzer

1839 First fuel cell is conceived

1959 Demonstration of five-kilowatt fuel cell that could power a welding machine

1962 Baker Hughes develops its first hydrogen reciprocating compressor

1966 Baker Hughes develops its first centrifugal compressor for a hydrogen recycle application

1990 First solar-powered hydrogen production plant produces less than a metric ton of green hydrogen a day

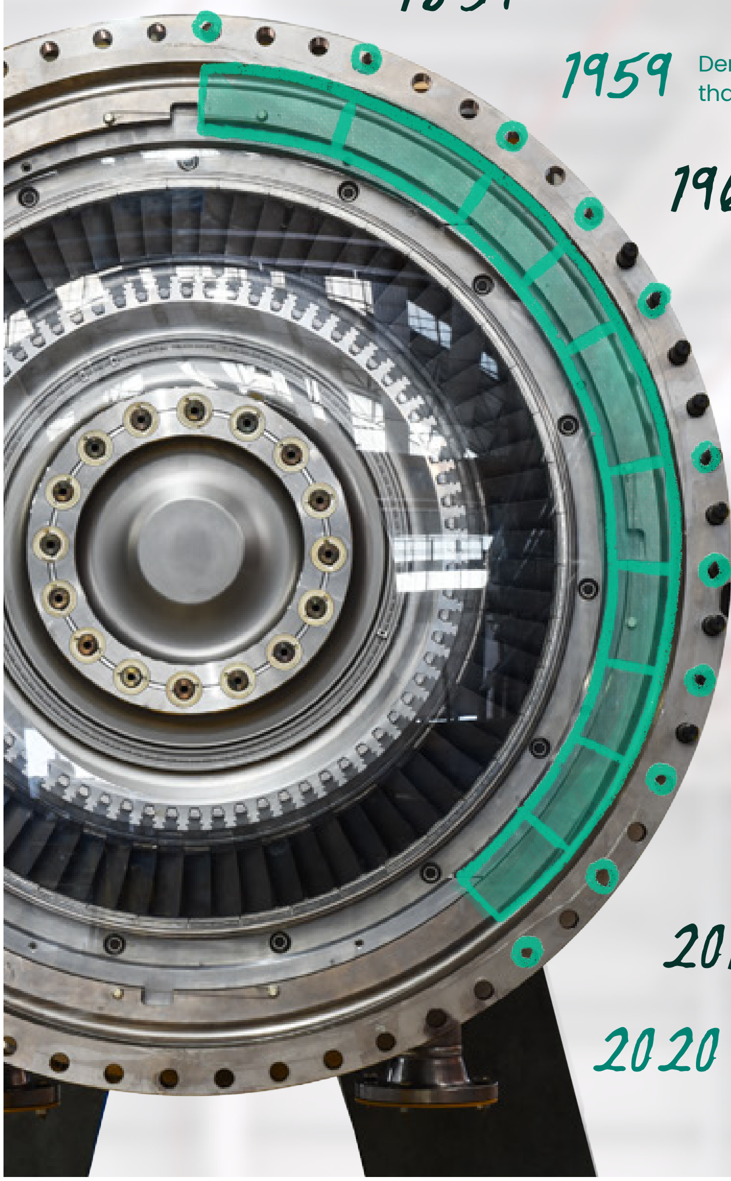
2008 Baker Hughes develops first turbine to run on 100% hydrogen

2013 First commercial 2-megawatt power to gas installation comes online

2017 First joint venture to mass produce advanced hydrogen fuel cell systems in auto industry

2019 Plans for a 20-megawatt electrolyzer plant announced

2020 New green hydrogen plant announced in Saudi Arabia that will use 5 gigawatts of solar and wind energy



Baker Hughes NovaLT™16 gas turbine

The future of hydrogen infrastructure

There are a number of cost levers along the hydrogen value chain. Among the most important of these is the cost of transportation, distribution, and storage. Cost models for each of these elements are still in their infancy, which means even the best cost estimates remain rough. However, much of the uncertainty stems from the large number of potentially transformative technologies that stakeholders are currently exploring. For example, Baker Hughes is exploring the utilization of traditional reservoir technologies to enable large-scale underground hydrogen storage. When large-scale underground storage becomes feasible, it could completely change the cost dynamic for hydrogen projects.

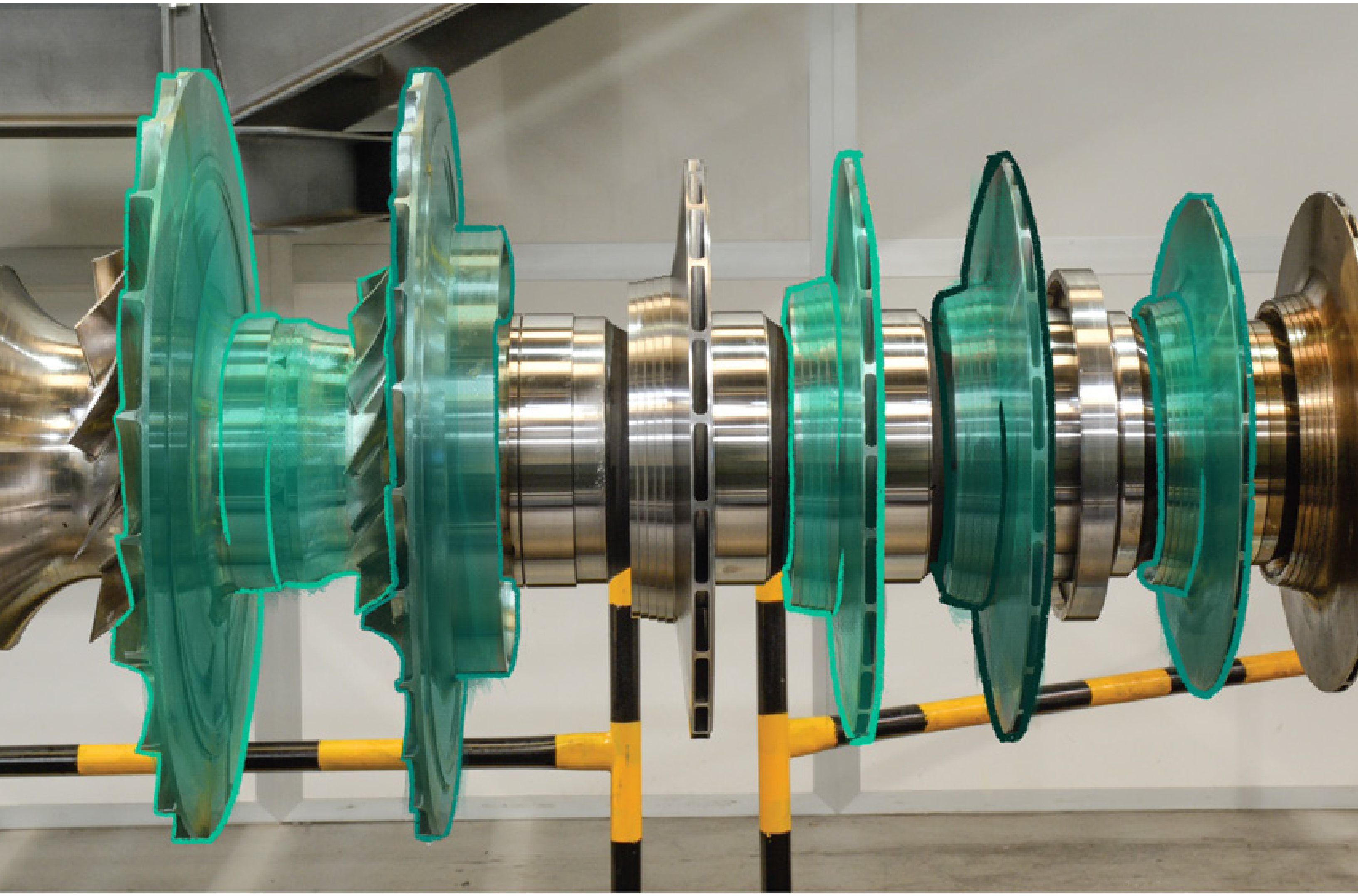
As with the development of hydrogen technology, historical examples provide a possible model for how hydrogen transportation and storage infrastructure may develop. Specifically, the story of natural gas infrastructure provides a potential blueprint for how hydrogen infrastructure will advance.

As recently as the 1950s natural gas was almost universally dismissed as a nuisance. The first step to commercializing gas was injecting it into fields to improve the production of oil, but eventually the energy industry recognized natural gas's potential as a cleaner fuel. Infrastructure to take advantage of the emerging fuel source was embraced by European governments.

In addition, technological advances like liquefaction played an essential role in the development of gas as a viable cleaner energy source. The combination of new technology and users committed to infrastructure development helped make natural gas a viable element of the global energy mix over a relatively short period of time.

Natural gas pipelines are also going to be an important element in the development of hydrogen infrastructure. The EU has announced its commitment to developing a "European Hydrogen Backbone" to connect industrial clusters to a 6,800 kilometer network largely made up of converted natural gas pipelines. But repurposing natural gas pipelines for hydrogen, whether in Europe or elsewhere, will involve valve replacements, adapted or new compressors, and new strategies and technologies to reduce the embrittlement risk associated with transporting hydrogen through pipelines built for gas.[11] There are potentially straight-forward solutions to these issues. A noncarbon steel liner could be a cost-effective solution for upgrading a pipeline network. And, in many cases, these technologies may not even need to be specific to hydrogen transport. For example, Baker Hughes' High Pressure Ratio Compressor (HPRC), a high-speed rotor compressor with high-performance stages can be used for a variety of applications, including hydrogen. This advanced hydrogen compression technology is currently being deployed at the NEOM carbon-free hydrogen project in the Kingdom of Saudi Arabia.

Another potential infrastructure solution is converting hydrogen to ammonia for the purposes of transportation. Ammonia is created when hydrogen is combined with nitrogen, and because ammonia is much easier to liquefy than hydrogen, it is also easier to store and safer to transport. As a result, ammonia can be employed as an effective carrier for hydrogen delivery while also requiring less infrastructure investment, because ammonia can be transported through marine shipping to key terminals and ports around the world. There are already more than 100 ports worldwide equipped with ammonia trading facilities.[12] Because an extensive ammonia delivery system already exists, fewer inputs will be necessary to move ammonia. When combined with ammonia's ability to serve as a practical feedstock, it's unsurprising that several large ammonia producers have already announced plans to make green hydrogen. In response, the global ammonia market will reach $89.6 billion by 2026.[18]



Baker Hughes high pressure ratio compressor (HPRC)

Reasons to believe in a bright future for hydrogen

These new developments in tech and infrastructure are some of the reasons policy makers across the globe are bullish on hydrogen. The British government announced that $1.25 billion of funding will be available to support hydrogen projects in Britain by 2030.[13] Germany pledged 9 billion euros for hydrogen support over the next decade, and in the United States, President Biden directed that $15 billion be allocated for hydrogen projects in his infrastructure plan.[14 15] Individual states in the U.S. are also signaling their support. In its 2021 budget the state of California earmarked $1.5 billion for electric and hydrogen vehicles.[16]

Usage of hydrogen appears promising in the medium term, especially in commercial transportation and possibly in aviation. While fueling planes with hydrogen will likely require utilizing hydrogen as ammonia or synthetic fuels based on hydrogen, new technologies are changing costs so quickly that such a development may be possible in the medium term.

In addition, new developments in hydrogen-driven turbines hold promise for ramping up hydrogen's contribution to the power system. Baker Hughes has developed commercial turbines that run on a mix of 10% hydrogen, and over 70 projects exist worldwide that use frame and aeroderivative gas turbines for a variety of fuel mixtures with hydrogen content. There are also gas turbines that can run on 100% hydrogen, and Baker Hughes has a tech development plan that will have turbines running on 100% hydrogen with Dry Low NOx combustion technology on a commercial scale by 2025.

Where we go from here

Baker Hughes BCL vertically split compressor

We believe that hydrogen is a critical part of the energy transition ecosystem. In fact, it is essential to meeting the goals of the Paris Climate Agreement.

However, for hydrogen to fulfill its potential, there are a number of challenges we must collectively address. We need to enact policies that ensure hydrogen remains safe, accessible, and economically viable as it displaces more carbon intensive fuel sources.

A large part of realizing hydrogen's potential involves incentivizing the use of carbon capture associated with the production of blue hydrogen. In addition, further development and deployment of technologies that enable production, transport, and utilization of both blue and green hydrogen will play a key role in addressing both access and cost.

But this will not happen automatically. It will require continued government support for fundamental R&D and the creation of industrial hubs to drive the economies of scale necessary to bring these technologies to market. It will also require strategic partnerships that leverage the innovation and organization of the private sector. Corporations with a proven track record of advancing complex projects will play a central role in commercializing and deploying hydrogen at scale.

Source Information:

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Endnotes