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HEADING FOR HYDROGEN

The oil and gas industry's outlook for hydrogen, from ambition to reality

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The future of hydrogen energy is wrapped up with the future of natural gas, renewable energy and carbon capture and storage (CCS). This yields useful synergies, but also political, economic and technical complexity. Nevertheless, our survey of more than 1,000 senior oil and gas professionals suggests a more certain future for hydrogen and that the time is right to begin scaling the hydrogen economy.

Hydrogen has been overhyped in the past,[1] so why is 2020 any different? It comes down to several interrelated trends.

A clear direction

Societies globally are aligning on the need to act faster to fight climate change. Over the past few years, nations including Germany, France and the UK[2] have committed to net zero targets for carbon dioxide (CO_2) emissions, and major oil and gas companies including Shell, BP, Eni, Equinor, Total, and Repsol[3] have committed to reducing or eliminating their emissions.

Our decade-long study of the oil and gas industry has captured a swing towards low carbon energy over recent years. For example, among the senior oil and gas professionals we surveyed,[4] there has been a significant rise in those reporting that their organization is actively adapting to a less carbon-intensive energy mix – up from 44% in 2018, to 51% in 2019, and up again to 60% in 2020. The proportion expecting to increase or maintain investment in decarbonization also rose from 54% for 2019 to 71% for 2020.

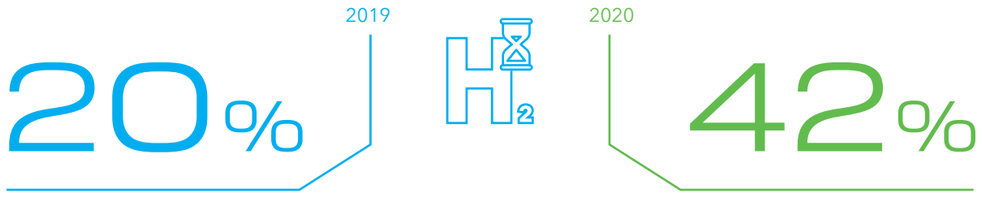
However, much has changed since we asked more than 1,000 senior oil and gas professionals in the fourth quarter of 2019 about their confidence and priorities for the year ahead. Nobody could have predicted the giant oil price shock that lay around the corner, as the COVID-19 pandemic destroyed global oil demand, and oil stores around the world rapidly filled up with excess supply.

Oil and gas operators have reacted to the crisis by slashing capital expenditure and rapidly reducing operating costs, but it seems that their strategic intentions for a low carbon future will remain largely unchanged. Indeed, some oil majors, such as BP and Shell, have already confirmed this.[5] After all, the transition to clean energy is a multi-decade-long project, and hydrogen has an increasingly significant part to play.

Hydrogen has surged up the priority list at many oil and gas organizations as part of broader decarbonization efforts and strategies to build or acquire[6] clean-energy businesses.

Remarkably, one in five (21%) of the senior oil and gas professionals we surveyed at the end of 2019 said that their organization was already actively entering the hydrogen market. Proportionally, twice as many said their organization intends to invest in hydrogen in 2020 (42%) as in 2019 (20%). Investment priorities may have changed for 2020, but this shows a clear trend towards hydrogen.

Extent to which respondents expected their organization to invest in or develop hydrogen in the year ahead



* Data for 2020 is based on a survey carried out in the fourth quarter of 2019. While priorities may have shifted for 2020, the drivers of the trend towards hydrogen remain in place.

A long-term project

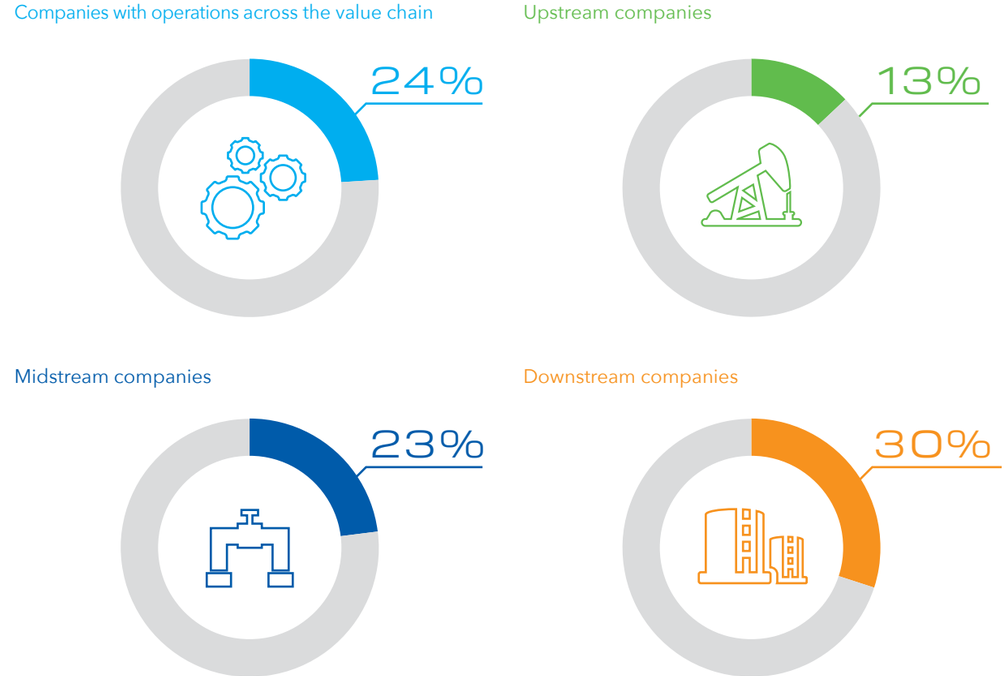
About half of the senior oil and gas professionals we surveyed (52%) said they expect hydrogen to be a significant part of the energy mix within just 10 years.

If they are right, there will need to be coordination of many organizations and governments that addresses key dependencies and balances a number of short- and long-term priorities. Today, the use of hydrogen as an energy carrier is still in its infancy and needs to scale up before it can play a significant role in the global energy system.

Crucially, there is already significant annual demand for hydrogen – just not for use as an energy carrier. In 2018, the International Energy Agency (IEA) estimated hydrogen demand at about 70 million tonnes, more than 99% of which was for industrial feedstock, oil refining, steelmaking, and chemical production (e.g. making ammonia or methanol).[7]

Almost all hydrogen is currently produced from natural gas or coal, which in 2018 emitted about 830 million tonnes of CO_2 – comparable to the combined annual emissions of Indonesia and the UK.[8] But that is set to change. Hydrogen's profile is rising among oil and gas companies as a path to decarbonization, meaning that the focus will be on producing low-carbon hydrogen, and at scale. (See 'Ecological and economical hydrogen?' on page four)

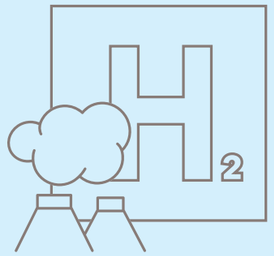
Extent to which respondents agreed that their organization is actively entering the hydrogen market



1 Fuel-cell producers jump on new hydrogen 'hype cycle', *Financial Times*: https://on.ft.com/3d2jTAt
2 The Net-Zero Challenge, *World Economic Forum*: https://bit.ly/2SorKR3
3 Look beyond European oil majors' steps to net zero, *Financial Times*: https://on.ft.com/3aPVgFx
4 'New Directions, Complex Choices: The outlook for the oil and gas industry outlook in 2020, DNV GL': https://bit.ly/3bTVtJo
5 Climate change is off the oil industry's agenda - or is it? *The Times*: https://bit.ly/2VSJuGp
6 Shell Leads Big Oil in the Race to Invest in Clean Energy, *Bloomberg*: https://bloom.bg/2Wihqv8
7 'The Future of Hydrogen', *IEA*: https://bit.ly/2zHrqWV
8 *Ibid*.

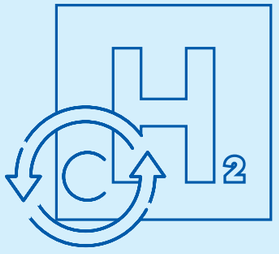
Ecological and economical hydrogen?

Hydrogen can be produced in several ways, but if it is going to help in the battle with climate change the process will have to be decarbonized.



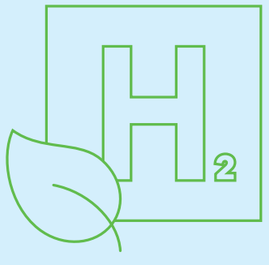
Grey & brown hydrogen

- Grey hydrogen is typically produced from natural gas in a process called steam methane reformation
- Brown hydrogen is produced from the gasification of coal (or lignite)
- These are by far the most dominant methods in use today
- They are relatively cheap, but emit large amounts of CO_2.



Blue hydrogen

- Blue hydrogen is produced from fossil fuels (typically natural gas, but also coal), but emissions are dealt with using CCS technology
- With abundant natural gas and coal available, blue hydrogen could help to scale the hydrogen economy[9]
- However, this is dependent on wider adoption of CCS
- Blue hydrogen could act as a stepping stone from grey/brown to green hydrogen.



Green hydrogen

- Green hydrogen is produced by the electrolysis of water
- The process is powered by zero-carbon electricity (e.g. wind and solar power)
- It is clean, but is currently too expensive[10]
- The cost of electrolyzers and renewable energy is expected to fall over the next decade, making green hydrogen more viable
- Green hydrogen is the ideal long-term, low-carbon way to produce hydrogen.

9 Green hydrogen 'cheaper than unabated fossil-fuel H2 by 2030': Hydrogen Council, *Recharge*: https://bit.ly/2SlITMe
10 'Path to hydrogen competitiveness: A cost perspective', *Hydrogen Council*: https://bit.ly/35mRgLB

A path from grey to green

Its reliance on natural gas makes blue hydrogen a particularly appealing place to begin scaling the hydrogen economy.

According to DNV GL's Energy Transition Outlook 2020, natural gas will become the world's largest energy source in the mid-2020s, accounting for nearly 30% of the global energy supply in 2050.[11]

Natural gas and hydrogen can play similar roles within the global energy system, and the synergies between them – in application and infrastructure – will drive the hydrogen economy.

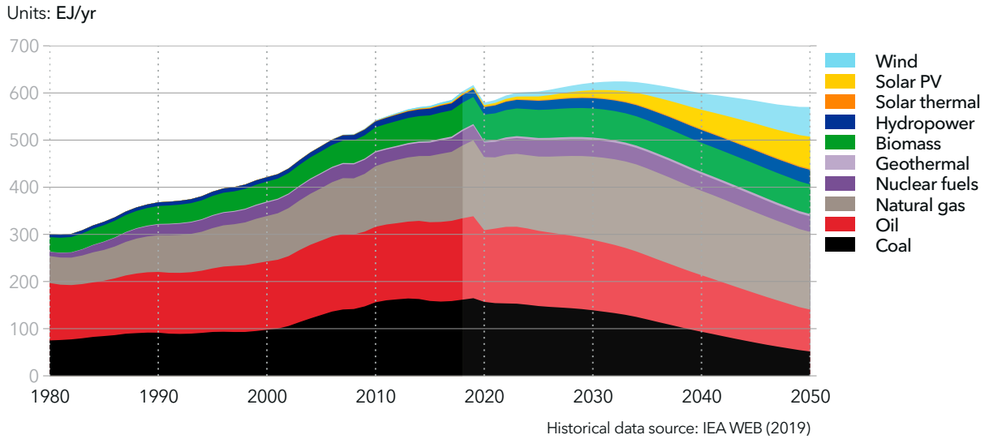
"We will ultimately move to a green hydrogen economy. But we are convinced that you can only make the step towards green hydrogen via blue hydrogen first."

Hans Coenen, vice president, corporate strategy and business development at Dutch gas network company, Gasunie

"This is because you can realistically only scale up to big volumes and large infrastructure with blue hydrogen, and so it can create a big enough market to then switch to green hydrogen more easily in the future," says Coenen.

Exploiting the synergies with natural gas is just one of the ways to make the hydrogen economy a reality. To get to the stage where societies and industry can enjoy the benefits of hydrogen at scale, all stakeholders will need to focus on four hydrogen "enablers": safety, infrastructure, CCS and policy.

World primary energy supply by source



Historical data source: IEA WEB (2019)

11 Energy Transition Outlook 2020, DNV GL: https://bit.ly/32sbFz2

Four enablers of the hydrogen economy

1) Safety comes first

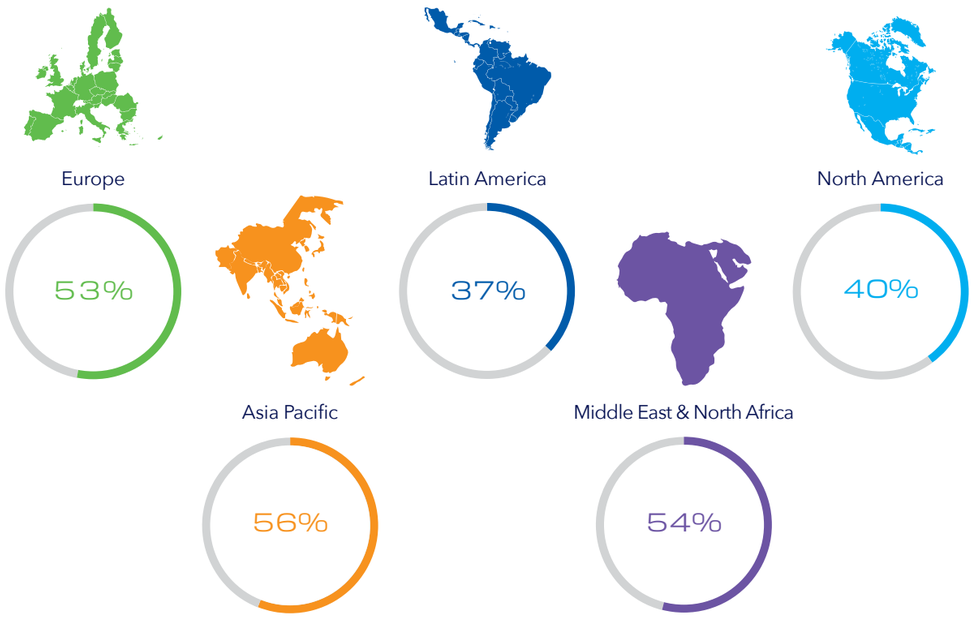
Hydrogen ignites with very low energy and has a wide flammability range, relative to familiar alternatives such as natural gas or petrol vapours. The dispersion behaviour is different to other gases, due to the small size of hydrogen atoms, and it is colourless, tasteless, and odourless. This means that specific sensors or odorization are required to detect it.

For hydrogen to gain broad acceptance and adoption – in domestic settings and for new applications beyond current industrial uses – industry and regulators will need to establish robust safety standards for each specific use case, just as they do for other potentially dangerous substances.

Work has already started. For example, gas network operators are collaborating to create guidelines for the introduction of hydrogen into natural gas networks.[12] Work is also underway, for example, to establish safety standards for hydrogen within homes,[13] determine minimum purity levels,[14] and explore small-scale, inner-city green hydrogen production.[15] This represents impressive progress towards wider adoption of hydrogen, but more is needed to give governments, industry, and the public confidence in its safety.

To manage the safety of hydrogen as an energy carrier, relevant stakeholders are undertaking pilot projects and employing a risk-based approach using safety modelling and experiments. Various oil and gas companies are following similar strategies, conducting research and development (R&D) into the safety, efficacy, and viability of hydrogen applications. In our survey, 17% of oil and gas companies are prioritizing hydrogen as an area for first or further R&D investment in 2020.

Extent to which respondents agreed that hydrogen will be a significant part of the energy mix within 10 years



12 'Industry collaboration supports the integration of renewable electricity by enabling hydrogen addition to natural gas', DNV GL: https://bit.ly/2WfGVgv
13 'Proving the safety case for hydrogen': DNV GL in *Gastech Insights*: https://bit.ly/2Wf5E4j
14 'DNV GL delivers a minimum purity standard for the future use of hydrogen in UK homes and businesses', DNV GL: https://bit.ly/3d1Yelw
15 'Heating Dutch homes with hydrogen', DNV GL: https://bit.ly/2WfH1on

2) Change through infrastructure

Whatever the application, the cost and technical challenges of hydrogen infrastructure will be significant. Even where existing infrastructure can be reused or repurposed, there will still be issues to resolve.

For example:

- Hydrogen may need to be operated at different pressures (or velocity) than natural gas/biogas
- Further research may be needed into whether hydrogen could have an adverse effect on materials (e.g. in pipes and valves)
- Various appliances would need to be converted or replaced (e.g. water heaters, compressors, pumps and sensors).

According to the Hydrogen Council, some USD280 billion in global investment will be needed between now and 2030 to fully realize hydrogen's role in the energy transition: roughly 40% would go into production; around 30% into storage, transport, and distribution; 25% into product development and manufacturing capacity; and the remainder into new business models.[16]

Many countries currently rely heavily on natural gas. One of the major benefits of hydrogen is that countries with extensive natural gas distribution infrastructure can continue to use those assets and avoid having to build electric substitutes.

One example is the potential introduction of a blend of hydrogen into national gas distribution networks. Exchanging just 5% of natural gas consumption for clean hydrogen would significantly boost hydrogen demand, which could spur further investment.[17]

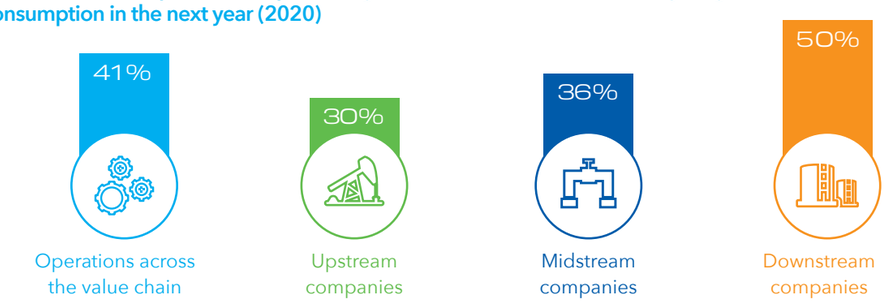
"The role of gas networks could be really important to kick-start broader deployment of hydrogen in society. If you can decarbonize the gas networks through hydrogen, then you can add this as part of a flexible, cost-effective decarbonization strategy."

Jørg Aarnes, global lead, low carbon solutions at DNV GL

It is difficult to use electrical substitutes in areas such as steelmaking and other heat-intensive industrial processes, jet-powered aircraft, and the ships, trains, and trucks that rely on the high torque of diesel engines. In future, some of these applications will be powered by natural gas, which is cleaner-burning than other fossil fuels but is still a major source of emissions. This is where hydrogen can again play a key role.

Significantly, end-to-end infrastructure developments are emerging. For example, Australia and Japan are collaborating on the Hydrogen Energy Supply Chain (HESC) project, which will convert coal into hydrogen in Australia for export to Japan.[18] The pilot emits CO_2, so currently produces brown hydrogen, but the commercial phase will include CCS, shifting to the cleaner blue hydrogen. The two countries are ideally placed for such a project: Japan has made hydrogen transportation central to its energy strategy but needs to develop supply lines;[19] Australia, meanwhile, has the natural resources needed to be a world leader in the production of blue – and ultimately green – hydrogen, along with the expertise needed to build large-scale energy projects and deliver to Asian markets.[20] The HESC will help to prove both the technical and business viability of new hydrogen supply chains.

Extent to which respondents expected significant increases in the use of hydrogen to decarbonize gas consumption in the next year (2020)



* Data is based on a survey carried out in the fourth quarter of 2019. While priorities may have shifted for 2020, the drivers of the trend towards hydrogen remain in place.

16 'Hydrogen scaling up', *Hydrogen Council*: https://bit.ly/2VNV3yk
17 'The Future of Hydrogen', *IEA*: https://bit.ly/2zHrqWV
18 'Construction begins on Australian hydrogen pilot project', *The Chemical Engineer*: https://bit.ly/2VTB8OR
19 'Momentum Builds for Hydrogen Fuel in Japan, Australia', *Scientific American*: https://bit.ly/2WbRG3d
20 'Australia's National Hydrogen Strategy', *COAG Energy Council*: https://bit.ly/3bV7Tk4

3) Carbon gets captured

Scaled production of blue hydrogen relies on scaled use of CCS. But CCS starts from a low base: the Global CCS Institute's CO_2RE database[21] shows only 23 large-scale CCS facilities in operation (capturing almost 40 million tonnes of carbon per year) or under construction.

DNV GL's Energy Transition Outlook 2020 forecasts that, under current regulatory frameworks, CCS will only begin to scale after 2035 (see chart), when carbon prices begin to approach the cost of implementing the technology.[22]

CCS is crucial to decarbonization. More than half of those we surveyed (55%) said that the oil and gas industry cannot decarbonize without greater uptake of CCS. A similar proportion (56%) believe that there will be a significant increase in CCS investments over the next five years as companies across the oil and gas value chain focus on contributing to national and international climate goals.

Once CCS is deployed at scale, blue hydrogen will be attractive to natural gas producers. It would allow all emissions from natural gas to be captured in bulk when producing blue hydrogen, instead of trying to capture emissions from millions of points of natural gas combustion in the distribution networks where they have less control over the carbon they produce.

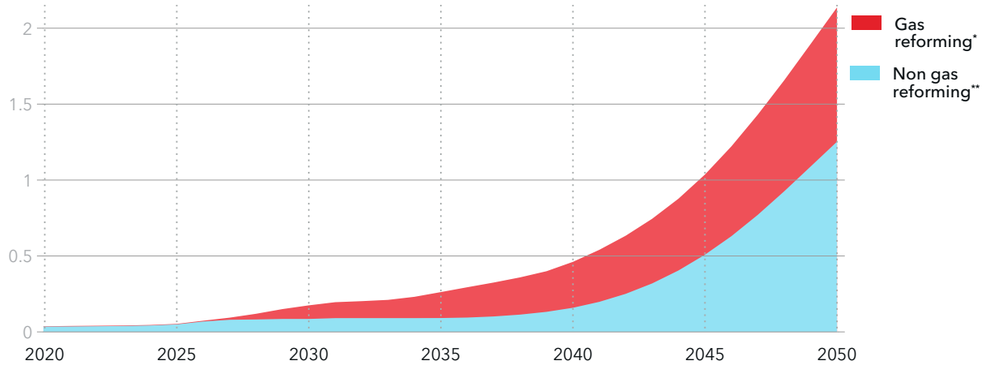
Today, however, it simply remains cheaper to release emissions than to capture them. So in competitive markets the strongest business cases do not include CCS. This seems to be true of the oil and gas industry: nearly three-quarters of respondents to our survey (73%) say that oil and gas companies will decarbonize only if it makes financial sense for them.

> "Large-scale uptake of CCS can happen if policymakers make bold decisions – the types of bold decisions that stimulated other clean technologies like solar and wind."
>
> **Liv Hovem,** CEO of DNV GL – Oil & Gas

Despite this, things have been moving forward in the past year, according to Ernst Axelsen, managing director of Technology Centre Mongstad, the world's largest facility for testing and improving carbon capture technologies. "The interest we are seeing is changing, with many organizations now eager to use CCS. There has always been interest, but now organizations are looking deeper into the technology and the business models, moving from more principles-focused discussions to talking about practical solutions and implementation."

World CCS capacity

Units: $GtCO_2/yr$



Source: Energy Transition Outlook 2020, DNV GL. *Gas reforming relates to the emissions captured in the production of blue hydrogen as an energy carrier. **Non gas reforming includes emissions captured in other areas such as gas-fired power plants, as well as in the production of hydrogen used as feedstock.

21 Global CCS Institute's CO_2RE database: https://co2re.co/
22 Energy Transition Outlook 2020, DNV GL: https://bit.ly/32sbFz2

Extent to which respondents agreed that there will never be a globally effective carbon price

In the research, more respondents than the previous year (62% compared with 56%), said the oil and gas industry should drive CCS adoption forward immediately, and not wait for government policies/incentives. However, while the technology to implement CCS is ready to go,[23] it is still hard to make the business case because there is not enough of an incentive (from government policies and regulations) for the world's largest polluters to use it.

"Government has a key role to play in driving CCS, but industry also needs to press forward," says Paul Denniff, network and safety director at UK gas distributor, SGN. "At some point CCS will become business as usual, but to build momentum we need the right regulatory and market environment which allows various players to come in to develop and progress new and innovative projects. While I'm pleased to say we're doing some ground-breaking work in the area, it's fair to say no one party can solve this challenge on their own."

It is a complex situation, with many stakeholders, but government policy is the only way to kick-start wider and faster CCS adoption. "To date, the fitting or retrofitting of CCS to power plants and industrial sources has only happened with government intervention," says Liv Hovem, CEO of DNV GL – Oil & Gas.

If bold decisions are taken on CCS, this could unlock significant opportunities for hydrocarbon and renewable energy technologies to work together to decarbonize the energy mix.

"Hydrogen has the potential to complement variable renewables during production lows or high demand, the same as natural gas currently does," Hovem adds. "It can even go beyond this, with surplus renewable energy being used to produce hydrogen, which can be stored as a gas for use in other applications."

Further, there is potential for stored hydrogen to be converted back to electricity when needed. "If the world is looking toward 100% renewable solutions for the electric grid, we will only get part of the way there with the recent introduction of lithium battery technology, even with the costs driven down by EVs," says Jason Goodhand, global energy storage lead at DNV GL.

In a recent study[24] by DNV GL on the seasonal storage required versus the hours of capacity in today's battery projects, hydrogen or hydrogen carriers were at the core of all the feasible solutions. "This conclusion is driving a revival in focus on green hydrogen solutions for the future," adds Goodhand.

Extent to which respondents believe "long-term opportunities for hydrogen produced from natural gas" was driving their organization's investment in natural gas or LNG

23 Full-scale CCS project in Norway, https://bit.ly/3bV8132
24 The promise of seasonal storage, DNV GL: https://bit.ly/3d2gvpk

Percentage of respondents who said their organization will invest in clean energy sources, by energy type, in 2019 and 2020

Hydrogen

2019 – 20%
2020 – 42%
108% increase

Solar thermal

2019 – 19%
2020 – 37%
91% increase

Solar PV

2019 – 24%
2020 – 44%
83% increase

Onshore wind

2019 – 24%
2020 – 44%
79% increase

Hydro-power

2019 – 15%
2020 – 25%
63% increase

Offshore wind

2019 – 40%
2020 – 63%
58% increase

Biomass/biogas

2019 – 27%
2020 – 35%
31% increase

Geothermal†

2020 – 19%

* Data for 2020 is based on a survey carried out in the fourth quarter of 2019. While priorities may have shifted for 2020, the drivers of the trend towards hydrogen remain in place.
** This question was only asked of the 51% (528 of the full sample of 1,031 respondents) who reported that in 2020 their organization would be increasingly focused on opportunities outside of oil and gas. Percentages reflect the proportion of these 528 respondents, not of the full sample.
† Question asked for the first time for 2020

4) Policy paves the way

Policy change will be vital if hydrogen is going to reach its potential as an energy carrier. And as we have seen, driving large-scale CCS uptake – such as by setting a globally relevant carbon price framework – is fundamental to this.

But it goes beyond that: If hydrogen is to be introduced more widely, public policies and corporate strategies need to align. This includes supporting applications across transport, homes, and factories, and in power generation and storage.

Use cases will create demand for hydrogen, and demand will lead to further investment, lower costs, greater acceptance, and the momentum needed to build sustainable supply chains. But to make use cases a reality, governments and inter-governmental organizations have to make more long-term policy commitments.

"Hydrogen is something that we're very excited about. We see its true potential. However, it's very capital intensive," says Elisabeth Brinton, executive vice president, New Energies at Shell. "This is where we need to really have governments work together, whether it's the EU block or other major governments, and offer a very clear and definitive decarbonization policy. That gives you the security needed to be able to invest more strongly."

A definitive national decarbonization policy can be extremely powerful. We saw in 2019 how the UK's net-zero 2050 legislation sparked immediate action, with hydrogen suddenly becoming an indispensable part of gas network operators' strategies.

"The UK's net-zero targets have put a massive impetus on utility networks to find the right path. As a result, we've seen collaboration like never before over this last 12 months."

Antony Green, project director for hydrogen, for Gas Transmission at National Grid, a British electricity and gas utility

"We have been working to find a sustainable future for gas networks, and hydrogen has been a key thread," says Green. "We've been focusing on what options are available to repurpose the national transmission network for hydrogen. We have highlighted gaps in our knowledge and where we need additional research. Collectively we are all understanding what the risks are, what proof of concept projects are needed over the next few years and how to execute a successful pathway."

Shift the timeline

Hydrogen is in the spotlight as the energy transition moves at pace – and rightly so. But to realize its potential, both governments and industry will need to make bold decisions. The challenge now is not in the ambition, but in changing the timeline: from hydrogen on the horizon, to hydrogen in our homes, businesses, and transport systems – today.

This is a challenge of adaptability, laid bare in 2020 as the world is blindsided by a dramatic black swan event.[25] But our research suggests that once the recovery gains momentum, the oil and gas industry will continue – or even accelerate – its diversification, with an ever-increasing focus on the most abundant element in the universe.

Report update: This report was updated in September 2020. The updates relate exclusively to data from DNV GL's Energy Transition Outlook, now referencing the latest 2020 data. Edits made on pages 5 and 8."

25 'Why the Coronavirus May Be a Black Swan Event', *Inc.*: https://bit.ly/2VNsh10

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