

# AMERICA'S NATURAL GAS

*SPECIAL REPORT*

2022



U.S. natural gas gains momentum.

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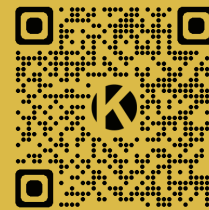
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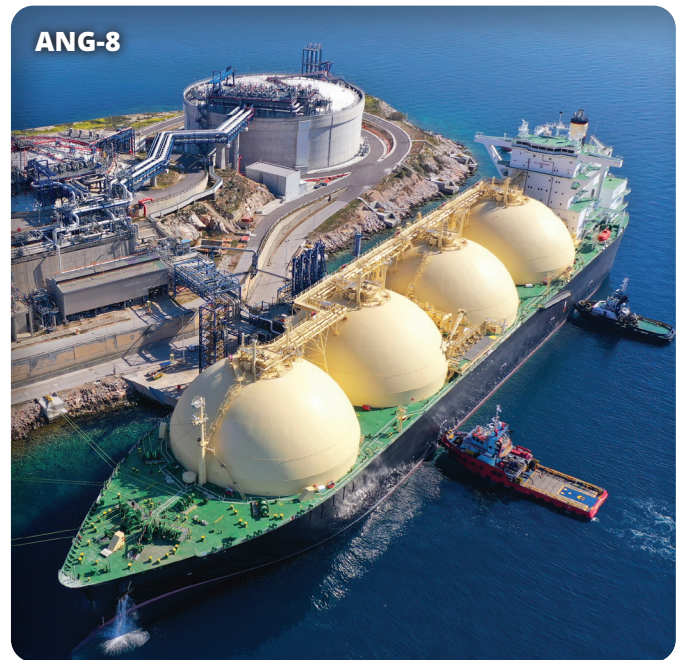
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**ABOUT THE COVER:** The demand and need for U.S. natural gas gains momentum. (Source: AlexLMX/Shutterstock)

# ALL EYES ON NATURAL GAS INVESTMENT

Strong demand and environmental awareness draw capital to the upstream and midstream sectors.

ARTICLE BY  
**GREGORY DL  
MORRIS**  
CONTRIBUTOR

**N**atural gas and associated investment opportunities are garnering a lot of attention from a very broad audience, according to Brad D. Nelson, managing director in the energy investment banking group at Stephens Inc.

"We believe this momentum has been building for a long time as natural gas has evolved from a local to a global commodity. We also believe the interest, demand and need for natural gas was occurring well before the Ukraine-Russia crisis," Nelson said.

"Pre-COVID, the acronym of the decade was ESG. Post-COVID, ESG is and will continue to be front and center for the conventional energy industry. More importantly, ESG is a factor in capital allocators' decision-making. As we all know, natural gas is much cleaner and more environmentally friendly than oil and other conventional energy sources."

The U.S. is well set to be a major player, now and long term, in the global natural gas industry, Nelson explained. "Generally speaking and compared to other countries, the U.S. contains one of the largest resources for natural gas in the world. In terms of reserves, the U.S. ranks fifth or sixth, but the U.S. is in the top one or two countries in the world based on production and consumption."

In summary, there are three primary reasons why people are allocating capital to natural gas, according to Stephens. First, gas is cleaner than other conventional energy sources. Second, the overall macroeconomic outlook for gas is set for

the commodity for the foreseeable future. Global demand is continuing to increase and supply is struggling somewhat to keep up with the pace. And third, many producers and investors are able to generate money and provide healthy returns while investing in an environmentally acceptable conventional commodity.

"Private capital continues to be the driving force behind investment across the natural gas value chain," said Nicholas Gole, senior managing director at Macquarie Capital. "While there are probably fewer investors in the space now, those of us who are still investing in the sector are seeing a lot of attractive opportunities."

In terms of capital allocation, Gole said, "We have not seen the same level of greenfield



**"We believe this momentum has been building for a long time as natural gas has evolved from a local to a global commodity."**

—Brad D. Nelson,  
Stephens Inc.

activity outside of LNG, but there is still significant interest from private investors, particularly in the context of gas supply for Gulf Coast liquefaction expansion.

"Midstream organic growth largely targeting value chain extension with multiple fee events from wellhead to water are receiving the majority of growth spending," Gole said.

Further, he noted that "strategics are still exercising capital discipline but will be opportunistic around established assets with compelling industrial logic and definable synergies. Consolidation is also key among public strategics."

At the same time, some banks are showing renewed interest. "While banks have stepped back from lending to the space during the downturn, it seems like some are coming back cautiously," said Gole. "And some have decided to exit the space entirely."

### Upstream, midstream activity

Geographically, there has been an increase in activity in basins that were marginal at lower gas prices. Takeaway from Appalachia is still constrained, which is allowing for other basins such as the Mid-continent to increase activity materially, albeit from a smaller base.

"On an absolute basis," Gole said, "key basins close to demand, like the Haynesville and Eagle Ford, have benefited, as has the Permian, which has seen significant gas debottlenecking in recent years. On the upstream front, we expect further consolidation to wring efficiencies and capitalize on new demand-pull sources, such as liquefaction—particularly with proximity to the Gulf Coast. We also expect significant newbuild residue gas pipeline capacity connecting the Permian to emerging liquefaction hubs along the Texas and Louisiana Gulf Coast."

In midstream, "existing capacity is likely not sufficient to accommodate growth and we expect, in addition to the recently announced Matterhorn Pipeline, several incremental Gulf Coast pipeline final investment decisions through 2030 to accommodate global gas demand," said Gole.

Continued investment in midstream "is certainly needed," he continued. "On the gathering and processing side, it seems that some operators are investing capital in relatively lower return midstream buildout that retains molecules across a captive system with multiple fee events, rather than pursuing step-out greenfield growth. We expect this may change if the current pricing environment continues and operators decide to divert more capital to higher return upstream capex to allow themselves the ability to still return cash flow to shareholders."

At the policy level, capital providers are beginning to differentiate between oil and gas, in terms of carbon in addition to the existing factors. "We



**"While there are probably fewer investors in the space now, those of us who are still investing in the sector are seeing a lot of attractive opportunities."**

—Nicholas Gole,  
Macquarie Capital

are certainly focused on the carbon footprint of the projects that we invest in and are looking for responsible partners with strong track records for lowering the carbon impact of their operations and looking for ways to continue to improve their overall carbon footprint," said Gole.

"Private equity has been consistent in its investment in the segment," said Stephen Ellis, senior equity analyst at Morningstar. "I don't see any change this year. Public investment has picked up a little bit, especially driven by merger and acquisition activity. Geographically, the consolidation in the Permian remains the biggest and best opportunity in terms of investment for producers and takeaway."

Today, most deals are done in cash plus a credit facility, said Ellis. "They used to be roughly 50:50 debt to equity, but these days they are usually announced as an 'all-cash' deal while the parties work out ways to finance the transaction. That can be a combination of debt and stock. What has made the difference, both upstream and midstream, is that there is so much cash being generated. They can use that to close the deal and work out any financing later."

As examples of both trends, he noted Targa Resources Corp.'s acquisition of Lucid Energy Group, a \$3.55 billion all-cash deal, as well as Whitecap Resources Inc.'s acquisition of XTO Energy Canada ULC from Exxon Mobil Corp. and Imperial for C\$1.9 billion (US\$ 1.48 billion)—again all cash.

Those structural preferences should not overshadow the fact that "banks are willing to finance gas," said Ellis, "whether that is exploration and production or midstream. That is especially true because midstream teams are being more selective. They tend to be focusing on developments that remain with Texas, or one of the other states that are favorable to the industry, and avoiding interstate jurisdictions to the extent possible. There are a few exceptions, but pipelines

generally have become hesitant to cross state lines.”

Beyond the Permian, other plays receiving investment attention are the Haynesville Shale as well as the Marcellus and the Utica in Appalachia, the latter with the acknowledgement of “chronic takeaway constraints,” Ellis added. “The Mountain Valley Line will be filled quickly.”

EQT Corp. said it expects the long-delayed Mountain Valley Pipeline from West Virginia to Virginia, the last big gas pipe under construction from Appalachia, to enter service in the fourth quarter of 2023.

### War and climate change

For several years, there has been reluctance in some quarters to invest in hydrocarbons for social and environmental reasons. That has been especially true in public markets. Nevertheless, natural gas has regained some credibility as the lower-carbon bridge fuel to a low-carbon future. Natural gas has also expanded to fill the available economic space as the world scrambles to restructure its energy mix without Russian hydrocarbons.

“There is certainly no certainty as to when the war in Ukraine will end,” said Ellis, “but there is growing certainty that the longer it continues, the more the European Union moves away from Russian energy—gas, oil, even uranium—and the more structural those changes become. Even as the new plans rely heavily on renewables, there is also a reliance on gas as the bridge fuel.”

That said, investors remain widely divergent on their willingness to invest in hydrocarbons, and the industry, both upstream and midstream, is widely divergent in its response to that pressure.

“I have reviewed the portfolios of the U.S. and Canadian midstream companies that I cover,” said Ellis, “which includes all the major names. About a third of them had committed to a net-zero carbon emissions policy by 2050. Another third had no program or even goal stated. And a third were somewhere in between. At the very least the sector could work on some clarity.”

For example, he noted that there has been a significant shift in the industry’s attitude about flaring.

“There is very much a focus on turning flared or released gas into revenue,” said Ellis. “The Mountain Valley Pipeline has agreed to be carbon neutral, using offsets. That is one notable effort to address the environmental issues raised by investors and the public.”

That is a sharp contrast to late 2019 when flaring in the Permian became a national issue. Williams Cos. sued the Texas Railroad Commission after the regulators allowed Exco Operating Co. to flare casinghead gas even though the Exco wells in the field were connected to Williams gathering lines.



**“There is very much a focus on turning flared or released gas into revenue.”**

—Stephen Ellis,  
*Morningstar*

In early 2020, Pioneer Natural Resources Co. CEO Scott Sheffield called on energy investors to sell shares or pull funding from companies that have high rates of natural gas flaring.

### Price decoupling: done and dusted

Another shift that has taken place quietly is how gas and oil prices have drifted apart. There was a time when producers, investors and analysts were watching for “decoupling” as a turning point, but Ellis noted that “with Henry Hub pricing, destination flexibility for LNG and oil-linked contracts just expiring,” the decoupling has been more evolution than revolution.

“We believe that oil and gas has been decoupled for a long time,” said Stephens’ Nelson. “Other than using a drilling rig to extract the two commodities, we believe that to be the only similarity today. Some source rock contains both commodities, but the primary supply is in very different parts of the country,” he continued.

“For oil, we think of the Permian, Bakken, Eagle Ford and Midcontinent as the key supply basins. For natural gas, the primary plays are the Marcellus, Utica and Haynesville. The same could be said for the demand side of the equation; end-use markets are very different.”

Transportation fuels and lubricants are among the major end-use markets for oil, as are numerous commodity and specialty chemicals. Power generation is a major demand for gas, as are heating and cooling. NGL is the primary feedstock for commodity thermoplastics.

Gole at Macquarie suggested that “to an extent, oil and gas prices have decoupled but are still highly correlated. While the U.S. seems to be the marginal supplier for each at the moment, we are now seeing overlapping but differentiated demand bases that are truly global in nature and will continue to drift independently as incremental liquefaction continues to knit the global gas value chain together.”

To that point Gole said, “We expect that more LNG liquefaction FIDs [final investment decisions] will keep long-term pricing attractive for North American producers and midstream companies while significantly reducing the spot price available to customers in Europe and Asia, relative to what is being paid today. This should make gas an important part of the energy transition for a long time to come.” 



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# THE RISE OF ASSOCIATED GAS

Associated gas is a crucial part of meeting the growing energy demand as the U.S. amps up its exports.

ARTICLE BY  
**JENNIFER  
PALLANICH**  
SENIOR EDITOR

**A**ssociated gas will drive North American gas production in the near term, positioning it to serve as a bridge fuel through the energy transition.

However, associated gas can be a mixed blessing, prompting operators to wrestle with choices on what to do about the additional production. Each choice has its pros and cons, and geopolitical uncertainty underlies major long-term investments that operators consider.

Wood Mackenzie defines gas production driven by oil economics to be associated gas and gas production driven by gas economics to be dry gas.

According to WoodMac, associated gas production in the Lower 48 is climbing, primarily due to increased gas production from the Permian Basin. Eugene Kim, research director for WoodMac's North America gas team, said the "tremendous growth" in production of associated gas from the Permian dwarfs associated gas output from all the other basins.

While associated gas output in the Permian was hitting about 4 Bcf/d in 2015, the basin currently produces over 15 Bcf/d of associated gas and is expected to produce more than 19 Bcf/d by the end of 2024, Kim said. In fact, he expects Permian associated gas production to continue growing into the 2040s, while other Lower 48 areas will start to plateau or decline by 2030 or 2035.

Alaska, Kim said, is producing less than 1 Bcf/d of associated gas, with the majority of that coming from Prudhoe Bay.

In the Gulf of Mexico, associated gas is down to about 2 Bcf/d from its heyday with output of more than 14 Bcf/d of gas, he said. Some of it was dry gas, while some was associated gas.

Earlier this year, the Bureau of Offshore Energy Management released its 2022 to 2031 U.S. Outer Continental Shelf Gulf of Mexico region oil and gas production forecast, which predicts associated gas production in the Gulf of Mexico will remain fairly steady during the next decade.

Most of the associated gas in the Gulf of Mexico is from deepwater fields, where dry gas wells are generally uneconomic to develop.

## North American gas market

Carol Johnston, vice president of energy, utilities and resources at IFS, said demand for natural gas is increasing because of its role as a backup energy source on the path of the energy transition.

"That is creating more demand and market opportunity" but also causing prices to fluctuate, she said.



**“Associated gas runs off of the oil economy. It’s not totally free, but it’s the lowest cost option.”**

—Eugene Kim,  
Wood Mackenzie

The overall North American gas market is set to expand quite a bit, including through export growth, and associated gas is needed to support that, according to Kim

"Look at how much new gas is required every year to come to the market ... to make up for existing production declines and market expansion," he said.

He projects needing 17 Bcf/d of new gas production on average during 2023 to 2025 to meet decline and expansion.

"That's a tremendous amount of gas considering we're now at 97 Bcf/d" of total gas output from the U.S., he said. "Every year, we need to drill enough to produce that 17 Bcf/d that the market will require."

And of course the mix of dry and associated gas that is added will affect the price of Henry Hub.

"Associated gas runs off of the oil economy. It's not totally free, but it's the lowest cost option," Kim



said. "The larger the amount of associated gas produced, the lower the price of Henry Hub will be."

Johnston said two main factors constrain associated gas production. If the price is not high enough, companies may throttle back production. On the other hand, infrastructure can be an issue, she said.

Further, she said some operators are reluctant to enter large multiyear projects due to geopolitical uncertainty or regulatory or permitting hurdles.

The Biden administration is pursuing renewable energy sources and moving away from fossil fuels.

The last offshore oil and gas lease sale was in November 2021, and a court vacated it. No offshore oil and gas lease sales are being held in 2022, and there is the potential that only one offshore lease oil and gas sale will occur in 2023. Offshore wind lease sales are happening, however, with sales in New York Bight and Carolina Long Bay earlier this year and plans for lease auctions in the Gulf of Mexico and offshore California.

### Working around flaring reductions

In 2016, the U.S. endorsed the World Bank's Zero Routine Flaring by 2030 initiative, and in 2020, U.S. regulators made it more difficult for operators to routinely flare associated gas production.

Historically, operators routinely flared associated gas as a safe method of disposal; however, flaring is determined as wasteful and emits greenhouse gases.

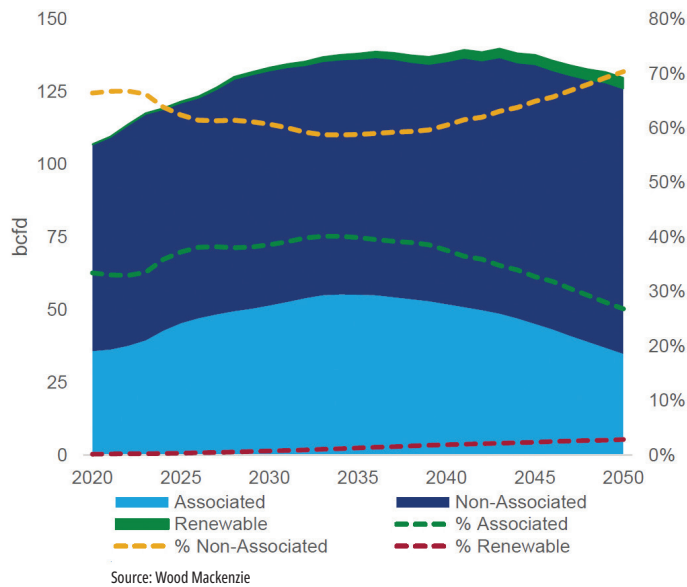
"There is still sizable flaring going on in the U.S.," Kim said.

Efforts to reduce flaring are helping, however.

According to the World Bank, in 2021, the top 10 flaring countries on an absolute volume basis accounted for 75% of all gas flaring and 50% of global oil production. At No. 4, in terms of absolute volume flared, the U.S. has been in the top 10 list for the past decade. But it has a distinction from other long-term members of this list, such as Russia, Iraq, Iran, Venezuela, Algeria and Nigeria, in that it is the only country to have successfully reduced absolute flare volumes while increasing production over the past decade. The U.S. decreased its flaring intensity by 46% and achieved an 8% reduction in terms of absolute volume over the decade, according to the World Bank.

Although flaring is off the table as the primary means of associated gas disposal, operators do have other options.

### North American Gas By Type



Source: Wood Mackenzie

**Wood Mackenzie projects production of associated gas to continue to rise through 2035.**

Associated gas can be gathered, processed and delivered down the supply chain, or stored, Kim said, but these options require infrastructure. It can also be reinjected in the reservoir to maintain pressure, such as in some Alaskan fields, although this also requires infrastructure.

"That whole process takes money to do. You need appropriate production systems to recycle and reinject it into the reservoir, which is an added cost to the producer," Kim said. "For a lot of new wells, we're not seeing as much effort to recycle that gas."

Associated gas can be used in the field for fuel purposes, he said, such as running compressors using associated gas instead of diesel or carrying out small-scale LNG liquefaction. And some producers are even talking about using excess gas to power gas turbines for bitcoin mining.

"There are some novel uses of excess gas production," Kim said.



**"The role of natural gas as a backup energy source 'is creating more demand and market opportunity.'"**

—Carol Johnston, IFS

# US CONTINUES TO RISE AS KEY LNG EXPORTER

The U.S. climbs the ranks to become one of the world's largest LNG exporters after recent liquefaction expansions.



**Global LNG trade in 2021**  
"reached an all-time high  
of 372.3 mtpa, according  
to the IGU."

AERIAL-MOTION / SHUTTERSTOCK

ARTICLE BY  
**PIETRO  
DONATELLO PITTS**  
ENERGY REPORTER

**T**he U.S. became the world's largest LNG exporter in the first half of 2022, thanks to recent liquefaction additions and high demand in Europe, the U.S. Energy Information Administration reported in July.

Strong demand for LNG and significant U.S. aspirational liquefaction capacity in the pre-final investment decision (FID) stage will assure the U.S. maintains its top-tier ranking for years to come, according to a International Gas Union (IGU) report.

Between January and April, new liquefaction capacity additions allowed Australia to boost its capacity to 87.6 million tonnes per annum (mtpa), while similar additions allowed the U.S. to boost its capacity to 86.1 mtpa. The growth pushed the North American country ahead of Qatar with its 77 mtpa and into the second position.

LNG trade, especially U.S. LNG exports, continues to grow amid geopolitical issues in Ukraine that threaten energy security for numerous countries

worldwide. At the same time, a continued global push to decarbonize economies has seemingly jettisoned a move away from fossil fuels such as oil and coal and to low- and zero-carbon sources like natural gas.

As of April, the global LNG trade was connecting 19 exporting markets with 40 markets equipped with LNG import facilities. China was the largest LNG importer in 2021, buying 79.3 mtpa in 2021, while Japan imported 74.3 mtpa. European LNG imports were 75.1 mtpa in comparison.

Global liquefaction capacity reached 459.9 mtpa in 2021, up 6.9 mtpa compared to 2020. The average global utilization rate was 80.4% in 2021, up compared to 74.6% in 2020 due to economic recovery following the lifting of COVID-19 restrictions, a prolonged European winter and an epic drought in Brazil, all which boosted demand for LNG, the IGU revealed in July in its "2022 World LNG" report.

LNG has evolved as a vital energy source to "secure and reliable functioning of energy systems around the world ... a vital tool for controlling emissions, particularly as the crisis in energy supply is forcing even the most climate-conscious economies to turn back to coal, wiping out emission reductions achieved in recent years," the IGU said, adding that "addressing supply constraints is going to be critical to energy security and economic stability in the world."

### LNG trade

Global LNG trade in 2021 "reached an all-time high of 372.3 [mtpa], as the strong post-pandemic recovery resulted in a surge in LNG imports," up 4.5% compared to 2020, according to the IGU.

To no surprise in 2021 Australia retained its position as the world's largest LNG exporter shipping 78.5 mtpa, followed by Qatar (77 mtpa), the U.S. (67 mtpa) and Russia (29.7 mtpa), and in that order. Effectively, these top four countries controlled 67.8% of the LNG export market share in 2021.

Impressively, the U.S. added 22.3-plus mtpa of capacity in 2021, up 50% from just 44.8 mtpa in 2020. The increase in capacity was "driven by increased utilization at five large liquefaction trains that started commercial operations in 2020 (Cameron LNG T2-T3, Corpus Christi T3, Freeport LNG T2-T3)," according to the IGU.

"The Atlantic Basin LNG markets grew in importance throughout 2021, with depleted gas storage in Europe and lower-than-average Russian pipeline deliveries driving Europe's evolution from the market of last resort to a premium LNG buyer," the IGU said.

### Aspirational liquefaction capacity

The present-day geopolitical situation in Russia-Ukraine has boosted the appetite for new liquefaction projects despite headwinds such as access to financing as lenders look to reduce their

exposure to fossil fuel investments as they instead eye clean energy projects.

The global decarbonization push will force the LNG industry to seek solutions to reduce emissions in the liquefaction process and across the entire LNG value chain. But "it is also important to have clarity and consistency in the policy environment, which impacts financial risk and liquidity provision," the IGU said.


Currently, 1,034.5 mtpa of aspirational liquefaction capacity is in the pre-FID stage, and the majority of that capacity is located in the U.S. (387.6 mtpa), Canada (210.4 mtpa) and Russia (136.7 mtpa). Another 52.2 mtpa corresponds to developments in Africa, which if they materialize could see the emergence of a key LNG export region, while Australia has 45.5 mtpa of liquefaction capacity currently in the pre-FID stage.

**“LNG trade, especially U.S. LNG exports, continues to grow amid geopolitical issues that threaten energy security for numerous countries.”**

The U.S. accounts for 37.5% of the total aspirational liquefaction capacity in pre-FID stage, followed by Canada (20.3%) and Russia (13.2%).

The growth in U.S. shale gas production in recent years is driving proposed projects such as Venture Global LNG's Plaquemines LNG (21.6 mtpa) and Driftwood LNG (27.6 mtpa), both located in Louisiana.

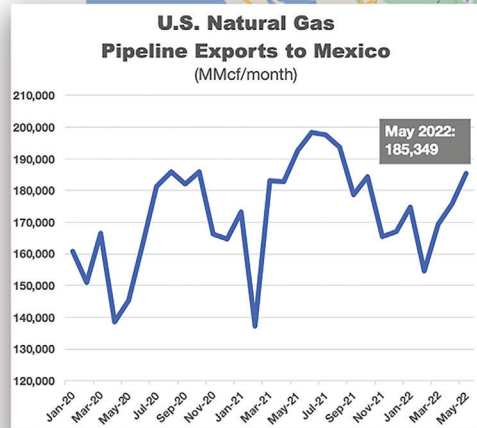
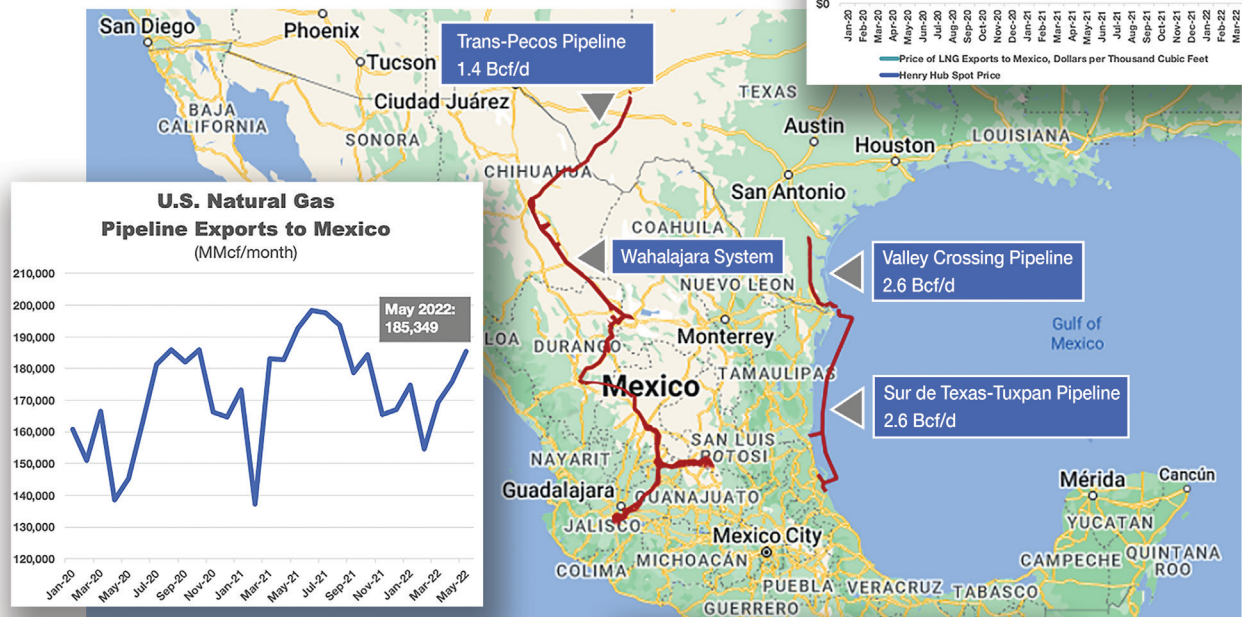
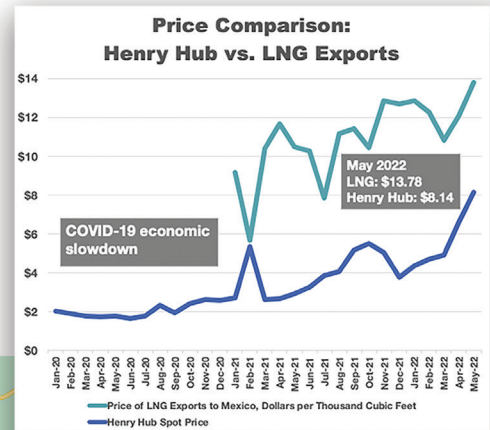
"While most operational U.S. LNG projects are brownfield conversion projects, the currently proposed U.S. LNG projects are mainly greenfield projects that consist of multiple small- to mid-scale LNG trains delivered in a phased manner," the IGU said. "This provides flexibility in securing long-term offtakers and increases competitiveness in project economics through modular construction."

These developments come as the Middle East, and especially Qatar, looks to drastically increase its liquefaction capacity with the recent FID taken by QatarEnergy related to the North Field East, the world's largest LNG project. The project will boost Qatar's LNG capacity to 110 mtpa from 77 mtpa by 2026 and involves the construction of four new LNG mega-trains with a capacity of 8 mtpa each. 

# CROSS-BORDER PIPELINES DRIVE INCREASE IN NATURAL GAS EXPORTS TO MEXICO

U.S. exports of natural gas to Mexico eased somewhat after a record June 2021, which saw shipments above 7 Bcf/d occur multiple times, the high mark set on June 17 of 7.4 Bcf. Since February 2022, however, exports have crept up each month and totaled about 176 Bcf in April for an average of about 5.9 Bcf/d.

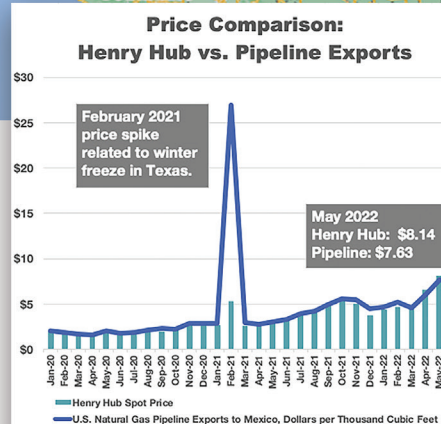
Two cross-border pipelines have driven growth in U.S. gas exports to Mexico. Energy Transfer Partners' Trans-Pecos Pipeline originates at the Waha Hub in the Delaware Basin and delivers natural gas to the U.S. border at Presidio, Texas, into the



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(Source: U.S. Energy Information Administration, Thomson Reuters, Rextag)

Wahalajara pipeline system. On the Gulf Coast, Enbridge Inc.'s Valley Crossing Pipeline on the Texas side of the border delivers gas to the Sur de Texas-Tuxpan Pipeline in Mexico, which is operated by a unit of TC Energy Corp.



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# QATAR ENERGY ENLISTS BIG OIL FOR MEGA LNG PROJECT

State-owned QatarEnergy has tapped supermajors from across the globe to lend a hand in the development of its LNG project in Qatar's North Field East.

ARTICLE BY  
**PIETRO DONATELLO PITTS**  
ENERGY REPORTER

State-owned QatarEnergy has enlisted European companies TotalEnergies SE, Eni SpA, Shell Plc as well as American companies ConocoPhillips Co. and Exxon Mobil Corp. to participate in the four-train, \$28.8 billion North Field East (NFE) expansion project. The project is the world's single largest LNG expansion and will boost Qatar's LNG production by 32 million tonnes per annum (mtpa) by 2026.

The project comes as global energy markets struggle to increase supply impacted by Russia's invasion in Ukraine. The initial project and others in the Middle Eastern country offer significant opportunities for U.S. companies looking to offer products and services related to the LNG production process, according to the Washington-based International Trade Administration (ITA).

NFE will boost Qatar's LNG production capacity to 110 mtpa in 2026 from 77 mtpa currently and in so doing see Qatar solidify its position as the world's top LNG exporter. This expansion, when coupled with the two-train, 16-mtpa North Field South (NFS) expansion project, will boost Qatar's total LNG production to 126 mtpa, according to QatarEnergy.

Through April 2022, Australia's reported LNG export capacity was 87.6 mtpa, which ranked the country as the world's largest exporter, while the U.S., with a capacity of 86.1 mtpa, ranked second, according to the International Gas Union's (IGU) annual LNG report released in July. Qatar, with a LNG export capacity of 77 mtpa, ranked third on IGU's list.

NFE will provide much-needed low-carbon energy supply to the world market. Beyond its massive price tag, the NFE expansion will employ

high health, safety and environmental standards, including carbon capture and sequestration to reduce the project's overall carbon footprint to the lowest levels possible, the Qatari company announced July 5 in a press statement.

Discovered in 1971, North Gas Field lies off the north-east shore of the Qatar peninsula and spans 6,000 sq km, equivalent to about half the land area of Qatar. The field has total recoverable gas of more than 900 Tcf, equivalent to approximately 10% of the world's known reserves.

Qatar's exports of LNG, crude oil and petroleum products make up the bulk of the government revenue, while earnings from the hydrocarbons sector account for more than 50% of the country's total government revenues, the ITA said.

## Five NFE JVs

Opportunities to invest in Qatar's LNG sector commenced in May 2021 with the lifting of a self-imposed 12-year moratorium on further developments related to LNG extraction from the country's North Field. As of July 2022, QatarEnergy has seemingly jettisoned development efforts with the signing of five joint venture (JV) deals in Doha with partners from the U.S., U.K., Italy and France. Collectively, the five JVs hold a 100% interest in NFE, with QatarEnergy holding the majority interests.

On July 5, an agreement was signed by QatarEnergy (75% working interest) and U.K.-based Shell (25% working interest) to form a new JV that will hold a 25% interest in the NFE project. The "announcement marks the successful conclusion of the selection of our international energy company partners in the North Field East

**Joint Ventures In Qatar’s North Field East (NFE) Expansion Project**

Date Signed	Partners (Working Interest)	Interest in NFE
July 5	Shell Plc (25%) QatarEnergy (75%)	25%
June 21	Exxon Mobil Corp. (25%) QatarEnergy (75%)	25%
June 20	ConocoPhillips Co. (25%) QatarEnergy (75%)	12.5%
June 19	Eni SpA (25%) QatarEnergy (75%)	12.5%
June 12	TotalEnergies SE (25%) QatarEnergy (75%)	25%
	<b>Total</b>	<b>100%</b>

Source: QatarEnergy


project,” the Minister of State for Energy Affairs Saad Sherida Al-Kaabi said in a press statement released by QatarEnergy.

On June 21, an agreement was signed by QatarEnergy (75% working interest) and Irving, Texas-based Exxon Mobil (25% working interest) for a JV that will hold a 25% interest in the NFE project. “We are collaborating with QatarEnergy on North Field East to accelerate the production of secure,

affordable and cleaner energy our world needs,” Exxon Mobil chairman and CEO Darren Woods said in a company statement.

An agreement was signed by QatarEnergy (75% working interest) and Houston-based ConocoPhillips (25% working interest) on June 20 for a JV that will hold a 12.5% interest in the NFE project. “Our collaboration will help produce cleaner energy to meet growing global demand and achieve a realistic energy transition toward achieving our climate change objectives,” Qatar Energy Minister Saad Sherida Al-Kaabi said in a press statement released by QatarEnergy.

On June 19, an agreement was signed by QatarEnergy (75% working interest) and Rome-based Eni (25% working interest) for a JV that will hold a 12.5% interest in the NFE project. The agreement marks Eni’s initial entry into Qatar’s upstream sector and “is a significant milestone for Eni and fits our objective to diversify into cleaner and more reliable energy sources in line with our decarbonization strategy,” Eni CEO Claudio Descalzi said in a press statement released by QatarEnergy.

On June 12, an agreement was signed by QatarEnergy (75% working interest) and Paris-based TotalEnergies (25% working interest) to form a new JV that will hold a 25% interest in the NFE project. “It is good news for the fight against climate change as gas and LNG are key to support the energy transition, and notably the shift from coal to gas in many countries,” said TotalEnergies chairman and CEO Patrick Pouyanné in a press statement released by QatarEnergy. 

**The North Field East expansion project will boost Qatar’s LNG production capacity to 110 mtpa in 2026 from 77 mtpa.**



ALEXIMV/SHUTTERSTOCK.COM

# QUANTIFYING RSG

Producers are going above and beyond regulatory requirements by certifying their natural gas.



ARTICLE BY  
**JENNIFER MARTINEZ**  
ASSOCIATE EDITOR

**A**s stakeholders begin to pay more attention to ESG factors when making investment choices, producers are looking for ways to quantify the practices and decisions they make in the field to optimize and improve their ESG performance. Some are seeking third-party certification of their responsibly sourced gas (RSG) to demonstrate their ESG practices to their stakeholders.

"Investors, banks and insurers understand that ESG/climate risk is financial risk," said Jennifer Stewart, principal advisor to Equitable Origin, an organization that provides independent certification of ESG practices. "Certification serves as external validation for these stakeholders that a company is doing what they say they are doing in their investor materials and sustainability reports."

Investors across the board are seeking transparency into the products they buy, she explained. "The climate and ESG attributes need to be measured, quantified, verified and reported and then validated by a qualified, independent third party."

The financial motivation to demonstrate ESG practices through RSG certification puts pressure on producers, with some positing that RSG certification may determine if a producer can sell their gas in the future.

"The theory here is that at some point in time, certified gas may become 'table stakes,' meaning that in order to sell gas at market price, a producer will need evidence that it was produced responsibly," Stewart said. "If the gas is not certified, a producer may not be able to respond to an RFP [request for proposal], or the gas will sell at a discount."

## Certification challenges

The strong push toward active and meaningful

ESG practices and certified RSG comes from the market, Stewart explained. But the transition hasn't been without its challenges.

Stewart lists cost, both in terms of cash and human resources, as a significant barrier.

"Certification under any of the current certification bodies is a robust process and requires significant data and document gathering, field visits, interviews, etc., so it creates a drain on already overworked staff," she said. "The [Equitable Origin] certification process is very inexpensive, but there is some upfront cost to hire an independent assessment body."



**"Investors, banks and insurers understand that ESG/climate risk is financial risk."**

—Jennifer Stewart,  
Equitable Origin

Another significant challenge is that despite being market driven, "the market doesn't know what it wants yet."

"It knows it wants clean, responsibly produced hydrocarbons," Stewart said. "But it is not dictating how that is evidenced, so producers are trying to meet the demand as best they can with certification."

A lack of standardization with regards to certification processes causes confusion as to which certifiers a producer should employ, she explained.

That confusion also affects the buying and trading of certified RSG. "What does not exist today



is an exchange," Stewart said. "[In other industries] there's exchanges where you can buy the digital attribute to the electron. There's no current exchange right now where certified volumes are listed on, so the volumes are listed on a registry right now to keep everyone accountable."

### Environmental stewardship

Smart financial decisions drive efforts to certify producers' ESG practices and responsible sourcing, but environmental concerns also play a role in the increased volume of third-party certified RSG being bought and sold.

In a July op-ed for HartEnergy.com, Chris Romer, co-founder and CEO of Project Canary, a Denver-based ESG data analytics firm that helps companies measure and minimize emissions, pointed out that the technology and means to tackle some of the main causes of global warming are here already.

He specified eliminating fugitive methane emissions as an obtainable and impactful goal. "It's not as well-known as CO<sub>2</sub> and not as virtue-signaling friendly as metal straws, but it is the best step we can take," he said.

Romer's words come on the tail of the Supreme Court ruling in June regarding the authority of the U.S. Environmental Protection Agency (EPA) to regulate greenhouse-gas emissions from existing coal- and gas-fired power plants. The ruling restricted the sweeping regulatory powers granted to the EPA under the Clean Air Act anti-pollution law, limiting the EPA's ability to create new regulations or enforce older ones.

"We have to act now," Romer said. "The urgency is only increasing. Regulation will not be the salve we were hoping for.

"We must now look to markets and consumers to solve this problem," he said.


Stewart argues that the push for certifying RSG and other ESG practices already comes from the market independent of regulations, and the latest Supreme Court ruling will not have much of an effect on the existing ESG and RSG culture.

"Right now, the whole notion of certification is based around producers or operators going beyond regulatory requirements," Stewart said. "[Producers] only have to inspect existing facilities two times a year in order to meet regulatory requirements. I don't know this for a fact, but every producer that has gone through certification so far probably conducts field-based inspections on all of their assets, new and existing, and probably does it on a quarterly or monthly basis.

"There's no regulatory requirement to do this," she said. "It's a way of recognizing that only inspecting your sources two time a year, and not inspecting some of them at all. ... It's not the right thing to do from an environmental stewardship perspective."

Stewart explained that many producers are stepping up and going above and beyond regulatory

requirements, independent of federal oversight.

"I think this is because they recognize that they have to do a lot," she said. "Those that are seeking certification are already good actors." 

## HOW TO SELL A HYDROCARBON

Equitable Origins assigns certificates to a volume of RSG which are then listed on a registry maintained by MiQ using a process similar to bitcoins and other cryptocurrency in order to monetize the certified gas that their clients produce and help those producers realize a profit off of the certification. These certificates are unique and finite, which ensures that the digital attributes of the hydrocarbons are sold only once.

But how does one differentiate certified RSG from regular gas?

Principal advisor to Equitable Origins Jennifer Stewart provides an example using a purchase by Bloom Energy of EQT Corp's certified gas:

- Bloom Energy in California reviewed the MiQ registry to see what volume of certified gas was available to purchase.
- Bloom Energy selected to purchase certified gas from EQT in Pennsylvania based on what was sold in the registry.
- Bloom Energy did not buy the physical gas from EQT but rather the digital attributes of the gas assigned in the MiQ registry.
- EQT sold its certified gas physically as normal and sold the environmental attributes to Bloom Energy.
- Once the specific certificate differentiating EQT's volume of certified gas has been purchased, the certificate is expired and cannot be sold again.

"Even if it's just a penny, EQT was able to realize a penny extra on its gas via the registry," Stewart said.

The market for certified gas is growing, but it still has elements that need to be established in order for the market to fully develop.

"What does not exist today is an exchange," Stewart said. "In the carbon credit market or with solar and wind, there's exchanges where you can buy the digital attribute to the electron."

Since there is no current exchange where certified volumes are listed on an exchange, those volumes are currently listed in MiQ's registry in order to ensure the authenticity of the gas and avoid double counting.

# RNG GROWTH ACROSS THE US

Renewable natural gas (RNG) has seen significant growth across the continent, according to two of the largest RNG producers in the U.S.

ARTICLE BY  
**MADISON RATCLIFF**  
ASSOCIATE EDITOR

**A**s the energy sector looks for any opportunity to decarbonize its operations, renewable natural gas (RNG) is becoming an increasingly attractive option for gas consumers looking for a product with net negative emissions.

Major RNG producers across the U.S. have noted the continual growth of the gas, and many don't expect that growth to end in the near future.

One of the largest producers of RNG in North America, TC Energy flows approximately 30 Bcf annually to its customers through a network of about a dozen facilities, as well as thousands of miles of pipelines.

According to Roger Williams, director of business development at TC Energy, the company expects to double its development to 15 Bcf this year.

"Last year, Trans Canada touched one in four gas molecules in the United States, so we're a pretty big transporter of regular natural gas," Williams told Hart Energy. "To that end, we've got a pretty large footprint, 40,000 miles domestically. And so our footprint is really well positioned to be in the areas where RNG is developed."

Houston-based Archaea Energy currently has 12 operational RNG projects and 19 electric facilities across the U.S. In 2021, the company's full year production was 5.7 MMBtu of RNG.

In addition to its current facilities, Archaea has 85 developmental projects in the works, which are anticipated to raise the company's RNG production from 5.7 MMBtu to 50 MMBtu a year upon completion.

"Archaea Energy is one of the larger producers of renewable natural gas in the United States," Megan Light, vice president of investor relations at Archaea Energy, told Hart Energy. "We are primarily focused on landfill gas-to-RNG projects, but we

also currently have landfill gas-to-electric projects in our portfolio that we expect to convert over to RNG projects."

## Localization

In the past, a critical barrier to local RNG use, according to Williams, was a historical reputation that the gas quality of RNG was poor.

"If you have poor gas quality, and you're putting a small amount of gas onto a large pipeline, when it blends, it becomes less of an issue," he said. "But if you have poor gas quality, and you want to inject into a smaller pipeline that may go directly into someone's home or business, then you have a much larger concern."

However, as the quality of RNG and its production continues to rise, so does its trustworthiness, as well as the interest it has garnered from local distribution companies, who are becoming willing to take gas from RNG developers directly into their systems, Williams explained.



**"One of the emerging trends we're seeing is local distribution companies having increased willingness to accept this gas directly into their system."**

—Roger Williams,  
TC Energy

“One of the emerging trends we’re seeing is local distribution companies having increased willingness to accept this gas directly into their system,” he continued. “They’re being incentivized at the state and municipal levels with grants and subsidies to help accommodate some of these intervention costs, which also would’ve been a deterrent to them.”



**“There’s this growing pool of demand for entities that want to use RNG, which is great news because it really outstrips supply, from a supply-demand dynamic.”**

—Megan Light,  
Archaea Energy

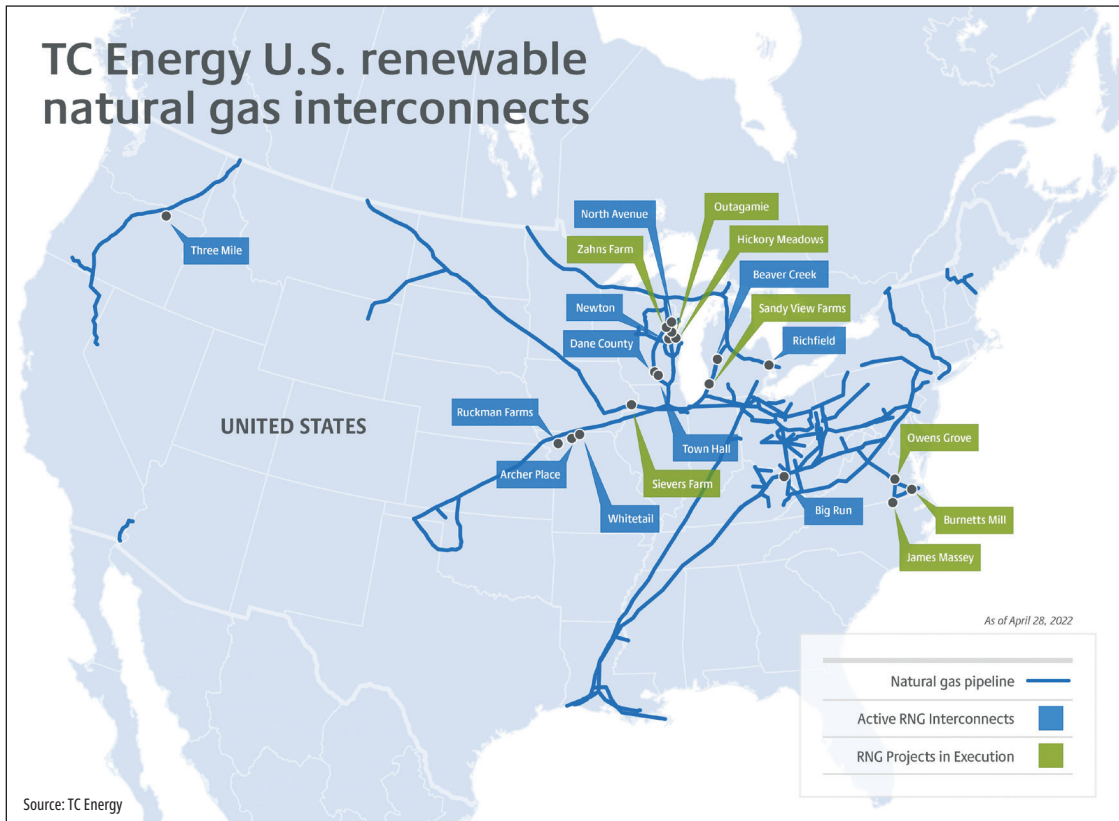
In a local capacity, RNG has primarily been used in the transportation sector in the past in the U.S., but its uses have grown to include power generation, thermal generation and potentially sustainable aviation fuel, Archaea’s Light said.

“Over the past couple years, we’ve seen the development of what we call the voluntary market for RNG,” she added. “That is a market that is driven by decarbonization initiatives in our target customers. In that voluntary market is any entity that uses natural gas in its infrastructure today and either has a mandate or a goal to decarbonize.”

“There’s this growing pool of demand for entities that want to use RNG, which is great news because it really outstrips supply, from a supply-demand dynamic,” Light continued.

Light predicts that local uses of RNG will expand beyond its current capabilities due to the positive impact it has on the environment and based on its current rate of growth. From a sustainability standpoint, she said, RNG makes more sense to use than traditionally produced natural gas in the long term.

“When we look at gas and renewable natural gas, which are chemically identical, you should say that if society is going to use any natural gas, it should use RNG first and then use fossil natural gas second from a purely environmental standpoint,” Light said. “I personally also think that on a global scale, there’s going to be immense natural gas demand, including fossil natural gas, through at least the rest of our lifetimes.”



**TC Energy currently has 11 facilities in operation across the country, with eight under development.**

**Role in the energy mix**

With energy insecurity playing a large role in the decision-making processes within the energy industry, RNG was considered as a means to reduce pressure on the U.S. energy supply. However, since RNG currently comprises such a small percentage of the U.S. energy mix, it isn't predicted to help much in that regard.

That being said, as a net negative solution, it is one of the most efficient ways for energy companies to reduce emissions output.


According to Williams' predictions, RNG will only account for 2% of the American energy mix due to the high cost to produce the gas. However, he maintained that it was worth producing because of its copious positive environmental impacts.

"I personally like it as a commodity because ... it is capturing something that is a net negative, no matter what," Williams said. "It's as a result of an ongoing business via dairy farming or chicken farms or whatever, the source or wastewater or all the different RNG sources—all that gas is just going to atmosphere. I'm always a big fan of efficiencies and capturing things that are harmful to the environment before they get there."

Light was more optimistic on the outlook of RNG's role in the energy mix. From a decarbonization standpoint, Light believes that RNG is "the most economic and reliable way" for companies focused on environmentally friendly energy solutions. Additionally, from an energy security standpoint, she believes it will play an important, albeit small, role in the global energy mix.

"I think we've seen over the past few months, with [critical] geopolitical events, that an energy shortage anywhere becomes a global energy shortage, and adding RNG production in the U.S. just adds to global energy security," she added.

While RNG distribution and usage is already expanding at a rapid rate, Light anticipates further growth, both in the U.S. and globally.

"There's so much opportunity in the U.S.—that's where our focus is now—but especially in large urban areas, population dense areas, there's a lot of landfill potential internationally that could [be used] to produce RNG," she said. "Compared to traditional natural gas resources, it's a very small piece of the pie, but I think that there is a lot of potential in the coming decades for this to play a role across the globe." 

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# BUILDING BLUE TO GREEN HYDROGEN

As the hydrogen color debate continues, companies are becoming color agnostic with focus on carbon intensity, economics and demand.

ARTICLE BY  
**VELDA ADDISON**  
SENIOR EDITOR

**T**he world is counting on blue hydrogen to help decarbonize sectors that rely heavily on fossil fuels, especially in instances in which electrification is not a viable option. Think aviation, shipping and industrial processes.

The technology is proven. It's cheaper to produce compared to some alternatives—for now.

Many believe that blue hydrogen—produced from natural gas or methane, via steam methane reforming (SMR), coupled with carbon capture and storage (CCS)—can move the world closer to emission reduction goals on the road to net zero. This is in spite of objections from critics who say it is not as clean as green hydrogen, created from water via the electrolysis process that uses electricity generated from renewable resources, along with concern about losing its cost edge and fugitive emissions.

Still, blue hydrogen supporters say the low-carbon resource is worth pursuing. Using existing infrastructure and technology could help accelerate development of the resource.

"To spur the hydrogen economy, we must be open to exploring natural gas and hydrogen blended infrastructure," Baker Hughes CEO Lorenzo Simonelli said during an energy transition conference in June. "Without the right infrastructure, we will not achieve a hydrogen economy. Today, we have technology ready to deploy with little to no major upgrade of current turbomachinery equipment, which will help enable the hydrogen economy."

Hopes are high on hydrogen's ability to decarbonize major sectors of the economy and generate electricity. However, the promise of a burgeoning hydrogen economy could go unfulfilled without greater demand.

## Making moves

Companies, including those known for their oilfield services and natural gas production, have already jumped into action working together and independently.

Baker Hughes, for example, is tapping natural gas

to provide hydrogen-ready, turbo-compression pipeline technology in Greece. It is supplying gas turbines and compressors capable of running on a blend of natural gas and hydrogen.

In the U.S., the energy services company is providing advanced hydrogen compression and gas turbine technology for global projects underway by Air Products, which is also developing a \$4.5 billion blue hydrogen complex in Louisiana. Developers say the proposed project will capture and sequester 95% of the process facility's CO<sub>2</sub> emissions, permanently sequestering over 5 million tons (MMton) per year of CO<sub>2</sub> in Louisiana.

The project is one of several blue hydrogen initiatives underway in the U.S. as the nation works to reduce emissions and advance major clean hydrogen initiatives. This includes awarding \$8 billion for regional clean hydrogen hubs to establish regional networks of hydrogen producers, consumers and infrastructure to speed adoption of hydrogen.

Indications from proposals submitted to the Department of Energy's \$8 billion H2Hubs program show developers don't overwhelmingly favor one feedstock over another. Targeted feedstocks include fossil fuels with CCS, renewables and nuclear.

While each comes with its own set of advantages and disadvantages, success may come down to carbon intensity and economics.

The most common form of hydrogen produced today is gray, which like blue hydrogen is produced from natural gas or methane, but with no carbon capture involved.

Only 1% of hydrogen is produced as blue hydrogen globally, according to DNV.

However, the potential is great, particularly in the U.S. where there's an abundance of natural gas. A 2020 resources assessment by National Renewable Energy Laboratory shows about 167 scf of natural gas would be needed to produce 1 kg of hydrogen via SMR with a production efficiency of 73%. About 1.7 Tcf of natural gas would be needed to produce 10 MMton of hydrogen.

**Amount To Produce 1 Kg Of Hydrogen By Resource**

Resource	Conversion Pathway	Amount to Produce 1 kg Hydrogen		Production Efficiency (E <sub>out</sub> /E <sub>in</sub> , LHV)
Natural gas	Steam methane reforming	167 scf	165 MJ	73.0%
Coal (bituminous)	Coal gasification	8.6 kg	225 MJ	53.3%
Nuclear (uranium)	High-temperature electrolysis	4.62×10 <sup>-5</sup> kg U	240 MJ	50.2%
Biomass	Biomass gasification	13.0 kg bone dry biomass	242 MJ	48.3%
Biomethane	Steam methane reforming	3.29 kg methane	165 MJ	73.0%
Wind power Solar power Water power Geothermal	Low-temperature electrolysis	51.3 kWh	185 MJ	64.9%

Source: NREL

**Facing challenges**

According to the Center for Strategic and International Studies (CSIS), producing hydrogen from fossil fuel feedstocks—such as natural gas or methane—with emissions intensity at or below 2 kg of CO<sub>2</sub> equivalent at the production facility is possible with processes such as SMR or auto-thermal reforming. Hydrogen is considered clean, according to the Infrastructure Investment and Jobs Act, at this carbon intensity level.

“However, capturing the carbon dioxide at high efficacy and at reasonable cost will require innovation,” CSIS said in its July 29 hydrogen hubs report. “A key challenge for fossil fuel hydrogen will be the emissions associated with natural gas production and distribution. Even at high capture rates, CCS might not be effective for producing clean hydrogen after taking into account fugitive methane emissions, other upstream emissions, and carbon emissions outside of the CCS process stream, particularly under the least favorable assumptions for methane-leak rates and high global warming potential.”

High gas prices are also among factors.

Henry Hub front-month futures were trading at \$7.84/MMBtu on Aug. 1, up 100% from a year earlier.

Rising gas prices come as demand increases due to heat waves, surging LNG exports and shifts away from coal-fired electric generation in parts of the world. Europe’s unprecedented energy crisis, as Russia squeezes flows of natural gas to the region following its invasion of Ukraine, is another factor.

Fears of near-term natural gas shortfalls also have emerged in other regions, including in Australia where the Australian Competition & Consumer Commission said Aug. 1 its LNG exporters must divert natural gas to domestic markets to avoid a potential 56 petajoules shortfall in 2023.

The short-term volatility comes as renewable costs fall.

Research shared in June by DNV indicates green hydrogen will reach cost parity with blue hydrogen within the next decade, becoming the cheapest form of production in most regions by 2050. By this time, grid-based electrolysis costs would have fallen to average about US\$1.50/kg, if forecasts hold true.

**‘Part of the equation’**

Backers of blue hydrogen say it shouldn’t be counted out.

DNV also forecasts blue hydrogen costs will drop from US\$2.5/kg in 2030 to US\$2.2/kg in 2050. Costs are already US\$2/kg in regions, such as the U.S., with access to cheap gas, it said.

“We absolutely think that blue hydrogen has to be part of the equation because there just isn’t enough renewable [energy] to make all the hydrogen out there,” Michelle Noack, global climate transition director for Dow, said during a June energy transition conference in New York. “There just isn’t from a practical standpoint.”

Today, nearly all of the world’s 90,000 ton per year of hydrogen produced is gray, but blue hydrogen, some believe, will have a bigger role in the shorter term.

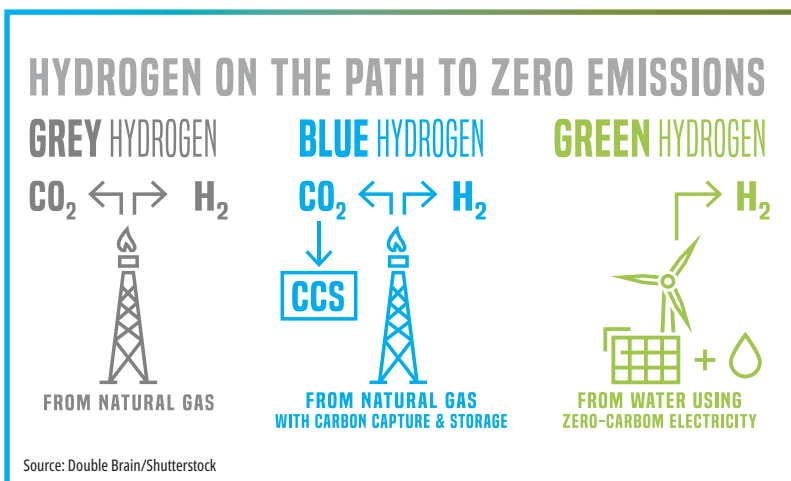
Investments in blue hydrogen continue today as green hydrogen costs fall.

“I’m not worried about the investments that we’re making,” Noack said of Dow’s blue hydrogen investments in Europe and Canada, where it will convert cracker off-gas into hydrogen as a clean fuel to be used in the production of polyethylene and ethylene derivatives at its Fort Saskatchewan, Alberta, site.

“We’re not going wholesale and fixing every single cracker that we have right off the bat. We recognize that technologies are going to change. And frankly, hydrogen probably isn’t going to be

**“We absolutely think that blue hydrogen has to be part of the equation because there just isn’t enough renewable [energy] to make all the hydrogen out there.”**

—Michelle Noack, Dow



the only way we go. ... We're expecting to have electrified crackers," adding the company is working on the technology.

Hydrogen is one of four key verticals for Chevron Corp., which plans to spend about \$2.5 billion in low-carbon hydrogen, according to media reports.

"There's going to be a lot of hydrogen opportunities. We're color agnostic in general," Chris Powers, vice president of CCUS for Chevron New Energies, told Hart Energy. "Blue hydrogen makes a lot of sense in a lot of jurisdictions coupled with CCS. You can take a relatively lower priced hydrocarbon feedstock, capture the CO<sub>2</sub>, and then you've got a nice low carbon intensity hydrogen stream. In other areas, especially as you look several years down the road as cost comes down, green hydrogen is going to make a lot of sense in areas where you've got abundant renewables."

Developing a hydrogen market is less about defining and debating hydrogen colors, experts say.

"It's more about what it takes to grow," added Vimal Kapur, the former president and CEO of Honeywell Performance Materials and Technologies, who was recently promoted to Honeywell president and COO. The company has technology for blue and green hydrogen, including a catalyst-coated membrane technology released this year for green hydrogen production.

Speaking at the June conference, Kapur added there are some limitations on technology, utilization and policy. "I think [hydrogen] can be scaled rather quickly if we get into the mindset of [discussing] what's missing versus trying to define the colors and keep debating [whether] this color is better."

### Addressing scale, demand

Regardless of the potential role hydrogen can play in the energy transition, the position of natural gas or which hydrogen production method dominates, demand and scale are key.

"There are multiple pieces of the value chain to put together. You've got to have pore space to put the CO<sub>2</sub>. You've got to have a source of fuel, good supply, relatively low cost. For instance, gas coming from the Permian or Appalachia," Powers said. "You've got to have an offtaker in a market

to go to. It's really about lining those three bits up; that'll underpin FID [final investment decision] on a big project at scale. We as well as others are doing a lot of work to move some of those projects forward."

Today hydrogen is used mainly in oil refining, fertilizer and industrial processes.

Policy support and incentives will be needed to spur more demand for hydrogen, which remains too


expensive for widespread use today, according to DNV. That is starting to happen, including in North America, where Canada and the U.S. have unveiled hydrogen strategies with focus on production hubs and funding.

"The 2040s will be the decade of demand diversification as more hard-to-abate sectors will be forced to use hydrogen or its derivatives to decarbonize," DNV said in its hydrogen report. "Although the cost of hydrogen will continue to fall and approach the US\$1/kg to \$2/kg, uptake will mostly still be driven by the increased cost of the alternative because of carbon pricing, or by decarbonization mandates."

To meet targets set in the Paris Agreement, hydrogen would need to meet about 15% of global energy demand by mid-century, according to DNV. It foresees slow uptake of hydrogen globally though, reaching 0.5% of the world's energy mix in 2030 and 5% in 2050. In some regions, however, hydrogen's share in the energy mix could be double these percentages.

"Much stronger policies are needed to scale beyond the present forecast, in the form of stronger mandates, demand-side measures giving confidence in offtake to producers and higher carbon prices," the report said.

Bruce Niemeyer, vice president of strategic planning for Chevron, explained how the company is putting the pieces together with collaboration. It has partnered with Caterpillar Inc. to develop hydrogen demonstration projects in transportation and stationary power applications. The two are working with BNSF Railway Co. to confirm the feasibility and performance of hydrogen fuel for line-haul rail.

"We produce a lot of hydrogen every day in our current refining operations. ... Caterpillar can build the engine that burns it, and BNSF has a use case to put it in a locomotive and create a hydrogen railway," Niemeyer said. "It takes all of those pieces to come together. And the reason we are involved in this is we see an opportunity to lead, to bring those pieces together, because that's ultimately all that's required in order to turn hydrogen from a concept into reality." 

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