

Poor Economics for Virgin Plastics

Petrochemicals Will Not Provide
Sustainable Business Opportunities in Appalachia

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November 2021

 **Ohio River
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Acknowledgements:

The authors would like to thank Sean O'Leary, Hector Aguirre, and Bill Holland for their valuable contributions to this report.



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Cover photo: Wikimedia Commons

Released November 2021 by the Ohio River Valley Institute.

The Ohio River Valley Institute is an independent, nonprofit research and communications center founded in 2020. We equip the region's residents and decision-makers with the policy research and practical tools they need to advance long-term solutions to some of Appalachia's most significant challenges. Our work includes in-depth research, commentary, and analysis, delivered online, by email, and in-person to policy champions, emerging leaders, and a range of community partners.

Format and design by Ben Hunkler, Communications Associate, Ohio River Valley Institute.

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Executive Summary

Supply chain constraints, shortages of key products, and volatile energy prices have led to speculation that the petrochemical and fossil fuel industries might “re-shore” virgin plastics production in the U.S. and in the Ohio River Valley, in particular. But, despite the U.S. economy’s strong recovery in 2021, hydrocarbon-based plastics face long-term headwinds. Recent developments in energy and petrochemicals, or “materials,” markets for oil and gas are raising doubts about future demand for virgin plastics—new plastic that isn’t part of a circular manufacturing process that repurposes existing material to reduce waste. Consequently, prospective investors have hesitated to fund major new projects because building out more ethylene production in Appalachia may result in stranded assets. And, even if such projects go forward, they are not likely to produce the economic benefits predicted by industry supporters and hoped for by local communities. For these reasons, the region’s business leaders and policymakers would be wise to shift their focus from virgin plastics production to other strategies for economic development.

Proponents of an Appalachian petrochemical build-out argue that new markets would be created for ethane produced by the region’s natural gas industry. Regional producers’ economic viability depends on selling gas and natural gas liquids (NGLs), since they produce almost no oil. Access to export markets on the East Coast and to new domestic customers outside Appalachia is critical to the region’s industry. In theory, a petrochemical build-out in the region would allow regional gas producers to boost profits by creating added demand for low-cost ethane feedstock for the ethylene industry.

Expanding market access for Appalachian natural gas has become increasingly challenging in the current regulatory environment. Pressure from environmental groups determined to stop pipeline construction and from consumers determined to move away from natural gas as a fuel source have already dampened the outlook for future demand. Ongoing legal challenges to the nearly completed Mountain Valley Pipeline have delayed its startup from 2018 to 2022. And the cancellation of the PennEast pipeline, which would have run from Pennsylvania to New Jersey, further illustrates the barriers regional producers face in attempting to expand their markets.

Oil and gas companies face a future of reduced demand for hydrocarbons as a transport fuel. Already, revenues and profits from the chemical divisions of integrated oil and gas companies are propping up the failing business models of upstream and refinery operations. When oil prices collapsed in 2014, global oil and gas companies embraced the chemical (or materials) portion of their businesses. Chemical divisions would, in theory, enable them to monetize their investments in hydrocarbon reserves. Although recent shortages of petrochemicals due to extreme weather events along the U.S. Gulf Coast and increased demand for consumer products have boosted 2021 revenues for chemicals producers, the long-term economic outlook remains uncertain.

The rapid expansion of the U.S. petrochemical industry over the past decade has been based on both low feedstock prices and the expectation of continued global growth in the petrochemical markets. Feedstock costs have remained competitive—so much so that many foreign companies are now importing U.S. raw materials to maintain and grow their own petrochemicals businesses. Domestic ethylene and propylene producers have targeted the Asian markets as their primary source of demand for their new “virgin” chemicals production. However, China, the primary export market, has begun to import U.S. ethane and propane feedstocks to support its own petrochemical production, displacing some of the demand that U.S. producers expected. In addition, the shift in consumer preferences for recycled and biodegradable materials has dampened projected demand growth for virgin plastics. Once projected to grow at or above the projected GDP growth rate—typically 3-4% per year for long-term planning—the virgin plastics industry is unlikely to see that growth rate in the future. A recent Deloitte study now projects a 50% reduction in the future growth rate for this market, to just 1.5% per year. Only a fraction of global demand for virgin plastics is expected to come from North America, according to the International Energy Agency (IEA).¹



New petrochemical capacity in Appalachia would face severe market headwinds.

Globally, competition within the petrochemical industry is intensifying as gigantic Chinese petrochemical plants come online. Global capacity additions, primarily from Asia and China in particular, will result in sharply lower global operating rates, from 89% in 2019 to closer to 80% through 2025, according to IHS Markit.² Chinese petrochemical plants and other Asian petrochemical plants coming online between 2020 and 2022 will likely satisfy demand coming from Asian markets. Without China as a reliable growth market, the U.S. domestic industry faces a supply glut that would result in capacity rationalization and reduced operating rates.

The environment that supported the “waves” of new petrochemical plant construction principally along the U.S. Gulf Coast and Canada over the past decade has also changed. Environmental, Social, Governance (ESG)-focused stakeholders, including downstream plastics converters, potential investors, and shareholders, have zeroed in on the industry, forcing a reckoning about plastic pollution. China and other Asian countries now refuse to recycle or import plastic waste from the U.S. Consumers demand alternatives, and countries, states, and counties are moving to ban single-use plastic as they run out of landfill space. Finally, local concerns about the health dangers of petrochemicals are growing. Citizens do not want Cancer Alleys in their neighborhoods.

Over the past decade, it might have made economic sense to build out the domestic petrochemical industry, capitalizing on abundant feedstock from the fracking boom in the U.S., global demand forecasts for plastics, and the growing importance of chemical divisions to global oil companies’ enterprise values. This is no longer the case. Between China’s 2017 ban on imports of plastic waste and intensifying pressure to replace difficult-to-recycle plastics with environmentally friendly alternatives, the economic rationale for expanding the virgin plastics industry no longer exists.

Even if federal and state policies support reshoring, much petrochemical production no longer requires 100% virgin plastic. Further, many petrochemical products require raw materials, such as aromatics, that cannot be derived from ethane. As the petrochemical industry moves from reliance on virgin plastic toward plastic alternatives and recycling, petrochemical complexes relying on continued growth in the virgin plastics markets are more likely to become stranded assets.

Over the past decade, particularly over the past five years, the petrochemical and fossil fuel industries have undergone rapid transition. Despite a financially robust first half of 2021, the virgin plastics segment of the petrochemical industry and the rest of the fossil fuel industry face a highly uncertain demand scenario. Both are mature and declining industries. Appalachia will be best served by tying its future to industries that are moving up the growth curve rather than starting to decline.

Weak Long-Term Fundamentals Plague Domestic Fossil Fuel Industry: Sector Remains Risky, Despite Higher Oil and Gas Prices

It’s little wonder that the domestic fossil fuel industry supports a continued petrochemical build-out in the U.S. Oil, natural gas, and natural gas liquids (NGLs) are feedstocks used to make petrochemicals and expand the industry’s domestic market. Conventional wisdom suggests a petrochemical build-out could rescue the fossil fuel industry. Before the recent run-up in oil and gas prices, which spurred sluggish company valuations, the fossil fuel sector had struggled to be profitable for more than a decade.

Much of the oil and gas industry’s woes can be blamed on fracking (a combination of horizontal drilling and hydraulic fracturing techniques). While fracking propelled the U.S. to become the world’s largest producer of both oil and gas, it has, paradoxically, created havoc within the global oil and gas industry. For a decade, the fracking-generated production boom in both oil and natural gas created an oversupply, or glut, which led to historically low oil and gas prices and financial failure for many exploration and production companies that have been buffeted by negative cash flow, consolidations, and bankruptcies. Investors abandoned the sector and stock prices of oil and gas companies plunged. The industry responded by trying to increase cash flows and drastically slashed capital expenditures.

Finally, in 2021, the global economy rebounded sharply and so did oil and gas, with prices in Europe and Asia hitting record highs. But Appalachian gas producers have not been able to capitalize due to shipping constraints and the unwillingness of investors to risk added investment in an industry and region that have burned them badly before.

Despite recent price spikes, financial success from fracking has always been elusive. In the U.S., between 2010 and 2020, frackers spent \$300 billion more to drill for oil and gas than they earned by selling them.³ This has been true for oil and gas producers. Smaller, independent producers fared especially poorly. Most reported negative cash flows nearly every year between 2010 and 2020. Unsurprisingly, bankruptcies have roiled the industry. Roughly \$177 billion of debt has had to be restructured since 2015 due to 266 bankruptcy filings,⁴ according to law firm Haynes & Boone, which publishes a quarterly bankruptcy monitor of business failures in the domestic oil and gas sector.

Oil and Gas Price Volatility Creates Uncertainty

As gas prices rebounded in 2021, gas-focused frackers should have finally seen financial success. But most gas producers use complicated derivatives to protect their cash flows when prices decline. These hedging strategies also limit the companies' profits when gas prices rise. Through the first half of 2021, gas producers recorded considerable losses—primarily because of their hedging strategies. For example, EQT, the nation's largest gas producer, lost nearly \$1 billion in the second quarter of 2021, and will lose nearly \$5 billion through the end of 2022 due to hedging strategies that its CEO recently acknowledged were “obviously” a bad idea.⁵

Though their profits plunged,⁶ gas producers' cash flows have improved throughout 2021 with the higher gas prices. Cash flows have also improved because both oil and gas frackers have slashed their capital spending (CapEx). Investors and lenders demanded frackers focus on generating—not spending—their cash. The frackers have complied. In 2020, they scaled back their CapEx to the lowest level in decades,⁷ and have continued to rein in spending.

Many industry analysts overreact to price fluctuations. Recent improvements in gas producers' financials must be viewed against the industry's history, which is characterized by extreme volatility. Simply, the business case for fracking has never been proved.

Still, large, integrated oil and gas companies, such as ExxonMobil, have increasingly relied on fracking, investing billions each year to earn millions. Between 2013 and 2020, for example, ExxonMobil invested \$61 billion in its upstream operations in the U.S. but managed to lose \$6 billion.⁸

Even industry leaders have long acknowledged the near impossibility of making profits. Steve Schlotterbeck, the former CEO of EQT, the nation's largest producer of natural gas, suggested the industry had effectively committed collective suicide. “The industry is self-destructing,” he noted at an industry conference in 2019. “The technological advances developed by the industry have been the cause of its slow suicide.”

For investors, the “shale gas revolution has frankly been an unmitigated disaster for the buy/hold investor,” he concluded.

More recently, Vicki Hollub, CEO of Occidental Petroleum, acknowledged at CERAWEEK in March 2021 that “the profitability of shale is much more difficult than people ever realized.”⁹ She should know, having led her firm in 2019 to outbid Chevron to acquire Permian-based Anadarko for \$57 billion, an acquisition Carl Ichan called one of the worst deals he'd ever seen.¹⁰ Hollub no longer believes shale “will get back to where it was in 2019.”

Perhaps Texas oilman Mike Shellman said it best. “The fact is the stuff is expensive to get out of the ground, declines like a ship anchor dropped at sea, and is marginally profitable, at best. That's the nature of the stuff.”¹¹

Gas Bans in Cities, Counties, Even Countries Threaten Role of Gas

Even as the world increasingly depends on natural gas as a fuel source, gas has come under pressure from environmentalists, climate-focused citizens, and regulators. The narrative that natural gas would serve as a bridge fuel as the world moves away from fossil fuels has shifted radically over the past few years. The role of gas is increasingly challenged in both the U.S. and abroad. The following examples illustrate growing concerns around gas, as those involved in doing Carbon Dioxide Equivalent (CO₂e) greenhouse gas emissions calculations for environmental impact reports have found that methane is considered to have more than 80 times more greenhouse gas impact on the climate in the short term than CO₂.

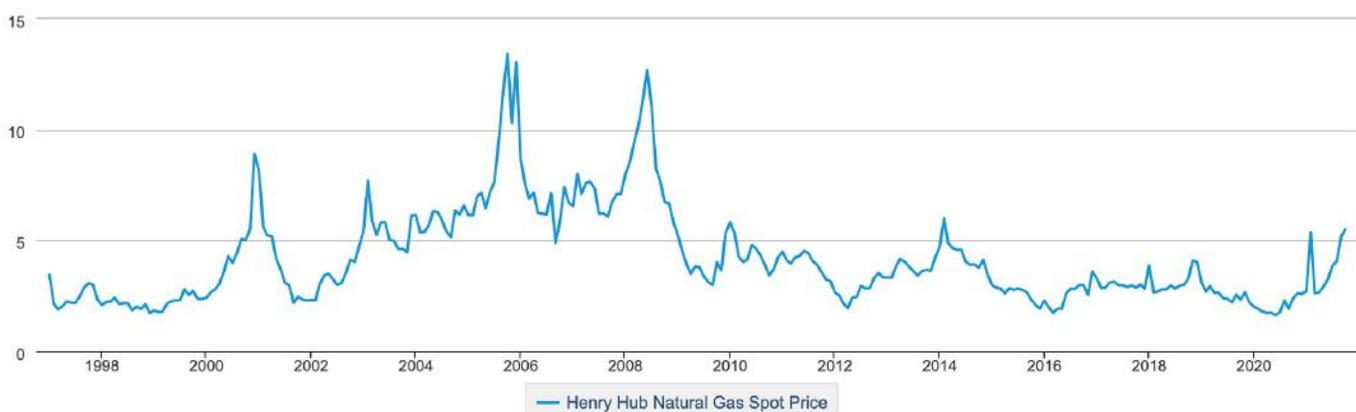
- Since 2019, cities throughout the U.S. have passed laws banning gas hookups in new construction as they seek to decarbonize. But some states are pushing back, including Ohio, which passed legislation to block cities from enacting such zoning restrictions. Notably, the Ohio Chemistry Technology Council and the Ohio Oil and Gas Association supported the legislation to block bans.¹²
- Natural gas's share of the nation's power generation essentially plateaued in 2020, and was expected to decline from 39% to 36% in 2021,¹³ according to the EIA's short-term outlook in January 2021. EIA's more recent forecast, in September 2021, had gas' share of electricity in 2021 at 35%, declining to 34% in 2022.¹⁴ Meanwhile, renewable energy generation capacity is increasing.
- The Biden Administration, in its January executive order, directed U.S. development agencies to “promote ending international financing of carbon-intensive fossil fuel-based energy while simultaneously advancing sustainable development and a green recovery.”¹⁵

- The Climate Leadership and Environmental Action for our Nation’s Future Act (or CLEAN Future Act), would reclassify water extracted from oil and gas wells as hazardous waste. Currently, only 200 sites in the U.S. can process hazardous waste. Most are along the Texas and Louisiana Gulf Coast.
- Internationally, fracking has become a dirty word. Some countries, including Ireland, have introduced legislation to ban imports of fracked gas. And the French government, a part-owner of electricity provider Engie, blocked a \$7 billion, 20-year contract to buy liquified natural gas (LNG) from the U.S., citing concerns about methane emissions.¹⁶
- Many gas producers now tout their gas as “certified Responsible Natural Gas” to assuage stakeholders’ concerns about their products. According to Project Canary, an organization that provides a Platinum, Gold, or Silver TrustWell™ rating to producers and end users, the certification process includes a review and analysis of producer operations and practices. These include prioritizing the reduction of GHG emissions throughout the production process and consideration of community needs and interests. Southwestern Energy participates in this program, and New Jersey Natural Gas has agreed to pay a premium price for this “certified” gas.
- The President of the European Investment Bank (EIB) declared, “To put it mildly, gas is over,” when announcing plans to end financing for fossil fuels by the end of 2021.¹⁷
- The International Energy Agency’s (IEA) Net Zero by 2050 energy sector roadmap, published in May 2021, concluded the world should add “no new oil and gas fields approved for development in our pathway.” The agency’s shifting stance on gas, in this report, was noteworthy.

The Future of the Fracking Business in Appalachia, *in Extremis* for the Past Decade, Remains Challenging Despite Sharply Higher Gas Prices; Oil Majors Abandon Region

Exploration and production (E&P) companies in Appalachia, which produce primarily natural gas and natural gas liquids (NGLs), such as ethane, have performed especially poorly over the past decade. A production glut pushed prices down from \$12.69/ MMBtu in June 2008 to \$1.63/MMBtu in June 2020,¹⁸ averaging \$2.05/MMBtu in 2020.¹⁹ The annual average has not topped \$3.15/MMBtu annually since 2015. Gas prices have recovered sharply in 2021, topping \$6.00/MMBtu in the U.S. (Fig. 1). Gas prices have risen far higher in Europe and Asia for a variety of reasons.

Fig. 1: Henry Hub Natural Gas Spot Price, 1998-2021
Dollars per Million Btu



Source: U.S. Energy Information Administration (EIA)

The billion-dollar question is: do price spikes signal a rebound for the industry, or do they temporarily obscure the longer-term trajectory of the industry? 2021 has seen extreme price volatility, with gas prices tripling.

Some will assert that Appalachian frackers may have finally stopped overspending, and will maintain production levels over the near-term to become consistently profitable. Others, who have watched the publicly traded Appalachian frackers for the past decade, remain skeptical.

Collectively, these frackers' cash flows have been consistently negative since 2010 (Fig. 2).

Fig. 2: Selected Appalachian Frackers' Free Cash Flow, 2010-2020

Company Name	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Free Cash Flow:											
Antero Resources Corporation	-	(635)	(1,347)	(2,131)	(3,088)	(1,332)	(1,254)	(210)	(129)	(319)	(109)
Cabot Oil & Gas Corporation	(372)	(389)	(276)	(170)	(458)	(222)	22	134	210	672	109
Chesapeake Energy	(8,396)	(8,547)	(11,905)	(2,994)	(1,984)	(2,537)	(2,324)	(1,747)	(267)	(640)	182
CNX Resources	(23)	349	(517)	(837)	(523)	(329)	292	16	(231)	(212)	308
EQT Corporation	(457)	(359)	(579)	(601)	(1,037)	(1,234)	(1,526)	(313)	(756)	525	325
Gulfport Energy Corporation	(16)	(130)	(559)	(619)	(926)	(1,271)	(420)	(1,753)	(121)	(1)	(139)
National Fuel Gas	4	(161)	(377)	35	(43)	(181)	118	150	3	(52)	(429)
Range Resources Corporation	512	630	645	742	(450)	(419)	(126)	(396)	(32)	(67)	(166)
Southwestern Energy Company	(80)	(290)	(454)	(344)	90	(218)	(95)	(171)	(67)	(135)	(238)
Total	(8,829)	(9,531)	(15,368)	(6,919)	(8,419)	(7,743)	(5,313)	(4,291)	(1,388)	(229)	(157)

Source: Company's financials and authors' calculations

These frackers, in general, can eke out positive free cash flows only when they drastically reduce capital expenditures—or long-term investments. However, failure to invest in new production is like eating seed grain, as fracked wells face steep decline rates that can exceed 60% in their first year or two. Ongoing CapEx is required just to maintain flat production levels.

More than a dozen producers in Appalachia have filed for bankruptcy in the past few years. The list includes Magnum Hunter (2015); Warren Resources, Penn Virginia, Stone Energy, Ultra Petroleum (2016); Rex Energy, EV Energy Partners, EXCO (2018); EdgeMarc, Arsenal Resources (2019); Chesapeake, Gulfport Energy, BJ Services, FTS (2020), and Rockdale Marcellus (2021).²⁰

Integrated Majors Abandon Appalachia, Taking Huge Write-offs or Accepting 'Fire-Sale' Prices

Global oil and gas companies have, by and large, given up on Appalachia. Royal Dutch Shell sold its remaining Appalachian gas assets in May 2020 for \$541 million to National Fuel Gas in a transaction described as a “fire sale”²¹ by the industry press. Shell had acquired these assets as part of a \$4.7 billion deal in 2010²² and had taken massive impairments of \$6.3 billion on its North American shale properties (which included these assets) in Q2, 2020.²³

Chevron, too, has walked away from Appalachia, selling its Appalachian gas properties to EQT for \$735 million. *Marcellus Drilling News*, an industry newsletter, described the sale price as “pennies on the dollar.”²⁴ Chevron had taken a \$10.4 billion asset write-down in the fourth quarter of 2019,²⁵ more than half of which was related to its Appalachian gas assets.²⁶

And ExxonMobil, which had long resisted taking impairments on its ill-fated XTO acquisition, finally acknowledged in late 2020 that its gas-producing assets were not economically viable and that it would no longer move to develop many of these assets. It took a \$19.3 billion impairment in late 2020, with nearly \$17 billion in U.S. upstream assets being written off. The impairments, according to Exxon, represented an effort to trim “less strategic assets,” specifically dry gas assets in the U.S., Canada, and Argentina.

Exxon had acquired most of its North American gas assets in 2010 with its \$35 billion acquisition of XTO. Exxon had only written off \$2 billion of that acquisition before the 2020 write-down, despite persistently low gas prices. Even Rex Tillerson, Exxon's then-CEO who oversaw the acquisition, had admitted in 2019 that Exxon had paid too high a price for XTO. Exxon's decision to write off its gas assets was long overdue.

Appalachian Frackers Face Ongoing Headwinds: Access to New Markets Thwarted

Though it declined in 2020 primarily due to economic disruptions caused by the pandemic, gas production continues to be robust in the U.S. Gas remains the largest fuel source for the electricity grid in the U.S., representing approximately 40% of the total. However, gas consumption in the U.S. may have peaked in 2019—at least according to the U.S. Energy Information Administration (EIA), which expects gas consumption in the U.S. to essentially remain flat in 2021 and 2022.²⁷ The EIA expects rising gas prices will cause power plants to switch to coal.²⁸

As gas prices have come off the 2020 average of \$2.05/MMBtu, the lowest annual average price in decades, the stock prices of Appalachian producers have also risen sharply. But, despite this apparent good news for the industry, structural headwinds that have battered this industry for a decade have intensified during the past few years.

The economic viability of gas producers in Appalachia depends on selling gas and natural gas liquids (NGLs). Access to export markets on the East Coast and new customers in other regions is critical. But Appalachian frackers have been consistently stymied in their attempts to develop new markets, a trend that seems likely to continue in the current regulatory environment.

New Interstate Gas Pipelines Unlikely, Constricting Take-away Capacity for Appalachian Producers

Pipelines are the primary means of market access. But new interstate gas pipelines are becoming more difficult to build. Even companies in that business recognize the new reality. "I do not think there will be any funding of any big cross-country greenfield pipelines....because of the money that's been wasted," noted Williams Company CEO Alan Armstrong.

Opposition to new pipeline construction by environmental groups and consumers has already curtailed some existing production of natural gas. In 2020, 8.7 Bcf/d of previously planned new pipeline capacity was canceled, including three pipelines in the Marcellus-Utica region. The \$8 billion Atlantic Coast Pipeline, which would have channeled gas 600 miles from West Virginia to North Carolina, was scrapped in 2020 by its two developers, Duke Energy and Dominion Energy, which had spent \$3.4 billion on the project.²⁹ In a joint statement, the companies noted the litigation risks of completing the project. Initial plans for the Atlantic Coast Pipeline included a completion date of 2018.

The Constitution Pipeline would have channeled gas 125 miles from Pennsylvania to downstate New York. When announcing it would abandon the project in February 2020, the Williams Company noted environmental opposition. The pipeline had been proposed and approved by the Federal Energy Regulatory Commission (FERC) in 2014.

The 116-mile PennEast pipeline, which would have carried natural gas from Pennsylvania to New Jersey, was canceled in September 2021. The developers opted to scrap the pipeline just months after winning a legal case against New Jersey in the Supreme Court. They noted that New Jersey was not supporting its efforts to obtain the additional required permits under the Clean Water Act.

Interestingly, developers of each of these pipelines opted to back away from completing the pipelines after they'd just won major legal battles. The U.S. Supreme Court had given the Atlantic Coast Pipeline the go-ahead for the pipeline to cross the Appalachian Trail, one of many legal challenges. The Williams, or Constitution, Pipeline had also received a favorable court ruling just days before announcing its decision to cancel the pipeline, but this legal victory was overshadowed by economic factors, according to S&P Global.³⁰ Williams and its partners, Duke Energy, Cabot Oil and Gas (Cabot), and AltaGas, had taken a \$354 million write-down on the pipeline in 2019.³¹

Pipelines will face ongoing legal challenges. The \$6 billion Mountain Valley Pipeline, covering 303 miles from West Virginia to Virginia, has again delayed its startup from 2021 to 2022. Legal and regulatory issues show no sign of ending. The Environmental Protection Agency (EPA) recommends that the Army Corps of Engineers deny necessary permits before the pipeline can be completed.³² The pipeline was initially expected to be in service by 2018.

Other pipelines that operate between the Gulf Coast and Appalachia face additional obstacles. TETCO, for example, has been ordered to reduce the flow on its outbound shipments because its pipes—some of which date to World War II era—have been deemed unable to handle the required operating pressure for the volume they were moving.

Energy Transfer, the developer of the Mariner East 2X NGL pipeline, in October, was charged by the Pennsylvania Attorney General with 48 counts of environmental crimes, which include criminal charges.³³ The charges relate to poor practices during the construction of the nearly completed pipeline.

Pipeline developers may think twice before embarking on new projects.

Exports of Liquefied Natural Gas (LNG), Ethane Unlikely to Rescue Appalachian Frackers

Liquefied natural gas (LNG) exports were once considered a strong potential market for Appalachian producers. LNG exports represent roughly 10% of natural gas production in the U.S. Gas can be transported to overseas markets from Appalachian producers through the Cove Point LNG facility in Maryland. However, between transport costs, the recent rise in gas prices, and take-away constraints, the prospect for LNG exports to rescue Appalachian frackers' financials is dwindling. Dominion Energy decided to sell 25% of its Cove Point LNG terminal along with its transmission and storage assets to Berkshire Hathaway in 2020. After a six-year attempt to build the Atlantic Coast Pipeline to move more gas to these markets, the company has decided to focus on "cleaner" energy as its future. The sale included its Hastings gas processing complex, one of the oldest facilities of its kind in North America.

Producers have supported investments in ethane extraction and transportation primarily to continue expanding gas production in areas where the ethane content of the gas was too high to allow it to be shipped in the gas pipeline grid. Initial sales were made to existing ethylene facilities in Canada, Northwest Europe, and the U.S. Gulf Coast, where Shell's ethylene complex at Norco, Louisiana, is located. These sales and investments to support them have reduced the "supply push" incentive to sell ethane at low prices. The Shell project received a hefty price subsidy from the State of Pennsylvania, amounting to a \$.05/gallon discount on its feedstock cost for the project's life. This amounts to a 10-25% reduction from the "index" price at Mont Belvieu, Texas, the primary posting point for U.S. ethane prices.

The fate of the New Fortress Energy "LNG by Rail" project proposed for gas in Northeast Pennsylvania illustrates the difficulty of expanding consumption of Appalachian gas without additional pipeline construction. The developer, Wes Edens, planned to build a facility to liquefy local gas production and export it for power generation overseas in markets that lack access to affordable fuels, such as Jamaica, Puerto Rico, and Brazil. The plan included constructing a facility at a port near Gibbstown, New Jersey, to load LNG onto ships. The company successfully pursued FERC approval to transport LNG by rail in order to eliminate the need for large trucks on a narrow, congested highway from the liquefaction site to the terminal. However, it could not secure the funding to build the special rail cars needed for the service. Although the project continues to be mentioned in corporate financial reports as a future source of supply for the company's power generation facilities, work on the site has been suspended.

Appalachian Producers Acknowledge Take-away Constraints, Invest Elsewhere

Appalachian producers acknowledge that their opportunities in the Marcellus and Utica basins have hit a wall. Cabot and Southwestern, two publicly traded Appalachian frackers, announced mergers or acquisitions in 2021 that demonstrate the limitations they face in Appalachia. Cabot merged with Cimarex, a producer with oil assets in West Texas. Cabot, it appeared, sensed both the limitations of producing only in Appalachia and producing only gas when its CEO, Dan Dinges, noted the combined company would "create a diversified energy company. . . that could thrive across commodity price cycles."³⁴ Industry watchers, however, viewed the merger as a sell-out by Cabot since its shareholders received less than 50% of the combined company in the all-cash deal. According to its filings, Cabot had been considering a merger since September 2019, when its management and board had already begun considering potential acquisition targets beyond gas and beyond the Marcellus Utica basin.³⁵

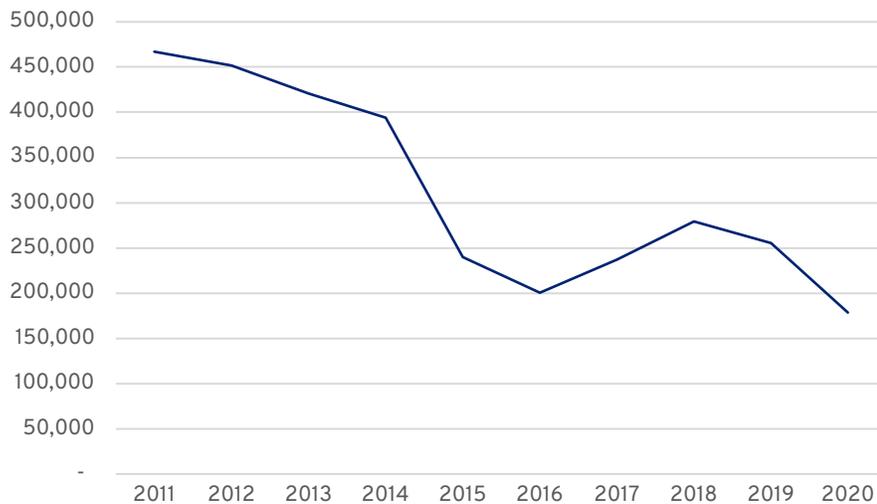
Southwestern Energy acquired Indigo, which has gas assets in the Haynesville Basin in northern Louisiana, for \$2.7 billion, partly to gain access to premier markets along the Gulf Coast, including petrochemical and LNG export terminal connections.

For Oil Majors, Petrochemicals to the Rescue?

Against the backdrop of a long-term decline in oil and gas revenues and relentless and intensifying pressure from ESG investors pushing companies to acknowledge and address financial risks from climate change, the fossil fuel industry is struggling to find a new business model. Petrochemicals have been seen as their lifeline, at least financially. According to the IEA, petrochemicals will become the largest driver of oil demand, comprising over a third of oil demand growth by 2030.³⁶

The industry has become increasingly dependent on its chemical divisions to deliver revenues and profits. [BP is an exception since it sold its chemical division to petrochemical giant Ineos in early 2020 for \$5 billion, noting that it would require too high an investment to build up that division. Ineos had previously acquired most of BP's chemical division in 2005 for \$9 billion.]

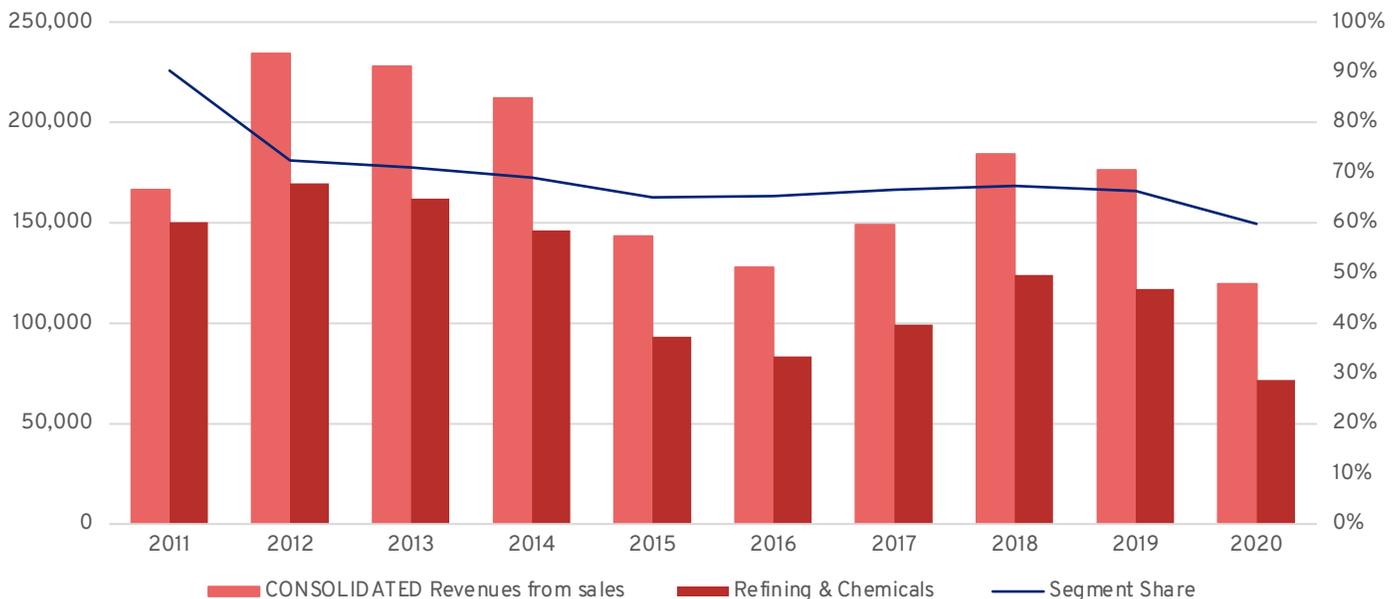
Fig. 3: ExxonMobil Sales and Operating Revenues, 2011-2020
Millions of Dollars



Source: Company's financials and authors' calculations

Total's Refining and Chemical division has comprised more than 50% of the company's revenues since 2011, contributing nearly 60% some years³⁸ (Fig. 4).

Fig. 4: TOTAL Company-wide Revenues Compared to Refinery and Chemicals Revenues, 2011-2020
Millions of dollars



Source: Company's financials and authors' calculations

During the oil price decline from 2014-2016, when oil prices declined from over \$100 per barrel to below \$30 per barrel, Chemical division profits were especially critical. In 2015, profits from their Chemical divisions made up most of Shell's and Chevron's profits, at 78% and 58%, respectively. Similarly, ExxonMobil's Chemical profits, including its share of equity companies, represented 59% of that company's total in 2016 (Fig. 5)

The largest publicly traded oil and gas companies, ExxonMobil, Royal Dutch Shell (Shell), Chevron, Total Energies, and BP,³⁷ have seen revenues from their upstream operations, which includes exploration and production for oil, gas, and natural gas liquids, decline by more than 50% from a decade ago. ExxonMobil's revenues, for example, declined an annual average of 8.5% between 2011 and 2020, with revenue declines each year except for 2017 and 2018 (Fig. 3). The other oil majors recorded similar revenue declines during the past decade. As revenues have declined, so too have profits.

Against this overall long-term declining financial performance over the past decade, these companies' chemical divisions have often contributed significantly to the top and bottom lines.

Fig. 5: ExxonMobil Chemical Division Earnings Compared to Company-wide Earnings, 2011-2020

Millions of Dollars

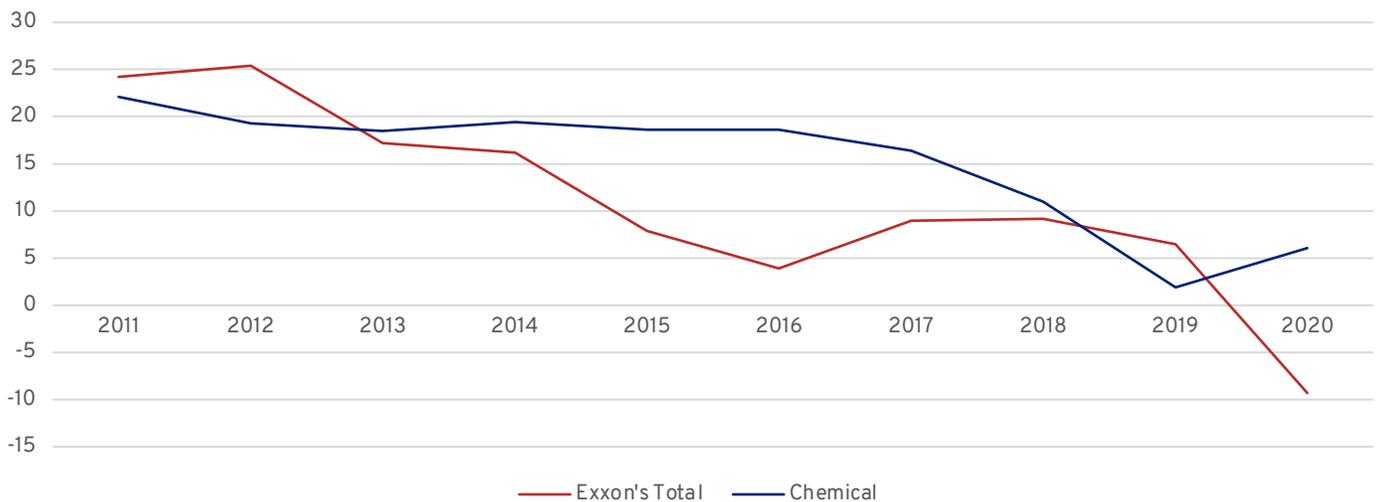


Source: Company's financials and authors' calculations

More significantly, Chemical divisions have boosted the overall *return on investment* of the integrated oil companies. The returns on capital employed (ROCE), a primary metric used in the oil and gas industry to analyze profitability, from the companies' chemical divisions, have been higher than company-wide averages. Profitability metrics from ExxonMobil and Total illustrate how Chemical divisions have propped up otherwise anemic and declining company-wide returns. Between 2011 and 2020, Exxon's Chemical division ROCE averaged 15%, compared to its company-wide ROCE average of 11%. The Return on Average Capital Employed (ROACE) for Total's Refinery and Chemical division has been higher each year than its firm-wide level and has averaged 22%—more than double the company's overall ROACE of 10.6% (Fig. 6, Fig. 7).

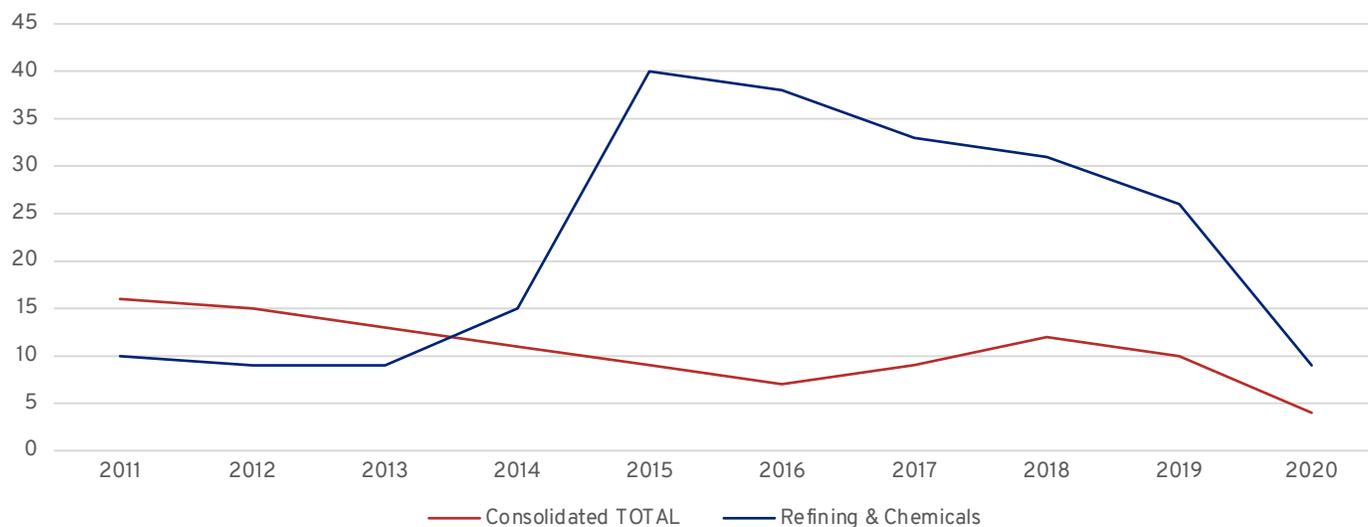
Fig. 6: ExxonMobil Return on Capital Employed (ROCE), Company-wide v. Chemical Division, 2011-2020

Expressed as a Percent



Source: Company's financials and author's calculations

Fig. 7: TOTAL Return on Average Capital Employed (ROACE), Company-wide v. Chemical Division, 2011-2020
Expressed as a Percent



Source: Company's financials and author's calculations

In short, as revenues and profitability from exploration and production have come under pressure, chemical divisions have often been companies' bright spots.

Chemical divisions have also propped up struggling Downstream operations of the oil majors. Profitability of the refining business has declined over the past decade as margins have eroded.³⁹ Stand-alone refineries are no longer financially viable. Their economics are poor unless they are connected to petrochemical facilities. Both ExxonMobil and Shell have divestment plans underway for refineries that are not connected to petrochemical facilities, such as Shell's Convent facility in Louisiana.

Oil and Gas Producers' Interests Should Not Justify Expansion

In conclusion, large and small gas producers in the U.S. have abundant financial reasons to support a petrochemical expansion in Appalachia. Increased production of ethane, a byproduct of the fracking boom, created a petrochemical build-out in the U.S. Frackers have been—and will remain—a critical part of the economic value chain of the petrochemical industry, providing the feedstock.

But frackers' interests in expanding their market are poor justification for further build-out.

Frackers are focused on the short-term. Their quarterly fortunes rely largely on a commodity price (oil or natural gas) and hedging strategies that shield them from adverse price fluctuations, while limiting their upside profits. Frackers' production cycles are extremely short. Many of the oil majors refer to their fracking operations as "short cycle." Fracked wells can be drilled quickly to ramp up production and newly drilled wells produce most of their volume during the first years of operation.

The petrochemical industry—in sharp contrast to frackers—must make its investment decisions based on assets that will have productive lives of at least 15 years. Economic development plans commissioned to justify new petrochemical plants often use a 40-year assumption. Given their different investment horizons, gas producers should not dictate the investment decisions of the petrochemical industry.

Beyond the narrow interests of fossil fuel producers, increasing virgin ethylene production capacity in Appalachia faces a separate set of challenges.

The Next Decade of Ethylene: Revisiting the Business Case for Virgin Plastics in Appalachia

While the post-pandemic recovery in oil and gas prices has improved the near-term financial outlook for the E&Ps and integrated oil and gas companies, issues have emerged since the Shell facility was approved for construction in 2016 that will affect the decision process for ethylene producers looking at new capacity investments for growth in the third decade of the century. Chemical plant outages on the U.S. Gulf Coast due to Winter Storm Uri in February 2021 caused shortages of ethylene and propylene and raised

prices across the plastics value chain during 2021. The Gulf Coast also has experienced plant outages resulting from hurricanes and floods. These events, together with shortages of PPE and other plastic products, have been mentioned as justification for expanding virgin plastic production elsewhere in the U.S., specifically in Appalachia.

To be profitable, a virgin plastics petrochemical complex must have an overall cost structure, including the initial investment and the projected operating costs, to pay back its investors over a 15- to 20-year period to support a multi-billion-dollar capital investment. Producing virgin plastics is ultimately a cyclical business that competes in a global market, one that faces tremendous uncertainty over the next decade. An update of the key factors in the decision process involved in adding virgin ethylene production capacity indicates Appalachia faces unique challenges as a location for new ethylene plant construction.

This assessment is based on the demand outlook for the types of virgin plastics these plants would produce, projected feedstock supply, availability within the region, and new market risks due to changes in trade policy.

The key issues that have impaired the economic outlook for new ethylene capacity in Appalachia are:

1. An increased focus on the environmental impact of plastics has changed the assumptions about demand growth for polyethylene (PE), which is the primary market for the ethylene derivatives these plants produce.
2. Pledges by major ethylene producers to reduce CO2 emissions in their manufacturing processes may change plant technology and affect siting decisions for new construction.
3. The outlook for future gas production and ethane supply in the region indicates that the available future ethane feedstock pool would only support one more ethylene plant at most, far fewer than the 5 or 6 that were initially projected 5 years ago. Future plant projects now face competition for feedstock from buyers in other U.S. regions and other countries that are now connected by pipelines to the Appalachian market.
4. Margin pressures resulting from changes in China's trade policies and focus on self-sufficiency.

The New Ethylene Plants' Products Are Commodities, Not Specialty Plastics

Understanding the products that would be made from the ethylene produced in the region is essential to understanding how the outlook for these plants could be impacted by changes in environmental and economic conditions. Ethylene is known as the "building block molecule" for a number of petrochemicals, and ethylene plants often have additional units on site besides the main "cracker" to produce ethylene derivatives. These derivatives are intermediate materials made (derived) from ethylene. Derivatives are made by attaching other molecules to the ethylene, rearranging the structure of the ethylene molecules, or blending them with other materials to create the type of plastic that's needed by the target market.

Polyethylene (PE) is the primary ethylene derivative and makes up about 60% of the global ethylene market.⁴⁰ Ethylene crackers can also produce higher-value, higher-margin derivatives such as ethylene oxide, a material used in the fibers, cosmetics, and automotive industries; ethylene dichloride, used to make vinyl; and ethylbenzene, used to make styrene (hard) plastics. This analysis focuses on the market outlook for PE because this is the value chain potential petrochemical projects in Appalachia, including the Royal Dutch Shell cracker in Beaver County, PA, would target.

Appalachian Ethylene Value Chain: From Ethane to Polyethylene (PE)

Ethylene can be produced from a number of hydrocarbons that can be sourced from natural gas or oil, as well as from recycled plastics. In Appalachia, producers with "rich" or "wet" gas, which contains significant amounts of NGLs (ethane, propane, butane, and natural gasoline) face challenges due to the relatively high ethane content of their gas streams. Ethane can usually be mixed with methane (what we typically think of as "natural gas") and sold as part of the gas stream unless the ethane content exceeds the level the regional pipeline grid will accept for transport. When that happens, ethane and other NGLs must be removed to meet gas pipeline specifications. They can then be used as feedstock for petrochemicals.

The supply chain for ethylene begins when the gas is moved to a processing facility where the NGLs are removed from the methane stream.



Berne Gas Processing Plant, Monroe County, Ohio

This is the **Berne Gas Processing Plant**⁴¹ in Monroe County, Ohio. The NGLs removed from the gas at this plant are still mixed. They are sent to the Natrium complex in West Virginia to be separated into components. The ethane portion of the stream is then shipped via pipeline to cracker plants along the Gulf Coast, Canada, or the ethane export terminal in Marcus Hook, Pennsylvania.

Shell has also built the Falcon Pipeline to gather ethane from the Markwest Houston (PA), UEO Midstream Harrison (OH), and the Markwest Cadiz (OH) complexes for use as ethylene feedstock at its new petrochemical complex in Monaca, Pennsylvania.⁴²

The final investment decision to build the Shell plant was announced in 2016, and operations are expected to begin in late 2021 or early 2022. The plant will use very high heat to ‘crack,’ or literally break, the bonds of ethane molecules, and rearrange them to produce ethylene in the furnace banks shown at the back of this picture. The molecules can then be combined with other molecules to produce intermediate materials known as “derivatives” whose composition can be altered depending on the product for which they are intended.



Shell Polymers petrochemical complex, Monaca, Pennsylvania

A process called polymerization converts the derivatives into a **solid resin that takes the form of pellets**, called “nurdles.”⁴³

The nurdles can be customized to make different types of plastics in various colors depending on the customer’s finished product. Nurdles destined for the domestic market are usually blown into special “hopper cars” and transported by rail. For the export market, they are usually packaged in plastic bags. Due to concerns around the amount of pellets that were escaping into the air and water during loading and transit, the American Chemical Council and the Plastics Industry Association have developed Operation Clean Sweep, “seek[ing] to reduce plastic pellet, flake, and powder loss.”⁴⁴ A number of railroads have signed on to be part of this program.



Nurdles, the solid resin pellets used in petrochemical production.

The next step is the plant where they will be turned into the products that consumers see. These facilities are called “converters”, and can be located near the

ethylene plant if the regional market is big enough. When the ethylene plant is in a more remote location to be closer to the feedstock supply, the resins are often shipped to converters that are closer to the customers. The one Appalachian ethylene plant under construction, and any others that are considered, would be located relatively far away from the major population centers in the Midwest and Northeast where existing converter capacity is located. The number of new converters that are likely to locate close to any new Appalachian ethylene plants is expected to be minimal.



Blow molds for plastic milk containers.

The picture at left⁴⁵ shows a machine used for **blow molding** milk containers. The resin is heated, and the liquid resin is pushed into the mold with air, then cooled to create the solid shape of the object. The development of 3D printing makes it much less expensive to create products since the printer allows a designer to make his or her own milk molds on site.

Another key market for PE is to make **film** used for packaging materials. The resin pellets are fed into a machine that heats them and pushes the material through holes that ‘extrude’ the melted resin into a film that is cooled and stretched. These so-called extrusion machines can be much larger than blow molders.

The picture below is from an Exxon Chemical facility near Houston. Since the population in the Houston region exceeds six million people, there is enough consumer demand in the area to co-locate a film plant near the chemical facility.



Exxon Chemical packaging materials facility near Houston, Texas.

Renewed Focus on Circular Production Reduces Future Virgin Plastics Demand

As of 2019, over 50% of polyethylene—60% of global ethylene plant output, and what the Appalachian plants would make—is for packaging.⁴⁶ Put differently, this means that 30% of global polyethylene production is used in the packaging sector. Demand for plastics in food packaging, takeaway orders, and shipping grew significantly in 2020 due to the pandemic. However, the amount of plastic pollution from these single-use plastics (SUPs) has also become a focal point of concern for communities around the globe. When China banned imports of plastic waste in 2017, waste collection companies that had shipped material from the U.S. to China were forced to find other ways to get rid of it. This has led to more plastics going to landfills and more plastic waste in the water.



Growing consumer and investor concern about the plastics pollution crisis stands to undercut future virgin plastics demand.

The discovery of microplastics at the top of Mount Everest and other examples of **plastic pollution**, such as pictured on a beach in Lebanon,⁴⁷ have made headlines. According to statistics posted by the Environmental Protection Agency (EPA), 76% of the plastic generated in the U.S. in 2018 ended up in a landfill.⁴⁸ As a result, the petrochemical industry has acknowledged its customers' increasing desire to convert plastics production into a circular process instead of a production line that ends in the garbage. This involves not only reducing the amount of plastic that's needed for certain applications, but also recycling to make products from post-consumer materials including returnable and refillable containers, and to create plastic from bio-based feedstocks instead of hydrocarbons.

In May 2018, the Plastics Division of the U.S. chemical industry trade association, the American Chemistry Council (ACC), announced "ambitious goals that crystallize U.S. plastics resin producers' commitment to recycle or recover all plastic packaging used in the United States by 2040 and to further enhance plastic pellet stewardship by 2022."⁴⁹ Steve Russell, the group's vice president of plastics, stated that "together with our value chain partners, we intend to transition to increasingly circular systems for designing, manufacturing, recycling and recovering our plastic packaging resources." One of the organization's goals that affect plans for new production capacity is to have 100% of plastic packaging be reused, recycled, or recovered by 2040.

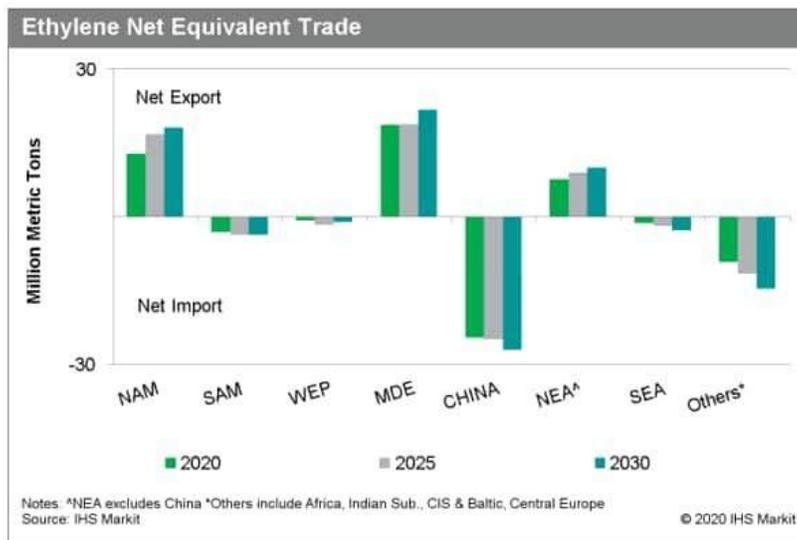
For companies looking to add future virgin plastics manufacturing capacity, these goals make forecasting more difficult. In the past, ethylene producers assumed that global demand for their products would grow at a rate slightly higher than Gross Domestic Product (GDP), which was assumed to increase at 3-5% a year or higher for developing economies that were increasing their consumption of

consumer products. Now, even though demand for plastics is still expected to expand, its overall growth rate is no longer expected to move in lockstep with GDP growth as part of the future growth in plastics demand will be supplied by recycled or reused materials.

A study by consulting firm Deloitte⁵⁰ notes that “there are a significant number of polyethylene plants that are currently being constructed worldwide—about seven million metric tons of polyethylene capacity is expected to come online between 2019 and 2022 in the U.S. The underlying assumption is that demand for plastics will grow at an average annual rate of 3%. But given the changing consumer preferences and regulatory risks, the growth rate in demand for plastics could potentially halve in the long run, and a decrease in SUP (Single Use Plastic) consumption could lead to overcapacity and a decrease in prices.”

Regardless of the pace of global growth, expectations are that U.S. capacity will be still greater than needed to satisfy domestic demand. An IHS Markit outlook in Fall 2020⁵¹ shows that net exports of ethylene from North America (NAM in Fig. 8) are expected to climb over the next ten years. The U.S. and the Mideast (MDE), with their lower-cost gas-based ethane and propane feedstocks, are expected to increase sales to China and other Asian countries by a significant amount.

Fig. 8: IHS Markit Ethylene Net Equivalent Trade Projections, 2020-2030



Source: IHS Markit

Uncertainty Around Single Use Plastics (SUPs) Demand Impacts High Density Polyethylene (HDPE) and Threatens Profitability of Shell Cracker Plant

One of the main materials used to manufacture SUPs is High Density Polyethylene (HDPE), which is one of the primary products Shell plans to produce in its Pennsylvania petrochemical complex. Efforts to increase recycling and reduce the use of SUPs could cause oversupply in this market, which presents risks that go beyond the typical risk of overbuilding in a down economic cycle to the Shell ethane plant and other potential Appalachian projects. Bans on SUPs in the U.S. and elsewhere in the world (China banned production of “ultra thin” plastic bags in 2008)⁵² are expected to significantly decrease the demand for the commodity grades of PE used for plastic bags and cutlery.

PTT, the Thai state-owned oil and gas company which, for many years, had considered building a petrochemical complex in Appalachia, has already taken steps to increase its use of recycled plastics. It was named number 19 on the Top 20 Plastic Waste Makers Index of 2019 for generating single use plastic waste in a study published by Australia’s Minderoo Foundation.⁵³ The company plans to stop making single use resins in Thailand.⁵⁴ In announcing its plans, “...PTT Global Chemical Plc (PTTGC), Thailand’s largest petrochemical maker . . . plans to spend 1 billion baht on a commercial recycling plant for single-use plastic products with a capacity of 30,000-40,000 tons per year. The facility is planned for Rayong Industrial Estate in Map Ta Phut.” The company’s spokesman said, “This move is part of PTTGC’s long-term strategy that aims to terminate the production of single-use plastic resin at its petrochemical complex (in Thailand) within the next five years.” “PTTGC produces 150,000 tons of single-use plastic resin per year, mostly for bottles, straws and bags.”

The Raw Materials Needed for Personal Protective Equipment (PPE), Medical Plastics and Other Consumer Goods Pose Challenges for Appalachian Ethane-Based Chemical Producers

Efforts to increase recycling also affect the plastics market throughout the health care sector. ExxonMobil is taking its experience with polymer-based technologies and partnering with the [Global Center for Medical Innovation](#) to redesign and manufacture reusable Personal Protective Equipment (PPE), such as face shields and N95 masks. This initiative, which is pending approvals from the Food and Drug Administration (FDA) and the National Institute for Occupational Safety and Health, will facilitate development and third-party production of a PPE gamechanger: safety equipment that can be sterilized and worn multiple times.⁵⁵

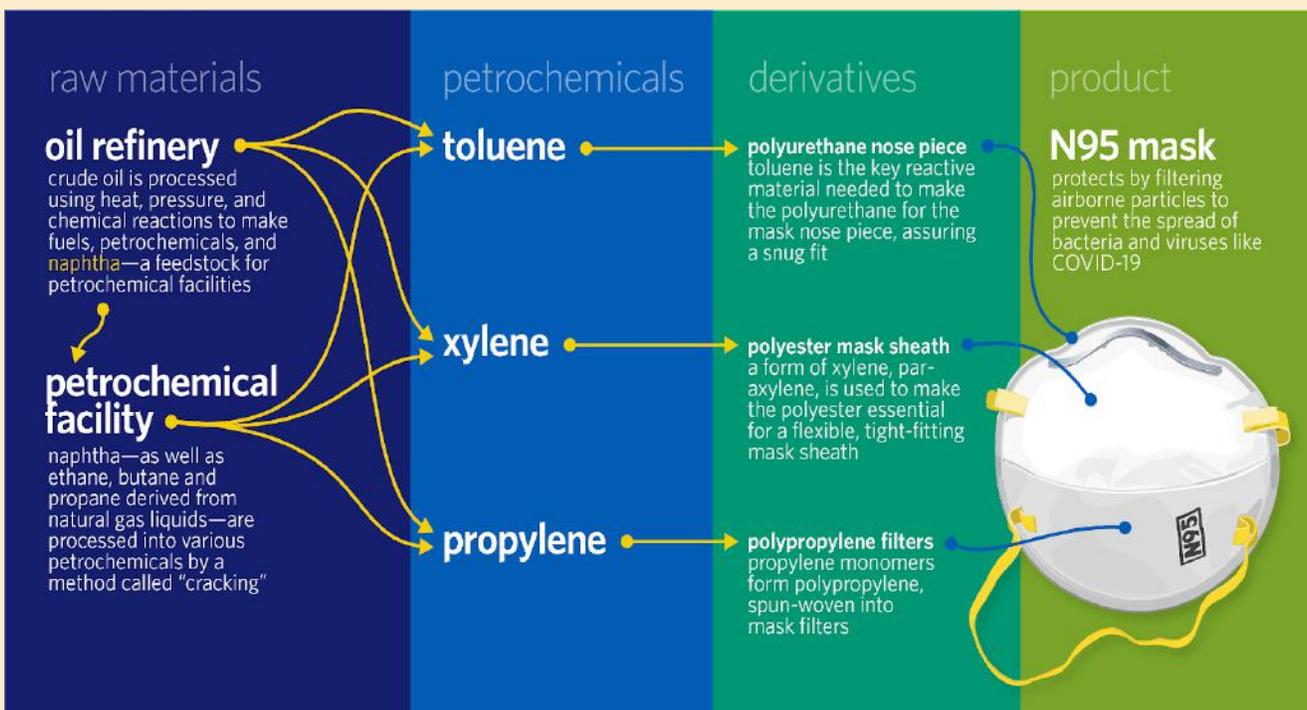
Even though the outlook for virgin plastic demand is less certain than it was prior to the “green” movement, the pandemic

has highlighted some glaring issues in the supply chain for materials used in the PPE and healthcare sectors. Americans experienced shortages of the N95 and other surgical masks, the preferred means of reducing airborne transmission of viruses.

The potential for reshoring parts of this value chain for PPE production has been raised to support additional ethylene production in Appalachia. However, the market for the production of PPE is unlikely to provide enough growth potential to justify investment in more world-scale ethylene production facilities in the region. Efforts are intensifying to reduce the use of virgin plastics for face masks and shields through recycling and reuse, as described in the previous section. But this is not the only obstacle facing a build-out of ethylene production in Appalachia.

A far greater challenge in targeting the PPE and health care industry as a primary market for the output of a world scale ethane-based ethylene plant in Appalachia is that face masks and other medical plastics are not, in fact, made from ethane. Fig. 9⁵⁶ shows the raw materials needed to make the so-called “gold standard” N95 mask, which was in short supply early in the pandemic.

Fig. 9: Supply Chain for N95 Mask



Source: American Fuel & Petrochemical Manufacturers

As Fig. 9 illustrates, the chemical derivatives that are used in medical masks are not produced from ethane. For example, the petrochemical “ingredient list” for medical masks, among other medical products, includes propylene, toluene and xylene. Toluene and xylene are also known as aromatics, and are by-products of crude oil refining or from cracking crude-based feedstocks such as naphtha, not ethane. Propylene also comes from refineries or from cracking propane feedstock. Prior to the shale drilling boom, propane was imported into Appalachia from the Gulf Coast and overseas for winter heating. Now, production has increased to the point where the region is a net propane exporter during the spring and summer, but inventory still needs to be built to meet winter demand. As a result of increased demand for propane overseas, regional propane prices are now high enough to make propylene production uneconomic in Appalachia.

Ethylene-Derivative Products Often Require Co-Products, Which Require Feedstocks Other than Ethane

Many products made from ethane-based ethylene products use significant amounts of polypropylene (propane feedstock), polyvinyl chloride (PVC), chlorine, polystyrene (PS), and benzene. These types of chemicals and feedstocks are far easier and less expensive to procure on the Gulf Coast than in Appalachia. The salt domes that are mined for the chlorine used to produce PVC and the refineries that are the primary sources of the benzene used to make polystyrene are located near the chemical plants along the Gulf Coast. Benzene, like toluene and xylene, is an aromatic that usually comes from crude oil refining, and is considered to be a potent carcinogen, with handling and storage governed by strict regulations.

In the May 2015 “Ethane Cracker Supply Chain Market Study,” prepared on behalf of the Mid-Ohio Valley Regional Council,⁵⁷ the authors assumed that virtually any petrochemical product that used ethylene as an input could be economically produced in the region. This assumption is faulty. Production of many of these ethylene-derivative products, such as synthetic rubber, PVC pipe, carpet fibers, polyester yarns, antifreeze, and clear plastic bottles, require co-products that aren’t produced by ethylene crackers that use ethane as a feedstock. The ethylene production facilities that make these are designed to use a wide range of feedstocks, such as propane, butane, and light naphtha, or are co-located near refineries that provide these feedstocks as by-products of transport fuel production. Ethylene facilities that use multiple feedstocks are also more expensive to build due to the need for additional processing units and facilities needed to separate, store, and ship the additional co-products. The primary appeal of the Appalachian region to ethylene producers was its potential access to cost-advantaged ethane feedstock and proximity to regional markets for the packaging materials and containers that are easily made from ethane-based ethylene.

Global Warming Has Emerged as a Real Challenge for Petrochemical Producers

In addition to the environmental issues around plastic pollution and recycling that affect land and water, the petrochemical industry faces challenges from groups that are protesting greenhouse gas (GHG) emissions, such as carbon dioxide (CO₂) and methane, that result from manufacturing processes.⁵⁸ The increasing focus on global warming and growing emphasis on reducing GHG emissions also puts pressure on petrochemical producers. In a March 2021 article, “The Search for Greener Ethylene,”⁵⁹ *Chemical & Engineering News* noted that the industry has searched for ways to reduce ethylene’s environmental footprint for decades. The industry’s search for solutions to reduce its emissions is ongoing. Many chemical companies, such as BASF, have made pledges to keep their CO₂ emissions flat. Others, including Shell and Dow, have pledged to be carbon neutral within the operating horizon of new ethylene plants. BASF’s new ethylene complex in Zhanjiang, China, which is currently under construction, could deliver 60% lower CO₂ emissions than a gas-based petrochemical facility of a similar scope.⁶⁰ This facility will be based on refinery-type feedstocks such as naphtha and will use some of the CO₂ and hydrogen it produces to power the plant.

A potentially promising avenue for emissions reductions is the use of electricity instead of natural gas as a heat source in the ethylene furnaces. The challenges this situation poses to further development in Appalachia are related more so to timing as opposed to technology. Parts of the region do have access to relatively low-cost power, although, ironically, it may be generated by natural gas.

New technologies that reduce emissions are currently not in use at production scale. Estimates are that it will take at least a decade for them to be commercially viable. Companies that are targeting emissions reductions through these types of efficiencies could delay the construction of new facilities to avoid early obsolescence.

Feedstock Cost and Availability is Changing—Will There Be Enough Cheap Ethane for Ethylene Producers?

The key factor in profitability for an ethylene plant producing a commodity product such as PE is cost structure. Low feedstock costs are key to sustainable margins. This is especially true in an industry that often overbuilds when times are good and feedstock costs are low.

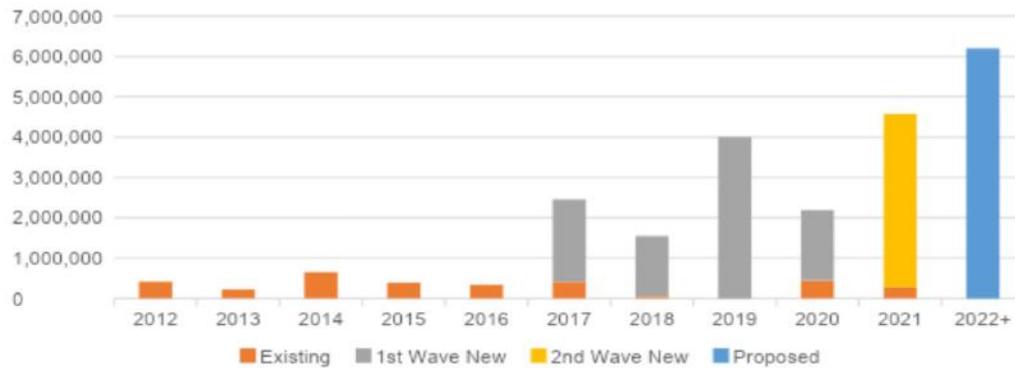
Specialty plastics have a higher margin since they are produced for targeted applications. In contrast, commodity plastics can be sold into a broader market, but face competition from other producers that make the same sorts of plastics. Ethylene producers in the U.S. expanded their capacity to use ethane for two reasons: 1. an abundance of supply, and 2. ethane prices were low enough in the U.S. to make their feedstock costs lower than crude oil-based feedstocks, such as naphtha from refineries.

One of the key decision factors for siting the Shell facility in Pennsylvania was a state tax subsidy that effectively provides a 20 to 25% discount on its ethane cost relative to other facilities. This was in the form of a credit of \$.05 per gallon of ethane it buys for the Monaca cracker. The value of the subsidy over a 15-year investment life could be enough to cover most of Shell’s direct payroll costs. This offered Shell a significant discount to the price of ethane on the Gulf Coast. At the time the Pennsylvania legislature passed the budget containing this provision, the subsidy was estimated to be worth \$1.65 billion to Shell.⁶¹

The initial assessments of ethane supply in the Appalachian region were made back in 2012 to 2015, as part of the development plans for the ‘first wave’ of new ethylene plants, which would be constructed during the ‘shale decade’ beginning in 2011. Fig. 10 shows the massive increase in U.S. ethane-based ethylene production capacity that occurred during this time. The ‘first wave’ ethylene plants are highlighted in gray. Between 2012 and 2021, nearly 17 million tons of additional production capacity was added in the U.S. market, increasing the total to 43.5 million tons. This is a 38% increase in just a decade.

The ‘second wave’ of U.S. ethylene capacity expansions had planned start dates between 2019 and 2022 and is highlighted in gold. This category includes the Shell plant in Pennsylvania. The PTTGC plant in Ohio, which had been under consideration for nearly a decade before being put on indefinite hold in 2021, is part of the “proposed” group, shown in blue. It is notable that final investment decisions (FIDs) for *all* plants in the group of world-scale proposed plants that were considered the next wave of capacity to be added by 2025 have currently been postponed.

Fig. 10: U.S. Ethylene Capacity Additions, 2012-2021
Millions of Tons

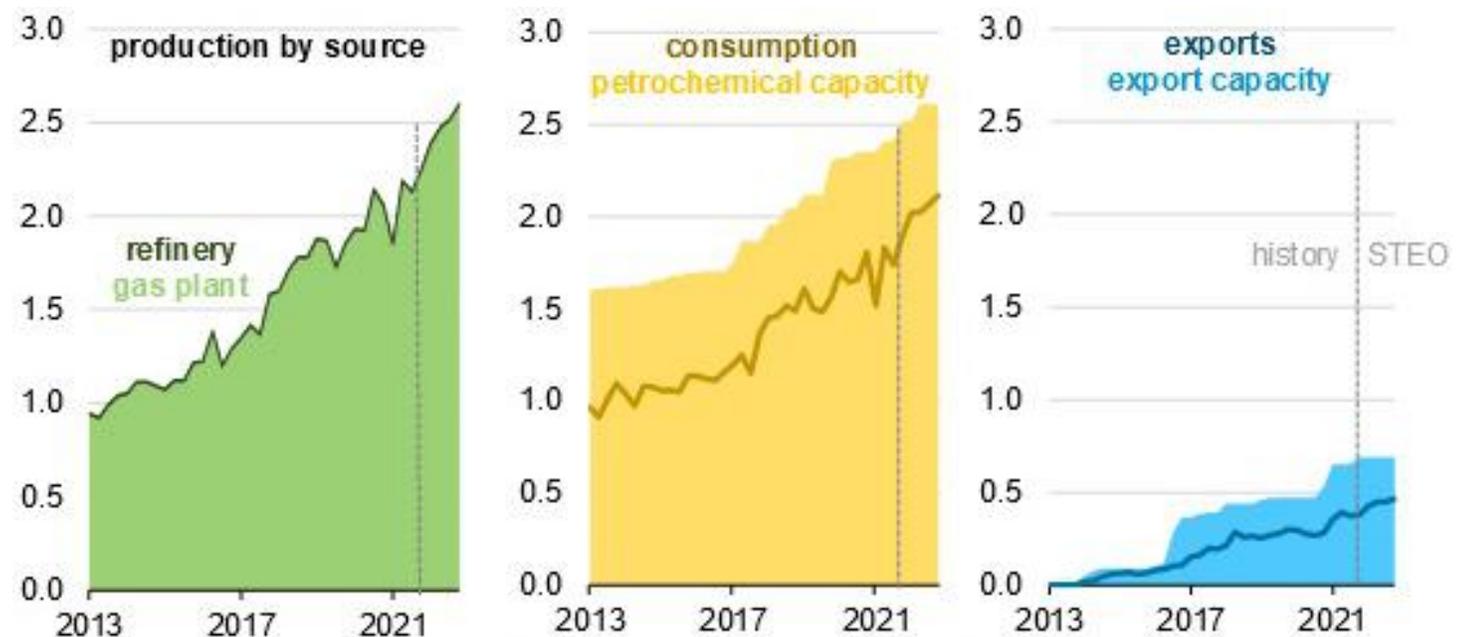


Demand for ethane feedstock has risen rapidly to accommodate the new petrochemical plant builds, many of which have ethane-only feedstock capabilities. The massive ethane-based ethylene capacity additions in the U.S. and China have tightened the U.S. ethane market. The EIA shows ethane exports reached a record high in March 2021, and are expected to go higher still as new ethylene plants begin operations in China, as illustrated in Fig. 11.

Source: Company websites and presentations, state permits, Midstream Energy Group infrastructure datafiles.

These EIA charts show how rapidly ethane demand has increased since the new big plants began operations on the U.S. Gulf Coast in 2017. The charts are also forecasting the growth in total U.S. export demand for ethane to reach 460,000 barrels a day by 2022. This is approximately twice the total ethane production in Appalachia.

Fig. 11: U.S. Quarterly Ethane Production, Consumption, and Exports, Jan. 2013–Dec. 2022
Millions of Barrels per Day

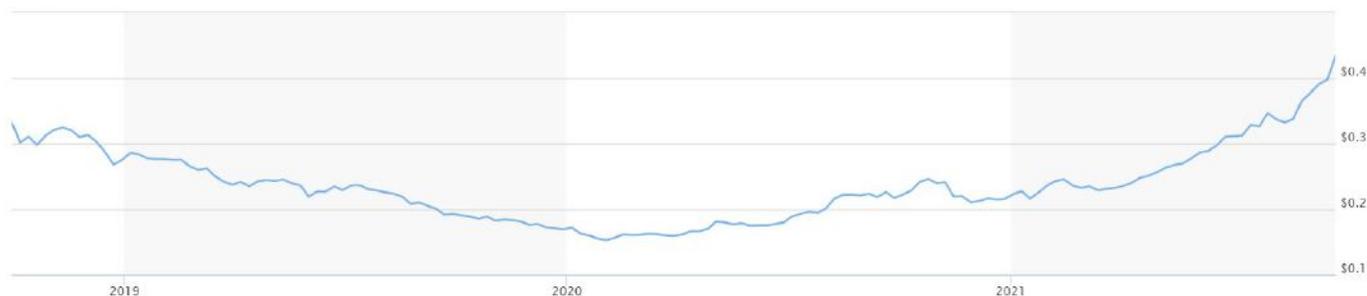


Source: U.S. Energy Information Administration (EIA)

Although previous forecasts emphasize that ethane is still available to be removed from the natural gas for use as ethylene feedstock, the Midstream Energy Group research indicates that the U.S. ethane market west of the Mississippi will be balanced by late 2022. This research includes the impact of increased demand for ethane from the start-ups of the Shell ethane cracker in Monaca, PA, and the expansion of the Nova petrochemical plant in Sarnia, Ontario. (Both will be supplied by ethane from Appalachia.)

The shift to a market that needs to rely on production farther from the U.S. Gulf Coast region, combined with higher natural gas prices, has nearly doubled ethane prices at the Mont Belvieu, Texas, hub in 2021. The three-year history chart, Fig. 12, shows ethane prices moving up from \$.23/gallon in January 2021 to \$.43/gallon at the end of September to exceed the highs of the prior three years. Further price increases could provide an incentive for producers in the Marcellus/Utica region to recover more ethane and ship it to the Gulf Coast.⁶²

Fig. 12: Mont Belvieu Ethane, 2019-2021



Source: MarketWatch

Other market opportunities for Appalachian ethane producers have emerged with the expected completion of two other projects by the end of 2022. The long awaited, often contested completion of the largest NGL pipeline in the Northeast,⁶³ Energy Transfer’s Mariner 2X to Marcus Hook, will enable an additional 250,000 barrels a day to be transported to the export terminal. To the West, Nova is expanding its ethylene and PE production complex in Sarnia, Ontario, by 50%, to an estimated 1.22 million tons. This unit will use additional ethane sourced from Appalachia, increasing demand for ethane exports to Canada by 25,000 barrels per day, or just over 10% of current regional production.

Midstream Energy Group’s current estimates show that there is now enough ethane separation (“de-ethanization”) capacity and pipeline space available in the region to put a potential 145,000 barrels a day of additional ethane into the market without additional midstream investments, after satisfying demand for the Shell cracker and the Nova plant expansion.⁶⁴ Based on critical assumptions—that drilling will continue to enable production levels to remain constant over the next 20 years and that the producers agree to contract it for local use—the ethane feedstock pool could support only one more Shell-sized facility in the region. This is far fewer than the five that were initially proposed a few years ago. Additional competition in the ethane market will likely increase the cost of feedstock, reducing the competitive advantage of making ethylene in the region.

In short, even if adequate ethane supplies were available to supply another petrochemical plant in Appalachia, the tighter U.S. ethane market and producers’ ability to access other markets will likely push ethane prices too high to make such a facility profitable.

Changes in Chinese Trade Policies Have Created Uncertainty Around Future Export Markets for U.S. Ethylene Producers

The petrochemical industry, as has become obvious during the pandemic with its shipping issues and supply-chain problems, is a global business. Previously, producers largely supplied their home and regional markets. This is changing. Since the pandemic, buyers increasingly source polyethylene from whatever region offers the lowest delivered cost material.

As was noted previously, companies that sell a commodity such as PE must focus on being the lowest-cost producer. Over the past decade, ethane’s low price relative to crude-based feedstocks created a capacity-building boom of ethane crackers. This significant production cost advantage, based on ethane feedstock, resulted in capacity growth in the Middle East, Canada, and the U.S. These regions became the world’s lowest-cost suppliers. The U.S. has had a particular cost advantage, since it has the largest amount of available ethane to supply new facilities.

Once regional markets were supplied, surplus low-cost ethylene produced in the Middle East, Canada, and the U.S. could be exported. China became the target market for much of the surplus ethylene, since it was the primary manufacturing region for many

of the products using PE as a raw material. Chinese manufacturers generally have lower labor costs. But they have faced shortages of raw materials.

The assumption that China, the target customer for the last pound produced, can and will absorb these products, has been challenged. Two primary factors have contributed to the change in assumptions: 1) Chinese companies have expanded their own ethylene production capacity, with a goal of leading China toward self-sufficiency in petrochemical production; and 2) Trade tensions between the U.S. and China have changed the market. These trade tensions are ongoing.

Chinese companies that were importing ethylene from the U.S. and were expected to continue to be the primary growth market for surplus U.S.-based production have expanded their own capacity. They can no longer be counted on to import PE—at least not at the scale once envisioned.

Fig. 13 provides a list of new cracker plants or cracker expansions in Asia, with start-up dates in 2020.

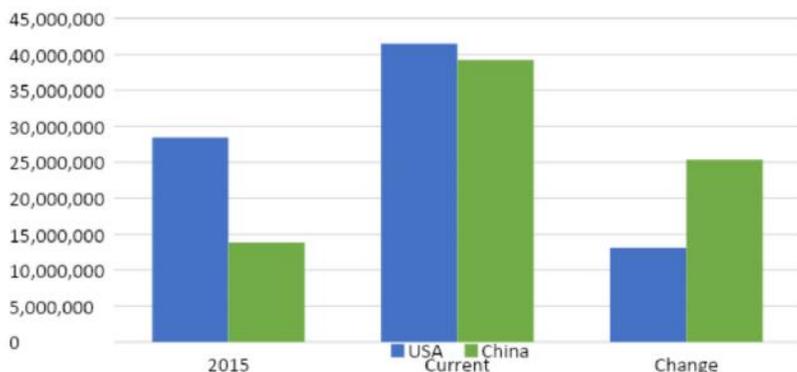
Fig. 13: IHS Markit—New Cracker Plant Additions in Asia in 2020⁶⁵

Start-up Date	Location	Company	City	C2	C3	Type	
2020	Jan	China (mainland)	Zhejiang PC	Zhoushan, Zhejiang	1,400	746	New Cracker
2020	Feb	China (mainland)	Hengli Petrochemical	Dalian, Liaoning	1,500	450	New Cracker
2020	Jul	China (mainland)	Sinochem Quanzhou	Quanzhou, Fujian	1,000	533	New Cracker
2020	Jul	China (mainland)	Sinopec-KPC JV	Zhanjiang, Guangdong	800	426	New Cracker
2020	Sep	China (mainland)	Liaoning Bora	Panjin, Liaoning	1,000	600	New Cracker
2020	Oct	China (mainland)	Wanhua PC	Yantai, Shandong	1,000	250	New Cracker
2020	Oct	South Korea	YNCC	Yeo Chon, Jeollanam-do	350	175	Cracker expansion
2020	Dec	Thailand	PTTGC	Map Ta Phut	500	250	New Cracker
2020	Dec	China (mainland)	Zhejiang Satellite PC	Lianyungang, Jiangsu	1,250	-	New Cracker
Total				8,800	3,430		

Source: IHS Markit

By early 2021, China’s ethylene capacity had increased to nearly 40 million tons, almost as much as the total capacity in the U.S. At least two new ethane-based crackers in China are expected to start up in 2021. Instead of importing more ethylene, Chinese manufacturers intend to become more self-sufficient by importing the ethane feedstock and making their own ethylene instead.

Fig. 14: Ethylene Capacity Expansions, U.S. and China, 2015 and Current Metric Tons



Source: Argus, ICIS, Company press releases

Fig. 14, at left, shows how rapidly ethylene production capacity has grown in both the U.S. and China, with China nearly catching up with the U.S. in total production capacity as of 2022.

The recent headlines around the financial collapse of China’s largest property developer, Evergrande, have raised questions around chemical demand growth rates in the Chinese market itself. The company is expected to continue building the units it has contracted for, but a slowdown in the rapid pace of housing development in China that cuts demand for petrochemicals in construction could allow that country to reach its goal of near self-sufficiency in the ethylene markets faster than initially expected.

U.S.-China Tensions Complicate Global PE Markets

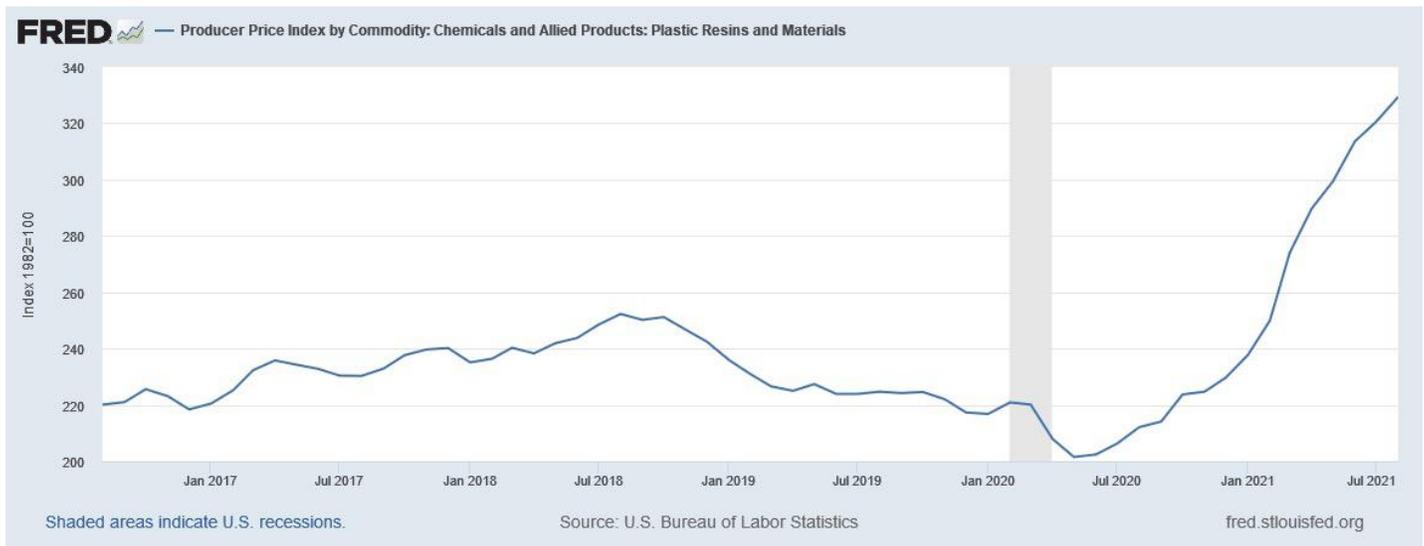
A major shift in U.S. PE markets occurred in 2018, when China imposed tariffs on imports of two of the most common forms of PE in response to the Trump administration’s change in U.S. trade policy. This “tit for tat trade war” was described by chemical industry consultant Fanny Zhang of ICIS.⁶⁶ [A 34% tariff was imposed on two of the most common types of PE, high density polyethylene (HDPE), and linear low density polyethylene (LLDPE), both of which are to be produced by the Shell plant.]

Although these tariffs were temporarily waived in 2020, the tariffs remain on the books, creating more uncertainty around export

demand for U.S. PE.

The following chart, Fig. 15, shows the impact on prices for U.S. commodity chemicals before and after the tariffs were imposed. The chart illustrates how Chinese tariffs significantly impacted U.S. plastic prices: Declines began in mid-2018, when tariffs were imposed, and continued through mid-2020, when China “temporarily” lowered its tariffs. Prices moved even higher when U.S. Gulf coast plants were shut down due to freezing weather in February 2021, tightening supply and causing their domestic customers to look elsewhere for product.

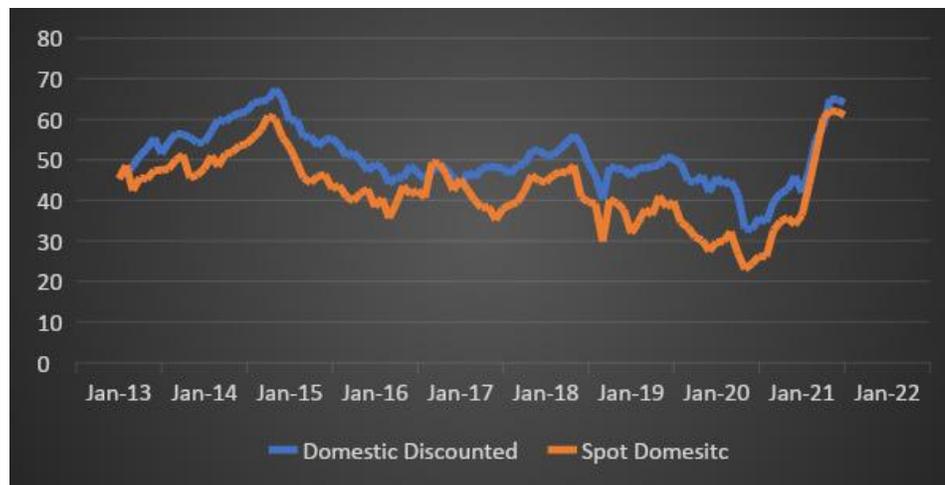
Fig. 15: Price Trends, Plastic Resins and Materials Adjusted for Inflation



Source: FRED, U.S. Bureau of Labor Statistics

The following chart, Fig. 16, shows the impact on margins of one of the primary PE products, HDPE.

Fig. 16: North America HDPE Integrated Margins, Jan. 2013-Jan. 2021



Source: Chemical and Polymer Market Consultants

petrochemical complex.⁶⁷ This suggests two possibilities: 1) The accessible market for ethylene oxide is not large enough to absorb more, without cannibalizing Shell’s existing production at its other facilities; or 2) Shell’s Pennsylvania plant is targeting a commodity market that could only be competitive with a feedstock cost subsidy offered by the state. The possible downside of exposure to a commodity market is buffered by this subsidy.

As with overall resin prices, HDPE margins, in particular margins on products sold in the spot market, began to decline after crude prices fell in late-2014, started to recover, and then fell again in mid-2018 when the Chinese tariffs began. The uplift during the pandemic was largely due to the interruptions in production due to freeze-offs and power outages at Gulf Coast plants.

The uncertainty around trade policy would seem to favor production of a higher margin product, such as ethylene oxide. However, even though Shell owns the proprietary technology used to produce nearly 50% of the world’s ethylene oxide, it does *not* intend to make this higher-margin derivative in its Pennsylvania

Lingering U.S.-China Trade Issues Create Ongoing Uncertainty for Ethylene Exporters

Complicating the matter, the U.S. withdrew from the Trans-Pacific Partnership (TPP), a trade group of 12 countries that comprises 40% of the global economy. China has recently announced its intent to join this group, leaving the U.S. out of a significant trade agreement with the countries that produce most of the plastic goods. Canada and Mexico, along with some of the same countries who are members of the TPP, have also formed another trade bloc known as the CPTPP (Comprehensive and Progressive Agreement for Trans-Pacific Partnership) that also does not include the U.S.

Companies considering more ethylene production capacity in the U.S. could now be at a competitive disadvantage compared to Canada and Mexico when competing for export sales. Dow Chemical recently announced that it will build a new ethylene cracker in Alberta, Canada. This facility will be world-scale, with a 1.8 million ton/year ethylene production capacity. It will use the same design template as the Dow LHC-9 unit in Freeport, Texas, and is aiming to be the world's first "net zero" carbon emissions ethylene production facility.⁶⁸ Since the market for ethylene on the plains of Alberta is limited, the facility is expected to be exporting its 'certified low carbon' materials to other countries. Being part of an existing trade agreement between Canada and Asia will be a big plus.

In spite of the tariffs it imposed on ethylene derivatives, China did not add an import tariff for the ethane feedstock from the U.S. to use in some of its new plants. This puts Chinese ethylene facilities in competition with those in the U.S. for ethane, further raising the odds of higher ethane prices in the U.S.

The combination of heightened uncertainty around future demand for the commodity chemicals the proposed ethylene plants would produce, increased emphasis on "net zero" manufacturing processes, the lack of the co-products needed to make higher value plastic products in the local area, and the prospect of higher prices for feedstocks represents a significant shift in the potential prospects for new ethylene facilities in Appalachia. Focusing on other types of materials production that would be sustainable in the circular economy would be of greater future benefit to the region.

Carbon Capture and Hydrogen Are Not Commercially Viable

Energy-related technologies, such as Carbon Capture and Storage (CCS), Carbon Capture Use (or Utilization) and Storage (CCUS), and hydrogen, may one day impact the economics and environmental impact of the fossil fuel industry and the petrochemical industry. But that day remains far off. The potential offered by low-carbon processes and fuels has garnered substantial policy support at federal, state and local levels.⁶⁹ But neither is commercially viable, as described below.

CCUS has been touted as an efficient way to capture carbon before it is emitted into the atmosphere. The technique involves capturing carbon dioxide gas (CO₂) from the smokestacks of coal- or gas-fired power plants, pressuring and liquifying the CO₂, shipping it via pipelines, and ultimately pumping it deep underground. Its promoters suggest CCUS could extend the life of coal- and gas-fired power plants, retrofitting them so they would emit fewer greenhouse gasses.

But CCUS has never been economically viable for either coal- or gas-fired power plants.

Aging coal-fired power plants would need to invest billions to retrofit plants that are already uneconomic. Despite billions of investment dollars, attempts to use CCUS in coal plants throughout North America have been notable, costly failures.⁷⁰

The rapidly declining costs of wind and solar already threaten to make most gas-fired power plants uncompetitive, according to an analysis by RMI.⁷¹ Attaching carbon capture technology to power plants makes operating them both more expensive and more energy-intensive. In short, deploying CCUS technology to gas-fired power plants, on top of existing costs to operate these plants, makes them even less competitive in power generation.

Similarly, producing hydrogen from renewables, so-called green hydrogen, will face a plethora of infrastructure and cost-related barriers that will likely limit its applicability to a few niche industries. It is unlikely to be cost-competitive with natural gas before 2050 in most parts of the world, according to an analysis by BNEF,⁷² and will require huge government subsidies. Other analyses suggest green hydrogen could be economically competitive at industrial scale, potentially within a decade, assuming renewable energy costs continue to fall.⁷³

These technologies may ultimately help with decarbonization efforts in the U.S. However, they are years, if not decades, away from becoming economically viable. Because of the poor financial prospects for these technologies over the near term, CCUS and green hydrogen do not change the findings in the report. ORVI will continue to monitor developments in these technologies.

Endnotes

1. IEA.org. [The Future of Petrochemicals](#). October 2018
2. IHS Markit. "Ethylene Market Outlook Considering the Impact of Covid-19." 10 September 2020.
3. Deloitte. ["The Great Compression: Implications of COVID-19 for the U.S. Shale Industry."](#)
4. Haynes & Boone. [Oil Patch Bankruptcy Monitor](#). June 30, 2021
5. Yahoo.com. [CEO of Natural Gas Producer EQT on Bad Hedges: 'Obviously Ily We Were Wrong.'](#) October 15, 2021.
6. <https://seekingalpha.com/article/4443947-natural-gas-ep-sell-off-hedging-gone-awry>
7. IEEFA. ["Frackers Cut CapEx to \\$5.8 Billion in Third Quarter, Lowest Level in a Decade."](#) December 8, 2020
8. ExxonMobil. [Company financials](#).
9. DeSmog. [Analysis: Some Fracking Companies Are Admitting Shale Was a Bad Bet – Others Are Not](#). March 5, 2021.
10. CNBC. ["Carl Icahn Calls Occidental's Deal For Anadarko One Of The Worst He's Ever Seen,"](#) August 9, 2019.
11. [OilyStuffBlog](#).
12. Loveland Magazine. [DeWine Signs Bill Blocking Ohio Cities from Banning Natural Gas](#). July 7, 2021.
13. EIA. [EIA Forecasts Less Power Generation from Natural Gas as a Result of Rising Fuel Costs](#). January 2021
14. EIA. [Short-Term Energy Outlook](#). September 8, 2021.
15. White House. [Executive Order on Tackling the Climate Crisis at Home and Abroad](#). January 27, 2021.
16. Politico. [French Government Blocks LNG Deal as Too Dirty](#). October 21, 2020.
17. Euractiv. [Gas is Over, EU Bank Chief Says](#). January 21, 2021.
18. EIA. [Natural Gas Monthly Prices](#).
19. EIA. ["In 2020, Natural Gas Prices Were the Lowest in Decades."](#) January 7, 2020.
20. Reports compiled from [MarcellusDrillingNews](#).
21. [MarcellusDrillingNews](#). [Fire Sale: Shell Sells All Remaining PA M-U Assets for \\$541M](#). May 5, 2020 and National Fuel. [National Fuel to Acquire Shell's Integrated Upstream and Midstream Assets in Pennsylvania](#). May 4, 2020.
22. OGJ. [Shell to Buy East Resources for \\$4.7 billion](#). May 28, 2020.
23. Shell. [Second Quarter 2020 Update Note](#). July 30, 2020 and Shell. [Q 2 2020 Results](#).
24. [MarcellusDrillingNews](#). [Sources: EQT Offering \\$750 Million for Chevron's Marcellus/Utica Assets](#). September 17, 2020
25. Chevron. [2019 10K](#).
26. [S&PGlobal](#). [Chevron to take \\$10B write-down on US shale-related assets, Mulls Divestitures. December 10, 2019](#)
27. EIA. [July Short Term Energy Outlook \(STEO\)](#). July 7, 2021, and [September Short Term Energy Outlook](#), September 8, 2021
28. Ibid.
29. EIA. [In the First Half of 2020, About 5/Bcf of Natural Gas Pipeline Entered Service](#). August 24, 2020
30. S&P Global. [Gas Pipelines Part of the Fight Against Climate Change, Williams' Armstrong Says](#). March 3, 2020.
31. EE News. [Developers Kill Constitution Pipeline Project](#). February 24, 2020.
32. Virginia Mercury. [EPA Recommends that Army Corps of Engineers Not Grant Mountain Valley Pipeline Stream Crossings Permit](#). July 8, 2021.
33. AttorneyGeneral.gov. [AG Shapiro Charges Mariner East Developer with Environmental Crimes](#). October 5, 2021.
34. Press Release. [Cabot and Cimarex Announce Merger of Equals](#). May 24, 2020
35. Business Times. [SEC Filing: Cabot Oil & Gas Had Mull'd 3-Way Mergers with Two Other Shale Companies in 2020](#). June 20, 2021
36. IEA.org. [The Future of Petrochemicals](#). October 2018
37. SaudiAramco, the largest publicly traded oil and gas company, was omitted from this analysis, as it did not have sufficient publicly available data, having only gone public in early 2020.
38. Total includes its Chemical division within its refinery division, making a thorough analysis of its Chemical division impossible.
39. The five oil majors do not break-out their refinery divisions from their downstream operations in their published financials, making a complete analysis impossible.
40. icis.com. [Ethylene Uses and Market Data. 2010](#). Accessed 6 July 2021
41. BizJournals.com. [Big Natural Gas Processing Complex Opening](#). Accessed 2 July 2021
42. Reuters. [Shell's Pennsylvania Cracker and Polyethylene Project See Completion in 2022 after Covid 19 Delays](#). February 22, 2021, Accessed 1 July 2021 Accessed 1 July 2021
43. Earth911. [What Are Nurdles and Why You Should Care?](#) November 10, 2020. Accessed 1 July 2021
44. Freightwaves, ["KCS, NS and CN sign onto campaign to prevent plastic pellet spill"](#), accessed 1 October 2021.
45. BidOnEquipment.com [Plastic and Rubber Equipment/Blow Molders](#). Accessed 2 July 2021
46. FortuneBusinessInsights. [Industry Reports: Polyethylene \(PE\) Market](#). Accessed 30 June 2021
47. BBC. [Lebanon Is Drowning in its Own Waste](#). March 28, 2018. Accessed July 2021
48. EPA. [Facts and Figures about Materials Waste and Recycling](#). Accessed 1 July 2021
49. AmericanChemistry. [US Plastics Producers Set Circular Economy Goals to Recycle or Recover 100% of Plastic Packaging by 2040](#). Accessed 4 July 2021
50. Deloitte. [The Changing Plastics Landscape](#). Accessed 15 June 2021
51. IHS Markit, ["Ethylene Market Outlook Considering the Impact of COVID-19"](#), Accessed October 2, 2021
52. BBC. [Single-use plastic: China to ban bags and other items](#). January 20, 2020. Accessed 4 July 2021.
53. Study referenced in NPR. [Half the World's Single-Use Plastic Waste is from Just 20 Companies, Study Finds](#), May 18, 2021, Accessed 2 July 2021
54. Bangkok Post. [PTTGC to Recycle Plastic. November 10, 2018](#). Accessed 4 July 2021
55. AFPM. [Supplying Armor in the Battle Against COVID-19](#). April 30, 2020. Accessed 2 July 2021.
56. Ibid.
57. ["Ethane Cracker Supply Chain Market Study,"](#) Camoin Associates Economic Development and Thomas P. Miller and Associates", May 2015.
58. Scientific American. [Plastics Plants Are Poised to be the Next Big Carbon Superpolluters](#). January 24, 2020. Accessed 2 July 2021
59. C&EN. [The Search for Greener Ethylene](#). March 15, 2021. Accessed 3 July 2021
60. ICIS. ["China petchem project cancellations on "common prosperity" may not mean higher imports"](#), accessed 7 October 2021
61. "GoodJobsFirst. [Shell Cracks Pennsylvania's Tax Code](#), Accessed 30 June 2021
62. Midstream Energy Group analysis, FERC pipeline tariff filings, ethane price history from MarketWatch, accessed 30 September 2021.
63. The Appalachian region is often referred to as the Northeast.

Endnotes

64. Midstream Energy Group base case forecast, based on gas production projection from Blackbird BI, 7 June 2021 data. Infrastructure data Midstream Energy Group database.
65. IHSMarkit. [What Lies Ahead for the Asian Ethylene Market for 2020](#). February 20, 2020.
66. icis. [China Offers Waivers of Extra Tariffs on US PE, Other Chemicals](#). February 18, 2020. Accessed 24 September 2021
67. Shell.com. Shell Products Portfolio: [Ethylene Oxide](#). Accessed 3 July 2021
68. CBS News. "[Dow unveils plans for net-zero ethylene plant for Alberta](#)", accessed 7 October 2021.
69. An example of a policy initiative that has federal, state, and local support in the Ohio River Valley is provided in the July 2021 [Workshop Summary, Ohio River Valley Hydrogen and CCS Hub Market Formation](#), sponsored by the Labor Energy Partnership ([energyfuturesinitiative.org](#))
70. IEEFA. [Holy Grail of Carbon Capture Continues to Elude the Coal Industry](#). November 2018.
71. RMI. [Clean Energy is Canceling Gas Plants](#). September 2020.
72. BNEF. [Hydrogen Economy Outlook](#). March 30, 2020.
73. Nature Energy. [Economics of Converting Renewable Power to Hydrogen](#). March 2019.



 Ohio River
Valley Institute