

# Updated Economics for Virgin Plastics:

Appalachian Petrochemicals Production Capacity  
Growth Prospects Dimming as Global Markets Shift

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Cover image: Shell's ethane cracker in Beaver County, Pennsylvania. Photo by Mark Dixon, Flickr, September 7, 2022, <https://www.flickr.com/photos/9602574@N02/52340282794/in/album-72177720301901720/>

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The Ohio River Valley Institute (ORVI) 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. We believe the Ohio River Valley is a place where communities can thrive by investing in, rather than exploiting, local resources, and we work to improve the region's economic performance and standards of living by charting a course for shared prosperity, clean energy, and more equitable civic structures.

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## Executive Summary

In November 2022, Shell officially began production at its long-anticipated ethane cracker plant in Beaver County, Pennsylvania,<sup>1</sup> churning out lentil-sized resin pellets, known as nurdles, by the ton. When it reaches full capacity, the complex will “crack” ethane into 3.5 billion pounds of plastic each year.

For more than a decade, policymakers and industry boosters have claimed Shell’s mammoth plastics facility would spur economic growth and renewed business investment, revitalizing the region’s economy. But data show that the project’s development has failed to deliver local prosperity thus far—since the plant’s announcement in 2012, Beaver County has fallen behind Pennsylvania and the nation in job growth, business development, population, and nearly every other measure of economic activity.<sup>2</sup>

Now operational, will the Shell facility’s enormous polyethylene production change the economic trajectory of Beaver County? And will new petrochemical development follow in its footsteps, increasing Appalachia’s plastic production capacity?

Not likely, this report finds. The global petrochemical industry is facing a severe “cycle low,” raising serious questions about the viability of new petrochemical development in Appalachia and the profitability of Shell’s Beaver County cracker. Here’s how the market has changed:

- **Global demand for virgin plastics is slowing** alongside a wave of public concern about plastic waste, plastic bag bans, sustainability pledges from major packaging companies, and decarbonization targets.
- **Appalachia’s ethane feedstock cost advantage has been eliminated.** When visions of a regional petrochemical ‘renaissance’ first took shape, Appalachia had an oversupply of cheap, fracked ethane, but nowhere to sell it. Petrochemical plants provided a solution to this problem—they could take advantage of the region’s cheap ethane to produce plastics. But when new (and converted) pipelines opened up Appalachia’s trapped ethane reserves to other markets, assumptions about feedstock costs for Appalachian petrochemical facilities changed.
- **Demand in China—once expected to be an enormous market for US polyethylene—has instead plummeted.** The country’s aims to minimize the spread of COVID and grow domestic plastics supply, as well as the collapse of the Chinese real estate market and the polyethylene products that supply it, have crushed demand for US petrochemical products.
- **The global polyethylene market has become extremely overbuilt.** North America has grown virgin plastic production capacity by 60% since 2017. The oversupply has created a glut, threatening industry margins.
- **The natural gas industry has become increasingly global, raising domestic prices toward world market levels.** Securing more expensive, market-rate ethane changes margin assumptions for petrochemical facilities.

These market shifts have eroded the profit margins of petrochemical facilities like Shell’s. From 2021 to 2022, ethane “cracking” margins—the difference between the value of the ethylene produced and the cost of ethane feedstock—plummeted by 90%, and Shell’s petrochemicals division earnings dropped by \$2.3 billion as capacity fell by 8%. The commodity plastics Shell’s facility creates are particularly vulnerable to market downturns, research shows. Since the beginning, the economic rationale for building the plant was only based on overly generous subsidies, something the company’s management has openly admitted.

In Appalachia, the natural gas industry is pivoting away from floundering petrochemical prospects. Natural gas producers that haven’t expanded beyond the region, like EQT, Range Resources, and Antero, are turning to other ventures, like liquified natural gas and blue hydrogen, in a last-ditch attempt to salvage their bottom line.

Today, it’s clear that the petrochemical “renaissance” once envisioned for Appalachia has largely failed. Plans for a sprawling regional build-out, complete with a network of world-class and small-scale ethane crackers, hydrogenation plants, an Appalachian Storage Hub, and 500 miles of new pipelines, were supposed to create more than 100,000 new jobs in the region. Shell’s Beaver County plant is the only remnant of this grand vision. Eroding plastics demand and a shaky global plastics market indicate it may be the region’s last petrochemical facility.<sup>3</sup>

## Background: The Petrochemical Build-Out in Appalachia Has Failed to Launch

Shell's new Monaca ethylene petrochemical plant in Beaver County, Pennsylvania began operations in November 2022. Industry boosters hoped it would be the first of many such projects, launching an industrial renaissance in the Ohio River Valley. Instead, the global outlook for virgin plastics has plummeted, and the regional feedstock cost advantage that “stranded” ethane was to provide has been eliminated.

At one time as many as five ethylene production projects were under consideration as part of efforts to create a new petrochemical hub in Appalachia, but only the Shell project and another sponsored by a group led by PTT Global Chemical (PTTGC), Thailand's largest petrochemical producer, moved forward to acquire sites for their projects. The PTTGC facility was planned for Dilles Bottom in Belmont County, Ohio, the site of a former FirstEnergy coal-fired power plant. It had received \$70 million from JobsOhio, a private economic development fund in Ohio, but recently reimbursed the \$20 million spent on preliminary engineering and site preparation costs for the proposed ethylene plant when it failed to move forward with a final investment decision (FID).

This year, PTTGCA (PTT Global Chemicals America) announced it signed a non-binding memorandum of understanding (MOU) with the state-run Solid Waste Authority of Central Ohio (SWACO)<sup>4</sup> to build a plastics recycling facility at SWACO's Green Economy business park. The project includes an MOU with Ohio-based Rumpke, a waste recycling and management company. The complex will be an enclosed operation that manufactures recycled polyethylene (PE) and polyethylene terephthalate (PET) into unspecified products. This recycling facility will apparently be built instead of the world-scale ethylene plant originally discussed, which would have produced new ethylene and polyethylene.

## The Case for a Petrochemical Hub: Circa 2012

The reasons for the support given to the petrochemical industry by state and regional economic development organizations in the Appalachian region included many rationales.

- [To] “encourage business growth along the Ohio River Valley based upon our abundance of low cost, natural gas that allows manufacturers to operate more efficiently while producing products more economically with access to water, and 70% of US polyethylene and 77% polypropylene demand within a day's drive,” according to Shale Crescent USA.<sup>5</sup>
- To create more than 100,000 jobs by 2025, according to the American Chemistry Council.<sup>6</sup>
- To create increased demand for natural gas liquid (NGL) production and stimulate further shale gas production.
- To geographically diversify petrochemical manufacturing, a reason added following a major hurricane on the US Gulf Coast in 2017 that shut down a number of ethylene plants in that region for an extended period.
- To support moving manufacturing of critical medical supplies back to the US from China, post COVID-19

## The “Ethane Problem”—A Gas Production Constraint Was Viewed as a Petrochemical Opportunity

The primary consideration in siting an ethylene production facility is the cost of feedstock in the region, as feedstock makes up most of the variable cost of operating the facility. Industry consultants IHS Markit note that “energy and feedstocks make up 60 to 70 percent of the costs of chemical production.”<sup>7</sup> These costs can be influenced by where the plant is located. Ethylene plants that exclusively use ethane as their feedstock cost less to build than plants that can use other types of feedstocks, so if ethane prices are lower than the prices of other types of feedstocks used by competing facilities, these plants will have a cost advantage in the markets for the plastics they produce. Even though the primary market for the polyethylene produced by the Shell plant is the Northeast regional market,<sup>8</sup> prices are influenced by global demand, since buyers can source their supply from a number of producers. Although the Shell facility does have an advantage in terms of freight costs to deliver its plastic pellets to consumers in the Northeast and Upper Midwest US, this market has been served by producers elsewhere ever since the former Union Carbide ethylene plant in Charleston, West Virginia was shuttered years ago.

The high ethane content of the Appalachian region's natural gas provided an excellent commercial opportunity for a potential ethylene production hub. The ethane content was so high that it limited natural gas production growth in the so-called “rich gas” plays with higher NGL content. An ethane-based petrochemical hub would—in theory—provide low-cost ethane feedstock and solve the excess ethane “problem” facing natural gas producers.

### Too Much of a Good Thing, or How Much Ethane is Too Much Ethane?

As early as 2007, Marcellus natural gas producers whose acreage included gas “rich” in NGLs—acreage that includes a significant number of leases in Southwest Pennsylvania, Eastern Ohio, and Northern West Virginia in the Ohio River Valley—expressed concerns about meeting regional gas pipeline specifications for heat content. The amount of ethane in the area's natural gas is very high compared to other parts of the US, with ethane making up 60 to 70 percent of the “barrel” of NGLs

that are removed from the natural gas stream by processing facilities, as compared to 50 percent elsewhere. This volume was high enough to cause the heating value of the gas stream to exceed the maximum regional pipeline limit of 1100 Btu of heating value per thousand cubic feet (MCF) of gas unless most of the NGLs are removed prior to delivery into the pipeline. As drilling activity increased during the early days of shale development in the region before 2010, producers saw that the increasing ethane content would limit production growth in the NGL-rich areas. They began to look for ways to solve “the ethane problem” by finding outlets for the additional ethane.

## **Looming Ethane Oversupply: Petrochemicals Were Viewed As Solutions**

In regions with pipeline access to ethylene plants, the demand for ethane typically is large enough to keep prices at a level that compensates producers for most of the cost of removing it from the gas stream and sending it to market. If prices fall below this level, producers usually have the option to put more ethane into the gas stream instead. In Appalachia, this wasn’t an option given the lack of local ethylene plants and limited ability to blend more ethane into gas. The looming ethane oversupply situation encouraged producers to view ethane extraction and transportation as a cost of producing natural gas to be minimized—instead of a source of value.

Since virtually all hydrocarbon production in Appalachia is natural shale gas or NGLs, as opposed to higher value oil, producer interest in regional ethylene facilities was focused on removing constraints to increasing gas production and sales. The “low-cost gas” advantage mentioned by petrochemical hub boosters would not have been a primary goal for a shale industry looking for higher gas revenues.

## **Unfinished Business: Many Proposed Ethane Cracker Plants in Appalachia Died on the Vine**

The so-called shale boom in Appalachia, fueled by the rapid increase in hydraulic fracturing (“fracking”) and horizontal drilling, created an expectation of a petrochemical hub in the region. In fact, many companies did explore building ethane crackers and petrochemical complexes in the region. They hoped to tap into the abundant supply of natural gas and ethane, an NGL.

But only the Shell petrochemical facility, including an ethane cracker plant, has moved forward. No domestic company has seriously considered building a petrochemical complex in Appalachia, including Dow/Dupont, ExxonMobil, or Chevron, even though ExxonMobil and Chevron had substantial hydraulic fracturing (“fracking”) presences in the region for many years. (Both oil giants have either sold off or written down substantially all their shale assets in the region. Chevron, in late 2019, took a pre-tax \$11 billion write-off, half of which was related to its holdings in Appalachia. And ExxonMobil took a \$20 billion write-off in 2020 of its shale holdings throughout North America, most of which were in the Appalachian region.)

The following companies once considered building cracker plants in Appalachia, but decided not to do so:

### **1. PTT Global Chemical America (PTTGCA)**

PTT Global Chemical America (PTTGCA) came the closest to issuing a Final Investment Decision (FID) to build an ethane cracker plant in Appalachia. Despite massive inducements, including \$70 million in JobsOhio grants, PTTGCA, which is majority Thai-owned, has not moved forward with an FID. It appears this project is effectively dead, though the company has not made this explicit.

PTTGCA had initially partnered with Marubeni, a Japanese trading firm, to build the complex in Dilles Bottom, Belmont County, Ohio, the site of a former FirstEnergy coal-fired power plant. In 2015, PTTGC and Japan’s Marubeni, a trading house, had announced plans for a \$5.7 billion cracker plant in Ohio, beating out West Virginia and Pennsylvania. In late 2017, after many delays, it announced it would make an FID in early 2018. It received \$30 million in funding from JobsOhio in July 2019. The proposed costs to build the plant had increased to \$7.5 to \$10 billion.

In 2018, Daelim, a Korean construction company, replaced Marubeni. No reason was given. Over the next three years, PTTGCA faced many legal challenges. Meanwhile, it exercised an option to purchase land and spent a portion of its \$100 million commitment to front-end engineering and design (FEED).

As of January 2020, PTTGCA had not entered into an FID, though it had begun clearing trees on 140-acres of the site in March 2019. As of 2022, PTTGCA appeared to be moving in a different direction, launching a plastic recycling

operation in Ohio, although it left open the possibility of building a petrochemical facility for virgin plastics, should it find an investment partner.

The PTTGC facility had received \$70 million from JobsOhio, a private economic development fund in Ohio, supported by liquor sales in the state. PTT's US subsidiary recently reimbursed the \$20 million spent on preliminary engineering and site preparation costs for the proposed ethylene plant when it failed to move forward with a final investment decision (FID).

## 2. Odebrecht/Braskem

Odebrecht/Braskem had plans to build a \$3.8 billion cracker in Wood County, West Virginia as early as 2012. Braskem, headquartered in Brazil, is Latin America's largest petrochemical company, and a subsidiary of Odebrecht. The project was formally announced in 2013. The plan was for Odebrecht to build the facility and for Braskem to operate it. The proposed plant included an ethane cracker, three polyethylene plants and associated infrastructure for water treatment and energy co-generation.

The project, called the Appalachian Shale Cracker Enterprise, or ASCENT, was to be modeled along the lines of its Mexican joint venture with IDESA, which sourced ethane from three Pemex gas plants to assure redundancy and a sufficient source of ethane. Like its Mexican facility, Braskem's proposed West Virginia cracker would source ethane from many regional gas plants to avoid the need for storage facilities.

In 2014, Antero Resources was tapped to supply 30,000 barrels of ethane per day, or half the ethane that would be needed to operate the proposed cracker.

In 2015, Odebrecht was involved in an international bribery scandal, which included the arrest of its CEO. The project was put on pause. In 2016, Odebrecht and Braskem pleaded guilty to bribery and agreed to pay a \$3.5 billion fine. The future of the proposed cracker plant build was further complicated in 2017 and 2018 when Dutch-based LyondellBasell entered discussions to acquire Braskem for a reported \$11 billion. LyondellBasell ended talks in June 2019, and in July, Braskem formally withdrew from the Appalachian cracker project, putting the land it had purchased in West Virginia up for sale. No buyers have surfaced to purchase the land.

## 3. Aither Chemical

Formed in 2010, Aither Chemical announced plans in 2012 to build a small-scale cracker plant based on a Union Carbide patented process developed in the 1970s. The cost was expected to be \$500 to \$750 million, only a quarter to a third of the typical cost of a cracker plant with similar capacity. The company planned to build several small cracker plants throughout the region using this innovative technology. The initial plan was to locate the first plant in West Virginia, which helped to fund a job-creation non-profit related to the project. The proposed plant would use a catalytic process to crack ethane, rather than the typical steam cracking process that uses heat and steam, and would use 80 percent less energy and produce 90 percent less carbon dioxide, according to the company. Aither engaged a company to assess market interest in the cracker plant's product and another company to secure funding. The company was apparently unable to secure funding or sufficient interest in its products to move forward,<sup>[39]</sup> making the prospect of building a new ethane cracker uneconomic by 2015.

## 4. Appalachian Resins

Houston-based Appalachian Resins announced plans in 2014 to build a \$1 billion ethylene and polyethylene production facility that could produce 500 million pounds per year each of ethylene and polyethylene. The initial plan was to build the facility in West Virginia. But in September 2014, the company announced plans to lease 50 acres in Salem Township, Ohio, claiming the West Virginia site was too small. It planned to open the facility in 2019.

The advantage of a smaller cracker, according to the company, was that it would not require storage infrastructure or large pipelines and would not be as capital-intensive. Larger facilities, so-called "world-scale" plants, are also "designed to run at, or above capacity. When feedstock runs low, is overpriced, or is interrupted by market factors, such crackers lose their ability to produce ethylene or polyethylene at a discount. A smaller facility doesn't have as many x-factors and can therefore produce such products at about the same price no matter what the circumstances."

The Appalachian Resins project was put on hold in 2015. Executives cited a potential shortage of qualified labor for the construction process due to competition from both cracker plant construction projects by Shell and PTTGCA.

## Pipelines Move in to Provide Market Access for Appalachian Ethane while Chemicals Projects Are In Study Mode

Petrochemical production appeared to offer an opportunity for ethylene producers to acquire feedstock at advantaged prices. Excess ethane was considered to be “trapped” in the region since there were no existing ethane pipelines from Appalachia to other North American markets. Because of this, a local chemical plant that would buy ethane at its natural gas equivalent value in the region could provide the producers with an outlet for their excess ethane that would avoid the cost of paying for transport to other markets and allow for continued drilling.

While negotiations were in progress around the development of the petrochemical hub, the regional gas pipeline networks were expanded to allow gas with lower heating values to be blended into the rich gas stream as a temporary option. Production growth was so rapid that projects for moving both gas and NGLs to other regions were top priority. The rest of the NGL components, such as propane and butane, could be moved to markets by trucks and railcars, but liquid ethane has to be moved via pipeline due to the very low temperatures required to keep it in a liquid state. By 2011, there were three proposed pipeline projects designed to move ethane to the US Gulf Coast and two projects targeting the existing export facility at Marcus Hook, Pennsylvania and NOVA’s Eastern Canada ethylene complex in Sarnia, Ontario. With natural gas prices rising, producers weren’t willing to wait years for an ethylene plant to be built.

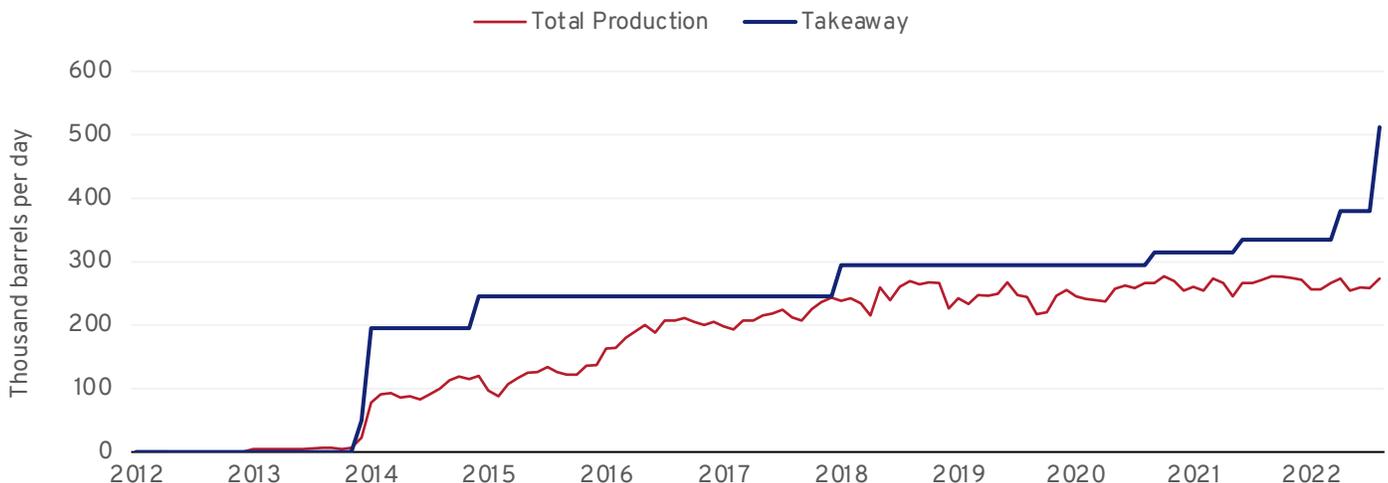
### Shell Delays While Ethane Goes Elsewhere

In spite of the supposed cost advantage for Appalachian ethane, and the building boom in the ethylene industry elsewhere in the US spurred on by the availability of ethane in other regions, it took Shell five years from site evaluation to the start of construction and another five years of construction to build its Pennsylvania ethylene cracker. By contrast, the last world-scale ethylene complex to start up on the US Gulf Coast, Gulf Coast Ventures, was completed and online in two years. This plant was also on a greenfield site, but was close to the coast, which allowed construction of the major units to be done overseas.

Although the delay in project execution was partly due to COVID, the lag between Shell’s initial site selection and construction posed a challenge for the region’s other petrochemical projects. By 2013, construction was underway on two of the pipeline projects intended to export ethane to existing markets on the US Gulf Coast and Canada. Since these projects involved converting existing pipelines, the system operators were able to avoid the lengthy and uncertain process of gaining regulatory approval from the multiple states they crossed and the high costs of building new lines. These pipelines connected the region to locations with multiple existing ethylene plants and underground storage, which allowed producers to immediately gain outlets for their excess ethane and boost drilling activity further while natural gas prices were high in 2012 through 2014.

By 2014, three major pipelines connected ethane produced in Appalachia with other markets. The feared ethane glut ended, as pipelines could now transport ethane to the US Gulf Coast, to Canada, and to an overseas export terminal (Figure 1). Shell was able to use this system to transport ethane it was placing under contract for its plant in Appalachia to their existing complex on the US Gulf Coast to allow the producers who agreed to provide feedstock to its plant to maintain their drilling programs while it was under construction. The sponsors of the other plants that were planned for the region didn’t have other facilities to use the ethane temporarily.

Figure 1: Total Ethane Production vs. Takeaway, Ohio, Pennsylvania, and West Virginia, 2012-2022



Source: Authors’ calculations<sup>9</sup>

The first project, the Enterprise ATEX (Appalachia to Texas Express) pipeline, used an existing line that had previously moved propane from the Gulf Coast to the Northeast markets. Once Appalachian propane production increased and was able to support regional demand, converting the line to another service was the most economic choice. Enterprise reversed the flow, and began transporting ethane from Appalachia to the Gulf Coast region. The lowest transportation rates were made available to producers willing to commit their volumes to the system for 15 years. This eliminated a portion of the ‘constrained’ ethane supply that would otherwise have been available for use in future regional petrochemical projects. The pipeline as currently configured can move 190,000 barrels a day—enough ethane for two large ethylene plants.

The second pipeline conversion project was the **Mariner West** line, developed to move ethane from Pennsylvania and Ohio west to NOVA’s ethylene plant and storage facility in Sarnia, Ontario. This line was owned by Sunoco Pipeline LP, now a subsidiary of Energy Transfer. The line was converted from refined products to ethane service, and again did not require the permitting process associated with new construction. NOVA was able to buy enough ethane to support an initial conversion of its entire existing Corunna ethylene plant to ethane feedstock. When its last capacity expansion begins operations early in 2023, the NOVA complex will use over 100,000 barrels a day of ethane.

### **Appalachian-Produced Ethane Goes Global Through Marcus Hook**

The third way for NGLs to be transported out of the region was yet another pipeline conversion: the eastern portion of the Mariner pipeline, which crosses the state of Pennsylvania and connects Appalachian NGLs to the global market via the Marcus Hook export terminal near Philadelphia. This pipeline was part of the Mariner line that had initially transported refined products. Once this conversion was completed, ethane could move on this **Mariner East** line to international markets in Europe and the United Kingdom, where existing ethylene plants that had originally used ethane from the North Sea were able to replace that declining supply with ethane from Appalachia. Current exports have reached 90,000 barrels a day. Capacity can be expanded beyond this level by expanding the ethane loading capability at Marcus Hook.

### **New Pipelines Further Expand Market Access for Appalachian Ethane—2018-2022**

Still another pipeline, **Utopia**, was put into service in 2018 to move additional volumes of ethane to Sarnia to supply the NOVA plant along a similar route as the Mariner West line. With the addition of two more new pipelines to the Mariner East system going from western Appalachia to Philadelphia (Mariner 2 and 2X), the combined capacity of the pipeline systems can now move at least 100,000 barrels a day more than the region’s current reported average 2022 production of 303,000 barrels a day of ethane to markets outside Appalachia.

### **The Search for Subsidies—Shell Wins in Pennsylvania, the Ethane Hub Dream Dies in Washington**

The search for subsidies to support an Appalachian petrochemical hub yielded mixed results. Shell’s facility received an estimated \$1.65 billion subsidy from the state of Pennsylvania that discounts the price of the ethane used by the plant by 1 cent/gallon. This would essentially cover the payroll for the Shell plant’s planned 600 permanent employees at \$90,000 per year each. In other words, Pennsylvania taxpayers are bankrolling the jobs Shell claims to have created.

In Shell’s case, the generous state subsidy and the ability to move ethane out of the region to its existing Louisiana facilities via the ATEX pipeline system while the Pennsylvania plant was under construction provided advantages that other project sponsors didn’t have. The company was able to provide a market for the gas producers’ excess ethane during construction, allowing its suppliers to execute their drilling plans.

The other potential projects were apparently unable to secure sufficient support to create a significant cost advantage over other locations that already had access to storage facilities and infrastructure to support the logistics required to move their plastics production to market. The Appalachian Ethane Storage Hub Study Act<sup>10</sup> directed the Department of Energy (DOE) and the Department of Commerce to study the feasibility of establishing an ethane storage and distribution hub in the Marcellus, Utica, and Rogersville shale plays in Appalachia. The study was to include potential locations for the hub, the economic feasibility and benefits of the project, infrastructure needs, and potential benefits of the hub to energy security. The effort resulted in an extensive report that extolled the benefits of the project, published in December 2018 as the *Ethane Storage and Distribution Hub in the United States*.<sup>11</sup> This show of government support included efforts to add hydrocarbon storage and distribution projects to the list of projects that would qualify for the DOE’s Title XVII loan program in 2017.<sup>12</sup> This program is designed to provide loan guarantees to support projects that “avoid, reduce, or sequester” air pollutants or greenhouse gas emissions and feature “new or significantly improved technologies.”

Environmental groups objected strongly to attempts to assert that a hydrocarbon storage project would reduce greenhouse gas (GHG) emissions by reducing the distance the ethane would have to travel to reach a market, and neither

the program modification nor the \$1.9 billion loan guarantee application were approved.

The commercial benefits of this project were unclear. Neither Shell nor any other ethylene producer opted to sponsor private industry's construction of a large ethane storage facility in the region without the loan guarantee. Additionally, the pipeline routes out of the region were connected to large capacity storage facilities elsewhere.

## **Petrochemical Demand from China Sputters + Changing Attitudes Toward Virgin Plastics = Reduced Growth Opportunities for Ethylene Producers**

Converted NGL pipelines have solved Appalachia's excess ethane problem just as global forecasts for petrochemical demand growth have stalled.

The assumptions about future demand growth that supported the need for more ethylene capacity this decade now seem overly optimistic. North American plastics producers are facing a different global market than the one they expected to be competing in ten years ago. Due to the significant cost advantage from using ethane feedstock, the North American ethylene industry targeted growing markets in Asia, in particular China, as growth opportunities for placing plastics that the domestic market couldn't absorb.

The assumption was that growing Asian markets would absorb the new "virgin" chemicals production in excess of North American demand. This assumption proved overly optimistic. China's COVID 19 lockdown policies, a collapsing real estate market, and an aging population have reduced expectations for strong export sales to China. John Richardson of ICIS notes: "Our base case assumes that 2022-2050 Chinese GDP growth will average 3.1% in 2022-2050. This would be a sharp decline from actual average 1978-2021 GDP growth of 9.2%. 1978 is when our database begins."<sup>13</sup>

Between 2000 and 2021, China imported 88 million tons of High Density Polyethylene (HDPE), one of the most common commodity forms of ethylene that's produced by the Shell plant and others. This compares to a total of 57 million tons of net imports of HDPE by the rest of the world COMBINED. But China's net imports of this material declined from 2020 to 2021 and are expected to decline further in 2022. China has also added a significant amount of ethylene production capacity to reduce its reliance on foreign suppliers. Ironically, these Chinese plants depend on continued access to US ethane. And China has begun to import US ethane and propane feedstocks to support its own chemical production.

Recent forecasts for petrochemical demand from China have become downright dire. According to petrochemical expert John Richardson of ICIS, polyethylene (PE) demand in China will remain in a "historic trough, the deepest we've seen in 25 years of following the industry."<sup>14</sup> He suggests potential for demand for Chinese HDPE imports will grow by only one percent/year between 2022-2040, if China increases the operating rates of its own plants and succeeds in "de-commoditizing" its economy by using more recycled materials. Richardson's advice for regions looking to China as a primary export market is succinct – "The...major HDPE exporters need...to focus on the tactics of managing ever-shrinking Chinese HDPE import demand."<sup>15</sup>

## **Future Growth Outlook for Virgin Plastics Dampening**

Future demand growth for virgin plastics is uncertain. "Net Zero" emissions targets and changes in consumer attitudes toward the use of disposable plastics, including consumer preferences for recycled and biodegradable materials, have dampened projected demand growth for virgin plastics. Once projected to grow at more than the projected GDP growth rate—typically forecast at three to four percent per year—the virgin plastics industry is unlikely to see that growth rate in the future. And the expectations for GDP growth have been dampened as well by the conflict in Ukraine and a recession that seems set to spread across the globe.

Another key issue in forecasting the need for more ethylene plants is the continued move to reduce Single Use Plastics (SUP's) that are increasingly piling up and breaking down into microplastics that have been found virtually everywhere on the planet. These products include packaging and serviceware, such as bottles, wrappers, straws, and bags. A large share of polyethylene is sold into this market. In its September 2022 Chemicals report,<sup>16</sup> the International Energy Agency (IEA) noted that "many countries have been taking action<sup>17</sup> to curb plastic pollution, with over 60 countries<sup>18</sup> introducing bans and levies on plastic packaging and single-use items.<sup>19</sup> Recent developments include a ban on many single-use plastic items in India<sup>20</sup> taking effect in 2022, and a ban on several new items announced in Canada."<sup>21</sup>

Since an estimated 40 percent of plastics are used for packaging, and most of this is discarded, changes in how these materials are handled will have a significant impact on the growth rate for virgin plastics. Coca-Cola was named world's biggest plastics polluter for the fourth year in a row as part of efforts by multiple organizations to identify and attempt to influence corporate behavior. Rounding out the top five plastic polluters were PepsiCo, Nestle, Unilever, and Procter & Gamble.<sup>22</sup> Notably, four of these companies have announced programs, goals, or progress toward increasing their use of recycled materials. For example, Nestle says that, as of

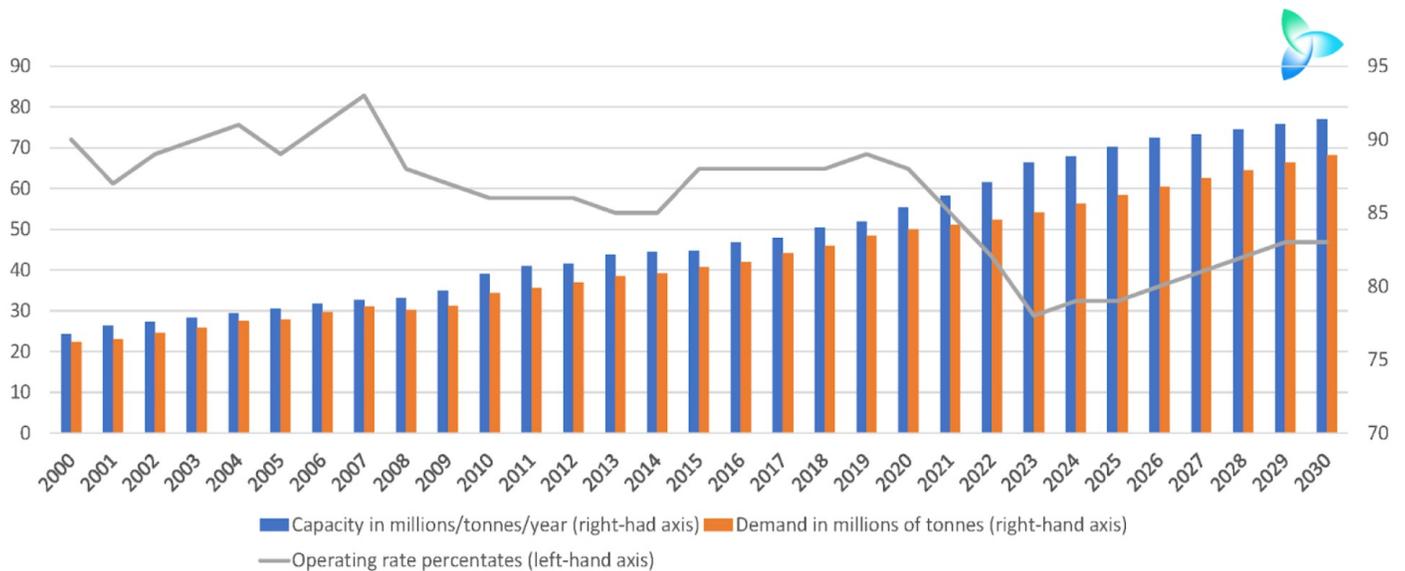
2022, 80 percent of its packaging is designed for recycling, 87 percent can be recycled or reused, and that it has reduced its use of virgin plastics by eight percent since 2018.<sup>23</sup> Coke has been criticized for falling short of its commitments to increase the use of recycled plastics, but recently announced a shift from green to clear plastic for its drink bottles to make them less expensive to recycle,<sup>24</sup> since the use of colorant requires the recyclers to separate the clear plastics for recycling.

US plastics producers have said they will recycle or recover all plastic packaging used in the United States by 2040, and have already announced more than \$7 billion in investments in both mechanical and chemical recycling. “I think we are on the cusp of a sustainability revolution where circularity will be the centerpiece of that,” noted Joshua Baca, vice president of the plastics division at the American Chemistry Council. “And innovative technologies like advanced recycling will be what makes this possible.”<sup>25</sup>

PTTGC’s decision to build a recycling plant instead of producing ethylene seems to indicate that the industry believes the trend toward increased recycling will continue.

The following chart issued by ICIS in December 2022 illustrates the potential impact on operating rates for global ethylene producers over the rest of this decade from projected changes in demand (Figure 2).<sup>26</sup>

**Figure 2: Global High Density Polyethylene (HDPE) Capacity, Demand, and Operating Rate Percentages**



Source: ICIS Supply & Demand

Note: Annual capacity in excess of demand averaged 4 million tonnes per year from 2000-2021. This will rise to 11 million tonnes per year in 2022-2025, and will still average 11 million tonnes in 2022-2030. This is reflected in operating rates:

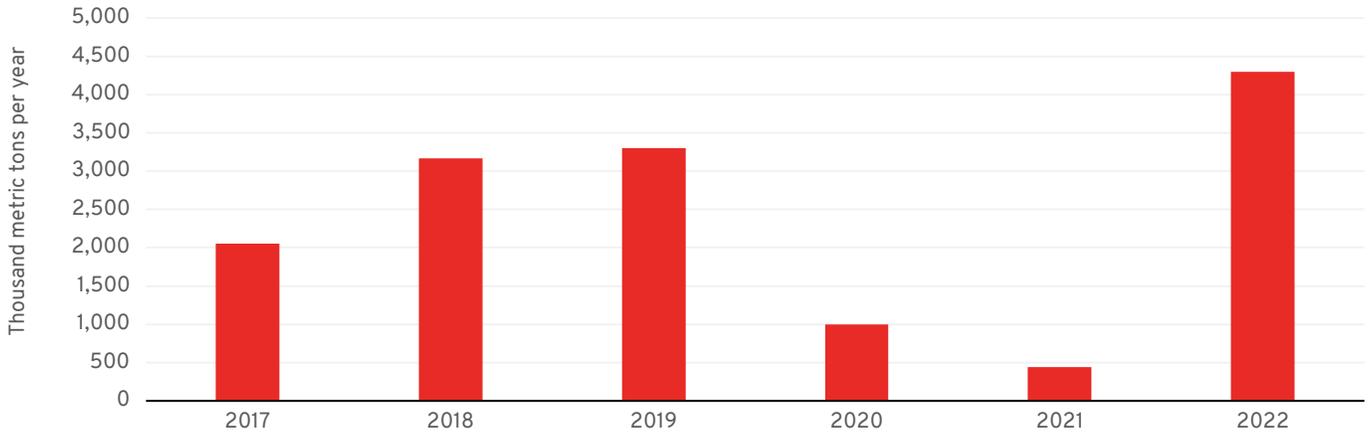
- 2000-2021 average: 88%
- 2022-2025 average: 80%, including just 78% in 2023, the lowest annual rate since 2000
- 2022-2030 average: 81%

Operating rates above 90 percent are generally considered strong, while sustained intervals of operating rates less than 85 percent indicate less favorable economic conditions and can result in rationalization of older units.

### North American Ethylene Capacity Start-Ups Hit Record in 2022, Creating Glut and Crushing Margins

Despite headwinds facing virgin plastics—between collapsing demand from China and waning appetite for virgin plastics as the world teeters on the brink of recession—the petrochemical industry in North America grew capacity by record amounts from 2017 to 2022 (Figure 3). In fact, 2022 will mark the biggest year on record for ethylene capacity startups in North America. In the past decade, the North American ethylene industry (United States, Canada, and Mexico) has increased virgin plastic production capacity by over 60 percent. These expansions were supported by the rapid growth in shale gas production. The abundant volumes of ethane that came with it provided a significant production cost advantage over producers using crude oil-based feedstocks such as naphtha.

**Figure 3: North American Capacity Additions, 2017-2022**



Source: C&EN Global Enterprise<sup>27</sup>

In the short term, ethylene producers are dealing with the consequences of overbuilding. During 2022, gross margins for ethylene crackers declined to below zero in the third quarter of the year, resulting in reduced operating rates.<sup>28</sup> In a report on the US ethylene market, industry analysts at Argus Media reported that ethane “cracking” margins, the difference between the value of the ethylene produced and the cost of the ethane feedstock, had declined from an average of 28 cents per pound in 2021 to 2.7 cents per pound by July—an astonishing 90 percent decline. This was the lowest level reached since 2018.

**Figure 4: Chicago Purchasing Managers’ Index (PMI) Shows Regional Manufacturing Activity Contracted Further in November 2022**



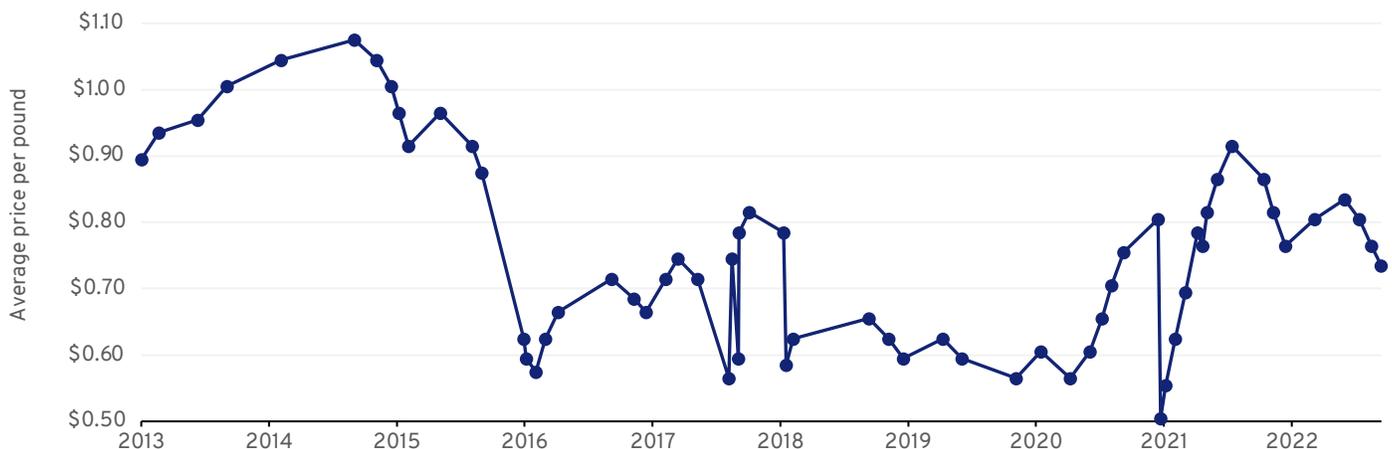
Source: ISM-Chicago<sup>30</sup>

Note: An index of 50 or above indicates the sector is expanding, while an index below 50 indicates it is declining.

ICIS Senior Economist Thomas Swift notes that the Chicago Purchasing Managers’ Index (PMI), also known as the Business Barometer™, “slumped 8.0 points to 37.2 in November, well below expectations and further into contraction territory” (Figure 4). This is an important regional index for the chemical industry as Chicago is a geographical focus for plastics processing, and the report suggests that the manufacturing sector in this region is contracting. Plastic resins sales correlate well with this index.<sup>29</sup>

In the last decade, the average price of commodity thermoplastics has fallen significantly from a 2014 peak (Figure 5).

**Figure 5: Pricing History, Commodity Thermoplastics, 2013-2022**



Source: Plastics News<sup>31</sup>

## Shell Chemical's Financial Results Illustrate Declining Profitability, Capacity Utilization

Shell Chemicals' earnings reports illustrate the rapid decline in industry earnings and capacity utilization over the past year, even before its Monaca and NOVA's Sarnia plants added their production to the North American supply pool (Figure 6).

Figure 6: Shell Chemicals Business Segment Earnings and Capacity Utilization, 2021-2022

Shell PLC Chemical Business Segment	2022			9 months		
	Q1	Q2	Q3	2022	2021	2022 vs 2021
Segment Earnings (Millions)	31	(158)	(555)	(683)	2,989	(3,672)
Capacity Utilization	85%	78%	76%	79%	87%	( 8%)

Source: Shell financial filings, 2021-Q3 2022<sup>32</sup>

In announcing the completion of construction of the Shell plant in August 2022, Shell CEO Ben van Beurden stated, “[T]he chemicals results are not strong this quarter. That is because the chemical sector that we are exposed to is actually still at a lower end, if not the bottom of the cycle.” He mentioned the feedstock cost advantage and the plant’s location near major markets as a plus for the facility. As for the earnings cycle, he noted “we will fix that, of course, once we have Pennsylvania on stream.”<sup>33</sup>

## Global Chemistry Industry Puts Brakes on New Ethylene Plants

The petrochemical industry has responded to the global slowdown and declining demand for virgin plastics. In addition to reducing operating rates for existing plants, it has effectively stopped building new ethylene facilities in North America.

“Looking further ahead, once we get beyond this big wave of capacity, there should be less and less coming on in 2023 and beyond,” noted chemical consultancy ICIS. “Minimal capacity is set to come on in the US and Canada from 2023 onwards, while the pace of global capacity additions slows markedly. The decarbonization drive to a target of net zero carbon emissions by 2050 will be a major factor in pumping the brakes on the pace of new projects.”<sup>34</sup>

A world-scale ethylene project proposed by Formosa for the US Gulf Coast has been shelved. Formosa Chemicals’ project on the Mississippi River in Louisiana is currently considered unlikely as its most recent attempt to obtain an environmental permit was rejected. Dow Chemical has announced that their proposed plant expansion in Fort Saskatchewan will be the world’s first net zero carbon emissions facility. If this facility goes forward on its initial schedule, it will start up in 2027. Facilities using these new technologies will need to be connected to infrastructure that can store and transport CO<sub>2</sub> and hydrogen and that have access to significant amounts of low-cost electricity. While these facilities can be built, using assets available in an existing industrial hub where refiners already have established hydrogen connections will reduce the initial cost.

## Rising LNG Exports: But Can Appalachian Producers Benefit?

As noted earlier, the initial driving force behind the plans to build a petrochemical hub in the Ohio River Valley has always been to take advantage of “trapped” ethane that needed to be removed from the gas stream to allow producers to continue to drill natural gas.

Since the region’s ethane production is no longer trapped, this potential advantage no longer exists. Instead, efforts by environmentalists have created another existential challenge for the region’s gas producers— the need to expand their access to gas markets. Liquefied Natural Gas (LNG) has been hailed as a solution for gas producers.

The rapid increase in natural gas prices internationally due to the war in Ukraine has resulted in a mad scramble to secure supplies of LNG. US prices are currently much lower than those in the rest of the world due to constraints in the ability to liquefy and load LNG for export.

This is likely to change. But the new question for Appalachia will be how regional producers can take advantage of the opportunity.

New large LNG terminals are likely to come online in late 2022 or early 2023. One is the restart of the Freeport LNG facility, located near Galveston, Texas, which has been down for repairs since June 2022, following an explosion and fire, after a 300-foot section of a pipe burst which released roughly 120,000 cubic feet of LNG. The facility had been responsible for nearly 20 percent of US exports of LNG. News that its reopening would be delayed, possibly through the end of the year, caused natural gas NYMEX prices to drop 20 percent to \$5.42/MMBtu. Shares of US natural gas producers also plunged on that news. Natural gas prices in the US had rallied sharply—roughly tripling—throughout the year, and traded over \$9/MMBtu earlier in June, before dropping back to roughly \$6/MMBtu, still double last year’s prices.

The timeline for Freeport’s reopening has been repeatedly delayed due to safety concerns, but the facility seems likely to come back online around the time that other new facilities (also called trains), at Sabine Pass in Texas and Calcasieu Pass in Louisiana are scheduled to begin service, likely at the end of 2022 or early 2023. Adding these new facilities, along with the reopening of the Freeport plant, will propel US LNG export capacity to become the largest in the world, overtaking Australia and Qatar.<sup>35</sup>

Increased demand for natural gas from these LNG facilities will likely pull US prices toward world market levels, which will begin the process of equalizing domestic gas prices with those of the world markets. Basically, domestic industries and consumers will be bidding against overseas buyers for the available supply of natural gas. The net result will likely be to reduce the cost advantage that North American ethylene plants using domestic ethane had before the expansion in LNG export capacity.

### Appalachian Gas Exploration and Production (E&P) Firms Face Ongoing Headwinds that Petrochemicals Won’t Solve

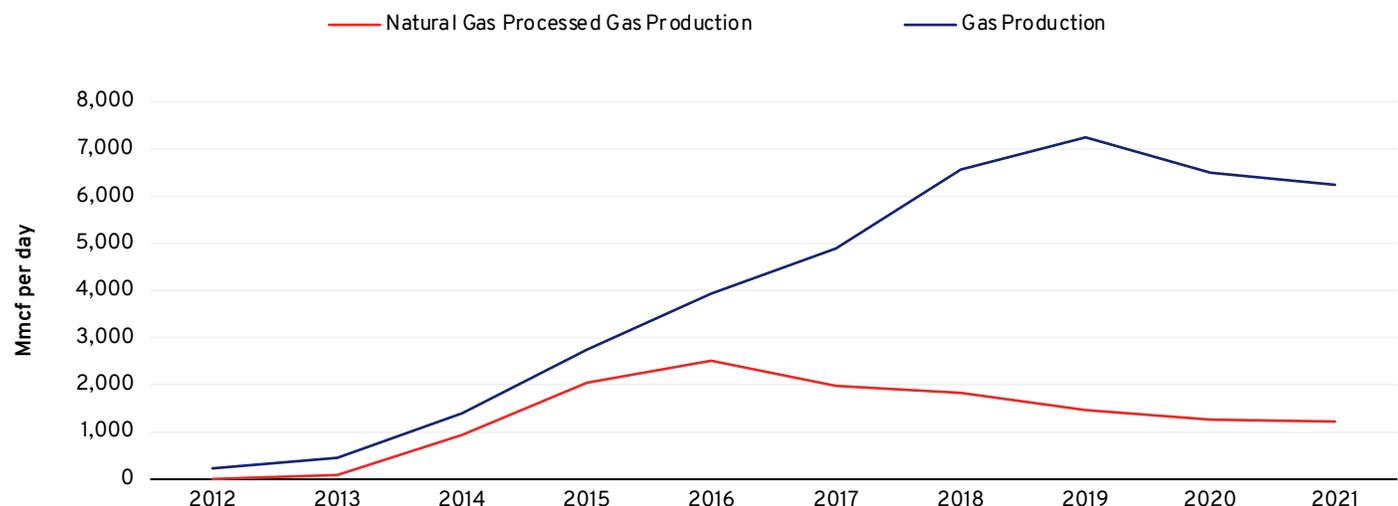
The Appalachian region is connected to global LNG markets with its proximity to the Cove Point LNG export facility, located in Lusby, Maryland. Cove Point is the first major LNG export facility on the East Coast, with storage capacity of 14.6 billion cubic feet (Bcf). Its owners recently filed a request with the Federal Energy Regulatory Commission (FERC) to increase export capacity. But regional producers currently face constraints on their ability to capture this growing market—there isn’t enough pipeline capacity to move a lot of new gas production to the coast for export.

Natural gas producers (also called exploration and production companies, or E&Ps) that have not diversified beyond the region face ongoing headwinds, largely due to gas take-away constraints.

Production of natural gas in the US has increased in 2022,<sup>36</sup> though less than had been predicted. Earlier in the year, the Energy Information Administration (EIA) had predicted a significant rise in domestic production,<sup>37</sup> but has revised its estimates downward throughout the year. Production from the Marcellus and Utica basins has only increased modestly through 2022, and production in Pennsylvania in 2022, appears to have essentially plateaued since 2020, based on quarterly data from the Pennsylvania Independent Fiscal Office (IFO).<sup>38</sup>

Some oil and gas industry experts say that Pennsylvania, even though it is the second largest producer of natural gas in the nation and produces more than 20 percent of the nation’s natural gas, is not well-positioned to feed gas production into export markets to satisfy demand from Europe, or even to supply additional domestic regions. In Ohio, gas production peaked in 2016 (Figure 7).

Figure 7: Ohio Natural Gas Production and Processing Trends, 2012-2021



Source: EIA<sup>39</sup>

Appalachian natural gas producers' growth plans remain stymied, unable to expand the natural gas pipeline grid to gain access to additional markets, whether it is to LNG export facilities or other domestic markets. Unlike three pipelines that transport NGLs out of the region (detailed above), pipelines to transport natural gas out of the region have been effectively halted due to regulatory pressure and opposition from local communities and environmentalists.

### **Takeaway Constraints Mount: New Natural Gas Pipelines Face Ongoing Opposition**

In recent years, a number of pipelines that would have connected production from the Marcellus-Utica shale region to the Northeast or into North Carolina and Virginia have been canceled, including the Penn East Pipeline, the Constitution Pipeline, and the Atlantic Coast Pipeline. In some cases, the developers noted that continued legal challenges would make the projects increasingly difficult to complete. In other cases, the developers acknowledged that market dynamics had changed. Pipeline developers wrote-off billions as these pipelines were ultimately scuttled.

A major unfinished pipeline, the Mountain Valley Pipeline, continues to face obstacles that have delayed its completion. More than 90 percent complete, the 300-mile pipeline would stretch from northwestern West Virginia to southern Virginia. A side deal that was part of the recently passed Inflation Reduction Act (IRA) would have fast-tracked permits for oil and gas infrastructure development, including those needed to complete the pipeline. This side deal, however, was scuttled in late September, after leaked details of the side legislation including a watermark from the American Petroleum Institute surfaced.

Bottom line? The Mountain Valley Pipeline is likely to face ongoing legal obstacles, and is unlikely to be completed any time soon.

### **Some Appalachian Producers Expand Beyond Region, Others Double Down**

Regional gas producers have approached the take-away constraints facing their industry differently, with some acquiring additional acreage outside of the Marcellus-Utica basins and others doubling down on gas production in Appalachia. Still others have sought strategic partnerships with companies in other basins.

Southwestern Energy, one of the nation's three largest gas producers, acquired two gas producers with primary operations in the Haynesville basin in Louisiana/eastern Texas in 2021. The purchases of Indigo Natural Resources (\$2.7 billion) and GEP Haynesville, a subsidiary of GeoSouthern (\$1.85 billion) represented growth opportunities not found in its home base in Appalachia. Southwestern's public statements focused on the advantageous location of the acquisitions, noting their proximity to petrochemical plants and LNG export facilities in the Gulf Coast. "We currently have arrangements in place with LNG operators in the Gulf," Southwestern CEO Bill Way said. "The acquired inventory is highly economic due to its tier-one rock and proximity to industrial and LNG markets."<sup>40</sup>

Cabot Oil and Gas in 2021 accessed regions outside Appalachia through a merger with Houston-headquartered driller Cimarex to form Coterra Energy. (An industry observer noted that Cabot was actually acquired by Cimarex).<sup>41</sup> Cimarex held significant acreage in the Permian and Anadarko regions, and diversified its portfolio with Cabot's acreage in Appalachia. However, this diversification into Appalachia has not been smooth. Coterra recently took a substantial write-down on what had been Cabot's Appalachian reserves, writing down their value by roughly a third.<sup>42</sup>

Other producers, such as EQT, Range Resources, and Antero, have bet their companies on the Appalachian region. They remain land-locked, with ongoing pipeline egress issues unlikely to end soon. These regional producers have, in effect, doubled down on Appalachia. EQT, the nation's largest gas producer, Range Resources, and Antero operate only in the Marcellus-Utica basins. A recent Wood Mackenzie report noted these shale pure plays have "scaled to remarkable size,"<sup>43</sup> due to synergies and, in EQT's case, opportunistic acquisitions in the region. "And for an E&P, building scale in its sole, core basin has been sound economics. Bigger shale operators can spread technical and commercial experience and prowess over larger lease positions, leverage oil field services and bargain with the all-important pipeline owners to get their volumes to market," noted the report.<sup>44</sup> But such "basin dominance" is inherently risky. Cash flow and dividends are threatened with such concentration, concluded the WoodMac report.

This is especially true when market conditions are poor, as they were for roughly a decade from 2010 to 2020, when natural gas prices dropped to multi-year lows, and seemed poised to remain lower for longer—forecast by the EIA to be \$4.00/MMBtu through 2050.<sup>45</sup>

Investors punished these companies when natural gas prices hit multi-year lows, sending stock prices to multi-year lows in 2020.

Even with rising natural gas prices, investors have pushed shale producers to focus more on shareholder returns than production growth.

## Hydrogen Hubs to the Rescue for Natural Gas Producers?

Given the difficulties facing natural gas producers in Appalachia, it's little wonder they have become boosters for potential regional hydrogen facilities. Regional producers are competing fiercely to secure funding to locate a blue hydrogen hub that will use Carbon Capture and Storage (CCS), which is currently not commercially viable. Given the uncertainty around future hydrogen hubs and the lack of financially successful CCS projects thus far, it is too soon to determine their impact on the region's natural gas and NGL producers or other industries in the region.

## Conclusion

The environment that supported the “waves” of new petrochemical plant construction throughout the US Gulf Coast and Canada over the past decade has changed.

Stakeholders, including downstream plastics converters, potential investors, and shareholders, have zeroed in on the industry, forcing a reckoning about plastic pollution. Consumers demand alternatives, and countries, states, and counties are moving to ban single-use plastic as their landfill space fills. Chinese demand has declined, even as massive Chinese petrochemical plants are coming online.

After a rebound in early 2020 for the global petrochemical industry as the world economy bounced back from COVID, the petrochemical industry has overbuilt, and is facing a bust cycle. Sharply lower global operating rates, from 89 percent in 2019, to closer to 80 percent through 2025 are forecast, which if sustained will result in the closure of smaller, less efficient plants.

Overly abundant supplies of ethane in Appalachia were once thought to provide a low-cost feedstock advantage for regional petrochemical plants. But pipelines can now transport the ethane to the US Gulf Coast, Canada, and even overseas. Ethane producers no longer need regional petrochemical plants as a market for their ethane. In short, the “ethane problem” that initially inspired the idea to create a petrochemical hub has been solved.

Meanwhile, the natural gas industry faces another challenge as opposition to pipelines to transport its product beyond Appalachia continues. Appalachian natural gas producers once hoped a regional petrochemical industry would expand their market. Most now recognize that producing virgin plastics in the region will not solve their long-term problems.

Given the headwinds facing the global petrochemical industry and the vanishing ethane feedstock advantage, future petrochemical facilities will not be located in Appalachia. Luis Sierra, CEO of NOVA Chemicals, summed it up best. “Conventional.....crackers—we won't see another one built [in North America]. It will be more expensive and involved.”<sup>46</sup> Policy makers and local communities would be wise to look elsewhere for economic development opportunities.

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