

Ethane Cracking in the Upper Ohio Valley: Potential Impacts, Regulatory Requirements, and Opportunities for Public Engagement

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The ongoing boom in shale gas production has created a market for shale gas byproducts, including ethane, in Pennsylvania, Ohio, and West Virginia. “Cracker” facilities convert ethane into usable chemical products, and several of these cracker facilities are proposed or already under construction in this region. However, many residents want to know more about the potential impacts of these facilities.

The Pittsburgh Post-Gazette observed in 2016 that so much information is available about Shell’s new ethane cracker in Beaver County, Pennsylvania, that “some residents feel it’s overwhelming and inaccessible to them.”¹ This report aims to deliver accessible, objective information about the operations of ethane cracker facilities, as well as their potential impacts and legal and regulatory requirements, in order to equip members of the public to participate effectively in decision-making with regard to this facility and others that appear likely to come to the region.

1. What is ethane cracking and why is it of interest?

When shale gas is extracted from the ground, it contains methane as well as other components, including natural gas liquids (NGLs) such as ethane. A separation unit at the drilling site divides methane from NGLs in order to yield “pipeline quality” natural gas, which is mostly pure methane that can be burned as fuel.² Meanwhile, the NGLs have other uses, and are separated into ethane, propane, butane, and other components at a fractionation plant. Ethane then can be transferred from the fractionation plant to an ethane cracker, which converts ethane into ethylene, the basic building block of many plastic products.

The Marcellus and Utica shale gas plays in Western Pennsylvania are an abundant source of ethane, making this region and other parts of the Ohio Valley greatly appealing for companies seeking to capitalize on easy access to ethane to produce ethylene at new ethane cracker facilities. Shell Chemical announced in 2012 that the site of a zinc smelter being shut down in Beaver County, Pennsylvania, was the most likely location for an ethane cracker it



¹ Litvak A. 2016 Dec 14. Potter Township hearing on Shell cracker still not closed [Internet]. Pittsburgh (PA): Pittsburgh Post-Gazette; [cited 2017 Dec 18]. Available from <http://powersource.post-gazette.com/powersource/consumers-powersource/2016/12/14/Potter-Township-hearing-on-Shell-Chemical-ethane-cracker-still-not-closed/stories/201612140190>

² U.S. Energy Information Administration. 2011 Apr 28. Today in Energy: Natural gas liquids play a greater role in oil and gas activity [Internet]. Washington (DC): U.S. Energy Information Administration; [cited 2017 Dec 18]. Available from <https://www.eia.gov/todayinenergy/detail.php?id=1150>

hoped to build in the West Virginia-Pennsylvania-Ohio area. Since then, Shell has purchased the site, secured permits to build the facility, and begun construction.

In a region that has faced economic hardship since the decline of the steel industry, many citizens and elected representatives are enthusiastic about the prospect of petrochemical production and the new jobs it promises. In March 2017, a report issued by the office of Pennsylvania Governor Tom Wolf estimated that the abundance of Natural Gas Liquids from shale gas extraction could support up to four more ethane crackers in Pennsylvania.³ Neighboring states also are trying to recruit new ethane crackers. The Thai petrochemical company PTT Global Chemical plc announced in July 2017 that it was purchasing a 167-acre site in Belmont County, Ohio, with the intention of building an ethane cracker there.⁴

However, many residents and environmental advocacy groups have expressed concerns about the impacts that ethane cracking could have on the environment and public health. Several groups have channeled public resistance to ethane cracking development. Although guarantees from Shell about emissions monitoring at its Beaver County site have satisfied some of these groups, other groups and individuals remain opposed. For example, as of December 2017, the environmental advocacy group Penn Future had gathered several thousand signatures on a petition to be sent to state and federal officials, opposing this cracker facility's construction.⁵

2. How does an ethane cracker work?

Although other methods exist for “cracking” petrochemicals, thermal cracking by steam is the most commonly employed method for producing ethylene.⁶ The process may be different at different facilities, but a general ethane steam cracker design involves several common steps.

The centerpiece of an ethane steam cracker is a furnace. In a typical arrangement, ethane (the “feedstock”) flows into a reactor tube that carries the ethane through the furnace.⁷ Hot, pressurized steam is added to the tube, which heats the ethane and dilutes it in order to minimize unwanted buildup of chemicals in the machinery.⁸ As the ethane passes through the tube, it absorbs heat from the furnace surrounding it. This absorption of heat causes the ethane to vaporize, splitting the chemical bonds between the carbon (C) and hydrogen (H) atoms that make up each ethane molecule. (An ethane molecule, consisting of two carbon atoms and six hydrogen atoms, may be thought of as the smallest unit of pure ethane.) Vaporization causes

³ Hurdle J. 2017 Mar 21. Pennsylvania could support four more ethane crackers, report says. NPR StateImpact [Internet]. [Cited 2017 Dec 18]. Available from <https://stateimpact.npr.org/pennsylvania/2017/03/21/pennsylvania-could-support-four-more-ethane-crackers-report-says/>

⁴ Cocklin J. 2017 Jul 7. Thai company purchases land for Ohio ethane cracker. Natural Gas Intelligence [Internet]. [Cited 2017 Dec 18]. Available from <http://www.naturalgasintel.com/articles/111010-thai-company-purchases-land-for-ohio-ethane-cracker>

⁵ PennFuture. 2017. Toxic Neighbor: Shell Chemical Cracker Plant [Internet]. [Cited 2017 Dec 18]. Available from <https://www.pennfuture.org/toxicneighbor>

⁶ Amghizar I, Vandewalle LA, Van Geem KM, Marin GB. 2017. New trends in olefin production. *Engineering* 3:171-178.

⁷ Amghizar et al. 2017.

⁸ Sage Environmental Consulting. 2012. ExxonMobil Baytown Olefins Plant Ethylene Expansion Project GHG permit application: Process description [Internet]. [Cited 2017 Dec 18]. Available from <https://archive.epa.gov/region6/6pd/air/pd-r/ghg/web/pdf/exxonmobil-olefins-processdescription.pdf>; Aronen S. 2016 Apr 19. Control valves for feedstock, dilution steam and fuel to furnaces [Internet]. Metso Corporation; [cited 2017 Dec 18]. Available from <http://www.metso.com/blog-hub/go-with-the-flow/control-valves-for-feedstock-dilution-steam-and-fuel-to-furnaces/>

the molecules to separate, or “crack”. After cracking occurs, most of the ethane molecules have been transformed into ethylene molecules (consisting of two carbon atoms and four hydrogen atoms) plus hydrogen gas (consisting of the leftover hydrogen atoms).⁹ The resulting mixture includes ethylene, steam, and other hydrocarbons (chemicals made up of carbon and hydrogen atoms).

The mixture flows into a quench tower.¹⁰ Water is sprayed into the quench tower, where it makes contact with the gas, cooling the vapor in order to prevent further chemical reactions from occurring, and to begin condensing the cracked gas into liquid.¹¹ Most of the quench water, taking with it small amounts of the ethylene and any other chemicals present, condenses and flows out of the bottom of the quench tower.¹² The water is separated from the other chemicals, and most of it is recycled, used again as steam for dilution.¹³ Some water is removed from circulation and treated so that it can be released.¹⁴

In the third step, the gas enters a compressor, which increases pressure on the gas in order to continue converting the gas into liquid.¹⁵ Often, the compression phase involves a sequence of several compressors.¹⁶ Hence, this step is sometimes called the compression train.

A refrigeration step, or “cold section”, follows the compression stage. It consists of several heat exchangers. One side of each heat exchanger carries the compressed gas that is being cooled. The other side holds a refrigerant fluid and liquid ethylene, which remove heat from the gas, helping convert it to liquid. By the end of the cold section, most of the hydrocarbons have been condensed into liquid, while hydrogen (a byproduct of the conversion of ethane to ethylene) remains a gas.¹⁷

Pipes carry the liquid into fractionation (separation) towers, which separate the liquid into ethylene and other components. A fractionation tower does this through the process of distillation. Temperatures are higher toward the bottom of the tower and lower toward the top. The tower contains sieve-like trays, spaced vertically like the floors of a tall building. Each tray holds liquid, but has valves that allow vapor to rise up into the tray from the level below. Lighter molecules such as ethylene turn into vapor at the same temperature that heavier molecules such as ethane remain a liquid. Therefore, the purified lighter chemicals only condense and collect in the trays that are closer to the top of the tower.¹⁸ A steam cracker plant generally will have several fractionation towers to remove different components of the liquid. One of these towers will be a de-ethylenizer, which is designed to separate the ethylene from heavier components.

⁹ Ben Franklin Technology Partners (2016)

¹⁰ Sage Environmental Consulting (2012)

¹¹ Sage Environmental Consulting (2012)

¹² Sage Environmental Consulting (2012)

¹³ Sage Environmental Consulting (2012)

¹⁴ Sage Environmental Consulting (2012)

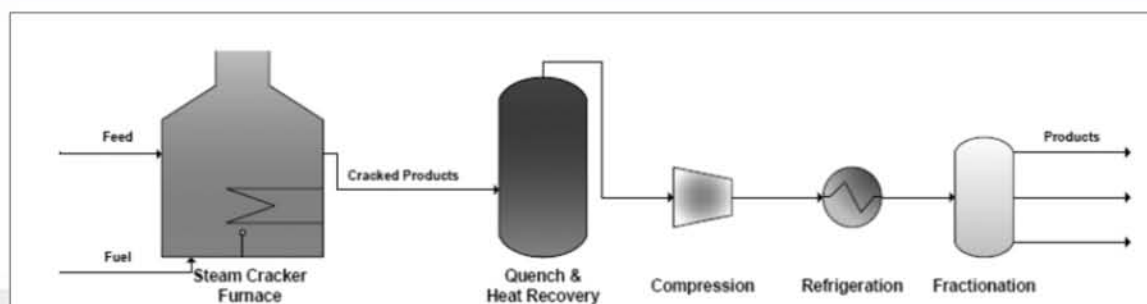
¹⁵ Benchaita T. 2013. Greenhouse gas emissions from new petrochemical plants [Technical Note]. Washington (DC): Inter-American Development Bank Environmental Safeguards Unit.

¹⁶ Siemens. 2013. Oil and gas industry case study: Process analytics in ethylene production plants [Brochure]. Siemens Industry, Inc. Available from <https://www.industry.usa.siemens.com/automation/us/en/process-instrumentation-and-analytics/process-analytics/pa-case-studies/Documents/Ethylene-PIACS-00009-0413.pdf>

¹⁷ Benchaita (2013)

¹⁸ Centre for Industry Education Collaboration. 2016. Distillation [Internet]. York (UK): University of York Centre for Industry Education Collaboration; [cited 2017 Dec 18]. Available from <http://www.essentialchemicalindustry.org/processes/distillation.html>

Figure 1: Ethane Cracker Schematic Diagram ¹⁹



Operating an ethane cracker requires an enormous amount of energy. The furnace alone requires large amounts of energy in order to achieve the high temperatures needed for cracking; ethane is heated at temperatures above 1500° Fahrenheit (800° Celsius).²⁰ At the Beaver County cracker, Shell will construct an on-site Combined Heat & Power (CHP) plant that will burn natural gas in order to generate steam and electricity for the cracker. If it generates more electricity than needed, it will sell this excess energy to the local power grid.²¹

Shell states that its Beaver County, PA, facility will include – in addition to the cracker and power plant – water cooling and treatment facilities; and facilities for storage, logistics, and offices; and three polyethylene production units.²² Polyethylene molecules are essentially long chains of ethylene. The polyethylene production units at this facility will turn the ethylene coming out of the cracker into tiny polyethylene pellets that will be shipped from the cracker to manufacturers via trains and trucks. Those manufacturers will make the polyethylene into a variety of plastic products for consumer uses.

3. What is the current state of infrastructure for ethane cracking in Western Pennsylvania?

Several fractionation plants – facilities where Natural Gas Liquids are separated into ethane and other components – are already operating in Pennsylvania, with more expected to be built.²³ Shell has signed contracts with 10 such fractionation plants that will supply ethane for the Beaver County facility.²⁴

Expanded petrochemical production will require developing new pipeline infrastructure to carry ethane from fractionation plants to cracker facilities. The developers will need to purchase rights to use land that the pipeline will cross, and may do this by buying easements (rights to use land owned by someone else for a specific purpose). Shell announced in August 2016 that it would build a 94-mile ethane transport system, known as the Falcon Ethane Pipeline System, with construction expected to begin in late 2018.²⁵ The network will receive ethane from drilling

¹⁹ From Gandler T (2010), in Benchaita (2013)

²⁰ Ben Franklin Technology Partners Shale Gas Innovation & Commercialization Center. 2016. Shell petrochemical complex (“cracker”) project overview

²¹ Ben Franklin Technology Partners (2016)

²² <http://www.shell.us/about-us/projects-and-locations/pennsylvania-chemicals-project/appalachian-petrochemical-project-frequently-asked-questions.html>

²³ Ben Franklin Technology Partners (2016)

²⁴ Ben Franklin Technology Partners (2016)

²⁵ Ben Franklin Technology Partners (2016)

sites in Pennsylvania and Ohio.²⁶ By January 2017, Shell Pipeline Co. already had contacted 200 landowners in the state about land surveying and easement purchasing, and had purchased a dozen easements from landowners in Beaver County.²⁷

New nitrogen and natural gas pipelines will also be built to supply the cracker.²⁸ Natural gas will be used for on-site power generation.²⁹ Although public information is scarce on how the cracker plant will use nitrogen, as an abundant and relatively inert (non-reactive) gas, it has a variety of possible uses in the petrochemical industry. These uses include pressure testing and nitrogen purging (replacing hazardous or undesirable chemicals with an inert dry nitrogen atmosphere).³⁰



4. What are some potential impacts of ethane cracking operations?

This section discusses the types of emissions and impacts that could be expected from an ethane cracking facility. As noted below, there is uncertainty associated with some of these potential impacts, and not all individuals will be affected equally, due to differences in biology and exposure.

Air Pollution

It is practically impossible to draw direct lines between a new facility's potential to emit air pollutants and the changes in exposure that residents of the surrounding area are likely to experience. This limitation exists because the distance from the facility will vary from resident to resident, and exposures will vary with time. For example, the wind may change directions and result in either an increase or a decrease in the amount of pollution to which a person in the same place faces exposure.

Volatile organic compounds (VOCs) are among the main air pollutants of concern associated with ethane crackers. VOCs are a family of chemicals that easily vaporize.³¹ Other

²⁶ Ben Franklin Technology Partners (2016)

²⁷ Litvak A. 2017 Jan 11. Shell ethane-cracker plant moves forward with local approval. Pittsburgh Post-Gazette [Internet]. [Cited 2017 Dec 18]. Available from <http://www.post-gazette.com/powersource/companies/2017/01/11/Shell-ethane-cracker-plant-moves-forward-with-township-approval-of-application/stories/201701120151>

²⁸ Litvak A (2017).

²⁹ Ben Franklin Technology Partners (2016).

³⁰ AirPro Gas Solutions. Nitrogen for oil, gas, and petrochemical industries [Internet]. [Cited 2017 Dec 18]. Available from <http://www.airpro.ie/nitrogen-for-oil-gas-and-petrochemical-industries/>

³¹ U.S. National Library of Medicine. ToxTown: volatile organic compounds [Internet]. Bethesda (MD): National Institutes of Health; [cited 2017 Dec 21]. Available from https://toxtown.nlm.nih.gov/text_version/chemicals.php?id=31

than industry, common sources of VOCs include the burning of fuel; emissions from gas fields; and many common products including solvents, paints, glues, and air fresheners.³²

Breathing low levels of **nitrogen oxides** can irritate the eyes, nose, throat, and lungs.³³ Higher levels can cause burning, swelling, and spasms in the throat and upper respiratory tract.³⁴ Common sources of nitrogen oxides are motor vehicle exhaust, the burning of fossil fuels, and certain industrial processes such as welding and engraving.

Ground-level ozone forms when nitrogen oxides and VOCs react in the presence of sunlight. Ozone is helpful in the upper atmosphere (stratospheric ozone), where it helps block damaging ultraviolet radiation from reaching Earth's surface.³⁵ However, in the lowest layer of Earth's atmosphere (the troposphere), it affects human health by worsening asthma, bronchitis, and emphysema symptoms, and has been linked to coughing, lung and throat irritation, and breathing problems during exercise or activities outdoors.³⁶

Based on government research and independent studies, the U.S. Environmental Protection Agency recognizes several VOCs as **hazardous air pollutants**, including a family of chemicals collectively known as BTEX: Benzene, Toluene, Ethylbenzene, and Xylene.³⁷ All of these chemicals may be present in an ethane cracker's air emissions.³⁸ Several studies have linked BTEX combined exposure to low birth weight, inhibited fetal brain growth, and increased odds of medically diagnosed asthma and wheezing attacks.³⁹ Studies also have linked health problems to environmental exposures to these compounds at levels below EPA's official chronic reference concentrations (chemical exposure levels that EPA does not believe will have a significant risk of harmful effects).⁴⁰ BTEX also are precursors (substances from which other substances are formed) to other air pollutants. These pollutants include tropospheric ozone (discussed above) and particulate matter, and are associated with respiratory, hormonal, and other health effects.⁴¹

³² U.S. National Library of Medicine

³³ U.S. Agency for Toxic Substances and Disease Registry (ATSDR). 2002. ToxFAQs for Nitrogen Oxides [Internet]. Atlanta (GA): ATSDR; [cited 2017 Dec 21]. Available from <https://www.atsdr.cdc.gov/toxfaqs/tf.asp?id=396&tid=69>

³⁴ U.S. Agency for Toxic Substances and Disease Registry (2002)

³⁵ U.S. Environmental Protection Agency. 2014. Good up high, bad nearby: What is ozone? [Internet]. Washington (DC): U.S. Environmental Protection Agency; [cited 2017 Dec 21]. Available from <https://cfpub.epa.gov/airnow/index.cfm?action=gooduphigh.index>

³⁶ U.S. Centers for Disease Control and Prevention. 2016. Air quality: ozone and your health [Internet]. Atlanta (GA): U.S. Centers for Disease Control and Prevention; [cited 2017 Dec 21]. Available from <https://www.cdc.gov/air/ozone.html>

³⁷ U.S. Environmental Protection Agency. Initial list of hazardous air pollutants with modifications [Internet]. Washington (DC): U.S. Environmental Protection Agency; [cited 2017 Dec 21]. Available from <https://www.epa.gov/haps/initial-list-hazardous-air-pollutants-modifications>

³⁸ RTP Environmental Associates. 2014. Air quality plan approval application for Shell Chemical Appalachia Beaver County, Pennsylvania, petrochemicals complex [Internet]. RTP Environmental Associates; [cited 2017 Dec 21]. Available from <http://gasp-pgh.org/wp-content/uploads/2014/05/Shell-Petrochemicals-Complex-Plan-Approval-Application.pdf>

³⁹ Bolden AL, Kwiatkowski CF, Colborn T. 2015. A new look at BTEX: Are ambient levels a problem? Environ. Sci. Technol. 49:5261-5276

⁴⁰ Bolden et al. (2015)

⁴¹ Bolden et al. (2015)

An ethane cracker may emit several other types of hazardous air pollutants. Documents that Shell provided while applying for air permits for its Beaver County cracker offer some examples of these pollutants.



- This cracker has the potential to emit **hexane** at 17.3 tons per year, coming primarily from the cracking furnaces. By mass, this is a major portion of the total hazardous air pollutant emissions for the facility. No evidence currently indicates that hexane causes cancer in humans, and although studies have demonstrated that long-term exposure can cause nervous system damage, these results have been observed for high concentrations that would be typical of industrial occupational exposure, rather than of concentrations that would be found in the environment near an industrial facility.⁴²
- The new Shell ethane cracker will emit a larger amount of **acrolein** than the zinc smelter that previously occupied its site.⁴³ A 2013 analysis of environmental health threats in the Pittsburgh region noted that acrolein, another hazardous air pollutant, was the “primary driver of noncancer respiratory risk” in the region.⁴⁴
- Some studies have suggested that chronic exposure to **1,3-butadiene**, another hazardous air pollutant that will be emitted by the Shell cracker, increases the risk of heart disease and cancer. Although research in humans has not yet confirmed a causal relationship (due, at least in part, to the ethical and methodological challenges of designing studies in human populations), studies of animals have shown that 1,3-butadiene causes cancer, and the EPA classifies the chemical as known to cause cancer in humans.⁴⁵

⁴² U.S. Agency for Toxic Substances and Disease Registry (ATSDR). 1999. Toxicological profile for *n*-Hexane. Atlanta (GA): ATSDR; [cited 2017 Dec 21]. Available from <https://www.atsdr.cdc.gov/toxprofiles/tp113.pdf>

⁴³ According to the 2013 analysis (Michanowicz et al.), the smelter emitted 91 pounds of acrolein per year. Shell’s air quality plan approval application estimates that it will emit about 0.058 tons (116 pounds) of acrolein per year, an increase of about 27%.

⁴⁴ Michanowicz D, Ferrar K, Malone S, Kelso M, Kriseky J, Fabisiak JP. 2013. Pittsburgh Regional Environmental Threats Analysis (PRETA) Report: Hazardous air pollutants. Pittsburgh (PA): University of Pittsburgh Graduate School of Public Health Center for Healthy Environments and Communities.

⁴⁵ U.S. Occupational Safety and Health Administration (OSHA). 1,3-Butadiene health effects [Internet]. Washington (DC): OSHA; [cited 2017 Dec 21]. Available from <https://www.osha.gov/SLTC/butadiene/healththeffects.html>

- **Benzene**, another hazardous air pollutant, comes from ethane crackers as well as cigarette smoke, gasoline vapors, and motor vehicle exhaust.⁴⁶ Benzene is known to cause cancer in humans.⁴⁷ Studies have linked low level benzene exposures to low birth weight, eczema, physician-diagnosed respiratory impairments, and wheezing.⁴⁸ Additionally, some studies have found evidence for health outcomes including asthma and obstructive bronchitis that increase significantly for every 1 $\mu\text{g}/\text{m}^3$ increase in benzene exposure concentration.⁴⁹

Sulfur oxides can worsen asthma symptoms, and can cause respiratory irritation symptoms including wheezing, shortness of breath, and chest tightness.⁵⁰ As a historical comparison, the new Shell ethane cracker is only permitted to emit about 0.6% of the sulfur dioxide released annually by the zinc smelter that formerly occupied its site.⁵¹

Particulate matter is expressed in terms of PM_{10} , which includes all particles with a diameter of 10 micrometers or less, and $\text{PM}_{2.5}$, a subset of PM_{10} that includes finer particles with a diameter of 2.5 micrometers or less. Coarse particulate matter included in PM_{10} can irritate the eyes, nose, and throat, while $\text{PM}_{2.5}$ is more dangerous because it is small enough to reach deep into the lungs, damaging them as well as the heart and blood vessels.⁵² Each 10 $\mu\text{g}/\text{m}^3$ increase in long-term exposure to $\text{PM}_{2.5}$ has been linked to a 6-13% increase in the risk of death from heart disease.⁵³

⁴⁶ U.S. Agency for Toxic Substances and Disease Registry (ATSDR). 2007. Public Health Statement for Benzene [Internet]. Atlanta (GA): ATSDR; [cited 2017 Dec 21]. Available from <https://www.atsdr.cdc.gov/phs/phs.asp?id=37&tid=14>

⁴⁷ U.S. Agency for Toxic Substances and Disease Registry (2007)

⁴⁸ Bolden et al. (2015)

⁴⁹ Bolden et al. (2015)

⁵⁰ California Air Resources Board (CARB). 2016. Sulfur dioxide (SO_2) and health [Internet]. Sacramento (CA): CARB; [cited 2017 Dec 21]. Available from <https://www.arb.ca.gov/research/aaqs/common-pollutants/so2/so2.htm>

⁵¹ Michanowicz et al. (2013); Commonwealth of Pennsylvania Department of Environmental Protection (DEP), Air Quality Program. 2016. Plan Approval No. 04-00740A, as revised 2016 Dec 30. Harrisburg (PA): Pennsylvania DEP. Available from <http://files.dep.state.pa.us/RegionalResources/SWRO/SWROPortalFiles/Shell/PA-04-00740A%20ERC%20Modified%2012-30-16.pdf>

⁵² U.S. Centers for Disease Control and Prevention. 2016. Air quality: particle pollution [Internet]. Atlanta (GA): U.S. Centers for Disease Control and Prevention; [cited 2017 Dec 21]. Available from https://www.cdc.gov/air/particulate_matter.html

⁵³ World Health Organization Regional Office for Europe. 2013. Health effects of particulate matter: Policy implications for countries in eastern Europe, Caucasus and central Asia. Copenhagen, Denmark: World Health Organization. Available from http://www.euro.who.int/__data/assets/pdf_file/0006/189051/Health-effects-of-particulate-matter-final-Eng.pdf

Choosing a Reference Point

Some have compared the expected emissions from the Shell ethane cracker with those of the previous occupant of the site, a zinc smelter owned by the Horsehead Corporation, which was a major air polluter. In 2009, the Horsehead Corporation settled a Clean Air Act lawsuit brought by the environmental advocacy group Clean Water Action, in which it agreed to pay penalties for past air quality violations at the Monaca site and to make contributions to conservation and public health groups.⁵⁴

In 2011, the Horsehead Corporation announced that it would move its zinc smelting operations to a new facility in North Carolina due to economic factors.⁵⁵ Shell first announced its intention to consider the site for a possible ethane cracker in 2012, and only in 2015 did it make a final decision to purchase the land from Horsehead.⁵⁶ Thus, it appears that Shell's interest in building an ethane cracker did not directly result in the closure of the zinc smelter. A better comparison for the impacts of the new ethane cracker would be any impacts that would happen if the site lay dormant or were used for different activities – not with the zinc smelter, which was already on the way out.

This case highlights the need to consider the alternatives when evaluating statements about the risks and benefits that ethane cracking, or other industrial development, may bring.

As an example case, Table 1 shows the types and quantities of air emissions that the new Shell facility in Beaver County, PA, may emit within any consecutive 12-month period, according to the terms of an air permit issued by the Pennsylvania Department of Environmental Protection (DEP).

Greenhouse Emissions

The Beaver County ethane cracker plans to emit greenhouse gases equivalent to about 2.25 million tons per year of carbon dioxide.⁵⁷ This is equivalent to the annual carbon dioxide outputs of approximately 430,000 typical cars.⁵⁸

⁵⁴ Arnowitt M. 31 Dec 2009. Horsehead Corp., Clean Water Action settle lawsuit over alleged Clean Air Act violations [Internet]. Pittsburgh Business Times. Pittsburgh (PA): Pittsburgh Business Times [cited 2017 Dec 21]. Available from <https://www.bizjournals.com/pittsburgh/stories/2009/12/28/daily22.html> Under the settlement, the company paid \$15,000 in penalties for past violations, and made contributions to the Independence Conservancy and the Graduate School of Public Health at the University of Pittsburgh.

⁵⁵ Spencer M. 19 Sep 2011. Horsehead picks North Carolina for new plant [Internet]. Pittsburgh (PA): Pittsburgh Business Times [cited 2018 Jan 3]. Available from <https://www.bizjournals.com/pittsburgh/news/2011/09/19/horsehead-picks-north-carolina-for-new.html>

⁵⁶ Litvak A. 2015 Jun 16. Shell buys Horsehead property for \$13.5 million for proposed ethane plant [Internet]. Pittsburgh (PA): Pittsburgh Post-Gazette [cited 2018 Jan 3].

⁵⁷ Pennsylvania DEP: Plan Approval No. 04-00740A (2016). This figure is the CO₂ equivalent—a reflection of the global warming potential of all greenhouse gases emitted by the facility, expressed in terms of the equivalent amount of CO₂.

⁵⁸ EPA reports that the typical car produces approximately 4.7 metric tons (about 5.2 U.S. tons) of carbon dioxide per year (See, e.g., <https://www.epa.gov/greenvehicles/greenhouse-gas-emissions-typical-passenger-vehicle-0>) This is an average figure; mileage driven and fuel economy of course have a large impact on the consumption of any individual car. Also, note that a car may release other greenhouse gases, but the amounts of these other releases may vary widely; the figure here expresses only the carbon dioxide emissions of the typical car, not the carbon dioxide equivalent.

Carbon dioxide (CO₂) accounts for the overwhelming majority (more than 99%) of greenhouse gases (GHGs) emitted by petrochemical plants, according to data reported by the dominant industry companies (Exxon, Chevron, BASF, and BP).⁵⁹ However, chemical analyses of process gas (i.e., gas associated with the formation of the product, rather than combustion gas, which is produced for operation of the facility) show that there is virtually no CO₂ present in the ethylene tower.⁶⁰ Therefore, the *energy* used to produce ethylene – as opposed to the chemical reactions that occur during the process – accounts for almost all of the cracker facility’s greenhouse gas emissions.⁶¹

Table 1. Shell Ethane Cracker Air Emissions Permitted by DEP

Contaminant	Annual Emissions (tons)
Volatile organic compounds (VOCs)	522
Nitrogen oxides (NO _x)	348
Hazardous Air Pollutants (all)	30.5
Sulfur oxides (SO _x)	21
Particulate matter	
10µm or less in diameter (PM ₁₀)	164
2.5µm or less in diameter (PM _{2.5})	159
Carbon monoxide (CO)	1,012
Ammonia	152
Carbon dioxide equivalent (CO ₂ e)	2,248,293

Water Quality

Most of the liquid wastewater discharged from a steam cracker comes from water used for dilution steam, cleaning the machinery, and the quench tower.⁶² When the Shell facility begins operations, it has been permitted to discharge more than 70 different substances in treated wastewater as well as stormwater. These substances include dissolved solids, oil and grease, and potentially hazardous chemicals, such as benzene, benzo[*a*]pyrene, and vinyl chloride. Table 2, below, provides more information about this small sample of chemicals that an ethane cracker may discharge into waterways.

Benzene is known to cause cancer, especially leukemia, in humans. Based on studies of benzene exposure, scientists have calculated that a benzene drinking water concentration of

⁵⁹ Benchaita (2013)

⁶⁰ Benchaita (2013)

⁶¹ Benchaita (2013)

⁶² Siemens (2013)

1 microgram per liter (about one cup of benzene in a swimming pool of water) is associated with an increase in lifetime cancer risk of one in a million.⁶³

Benzo[a]pyrene also causes cancer in humans.⁶⁴ Studies of the chemical's effects on animals show that it also may harm learning and movement abilities, reproductive organs, and other systems.⁶⁵

Vinyl chloride causes cancer in humans, as well. There is especially strong evidence linking long-term exposure to liver cancer. Some studies have suggested that vinyl chloride exposure may lead to reproductive difficulties, but the data are not conclusive.⁶⁶

Table 2. Select Shell Cracker Water Emissions Permitted by DEP ⁶⁷

Chemical	Maximum Daily Average Discharge in a Month (lbs/day)	Max. Avg. Discharge Concentration in a Month (µg/L)
Benzene	0.790	37
Benzo [a] pyrene	0.490	23
Vinyl chloride	36.2	104

Although we can know the maximum permitted outputs from an ethane cracker, understanding exposure to the public would further require knowing (a) the resulting concentrations of these substances in the waters they enter, and (b) the concentrations in water that people drink. For example, the maximum permitted concentration of vinyl chloride in the water that Shell's cracker plant releases is 104 µg/L - the equivalent of about 10 cups of vinyl chloride in a swimming pool of water. However, the concentration will be much lower once the water is discharged into the receiving water bodies, where it will become more dilute and will volatilize (enter the air) easily. Furthermore, other existing sources of water pollution could overshadow any impact that the ethane cracker might have on water quality and human exposure, because the Ohio River is not pollution-free in the absence of the ethane cracker.

⁶³ World Health Organization. 2003. Benzene in drinking-water. Geneva, Switzerland: World Health Organization. Available from http://www.who.int/water_sanitation_health/dwq/benzene.pdf

⁶⁴ International Agency for Research on Cancer (IARC). Benzo[a]pyrene. Lyon, France: IARC. Available from <https://monographs.iarc.fr/ENG/Monographs/vol100F/mono100F-14.pdf>

⁶⁵ Minnesota Department of Health, Environmental Health Division. 2012. Benzo(a)pyrene in drinking water [Internet]. [Cited 2017 Dec 21]. Available from <http://www.health.state.mn.us/divs/eh/risk/guidance/gw/bapinfosheet.pdf>

⁶⁶ World Health Organization. 2004. Vinyl chloride in drinking-water. Geneva, Switzerland: World Health Organization. Available from http://www.who.int/water_sanitation_health/dwq/chemicals/vinylchloride.pdf

⁶⁷ Commonwealth of Pennsylvania Department of Environmental Protection (DEP). 2017. NPDES Permit No. PA0002208, as amended 2017 Jun 23. Harrisburg (PA): Pennsylvania DEP. Available from <http://files.dep.state.pa.us/RegionalResources/SWRO/SWROPortalFiles/Shell/06.23.17/FINAL%20-%20NPDES%20Permit%20PA0002208%20A-1.pdf>

Indeed, building the Beaver County ethane cracker may have some benefits for water quality, because this cracker facility will occupy the site of a former zinc smelter owned by the Horsehead Corporation. That facility was responsible for cadmium, mercury, lead, and arsenic contamination. Shell agreed to conduct \$80 million worth of environmental cleanup, which included capping the contaminated soil with clean soil in order to prevent rainfall from traveling down through the contaminated soil and carrying toxic metals into groundwater.⁶⁸ Shell already has built retention ponds in order to prevent rainwater from carrying contaminants off of the site and into the Ohio River.⁶⁹ A Pennsylvania law, known as Act 2, provides that, in return for fulfilling this state-approved cleanup plan, Shell will not face any further liability for cleaning up the site—although this law does *not* shield Shell from liability for cleaning up any contamination that Shell itself may cause.⁷⁰

If a pipeline is to be installed in a way that requires construction to disrupt or otherwise impact a navigable waterbody, the developer would need to seek water quality permits for that process. Residents of Beaver County have expressed concerns about the potential for the Falcon Ethane Pipeline, which will deliver ethane feedstock to the Shell cracker, to contaminate waterbodies. Shell has stated that its plans for the Falcon Ethane Pipeline will not involve crossing the Ambridge Reservoir, and that a line will be drilled about 60 feet underneath Service Creek (which does not feed drinking water sources).⁷¹ However, the pipeline will cross hundreds of streams and wetlands, as well as the Ohio River.⁷²

Emergencies and Unplanned Impacts

Although safety standards exist and companies have incentives to prevent industrial disasters, unfortunate incidents involving ethane crackers have occurred. In 2013, an explosion killed 2 and injured 114 at the Williams Olefins Plant in Geismar, Louisiana, a facility that produced ethylene and other petrochemicals by steam cracking ethane and propane.⁷³ It also released roughly 16 tons of volatile organic compounds, including 48 pounds of benzene. Air monitors did not detect unsafe concentrations of chemicals in the surrounding air on the day of the explosion or on the two days following; however, of 67 people living nearby who were surveyed after the incident, 24 reported health problems including respiratory and eye irritation, headaches, and nausea. A U.S. Chemical Safety Board investigation blamed the explosion on a heat exchanger that was not properly

⁶⁸ Litvak A. 2015 Sep 22. Shell plans to spend \$80 million to clean up contamination at Horsehead site [Internet]. Pittsburgh (PA): Pittsburgh Post-Gazette. Available from <http://www.post-gazette.com/powersource/companies/2015/09/22/Paying-for-anothers-contamination-Shell-to-spend-80-million-at-Horsehead-zinc-smelter-monaca-beaver-county/stories/201509220017>

⁶⁹ Litvak A. (2015 Sep 22)

⁷⁰ Pennsylvania General Assembly. 1995. Statutes of Pennsylvania: 1995 Act 2.

⁷¹ Fawcett E. 2017 Jul 19. Ambridge residents worried that Shell pipelines could endanger water supply [Internet]. Pittsburgh (PA): Pittsburgh Post-Gazette; [cited 2017 Oct 5].

⁷² Litvak A. 2018 Jan 29. Building a pipeline, one landowner at a time [Internet]. Pittsburgh (PA): Pittsburgh Post-Gazette; [cited 2018 Jan 30].

⁷³ Jones TL. 2016 Sep 26. Company found negligent in Williams Olefins explosion case; four plaintiffs awarded \$13.6 million [Internet]. Baton Rouge (LA): The Advocate; [cited 2017 Dec 21]. Available from http://www.theadvocate.com/baton_rouge/news/communities/westside/article_e41259a4-8435-11e6-a5d0-a7e34674fd30.html

protected from over-pressurization due to weaknesses in the plant's safety management programs.⁷⁴

On occasion, pipelines carrying flammable materials such as natural gas have ruptured. The main causes of these failures are external interference (a puncture, gouge, or dent), external or internal corrosion, faulty materials or construction, and ground movement (earthquakes).⁷⁵ Ethane is transported in pipelines as a liquid, but it vaporizes easily when exposed to the atmosphere, and is highly flammable. Unlike natural gas (which is mostly methane), ethane is heavier than air, which means that in case of a release it will form a vapor cloud instead of dissipating.⁷⁶ Therefore, any leak is extremely dangerous. In February 2015, the Appalachia-Texas Express (ATEX) ethane pipeline ruptured in Brooke County, WV, producing an explosion that burned more than 23,000 barrels of ethane and scorched approximately 5 acres of land. Local media reported that flames from the explosion shot hundreds of feet into the air.⁷⁷

The Emergency Planning and Community Right to Know Act requires all local governments in the United States to develop chemical emergency response plans and review them at least annually. Facilities that keep more than specified amounts of substances designated as "Extremely Hazardous" must reveal these substances to local emergency planning and coordination officials and supply information needed to help contain and respond to potential incidents. These facilities are also required to report accidental releases of hazardous substances to state and local officials immediately, and this information must be made available to the public.⁷⁸ The advocacy group Fractracker Alliance reports that, according to local emergency management officials, emergency planning for the Beaver County ethane cracker will happen once that facility is closer to operational readiness.⁷⁹

The final product of ethane cracker facilities may result in certain downstream ecological impacts. Most of the polyethylene pellets will eventually become plastic products after they are shipped from the cracker to manufacturers on both trains and trucks.⁸⁰ However, a small fraction of these pellets accidentally spill during transportation, eventually reaching

⁷⁴ Schleifstein M. 2013 Jun 26. Geismar explosion and fire released more than 31,000 pounds of toxic chemicals, company reports. New Orleans (LA): The Times-Picayune; [cited 2017 Dec 21]. Available from http://www.nola.com/environment/index.ssf/2013/06/geismar_eplosion_and_fire_rele.html

⁷⁵ Hopkins P, Goodfellow G, Ellis R, Haswell J, Jackson N. 2009. Pipeline Risk Assessment: New Guidelines. WTIA/APIA Welded Pipeline Symposium, 2009 Apr 3. Available from <http://www.penspen.com/wp-content/uploads/2014/09/risk-assessment-new-guidelines.pdf>

⁷⁶ Colaneri K. 2013 Dec 17. Safety concerns arise over cross-state natural gas liquids pipeline. NPR StateImpact [Internet]. [Cited 2017 Dec 21]. Available from <https://stateimpact.npr.org/pennsylvania/2013/12/17/safety-concerns-arise-over-cross-state-natural-gas-liquids-pipeline/>

⁷⁷ WHSV. 2015 Feb 1. W.Va. pipeline blast burned 23,901 barrels of ethane. WHSV [Internet]. [Cited 2017 Dec 21]. Available from <http://www.wHSV.com/news/headlines/WVa-pipeline-blast-burned-23901-barrels-of-ethane--290477801.html>

⁷⁸ Beaver County. Hazardous Materials Response Program [Internet]. [Cited 2017 Dec 21]. Available from <http://www.beavercountypa.gov/Depts/EMS/Pages/SARA-EPCRA.aspx>

⁷⁹ Leiter L, Marcucci LG, Jalbert K. 2017 May 3. Understanding in order to prepare: Ethane cracker risk and disclosure [Internet]. Fractracker Alliance. [Cited 2017 Dec 21]. Available from <https://www.fractracker.org/2017/05/ethane-cracker-risk-and-disclosure/>

⁸⁰ KallanishEnergy Daily News & Analysis. 2017 Sep 29. Shell to ramp up construction on Pa. ethane cracker [Internet]. [Cited 2017 Dec 21]. Available from <http://www.kallanishenergy.com/2017/09/29/shell-to-ramp-up-construction-on-pa-ethane-cracker/>

waterways and, ultimately, the oceans.⁸¹ Many persistent (not easily broken down) toxic pollutants, such as PCBs and PAHs, stick to these plastic pellets because of their chemical properties.⁸² Animals eat them, drawing the chemicals into food webs.⁸³ The release of general plastic waste (i.e., products that are made from the polyethylene pellets and other plastic building blocks) also adds to plastic pollution in the world's oceans.

Noise Pollution

Noise pollution is defined as unwanted or disturbing sound.⁸⁴ In general, environmental noise can affect wellbeing by contributing to tinnitus (sound perception that is not attributable to external sources), sleep disturbance, annoyance, high blood pressure, and heart disease.⁸⁵ In the United States, the EPA has left it up to states and local governments to regulate noise pollution.⁸⁶

A noise effect analysis for a Houston-area facility that was expanding to include new ethane cracking furnaces and other process components indicated that, at a distance of 50 feet, the average noise level associated with construction would be about 85 dBA (decibels adjusted for the human ear's perceptiveness to different frequencies).⁸⁷ This level is approximately equivalent to a garbage disposal at a distance of 3 feet.⁸⁸

A conditional use permit granted by the Potter Township board of supervisors requires the new Shell ethane cracker to limit and monitor light and noise.⁸⁹ Construction noise levels are not to exceed 75 decibels during the daytime (7:00 AM – 9:00 PM, Monday through Saturday) and 65 decibels during all other times, at any point 100 feet from the nearest residence or public building (or at that building's property line, whichever is closer to the affected building).⁹⁰ During normal operations, the facility must keep its noise level below 65 dBA – roughly equivalent to the noise level of heavy traffic at a distance of 300 feet.⁹¹ Truck and train activity associated with ethane cracking operations also could produce annoyance, although the exact degree and locations of those potential effects are unknown.

⁸¹ Mato Y, Isobe T, Takada H, Kanehiro H, Ohtake C, Kaminuma T. 2001. Plastic resin pellets as a transport medium for toxic chemicals in the marine environment. *Environ. Sci. Technol.* 35:318-324.

⁸² Rochman CM, Hoh E, Hentschel BT, Kaye S. 2013. Long-term field measurement of sorption of organic contaminants to five types of plastic pellets: Implications for plastic marine debris. *Environ. Sci. Technol.* 47:1646-1654.

⁸³ Rochman et al. (2013)

⁸⁴ U.S. Environmental Protection Agency. Clean Air Act Title IV – Noise Pollution [Internet]. [Cited 2017 Dec 21]. Available from <https://www.epa.gov/clean-air-act-overview/clean-air-act-title-iv-noise-pollution>

⁸⁵ World Health Organization Regional Office for Europe. 2011. Burden of disease from environmental noise: Quantification of healthy life years lost in Europe [Internet]. Copenhagen, Denmark: World Health Organization; [Cited 2017 Dec 21]. Available from http://www.euro.who.int/__data/assets/pdf_file/0008/136466/e94888.pdf

⁸⁶ U.S. Environmental Protection Agency. Clean Air Act Title IV – Noise Pollution.

⁸⁷ Raven Environmental Services and Sage Environmental Consulting. 2013. Biological assessment for ExxonMobil Chemical Company for the Baytown Olefins Plant ethylene expansion unit project. Available from <https://archive.epa.gov/region6/6pd/air/pd-r/ghg/web/pdf/exxonmobil-baytown-olefins-final-bio.pdf>

⁸⁸ California Department of Transportation. Loudness comparison chart (dBA). Available from <http://www.dot.ca.gov/dist2/projects/sixer/loud.pdf>

⁸⁹ Frazier R. 2017 Jan 19. Beaver County township green-lights ethane cracker [Internet]. NPR StateImpact. [Cited 2017 Dec 21]. Available from <https://stateimpact.npr.org/pennsylvania/2017/01/19/beaver-county-township-green-lights-ethane-cracker/>

⁹⁰ Potter Township Resolution No. 3 – 2017. Available upon a public records request from Potter Township, Beaver County, PA.

⁹¹ California Department of Transportation. Loudness comparison chart (dBA). Available from <http://www.dot.ca.gov/dist2/projects/sixer/loud.pdf>

Land Use Changes

Construction of an ethane cracker can result in land use changes, but the extent of these changes will vary between sites, depending on how land is currently used. Building the Beaver County ethane cracker itself is unlikely to result in significant land use changes, given that it is being constructed where another industrial facility once was. However, some wetlands will be impacted due to site modifications, including the relocation of the adjacent state highway.⁹²

A new ethane cracker may lead to other construction designed to capitalize on business opportunities that result from the plant's economic impact. In Beaver County, a local economic development fund already has provided loans to clear land and prepare it for use as an industrial park. The group reports increased demand for real estate in the vicinity of the cracker facility.⁹³

5. What permits and approvals does an ethane cracker need?

Water

A National Pollutant Discharge Elimination System (NPDES) permit is required when pollutants will be released from a specific source into waters of the United States. These permits establish limitations on pollutant discharges and monitoring requirements in order to achieve the water quality goals of the federal Clean Water Act (and state law, where applicable). Shell received the required NPDES discharge permit for stormwater runoff (water from rain or snow that washes off of the site) and treated process water from the Beaver County ethane cracker on June 12, 2015, from the Pennsylvania Department of Environmental Protection (DEP). This permit is an amendment to the NPDES permit held by the previous owner of the site; the DEP allowed the Horsehead Corporation to transfer the NPDES permit to Shell along with the land. The permit is valid until June 30, 2020, when Shell would need to apply for a permit renewal. The renewal will be subject to public comment. Shell does not expect the facility to be operational until the early 2020s, so this permit covers only the construction and start-up period.⁹⁴

Clean Water Act Section 404 permits, issued by the U.S. Army Corps of Engineers, are required when an activity would result in the discharge of dredge or fill material into waters of the United States, as may be the case with construction of an ethane cracker itself or of feedstock pipelines.

State law also may require permits for such activities. For example, the developer of the Atlantic Sunrise Pipeline – a natural gas transport system – needed to lay a pipeline under or through several floodways, streams, and wetlands. Because of Pennsylvania's Clean Streams Law (through which the state implements the federal Clean Water Act), the developer was required to obtain permits from the Pennsylvania DEP for water obstruction

⁹² Commonwealth of Pennsylvania Department of Environmental Protection (DEP). 2015 Jun 12. Water Obstruction and Encroachment Permit E04-250-A1. Available from http://files.dep.state.pa.us/RegionalResources/SWRO/SWROPortalFiles/Shell_FINAL/Encroachment.pdf

⁹³ Moore D. 2017 Sep 25. Shell cracker plant spurs \$7 million development loan for nearby site [Internet] Pittsburgh (PA): Pittsburgh Post-Gazette; [cited 2017 Dec 21]. Available from <http://www.post-gazette.com/business/development/2017/09/25/Shell-ethane-cracker-plant-Beaver-County-7-million-loan-Allegheny-Conference-Turnpike/stories/201709250114>

⁹⁴ Moore (2017)

and encroachment, and for erosion and sediment controls.⁹⁵ Similarly, Shell was required to obtain a state water obstruction and encroachment permit for its construction activities at the site of its new cracker. This permit allowed Shell to reroute a state road and build or modify structures in the adjacent waterways, but required it to restore or enhance wetlands and streams at a site approximately 30 miles away in order to compensate for the on-site damages.⁹⁶

Air Emissions

The regulation of air pollution from an ethane cracker depends on the types and amounts of pollutants that the facility proposes to emit, as well as the environmental conditions already existing in the facility's proposed location. The Clean Air Act requires the EPA to regulate six common "criteria air pollutants" – ground-level ozone, particulate matter, carbon monoxide, lead, sulfur dioxide, and nitrogen dioxide – as well as hazardous air pollutants that cause serious health effects such as cancer. EPA has turned over much of this regulatory authority to state environmental protection agencies.

Shell's plans for the Beaver County ethane cracker showed a potential to emit nitrogen dioxide, particulate matter, carbon monoxide, greenhouse gases, and hazardous air pollutants above the threshold levels for designation as a "major source" of those pollutants under the Clean Air Act.⁹⁷ This means that the facility is required to seek and comply with an air permit issued by the Pennsylvania Department of Environmental Protection, which implements the Clean Air Act in accordance with EPA policies.

Two types of permits are required for a non-moving source of air pollution:

1. Preconstruction permits – Facilities must obtain these permits before beginning construction. Based on plans submitted by the facility developer and considerations of existing air quality in the area, the permit sets the maximum rates of emissions for criteria and hazardous air pollutants. In areas that have higher than acceptable levels of criteria air pollutants ("nonattainment areas"), the permit must ensure that the new source does not further degrade air quality.⁹⁸ The Beaver County ethane cracker received its preconstruction permit on June 18, 2015, with an expiration date of June 18, 2019.
2. Operating permit (i.e., Title V permit) – Once construction is complete, the facility must seek an operating permit, which includes the requirements of the

⁹⁵ Cusick M. 2017 Aug 31. DEP issues water permits for Atlantic Sunrise Pipeline [Internet]. NPR StateImpact; [cited 2017 Dec 21]. Available from <https://stateimpact.npr.org/pennsylvania/2017/08/31/dep-issues-water-permits-for-atlantic-sunrise-pipeline/>

⁹⁶ Commonwealth of Pennsylvania Department of Environmental Protection (DEP). 2015 Jun 12. Water Obstruction and Encroachment Permit E04-250-A1. Available from http://files.dep.state.pa.us/RegionalResources/SWRO/SWROPortalFiles/Shell_FINAL/Encroachment.pdf

⁹⁷ RTP Environmental Associates. 2014. Air quality plan approval application for Shell Chemical Appalachia Beaver County, Pennsylvania, petrochemicals complex [Internet]. RTP Environmental Associates; [cited 2017 Dec 21]. Available from <http://gasp-pgh.org/wp-content/uploads/2014/05/Shell-Petrochemicals-Complex-Plan-Approval-Application.pdf>

⁹⁸ James CA, Schultz RA, Radway A. 2016. Air emissions source permitting programs in the United States and European Union: Lessons for China. Beijing, China: Clean Air Alliance of China, and San Francisco (CA): Energy Foundation China. [Cited 2017 Dec 21]. Available from <http://www.raponline.org/knowledge-center/air-emissions-source-permitting-programs-united-states-european-union-lessons-china/>

preconstruction permit and may also impose additional performance standards, including any state and local requirements.

The Clean Air Act allows a facility to emit more than the amount of an air pollutant specified in its air quality permit, if the facility purchases emission reduction credits (ERCs) from nearby sources of that pollutant that voluntarily reduce their emissions. Shell planned to buy VOC emission reduction credits in order to lower its net VOC emissions to levels allowed under the permit it received from the DEP in June 2015. However, Shell was unable to find enough VOC credits for sale in the local area. Therefore, Shell petitioned the Pennsylvania Department of Environmental Protection to allow it to purchase more nitrogen oxide emission reduction credits than it needed for compliance with the permit, instead of purchasing the amount of VOC credits that would be required.⁹⁹ Shell justified this request by submitting air modeling that indicated that nitrogen oxide was the limiting factor in ground-level ozone formation in Beaver County, and in western Pennsylvania, and therefore that nitrogen oxide reductions would result in at least as much ozone prevention as VOC reductions.¹⁰⁰ On December 30, 2016, the DEP signed off on a revised air quality plan for the Beaver County cracker that allows it to purchase nitrogen oxide credits instead of VOC credits at a 1:1 ratio.¹⁰¹

This bargain is an example of the longstanding EPA-approved practice of interprecursor trading (IPT), under which regulators may treat NO_x and VOC emissions as interchangeable for purposes of ozone reduction.¹⁰² As discussed above, elevated VOC concentrations are associated with impacts beyond those that are ozone-related, but VOCs that are considered hazardous air pollutants are subject to the separate limitations applicable to that category of pollutants.

Shell's air quality permit places a 30.5 ton per year limit on total Hazardous Air Pollutants from the facility – somewhat more restrictive than the 41.9 ton per year potential to emit that Shell declared in its original application. However, the permit does not specify limits for each Hazardous Air Pollutant that has been identified as a potential output. (The air permit does, however, restrict the total amount of benzene in the facility's waste.)

Zoning and Local Land Use

In Pennsylvania, planning and zoning happens only at the local level. The state Municipalities Planning Code requires counties to develop a comprehensive plan.¹⁰³ It also allows municipalities to choose whether or not to enact planning and zoning ordinances, which govern the types of activities (residential, commercial, industrial, etc.) that may take

⁹⁹ Frazier R. 2016 Dec 16. Shell proposes bargain to meet pollution targets for ethane cracker [Internet]. NPR StateImpact; [cited 2017 Dec 21]. Available from <https://stateimpact.npr.org/pennsylvania/2016/12/16/shell-proposes-bargain-to-meet-pollution-targets-for-ethane-cracker/>

¹⁰⁰ Shell Chemical Appalachia. 2016. Updated request for approval of interprecursor offset trading between VOC and NO_x for the construction of the Shell Chemical Appalachia LLC - Petrochemicals Complex [Internet]. Available from <http://files.dep.state.pa.us/RegionalResources/SWRO/SWROPortalFiles/Shell/Shell%20Ozone%20NOx%20for%20VOC%20Submittal%208-15-16.pdf>

¹⁰¹ Pennsylvania DEP (2016) - Plan Approval No. 04-00740A, as revised 2016 Dec 30

¹⁰² Shell Chemical Appalachia (2016)

¹⁰³ Pennsylvania Land Trust Association - ConservationTools.org. N.D. Planning and Land Use Ordinance Basics. [Cited 2017 Dec 21]. Available from <http://conservationtools.org/guides/58-planning-land-use-ordinance-basics>

place in a given zone.¹⁰⁴ If a municipality chooses not to enact zoning laws, then the county in which it is located may implement zoning law.¹⁰⁵ However, the state does not step in to implement land use law if local government does not do so.¹⁰⁶ If any part of a municipality is zoned, then all of its areas must be zoned.¹⁰⁷

Local zoning laws may list certain “conditional uses” that require approval from a local governing body, such as a board of supervisors, before they are allowed. These uses tend to be ones that might directly impact all the members of a community.¹⁰⁸ The governing body approves or denies applications for conditional uses according to criteria and standards set out in local planning and zoning law. At its discretion, this governing body may impose reasonable conditions on the permittee in order to protect the public welfare. The Potter Township Board of Supervisors voted unanimously to approve a conditional use permit for the Beaver County ethane cracker at a meeting on January 18, 2017.¹⁰⁹

Feedstock Pipelines

The federal and state governments share responsibility for permitting and inspecting pipelines that cross state lines, such as the Falcon and ATEX pipelines. The Federal Energy Regulatory Commission (FERC) regulates natural gas pipeline construction, but does *not* regulate the siting or construction of pipelines carrying ethane and other hazardous liquids.¹¹⁰ The Pipeline and Hazardous Material Safety Administration (PHMSA), within the U.S. Department of Transportation, monitors and enforces safety regulations, although state agencies conduct most safety



¹⁰⁴ Salzmann GB, Wyland ST, Williams KE, Cartwright TM. 2012. Zoning, subdivision and land development law in Pennsylvania [Internet]. Salzmann Hughes; [cited 2017 Dec 21]. Available from <http://salzmannhughes.com/wp-content/uploads/2012/05/ZONING-PSATS-Spring-2012.pdf>

¹⁰⁵ Salzmann et al. (2012)

¹⁰⁶ Pennsylvania Land Trust Association (N.D.)

¹⁰⁷ Salzmann et al. (2012)

¹⁰⁸ Pennsylvania Governor’s Center for Local Government Services. 2001. Special Exceptions, Conditional Uses and Variances [Internet]. Pennsylvania Governor’s Center for Local Government Services; [cited 2017 Dec 21]. Available from http://www.adamswatersheds.org/images/se_cu_and_v.pdf

¹⁰⁹ The conditional use permit does not appear to be available online, nor are the proceedings of the hearing at which it was approved.

¹¹⁰ FERC claimed jurisdiction over interstate ethane transmission pipelines under the Interstate Commerce Act, including in cases where the ethane is not intended for use as a fuel product, in an order issued December 31, 2013. The Commission cited the fact that ethane has current and future potential uses that are energy-related. *See* Williams Olefins Feedstock Pipelines, LLC, 145 FERC ¶ 61,303 (2013)

inspections.¹¹¹

How does using a former industrial site affect regulatory and permitting requirements?

Shell's strategy of building on available industrial land will exempt it from at least one environmental regulation. In 2010, Pennsylvania introduced new standards for total dissolved solids (TDS) in industrial wastewater discharges.¹¹² Because Shell obtained the former Horsehead smelter's NPDES permit when it bought the site, it is not required to submit a completely new permit application; instead, it is considered an existing facility, so it is not required to meet the new, stricter dissolved solids discharge requirements.¹¹³

As discussed above, Shell has performed environmental remediation of the former Horsehead zinc smelter site in accordance with a Pennsylvania statute known as Act 2. Because it is doing so, it will be shielded from liability for any further environmental damages resulting from the environmental contamination that was on the site before. According to Shell, the state approval of Shell's Act 2 plan was crucial in the company's decision to move forward with the project in Pennsylvania.¹¹⁴

6. What monitoring will be conducted at the Beaver County ethane cracker?

Air

The Clean Air Council and the Environmental Integrity Project, two environmental organizations, appealed the Pennsylvania DEP's decision to award permits to Shell's Beaver County ethane cracker project. The groups reached a settlement with Shell, under which Shell agreed to additional emissions monitoring and reporting requirements, in exchange for the environmental groups agreeing not to sue Shell.¹¹⁵ The agreement requires Shell to maintain a Continuous Air Monitoring System (CAMS) on the facility's premises, which will track total non-methane, non-ethane VOC (NMNEVOC) concentrations; as well as a Passive Air Monitoring System (PAMS), which will detect the concentrations of several "chemicals of potential concern" over two-week periods. These chemicals are:

- Benzene
- 1,3-butadiene
- *n*-hexane

¹¹¹ Pless J. 2011. Making state gas pipelines safe and reliable: An assessment of state policy [Internet]. National Conference of State Legislatures; [cited 2017 Dec 21]. Available from <http://www.ncsl.org/research/energy/state-gas-pipelines-federal-and-state-responsibili.aspx>

¹¹² Commonwealth of Pennsylvania Department of Environmental Protection (DEP). 2010 Jun 17. Governor Rendell praises regulatory panel vote protecting PA's stream, rivers from drilling wastewater [Press Release]. DEP Newsroom; [cited 2017 Oct 11]. Available from <http://www.ahs.dep.pa.gov/NewsRoomPublic/Print.aspx?id=12222&typeid=1>

¹¹³ Litvak A. 2016 Dec 22. Transfer permit could allow Shell to avoid pollution limits [Internet]. Pittsburgh (PA): Pittsburgh Post-Gazette; [cited 2018 Jan 9]. Available from <http://www.post-gazette.com/powersource/companies/2016/12/22/Transfer-permit-could-allow-Shell-to-avoid-pollution-limits/stories/201612220067>

¹¹⁴ Petrochemical Update. 2016 Jul 8. Location and tax breaks key to Shell's Pennsylvania cracker plant approval [Internet]. Petrochemical Update; [cited 2017 Dec 21]. Available from <http://analysis.petchem-update.com/engineering-and-construction/location-and-tax-breaks-key-shells-pennsylvania-cracker-plant-approval>

¹¹⁵ Settlement agreement between Shell Chemical Appalachia LLC and Clean Air Council and Environmental Integrity Project. 2017 Aug 25. [Cited 2017 Dec 21]. Available from <http://cleanair.org/wp-content/uploads/Final-Settlement-Agreement-1.pdf>

- Naphthalene
- Toluene

Levels of these “chemicals of potential concern” at the facility’s fenceline will be posted online, in accordance with the monitoring agreement.

The agreement also sets “action levels” of air pollutants. If monitors at the facility’s boundary detect pollutant concentrations above these action levels, Shell is required to conduct an investigation within 24 hours. The investigation team will survey potential sources of leaks and make corrective actions. The agreement sets initial action levels, and provides that these levels automatically will be adjusted upward if they are exceeded frequently or downward if investigations are rarely triggered. (The exact frequency and adjustment amounts depend on the time since the monitoring system started operating; those numbers are available in the agreement itself.)

A passive air monitoring system (PAMS) determines the levels of benzene in the air, which indicate whether volatile organic compounds are leaking. Benzene, like the other chemicals of potential concern, “sticks” to passive samplers that are placed strategically around the site. Every two weeks, the samplers are analyzed in a lab in order to find the average concentrations of chemicals of potential concern over the past two weeks. The estimated amount of benzene pollution resulting from the plant is calculated as the difference between the highest-concentration sample and the lowest-concentration sample. Wind speed and direction data will be collected, but the calculation of the benzene concentration as described above does not directly take them into account.¹¹⁶

Water

The ethane cracker’s NPDES permit, which Shell must hold in order to discharge waste into waters of the United States, specifies monitoring requirements to determine the water quality impacts of the facility’s operations. The permit sets forth the sample types and minimum monitoring frequencies, which vary based on the precise location from which the discharge is released, and on the chemical or water quality parameter (e.g., pH) being monitored. Furthermore, the permit requires that analysis of water samples be completed in a laboratory that meets state accreditation requirements and that follows government-approved analytical methods. The permit holder must submit discharge monitoring reports (DMRs) to the state Department of Environmental Protection at regular intervals, and the department, as well as EPA, must be able to conduct quality assurance inspections in order to ensure the validity of the facility’s self-reported data.¹¹⁷

7. How can citizens become involved in decision-making?

Permit issuances provide important opportunities for the public to engage in the process of decision-making.

¹¹⁶ Leone N. 2016 Dec. Benzene fenceline monitoring: where should you be by now? [Internet]. ALL4 Inc.; [cited 2018 Jan 9]. Available from <http://www.all4inc.com/benzene-fenceline-monitoring---where-should-you-be-by-now>; see also U.S. Environmental Protection Agency. 2017. Method 325A – Volatile Organic Compounds from Fugitive and Area Sources: Sampler Deployment and VOC Sample Collection [Internet]. U.S. Environmental Protection Agency; [cited 2018 Jan 9]. Available from <https://www.epa.gov/emc/method-325a-volatile-organic-compounds-fugitive-and-area-sources-sampler-deployment-and-voc>

¹¹⁷ Pennsylvania DEP (2017) – NPDES Permit No. PA0002208, as amended 2017 Jun 23

- Before a Clean Air Act preconstruction permit can be issued, notice of this permit must be issued electronically and/or in a local newspaper.¹¹⁸ The public must have at least 30 days to request a hearing and to comment on a draft permit, and the issuing agency must respond to these comments.¹¹⁹ For an operating permit, the EPA has 45 days to review a permit, and may object if the permit does not meet the requirements of the Clean Air Act; citizens have 60 days to petition the EPA to object to the permit if the EPA does not do so on its own.¹²⁰ Operating permits cannot be issued for more than 5 years at a time, ensuring that there are continuing opportunities for review and public input. Major revisions to operating permits also trigger opportunities for public participation without extending the life of the permit.
- A draft NPDES (Clean Water Act) permit is subject to a public notice period of at least 30 days, during which members of the public may submit comments and/or request a hearing. The permitting agency must respond to all significant comments when a final permit is issued. The permitting authority also must publish a public notice of the draft permit in a local newspaper and mail copies of the notice to people who have joined the permitting authority's mailing list.¹²¹ Permits cannot be issued for more than 5 years at a time.
- Where local governments must decide whether to issue a conditional use permit or other exception to local planning and zoning law, citizens typically have the opportunity at a public hearing to submit input to the local officials who will approve or deny the conditional use permit. Rights to participate and procedures for doing so may vary between municipalities.

Some permits also include information reporting requirements that the public can use to hold facilities accountable. The results of monitoring required under a NPDES permit are publicly available from the authority that granted the permit.¹²² Anyone harmed by a violation of the permit can file a lawsuit against the alleged violator, and if the state or EPA fails to adequately enforce the law against a polluting facility, citizens can file suits to make sure the law is enforced.¹²³ The Clean Air Act has similar monitoring, reporting, and citizen suits provisions.

Elected officials have considerable ability to influence whether a facility like an ethane cracker will be constructed in a particular area. The vice president of Shell's Pennsylvania Chemicals Project has stated that the 25-year package of tax incentives authorized by the state legislature, valued at approximately \$1.65 billion, was a critical factor in Shell's decision to move forward with the facility at its Beaver County location.¹²⁴ Citizen engagement with both elected officials and candidates for office therefore affects the ordering of an area's economic, environmental, and public health priorities.

¹¹⁸ U.S. Environmental Protection Agency. 2016 Oct 8. Revisions to Public Notice Provisions in Clean Air Act Permitting Programs [Internet]. Federal Register 81(201):71613-71631; [cited 2017 Nov 21].

¹¹⁹ James et al. (2016)

¹²⁰ James et al. (2016)

¹²¹ U.S. Environmental Protection Agency (EPA). 2013. Public participation in the NPDES permit issuance process (Document 832-F-12-033). Washington (DC): U.S. Environmental Protection Agency; [cited 2017 Dec 21]. Available from <https://www3.epa.gov/npdes/pubs/publicparticipation.pdf>

¹²² U.S. EPA (2013)

¹²³ U.S. EPA (2013)

¹²⁴ Petrochemical Update (2016)

8. Conclusion

Given the projected expansion of ethane cracking in the Ohio Valley over the next few years, communities should anticipate the need to make involved and informed decisions about the construction of these plants and their associated infrastructure. Much of the relevant information is highly technical and complex, and decision-making is all the more difficult due to uncertainties about the ways that certain pollutants and activities may affect the environment and human health.

Nonetheless, communities must be prepared to balance the benefits and the risks of ethane cracking through public decision-making processes. While reasonable people may disagree about how to balance these priorities, the integrity of the collective decision-making process is improved when citizens more fully understand the issue.



Appendix 1: List of Key Terms and Abbreviations

Ambient concentration – the concentration (e.g., of a pollutant) in the surrounding area (e.g., around a polluting facility)

CAMS – “Continuous Air Monitoring System”, a system that measures air pollution constantly and sends it to a computer for analysis; at Shell’s Beaver County ethane cracker, CAMS will monitor NMNEVOC concentrations

CAPS – “Chemicals of Potential Concern” as defined in the Beaver County ethane cracker monitoring settlement agreement and specified above

Carcinogen – A substance or exposure that promotes the formation of cancer

DEP – Pennsylvania Department of Environmental Protection

EPA – U.S. Environmental Protection Agency

Feedstock – the raw material supplying a system of production; in the context of an ethane cracker, ethane is the feedstock

Fenceline – the external boundary (e.g., of an industrial facility), often the location for pollution monitoring since it represents the closest place to the facility where members of the public might be exposed to pollution.

NMNEVOC – non-methane, non-ethane Volatile Organic Compounds

NO_x – Nitrogen oxides

NPDES – National Pollutant Discharge Elimination System, the system established by the Clean Water Act for regulating discharges from specific locations (point sources) into waters of the United States

Ozone, ground-level (tropospheric) – Ozone that forms due to interactions between VOCs, nitrogen oxides, and sunlight. Ground-level ozone causes breathing problems. It is not to be confused with stratospheric ozone, which composes the ozone layer - a natural shield that deflects harmful ultraviolet radiation from Earth’s surface, allowing life on Earth to survive.

PAMS – “Passive Air Monitoring System”, a method for measuring air pollutant concentrations in which pollutants gradually accumulate on a monitoring device and are then chemically analyzed to provide concentration data over a specified time interval; at Shell’s Beaver County ethane cracker, PAMS will indicate the concentrations of Chemicals of Potential Concern as described in the monitoring agreement and the present report

PM₁₀ – Particulate matter suspended in the air that has a diameter of 10 micrometers or less – between one tenth and one fifth of the width of a typical human hair

PM_{2.5} – Particulate matter suspended in the air that has a diameter of 2.5 micrometers or less

Precursor – a substance from which another substance is formed

SO_x – Sulfur oxides

VOC – Volatile Organic Compounds, a family of chemicals that contain carbon and vaporize easily, some of which are toxic to humans

Volatile – tending to evaporate easily under normal conditions