# HOW FRACKING SUPPORTS THE PLASTIC INDUSTRY

ISSUE BRIEF • FEBRUARY 2017

The plastics industry has reaped under-the-radar benefits from the environmentally destructive fracking boom.[1] The fossil fuel industry has surged over the past decade by employing new techniques and technologies that combine horizontal drilling and hydraulic fracturing (or fracking) to extract oil and gas from shale and other underground rock formations. Fracking injects large quantities of water, sand and toxic chemicals under high pressure to release oil and gas that are tightly held in rock layers.[2]

The fracking boom has also produced an oversupply of cheap ethane in the past few years. This surge has been a boon for the plastics industry, which relies on petrochemical manufacturing to turn ethane (a hydrocarbon present in natural gas) into plastics.[3] Beginning in 2012 chemical companies started aggressively investing in petrochemical plants and export facilities focused on tapping the ethane glut.[4] The petrochemical industry produces hydrocarbon-based chemicals derived primarily from processed natural gas and, to a lesser extent, crude oil. Petrochemicals are the building blocks to manufacture a wide range of goods, including plastic packaging, beverage bottles, tires and more.[5] In 2012 an estimated 221,483,538 barrels of oil equivalent of natural gas and 99,520,690 barrels of crude oil were used to produce plastic resins.[6]

The fracking boom and low-priced natural gas have spawned a resurgence in plastics manufacturing — and the pollution that comes with it. Transforming ethane into plastics and other products is inherently toxic, polluting the environment and imposing public health risks on petrochemical workers and the communities near the plants.

## Converting Fracked Gas Into Petrochemicals

The fracking boom across the U.S. Midwest and Northeast has produced large volumes of ethane. A few shale plays — including the Utica and Marcellus shale gas reserves underlying vast portions of northeastern Appalachia — contain what the industry calls "wet" natural gas.[7] Natural gas contains primarily methane and smaller amounts of other hydrocarbons, but wet natural gas has higher concentrations of natural gas liquids (NGLs).[8] NGLs — predominantly ethane but also propane, butane, isobutane and pentanes — are the raw materials for manufacturing petrochemicals.[9]

Turning ethane into plastic is an energy-intensive process that requires separation from the other hydrocarbons present in natural gas. Once isolated, ethane is transported to a type of petrochemical facility known as a cracker plant, where a series of processes involving steam (or just heat) "crack" ethane into ethylene.[10] Ethylene is the most frequently produced petrochemical and creates the most common type of plastic.[11] Ethylene then goes through another chemical procedure called polymerization to convert it into small plastic pellets (called polyethylene resin). This resin is used to manufacture plastic products.[12]

## Plastics Industry Surging From the Fracking Boom

The fracking boom has generated a plastics bonanza. According to *Plastics News*, "shale-based natural gas represents a once-in-a-generation opportunity" for the North American plastics market.[13] In November 2013 representatives from the oil and gas, petrochemical and plastics industries convened a three-day summit — the first of its kind — to address the "opportunities and challenges of a 'coming renaissance' in North American plastics."[14]

By 2023 the chemical industry is slated to spend over $164 billion on 264 new facilities and expansion projects specifically to take advantage of shale gas, according to the American Chemistry Council (ACC).[15] As of April 2016, 40 percent of these had been completed or were under construction, and more than half were in the planning phase.[16] "Thanks to the shale gas production boom, the United States is the most attractive place in the world to invest in chemical and plastics manufacturing. It's an astonishing gain in competitiveness," said ACC's president and CEO Cal Dooley.[17]

Unfortunately plastics production is inherently wasteful. The largest sector of the plastics industry is packaging, which creates materials that are immediately thrown away.[18] Take, for example, the bottled water industry, which relies on polyethylene terephthalate (PET) plastic to package its single-serve bottles.[19] On average, each U.S. citizen guzzles 36.7 gallons of bottled water each year.[20] But all this consumption is stacking up as waste in our landfills and garbage incinerators. According to the Container Recycling Institute, 71 percent of PET plastic bottles are not recycled, and in 2010 over 1.5 million tons of PET plastic bottles ended up in the trash (See Figure 1).[21] A 2015 industry study found that under a third of PET bottles are recycled.[22]

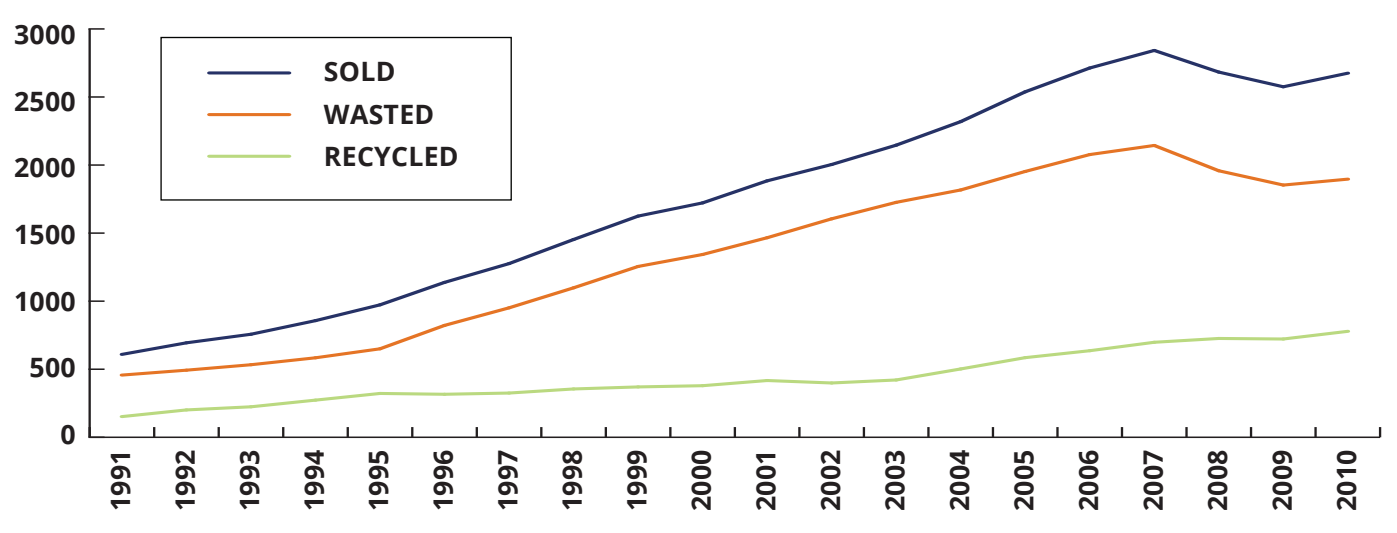
Much of this plastic waste ends up in our oceans and surface waters. A 2015 study estimated that nearly 200 coastal countries generated over 600 billion pounds of plastic waste in 2010 — and between 11 and 27 billion pounds of this ended up in the oceans.[23] In the central Pacific Ocean, a slow-moving "plastic soup" circulates among four major ocean currents. Dubbed the Great Pacific Garbage Patch, it is the world's largest dump.[24] The fracking-driven industry expansion will likely generate even more ocean plastics as more ethane crackers come online and produce more plastic resins.

## Cracking, Like Fracking, Is Toxic to the Environment and People

The petrochemical boom does more than generate plastic that is overfilling our landfills and spilling into the oceans; the manufacturing process itself releases numerous pollutants into our air, water and land. On top of that, many of the proposed new ethane cracker projects are co-located with fracking and drilling operations, potentially compounding the pollution problems that residents already endure.

Plants that convert natural gas into petrochemicals are known to emit massive amounts of air and climate pollutants including polycyclic aromatic hydrocarbons, carbon dioxide and ozone-creating volatile organic compounds (such as benzene and toluene) and nitrogen oxide.[25] A 2012 study of petrochemical pollution in Houston, Texas by a researcher at Houston

**FIGURE 1: PET Bottle Sales, Recycling and Waste** *(in Thousands of Tons)*




**SOURCE**: Container Recycling Institute.

Advanced Research Center found that "large petrochemical flares lead to very rapid ozone formation that, if properly detected, would make attainment of the current federal ozone standard very difficult in Houston."[26] The study also noted that petrochemical flaring could expose nearby communities to high levels of formaldehyde, a carcinogenic air pollutant and ozone precursor.[27]

Prolonged contact with ground-level ozone is linked to asthma and chronic obstructive pulmonary disease. When mixed with particulate matter, which has been linked to various cancers, smog can form.[28] In addition to asthma, long-term exposure to smog has been connected to premature deaths in adults and to low birthweight in babies.[29] Further, chronic exposure to air pollution can cause various illnesses, including cognitive deficits.[30] Several studies have demonstrated that people's exposure to petrochemical facility pollutants is associated with heightened cancer risks, acute irritative symptoms (such as nausea and eye and throat irritation) and respiratory-related illnesses, especially for children.[31]

The Houston Ship Channel produces about a quarter of U.S. petrochemicals.[32] In 1999, when Houston's ozone levels were the highest in the nation, the state of Texas conducted several studies that found large industrial leaks. The worst originated from cracker plants producing ethylene and propylene. "The plants were having 1,000-pound releases, 5,000-pound releases, 20,000-pound releases, in one case 200,000-pound releases," explained a now-retired University of North Carolina chemist responsible for studying Houston's air pollution problem.[33]

These studies led regulators to specifically target the petrochemical industry, and, despite some temporary progress, Houston continued through 2015 to fail to meet federal ozone standards.[34] Millions of pounds of pollution are still emitted from these facilities each year. An analysis of data from the U.S. Environmental Protection Agency's (EPA) Toxic Release Inventory found that in Texas in 2014 and 2015, 28 facilities with the primary function of petrochemical manufacturing released 14 million pounds of on-site pollution each year into the air and waterways and on land. For those two years in the neighboring state of Louisiana, 13 facilities emitted more than 4 million pounds anually (see Appendix on page 5).[35]

## Ethane Crackers and New Infrastructure Coming to Appalachian States

In 2016 all but three ethane crackers in the United States were located in Texas and Louisiana. A 2014 inventory taken by the *Oil & Gas Journal* listed 38 crackers, but, as an EPA employee explains, some plants have multiple crackers and the total number of facilities comes out to 29. The EPA observed that 3 of the facilities are "not major sources" or are shut down, so only 26 plants were subject to the EPA's federal air regulations.[36]

More than 20 new crackers and ethylene production expansion projects have been proposed in the United States because of the natural gas boom.[37] Most have been proposed for the Gulf region, one is slated for North Dakota, and five more have been proposed in states with large Marcellus and Utica shale plays: West Virginia, Ohio and Pennsylvania (see Table 1).[38]

As the oil and gas and petrochemical industries expand their infrastructure projects (NGL pipelines, storage facilities and crackers) in the Appalachian basin, the industry expects that this development will transform the region into a global hub.[39] The industry and its supporters are seemingly wanting to make western Pennsylvania the next Houston.

Already natural gas proponents are pushing a $10 million natural gas storage complex, and an associated network of gas pipelines, in the Appalachian region to "take full advantage of chemical and plastic raw materials" found in shale gas and to service the pending regional ethane crackers.[40] The storage complex, which is currently in the conceptual stage, allegedly has bipartisan support from West Virginia lawmakers. It is being endorsed by a non-profit, market-driven research organization that focuses on advancing the petrochemical industry: Mid-Atlantic Technology, Research and Innovation Center (MATRIC).[41] More gas hubs and more plastics factories means building even more pipeline infrastructure to transport NGLs to petrochemical facilities.[42]

Shell is building one of the nation's largest ethane crackers in western Pennsylvania. It is the first new facility of its type to be constructed outside of the Gulf Coast in two decades.[43]

**Table 1: Ethane Crackers Proposed for the Marcellus and Utica Shale Regions**[45]

| Project | Location | Ethane Capacity (barrels per day) | Status and Estimated Start Date |
|---|---|---|---|
| Aither Chemicals | Charleston, WV | 16,000 | Off Track, 2017+ |
| Appalachian Resins (AR) | Monroe County, OH | 13,000 – 15,000 | On Hold, 2019 |
| Appalachian Shale Cracker Enterprise (Ascent) | Parkersburg, WV | 57,000 | Delayed |
| PTTGC America & Marubeni | Belmont County, OH | 57,000 | On Track, 2020+ |
| Shell Appalachia Ethane Cracker | Monaca, PA | 78,000 – 100,000 | On Track, 2019 |

**SOURCE**: Platts 2016; NaturalGasIntel 2016; Petrochemical Update 2016; OneOK Partners 2016.

The location was meticulously chosen to thrive off of Marcellus and Utica shale gas production from the Pennsylvania, Ohio and West Virginia tri-state area.[44] This ethane cracker would reinforce the northeastern plastics market, generating not only industry profits but also more regional pollution.

## The Human Costs: Shell's Western Pennsylvania Cracker Plant

Pennsylvanians do not deserve another risky natural gas facility. Fracking causes many public health and environmental problems.[46] The last thing that Pennsylvanians need is another way for the oil and gas industry to capitalize on shale at the expense of their health and well-being.

Fracking has expanded rapidly in areas across the United States, especially in Pennsylvania, which has been at the epicenter of the nation's fracking boom, with almost 10,000 shale wells drilled between 2005 and October 2016.[47] Beaver County, where Shell's cracker will be located, is currently home to 69 active unconventional wells.[48]

Once a well is fracked, during oil or gas production, escaping methane from leaks can mix with nitrogen oxide emissions from diesel-fueled vehicles and drilling equipment to form ground-level ozone.[49] When combined with particulate matter of a certain size (less than 2.5 micrometers), ozone can form smog. Chronic exposure can lead to asthmatic conditions and chronic pulmonary disease.[50] These emissions contribute to climate change, and the region's air quality could conceivably worsen once the cracker plant is completed.

Although the cracker plant will bring pollution to the region, the industry, its supporters and Pennsylvania Governor Tom Wolf all tout that it will bring jobs.[51] What they fail to mention is that these jobs are potentially dangerous and hazardous to health.

Some studies have found that certain petrochemical workers and research employees that handle or are exposed to toxins (such as organic solvents, plastic monomers, metals, ionized radiation and aromatic hydrocarbons) are inclined to have a relatively higher risk for brain cancer compared to people employed in other professions.[52] Petrochemical workers also can experience hearing loss and develop liver disease, and are regularly exposed to volatile organic compounds like benzene, toluene and xylene.[53]

Many of the chemicals that petrochemical workers are exposed to can have negative impacts over the long term. Benzene, toluene and xylene are neurotoxic, carcinogenic and classified as "priority pollutants" by the EPA.[54] It is believed that long-term exposure to certain amounts of benzene, a known carcinogen and mutagen, can increase the risk of leukemia.[55] In addition, petrochemical facilities produce and emit dozens of chemicals, including but not limited to: polycyclic aromatic hydrocarbons, nickel, lead, mercury, methanol and naphthalene.[56]

Acute and chronic exposures to these chemicals can have significant health effects. Long-term exposure to methanol, a colorless, flammable liquid, can cause dizziness, insomnia, gastric issues, headaches, nausea, blurred vision and blindness.[57] Exposure to naphthalene, a possible human carcinogen, has been linked to anemia, liver and neurological damage, retinal impairment and the development of cataracts.[58] Lead, nickel, mercury and polycyclic aromatic hydrocarbons are all believed to be endocrine disruptors, which are chemicals that can alter hormone functions and negatively impact the metabolism and the neurological, immune and reproductive systems.[59] Some polycyclic aromatic hydrocarbons are also "reasonably anticipated to be human carcinogens."[60]

In addition to the long-term health impacts of these releases, many of the vapors produced at petrochemical work sites are highly flammable.[61] When petrochemical plant accidents do occur they are frequently large and not only can injure the workers but also can impact nearby communities.[62] For example, in June 2013 an explosion at a petrochemical plant in Louisiana killed 2 workers and injured 167. The fire blazed for three and a half hours, releasing more than 30,000 pounds of combustable hydrocarbons into the air. The damage was so great that the plant had to close down for a year and a half.[63]

## Conclusion

The expansion of drilling and fracking is associated with significant quality-of-life and public health problems and endangers society by exacerbating climate instability. Instead of creating a "bridge" to renewables, shale gas has only substituted one dirty fuel (coal) for another (fracked gas), making climate change even more costly and destructive in the coming decades.

This cheap and dirty fossil fuel is also proliferating its toxic legacy by facilitating the expansion of petrochemical plants, which are polluting and unsustainably producing materials that often end up in landfills. Rather than continually investing in fossil fuels and chemical industries, we must invest in clean, renewable energy.

Our country's leadership needs to enact serious changes, from terminating public funding of the oil and gas industry to enacting aggressive conservation policies to reduce energy demand, including substantial investments in public transportation, community planning and the deployment of energy efficiency solutions.

Consumers also can play a role in securing a sustainable future by making conscientious shopping decisions. People should limit their purchases of non-biodegradable, plastic products, an activity that effectively supports and finances the oil and gas industry.

# APPENDIX

| TABLE 2: Petrochemical Plants in Texas and Louisiana and Their On-site Pollution Releases, 2014 and 2015 | | | | |
|---|---|---|---|---|
| **Plant Name** | **County** | **Plant's Other Uses** | **Pounds of On-site Pollution Released, 2014** | **Pounds of On-site Pollution Released, 2015** |
| TEXAS | | | | |
| Arkema Inc Clear Lake | Harris | | 19,388 | 62,284 |
| BASF Corp Pasadena Plant | Harris | | 3,430 | 2,706 |
| BASF Total Petrochemicals LLC | Jefferson | | 426,381 | 375,693 |
| BP Amoco Chemical Co. | Galveston | | 131,311 | 97,110 |
| Chevron Phillips Chemical Co LP | Harris | Plastics Material and Resin Manufacturing | 424,145 | 384,672 |
| Chevron Phillips Chemical Co LP Sweeny Complex | Brazoria | | 403,434 | 492,756 |
| DuPont Sabine River Works | Orange | Plastics Material and Resin Manufacturing, Hazardous Waste Treatment and Disposal | 2,114,947 | 1,525,505 |
| Equistar Chemicals LP | Nueces | | 114,567 | 255,507 |
| ExxonMobil Oil Corp Beaumont Chemical Plant | Jefferson | | 477,068 | 498,089 |
| ExxonMobil Chemical Co Baytown Chemical Plant | Harris | Industrial Gas Manufacturing, Plastics Material and Resin Manufacturing, Synthetic Rubber Manufacturing | 857,274 | 861,425 |
| ExxonMobil Chemical Co Baytown Olefins Plant | Harris | | 394,733 | 498,089 |
| Flint Hills Resources Houston Chemical LLC | Harris | | 486,612 | 255,507 |
| Flint Hills Resources Port Arthur LLC | Jefferson | | 283,646 | 305,610 |
| Huntsman International | Harris | | 2,200 | 2,074 |
| JX Nippon Chemical Texas Inc | Harris | | 9,089 | 7,938 |
| Lyondell Chemical Co | Harris | All Other Basic Organic Chemical Manufacturing | 5,366,159 | 4,875,988 |
| Lyondell Chemical Co Bayport Facility | Harris | | 280,653 | 308,716 |
| Nalco Co | Bowie | | 1 | 10 |
| Nalco Co Odessa Plant | Ector | | 8,306 | 7,291 |
| Rohm & Haas Texas Inc | Harris | | 363,741 | 434,756 |
| Sasol Chemicals (USA) LLC | Jefferson | | 1,196 | 1,262 |
| Sasol Chemicals (USA) LLC (2) | Harris | | 1,476,627 | 1,553,425 |
| Shell Chemical LP | Harris | | 505,332 | 812,664 |
| South Hampton Resources Inc | Hardin | | 3,900 | 8,136 |
| Styrolution America LLC | Galveston | | 48,025 | 53,287 |

| **TABLE 2: Petrochemical Plants in Texas and Louisiana and Their On-site Pollution Releases, 2014 and 2015** *(continued)* | | | | |
|---|---|---|---|---|
| **Plant Name** | **County** | **Plant's Other Uses** | **Pounds of On-site Pollution Released, 2014** | **Pounds of On-site Pollution Released, 2015** |
| Styrolution America LLC (2) | Harris | | 44,917 | 30,036 |
| TPC Group Baytown Plant | Harris | | 5,230 | 4,290 |
| Union Carbide Corp Texas City Plant | Galveston | | 143,522 | 100,040 |
| **TEXAS TOTAL POUNDS OF ON-SITE POLLUTION:** | | | **14,395,834** | **13,814,866** |
| LOUISIANA | | | | |
| Americas Styrenics LLC | St. James | | 118,623 | 122,175 |
| Cos-Mar Co | Iberville | | 157,566 | 184,954 |
| DuPont Pontchartrain Works | St. John the Baptist | Synthetic Rubber Manufacturing, Other Basic Inorganic Chemical Manufacturing, All Other Basic Organic Chemical Manufacturing, Artificial and Synthetic Fibers and Filaments Manufacturing | 1,200,801 | 1,138,135 |
| Enterprise Products Operating LLC | West Baton Rouge | Natural Gas Liquid Extraction | 32,129 | 31,587 |
| ExxonMobil Chemical Co Baton Rouge Chemical Plant | East Baton Rouge | Synthetic Rubber Manufacturing | 1,644,949 | 1,812,327 |
| Georgia Gulf Lake Charles LLC | Calcasieu | | 15,711 | 18,390 |
| Nalco Co-St. John the Baptist | St. John the Baptist | | 42,431 | 5,234 |
| Nalco Co West Baton Rouge | West Baton Rouge | | 0 | 0 |
| Shell Chemical LP | Ascension | | 302,443 | 312,764 |
| Shell Norco Chemical Plant East Side | St. Charles | | 746,982 | 492,169 |
| Shell Norco Chemical Plant West Site | St. Charles | | 82,855 | 81,477 |
| Westlake Petrochemicals Ethylene* | Calcasieu | Plastics Material and Resin Manufacturing (Primary) | 265,343 | 152,742 |
| Williams Olefins LLC Geismar Ethylene Plant | Ascension | | 33,254 | 556,545 |
| **LOUISIANA TOTAL POUNDS OF ON-SITE POLLUTION:** | | | **4,643,087** | **4,908,499** |

*This facility lists Plastics Material and Resin Manufacturing as a primary use as well.

**SOURCE**: Analysis of all chemical facilities (NAICS Code 325) that list petrochemical manufacturing (NAICS 32511) as their primary function. Data from U.S. Environmental Protection Agency (EPA). Toxics Release Inventory (TRI). TRI On-site and Off-site Reported Disposed of or Otherwise Released (in pounds), all facilities (of 412) for facilities in NAICS 325 - Chemicals, for All chemicals, Texas, 2014. Available at https://iaspub.epa.gov/triexplorer/tri_release.chemical. Accessed August 23, 2016; U.S. EPA. TRI. TRI On-site and Off-site Reported Disposed of or Otherwise Released (in pounds), all facilities (of 129) for facilities in NAICS 325 Chemicals, for All chemicals, Louisiana, 2014. Available at https://iaspub.epa.gov/triexplorer/tri_release.chemical. Accessed August 22, 2016; U.S. EPA. TRI. TRI On-site and Off-site Reported Disposed of or Otherwise Released (in pounds), all facilities (of 412) for facilities in NAICS 325 - Chemicals, for All chemicals, Texas, 2015. Available at https://iaspub.epa.gov/triexplorer/tri_release.chemical. Accessed November 15, 2016; U.S. EPA. TRI. TRI On-site and Off-site Reported Disposed of or Otherwise Released (in pounds), all facilities (of 128) for facilities in NAICS 325 Chemicals, for All chemicals, Louisiana, 2015. Available at https://iaspub.epa.gov/triexplorer/tri_release.chemical. Accessed November 15, 2016.

# Endnotes


1 U.S. Energy Information Administration (EIA). "Ethane production expected to increase as petrochemical consumption and exports expand." April 1, 2016; "Energy upside: the surge of ethane." *Oil & Gas 360*. April 1, 2016; Ghanta, Madhav et al. "Environmental impacts of ethylene production from diverse feedstocks and energy sources." *Applied Petrochemical Researc*h. Vol. 4, Iss. 2. 2014 at 167; American Chemistry Council, Economics & Statistics Department. "Plastic Resins in the United States." July 2013 at 14 and 15.

2 American Petroleum Institute. "Freeing Up Energy. Hydraulic Fracturing: Unlocking America's Natural Gas Resources." July 19, 2010 at 1, 2 and 4; U.S. House of Representatives. Committee on Energy and Commerce. [Minority staff report]. "Chemicals Used in Hydraulic Fracturing." April 2011 at 2 and 8 to 9; U.S. Geological Survey. "Hydraulic Fracturing ('Fracking') FAQs. How much water does the typical hydraulically fractured well require?" Available at https://www2.usgs.gov/faq/categories/10132/3824. Accessed December 1, 2016.

3 U.S. EIA. April 1, 2016; "Energy upside: the surge of ethane." 2016; Ghanta et al. 2014 at 167; American Chemistry Council, Economics & Statistics Department. 2013 at 14 and 15.

4 U.S. EIA. April 1, 2016; U.S. EIA. "Growing U.S. HGL production spurs petrochemical industry investment." January 29, 2015.

5 American Chemistry Council, Economics & Statistics Department 2013 at 14 and 15; Lyle, Sarah K. Magruder. American Fuel & Petrochemical Manufacturers. National Conference of State Legislatures, Capitol Forum, Energy Supply Task Force. [PowerPoint.] "The Shale Revolution: Realizing America's Manufacturing Renaissance." December 8, 2015 at Slides 5 to 7.

6 Food & Water Watch calculation based on data from American Chemistry Council, Economics & Statistics Department. 2013 at 15; U.S. EIA. Monthly Energy Review. Table A2. Approximate Heat Content of Petroleum Production, Imports, and Exports. May 2016; U.S. EIA. U.S. Heat Content of Natural Gas Consumed. BTU per Cubic Foot. May 31, 2016; U.S. EIA. "Performance Profiles of Major Energy Producers 2009. Oil and Natural Gas Production." 2009 at 15; Society of Petroleum Engineers. "Unit Conversion Factors." Available at http://www.spe.org/industry/unit-conversion-factors.php. Accessed June 15, 2016.

7 Pickett, Al. "Marcellus, Utica shales make northeast focal point of growing U.S. production." *American Oil & Gas Reporter*. November 2013 at 3 and 5; Brackett, Will. *Powell Shale Digest*. Penn State Extension Webinar. [PowerPoint.] "How Marcellus & Utica Compare to Other Shale Basins." August 27, 2015 at Slides 7 and 8; Energy Ventures Analysis, Inc. "Outlook for Natural Gas Supply and Demand for 2015-2016 Winter." 2015 at 23 and 25.

8 U.S. EIA. "Glossary: natural gas." Available at https://www.eia.gov/tools/glossary/?id=natural%20gas. Accessed August 15, 2016; Soylu, Seref. Iowa State University. "Autoignition of modeling of natural gas for engine modeling programs- an experimental and modeling study." Retrospective Theses and Dissertations. 2001 at 1; Troner, Al. James A. Baker III Institute for Public Policy, Rice University. "Natural Gas Liquids in the Shale Revolution." April 29, 2013 at 4.

9 U.S. EIA. "What are natural gas liquids and how are they used?" April 20, 2012; von Oettingen, Wolfgang Felix. "The toxicity and potential dangers of aliphatic and aromatic hydrocarbons." *Yale Journal of Biology and Medicine*. Vol. 15, Iss. 2. December 1942 at 167.

10 PennState Extension. "Fractionator? Cracker? What Are They?" April 15, 2012; Emerson Process Management. "Chapter 1. Ethylene Production." 2010 at 1 to 2; Ghanta et al. 2014 at 168 and 169.

11 PricewaterhouseCoopers. "Shale Gas. Reshaping the U.S. Chemicals Industry." October 2012 at 6; Lyle. December 8, 2015 at Slide 7; Lippe, Dan. "Pipelines expand to meet NGL growth." *Oil & Gas Journal*. November 3, 2014.

12 U.S. Department of Energy. Energy Efficiency and Renewable Energy. "Formosa Plastics Corporation: Plant-Wide Assessment of Texas Plant Identifies Opportunities for Improving Process Efficiency and Reducing Energy Costs." January 2005 at 1; Siemens. "Process Analytics in Polyethylene (PE) Plants." December 2007 at 2.

13 Eisenberg, Barry. "Plastics in today's re-emerging U.S. economy." *SPI Magazine*. Fall 2013 at 8.

14 Callari, James. [Editorial.] "The shale gas game changer." *Plastics Technology*. January 2014; Callari, James. [Editorial.] "Mark your calendar for first-ever Global Plastics Summit." *Plastics Technology*. October 2013.

15 American Chemistry Council. [Fact Sheet.] "U.S. Chemical Investment Linked to Shale Gas: $164 Billion and Counting." April 2016.

16 *Ibid.*

17 American Chemistry Council. [Press Release.] "U.S. Chemical Investment Linked to Shale Gas Reaches $100 Billion." February 20, 2014.

18 Jambeck, Jenna R. et al. "Plastic waste inputs from land into the ocean." *Science Magazine*. Vol. 347, Iss. 6223. February 13, 2015 at 768.

19 Grady, Caitlin and Tamim Younos. "Bottled water technology and its global ramifications: An overview." *International Water Technology Journal*. Vol. 2, No. 2. June 2012 at 187; Sax, Leonard. "Polyethylene terephthalate may yield endocrine disruptors." *Environmental Health Perspectives*. Vol. 118, Iss. 4. April 2010 at 445.

20 Beverage Marketing Corporation. [Press Release.] "Bottled Water's Impact on U.S. Caloric Intake 2000-2015." June 6, 2016.

21 Container Recycling Institute. "Bottled Up: Beverage Container Recycling Stagnates (2000-2010), U.S. Container Recycling Rates & Trends, 2013." October 2013 at 18, 20 and 26; Container Recycling Institute. Plastic Data. "PET Bottle Sales and Wasting in the U.S." Available at http://www.container-recycling.org/index.php/pet-bottle-sales-and-wasting-in-the-us. Accessed August 29, 2016.

22 National Association for PET Container Resources and The Association of Postconsumer Plastic Recyclers. "Postconsumer PET Container Recycling Activity in 2014." October 13, 2015 at 4 and 5.

23 Jambeck et al. 2015 at 768, 769 and 770.

24 National Oceanic and Atmospheric Administration (NOAA.) Office of Response and Restoration. "How Big is the "Great Pacific Garbage Patch"? Science vs. Myth." February 7, 2013; Harse, Grant A. "Plastic, the Great Pacific Garbage Patch, and international misfires at a cure." *UCLA Journal of Environmental Law and Policy*. Vol. 29, Iss. 2. 2011 at 332 to 334 and 344; Grant, Richard. "Drowning in plastic: the Great Pacific Garbage Patch is twice the size of France." *The Telegraph*. April 2009.

25 Benchaita, Tayeb. Inter-American Development Bank, Environmental Safeguards Unit. "Greenhouse Gas Emissions from New Petrochemical Plants. Background Information Paper for the Elaboration of Technical Notes and Guidelines for IDB Projects." July 2013 at 3 to 5, 10 and 15; Frazier, Reid R. "'Cracker' plant will bring jobs, but what about the air?" *The Allegheny Front*. March 24, 2012; Chen, Mei-Hsia. "A feasible approach to quantify fugitive VOCs from petrochemical processes by integrating open-path fourier transform infrared spectrometry measurements and industrial source complex (ISC) dispersion model." *Aerosol and Air Quality Research*. 2015 at 1110; Rivas-Arancibia, Selva et al. "Oxidative stress caused by ozone exposure induces loss of brain repair in the hippocampus of adult rats." *Toxicological Sciences*. Vol. 113, No. 1. 2010 at 187.

26 Olaguer, Eduardo P. "Near-source air quality impacts of large olefin flares." *Journal of the Air & Waste Management Association*. Vol. 62, Iss. 8. 2012 at 986.

27 *Ibid.* at 978 and 986.

28 Colborn, Theo et al. "Natural gas operations from a public health perspective." *International Journal of Human and Ecological Risk Assessment*. September 2011 at 1042; Wong, Chit Ming et al. "Cancer mortality risks from long-term exposure to ambient fine particle." *Cancer Epidemiology, Biomarkers & Prevention*. May 2016 at 839.

29 Salam, Muhammad T. et al. "Birth outcomes and prenatal exposure to ozone, carbon monoxide, and particulate matter: Results from the Children's Health Study." *Environmental Health Perspectives*. Vol. 113, No. 11. November 2005 at 1638 and 1643; Bravender, Robin. "Study links smog exposure to premature death." *New York Times*. March 12, 2009.

30 Calderón-Garcidueñas, Lilian et al. "Exposure to severe urban air pollution influences cognitive outcomes, brain volume and systemic inflammation in clinically healthy children." *Brain and Cognition*. Vol. 77, Iss. 3. 2011 at 345 and 353; Mokoena, Mmalebuso Lynnette et al. "Ozone inhalation induces central oxidative stress, cognitive deficits, depressogenic-and anxiogenic-

like behavior in stress sensitive rats." *FASEB Journal*. Vol. 27, No. 1. April 2013 at Abstract; Rivas-Arancibia et al. 2010 at 187, 195 and 196; Wong et al. 2016 at 839.

31 Yang, Chun-Yuh et al. "Respiratory and irritant health effects of population living in a petrochemical-polluted area in Taiwan." *Environmental Research.* Vol. 74, No. ER973762. 1997 at 145, 147 and 148; Belli, S. et al. "Case-control study on cancer risk associated to residence in the neighborhood of a petrochemical plant." *European Journal of Epidemiology*. Vol. 19. 2004 at 49, 50 and 53; Wichmann, Fernando A. et al. "Increased asthma and respiratory symptoms in children exposed to petrochemical pollution." *Journal of Allergy and Clinical Immunology*. Vol. 123, No. 3. 2009 at 632; White, Neil et al. "Meteorologically estimated exposure but not distance predicts asthma symptoms in schoolchildren in the environs of a petrochemical refinery: a cross-sectional study." *Environmental Health*. Vol. 8, No. 45. September 25, 2009 at 1; Sopian, Nor Ashikin. "Risk of respiratory health impairment among susceptible population living near petrochemical industry - a review article." *Iranian Journal of Public Health*. Vol. 45, No. 1. February 2016 at 9, 10, 11 and 15; Kongtip, Pornpimol et al. "Health effects of people living close to a petrochemical industrial estate in Thailand." *Journal of the Medical Association of Thailand*. Vol. 96, No. 5. 2013 at S67 and S70.

32 Fraizer, Reid R. "Houston cleaning up pollution by going after ethane cracker emissions." *The Allegheny Front.* October 27, 2013.

33 *Ibid.*

34 Carroll, Susan. "Houston saw smoggier skies in 2015, analysis shows." *Houston Chronicle.* December 20, 2015; Fraizer, 2013; Carroll, Susan. "Obama administration issues rules to curb ozone." *Houston Chronicle.* October 1, 2015; See Couzo, Evan et al. "Houston's rapid ozone increases: preconditions and geographic origins." *Environmental Chemistry.* Vol. 10, Iss. 3. June 2013.

35 Analysis of all chemical facilities (NAICS Code 325) that list petrochemical manufacturing (NAICS 32511) as its primary function. Data from U.S. Environmental Protection Agency (EPA). Toxics Release Inventory (TRI). TRI On-site and Off-site Reported Disposed of or Otherwise Released (in pounds), all facilities (of 412) for facilities in NAICS 325 - Chemicals, for All chemicals, Texas, 2014. Available at https://iaspub.epa.gov/triexplorer/tri_release.chemical. Accessed August 23, 2016; U.S. EPA. TRI. TRI On-site and Off-site Reported Disposed of or Otherwise Released (in pounds), all facilities (of 129) for facilities in NAICS 325 Chemicals, for All chemicals, Louisiana, 2014. Available at https://iaspub.epa.gov/triexplorer/tri_release.chemical. Accessed August 22, 2016; U.S. EPA. TRI. TRI On-site and Off-site Reported Disposed of or Otherwise Released (in pounds), all facilities (of 412) for facilities in NAICS 325 - Chemicals, for All chemicals, Texas, 2015. Available at https://iaspub.epa.gov/triexplorer/tri_release.chemical. Accessed November 15, 2016; U.S. EPA. TRI. TRI On-site and Off-site Reported Disposed of or Otherwise Released (in pounds), all facilities (of 128) for facilities in NAICS 325 Chemicals, for All chemicals, Louisiana, 2015. Available at https://iaspub.epa.gov/triexplorer/tri_release.chemical. Accessed November 15, 2016.

36 Koottungal, Leena. "International survey of ethylene from steam crackers – 2014." *Oil & Gas Journal*. January 1, 2014; Food & Water Watch staff correspondence with a representative of the U.S. EPA. August 25, 2016 to October 6, 2016. Summary on file with Food & Water Watch.

37 Frazier, Reid R. "'Cracker' plant will bring jobs, but what about the air?" *The Allegheny Front.* March 24, 2012; Fallas, Benardo and Pavel Paclov. "Special report - petrochemicals. Time to get cracking." *Platts.* January 2013 at 2; OneOk Partners. [PowerPoint.] "Investor Update." March 1-2, 2016 at Slides 40 and 41; "Ethylene projects in the ethane-heavy northeast US." *Platts.* March 1, 2016.

38 OneOk Partners. 2016 at Slides 40 and 41; Fallas and Paclov. 2013 at 2, 4 and 5; "Ethylene projects in the ethane-heavy Northeast US." 2016; Cocklin, Jamison. "Ohio ethane cracker site being cleared; investment decision still to come." *NaturalGasIntel.* January 8, 2016; "Location and tax breaks key to Shell's Pennsylvania cracker plant approval." *Petrochemical Update.* July 8, 2016.

39 Stephen, Dominik. "10 billion dollar gas storage hub shall make Appalachia the new shale-hotspot in the US." *Process Worldwide.* September 9, 2016; Nelson, Gabriel. "Shale boom has Appalachia dreaming of industrial renaissance." *E&E News.* December 15, 2011; Council for Growth, Greater Philadelphia Chamber of Commerce, and Select Greater Philadelphia. "A Pipeline for Growth. Fueling Economic Revitalization With Marcellus and Utica Shale Gas." March 30, 2016 at 15 and 20.

40 Stephen, 2016; "The $10 billion petchem growth engine for Appalachia." *Rigzone.* September 6, 2016.

41 Henrick, Steve. [Editorial.] "Appalachian storage hub critical to realizing potential." *State Journal* (Charleston, WV). February 18, 2016; Mid-Atlantic Technology, Research & Innovation Center (MATRIC.) "Our Story." Available at http://www.matricinnovates.com/our-story/. Accessed October 26, 2016; Cart, Samantha. "Appalachian storage hub: realizing our potential." *West Virginia Executive.* June 2, 2016.

42 Morris, Gregory DL. "Shale gas, NGLs fuel large-scale petrochemical investments." *American Oil & Gas Reporter.* April 2012; Lippe, Dan. "Pipelines expand to meet NGL growth." *Oil & Gas Journal.* November 3, 2014; Council for Growth, Greater Philadelphia Chamber of Commerce, Select Greater Philadelphia. 2016 at 15 and 20.

43 Allegheny Conference on Community Development. [Press Release.] "Allegheny Conference: Shell Petrochemical Complex is "Once-in-a-Generation" Investment for Greater Pittsburgh Region." June 7, 2016.

44 Shell Global. "Our Growth Projects." Available at http://www.shell.com/business-customers/chemicals/about-shell-chemicals/our-growth-projects.html. Accessed September 27, 2016; Bradwell, Michael and Rick Shrum. "Business leaders see broad impact from Shell cracker decision." *Observer-Reporter* (Washington County, PA). June 7, 2016.

45 "Ethylene projects in the ethane-heavy northeast US." 2016; Cocklin, 2016; "Location and tax breaks key to Shell's Pennsylvania cracker plant approval." 2016; OneOk Partners. 2016 at Slide 41.

46 See McDermott-Levy, Ruth et al. "Fracking, the environment, and health." *American Journal of Nursing*. Vol. 113, No. 6. June 2013.

47 Pennsylvania Office of the Governor. 2010-11 Executive Budget Facts. "Booming Natural Gas Industry Should Pay Its Fair Share." February 2010; Pennsylvania Department of Environmental Protection. Oil and Gas Reports, SPUD Data Report Wells Drilled By County, Unconventional Only. 1/1/2005 to 10/14/2016. Available at http://www.depreportingservices.state.pa.us/ReportServer/Pages/ReportViewer.aspx?/Oil_Gas/Wells_Drilled_By_County. Accessed October 14, 2016.

48 Pennsylvania Department of Environmental Protection. Oil and Gas Reports, Oil and Gas Operator Well Inventory, Active Wells, Unconventional Only, Beaver County. Available at http://www.depreportingservices.state.pa.us/ReportServer/Pages/ReportViewer.aspx?/Oil_Gas/OG_Well_Inventory. Accessed November 16, 2016.

49 Colborn et al. 2011 at 1042.

50 *Ibid.* at 1042.

51 Frazier, Reid. "New chemical plant promises jobs, but could turn back the clock on air pollution." *The Allegheny Front.* June 23, 2016; Frazier, Reid. "Wolf: Ethane cracker will bring jobs for years." *The Allegheny Front.* July 22, 2016; Litvak, Anya. "Shell cracker plant in Beaver County to provide 600 jobs when it opens." *Pittsburgh Post-Gazette.* June 7, 2016.

52 Gomes, J. et al. "Occupational and environmental risk factors of adult primary brain cancers: a systemic review." *International Journal of Occupational and Environmental Medicine.* Vol. 2, No. 2. April 2011 at 85, 88 to 90, 99, 101 and 103; Sathiakumar, Nalini et al. "Cancer incidence among employees at a petrochemical research facility." *Journal of Occupational and Environmental Medicine.* February 2001. Vol. 43, Iss. 2 at Abstract.

53 De Barba, M. C. et al. "Audiometric findings in petrochemical workers exposed to noise and chemical agency." *Noise & Health.* Vol. 7, Iss. 29. 2005 at Abstract; Rahimpoor R. et al. "Biological monitoring of petrochemical industry workers exposed to benzene, toluene, xylenes, methyl ethyl ketone, and phenol in Southern Iran." *Journal of Occupational Health and Epidemiology.* Vol. 3, Iss. 2. Spring 2014 at 61 and 62; Cotrim, Helma P. et al. "Nonalcoholic steatohepatitis: a toxic liver disease in industrial workers." *Liver.* Vol. 19. 1999 at 299 to 303.

54 Lee, Eun Young et al. 2011 3rd International Conference on Chemical, Biological and Environmental Engineering. "Characterization biodegradation of benzene, toluene, ethylbenzene, and xylenes by the newly isolated bacterium *Pseudomonas putida* AY- 10 in rhizosphere of wastewater treatment reed." *IPCBEE*. Vol. 20. 2011 at 37.

55 International Agency for Research on Cancer. Chemical Agents and Related Occupations. Vol. 100 F, A Review of Human Carcinogens. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans: Benzene. 2012 at 257 to 262, 276 and 285.

56 U.S. EPA. TRI. Facility Profile Report. "Shell Norco Chemical Plant East Site." Available at https://iaspub.epa.gov/triexplorer/release_fac_profile?TRI=70079SHLLL1205R&TRILIB=TRIQ1&FLD=&FLD=RELLBY&FLD=TSFDSP&OFFDISPD=&OTHDISPD=&ONDISPD=&OTHOFFD=&YEAR=2014. Accessed October 26, 2016; U.S. EPA. TRI. Facility Profile Report. "Sasol Chemicals (USA) LLC." Available at https://iaspub.epa.gov/triexplorer/release_fac_profile?TRI=77015MRCHM1914H&TRILIB=TRIQ1&FLD=&FLD=RELLBY&FLD=TSFDSP&OFFDISPD=&OTHDISPD=&ONDISPD=&OTHOFFD=&YEAR=2014. Accessed October 26, 2016; U.S. EPA. TRI. Facility Profile Report. "BASF Total Petrochemicals LLC." Available at https://iaspub.epa.gov/triexplorer/release_fac_profile?TRI=77643BSFFNNEOFI&TRILIB=TRIQ1&FLD=&FLD=RELLBY&FLD=TSFDSP&OFFDISPD=&OTHDISPD=&ONDISPD=&OTHOFFD=&YEAR=2014. Accessed October 26, 2016.

57 U.S. EPA. [Fact Sheet.] "Methanol." January 2000.

58 U.S. EPA. [Fact Sheet.] "Naphthalene." January 2000.

59 Arcaro, Kathleen F. et al. "Antiestrogenicity of environmental polycyclic aromatic hydrocarbons in human breast cancer cells." *Toxicology*. Vol. 133. 1999 at 116; Schug, Thaddeus T. et al. "Elucidating the links between endocrine disruptors and neurodevelopment." *Endocrinology*. Vol. 156, No. 6. June 2015 at 1941 and 1946; Georgescu, Bogdan et al. "Heavy metals acting as endocrine disrupters." *Scientific Papers: Animal Science and Biotechnologies*. Vol. 44, Iss. 2. 2011 at 89; Schug, Thaddeus T. et al. "Endocrine disrupting chemicals and disease susceptibility." *Journal of Steroid Biochemistry and Molecular Biology*. Vol. 127, Iss. 3-5. November 2011 at 1, 11 and 28.

60 U.S. Department of Health and Human Services, National Toxicology Program. "Report on Carcinogens, Twelfth Edition." 2011 at 353 and 354; Agency for Toxic Substances and Disease Registry. "Polycyclic Aromatic Hydrocarbons (PAHs)."

61 Chung, Eun-Kyo et al. "Characteristics of occupational exposure to benzene during turnaround in the petrochemical industries." *Safety and Health at Work*. Vol. 1, No. 1. 2010 at 51.

62 "Chemical plants bring dangers and jobs for workers and community." *The Allegheny Front*. October 31, 2013.

63 U.S. Chemical Safety and Hazard Investigation Board. [Case Study.] "Williams Geismar Olefins Plant. Reboiler Rupture and Fire. Geismar, Louisiana." October 2016 at 11 and 12.

**Food & Water Watch** works to ensure the food, water and fish we consume is safe, accessible and sustainable. So we can all enjoy and trust in what we eat and drink, we help people take charge of where their food comes from, keep clean, affordable, public tap water flowing freely to our homes, protect the environmental quality of oceans, force government to do its job protecting citizens, and educate about the importance of keeping shared resources under public control.