Fossil Fumes

A public health analysis of toxic air pollution from the oil and gas industry

CLEAN AIR TASK FORCE

Alliance of Nurses for Healthy Environments

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Abbreviations

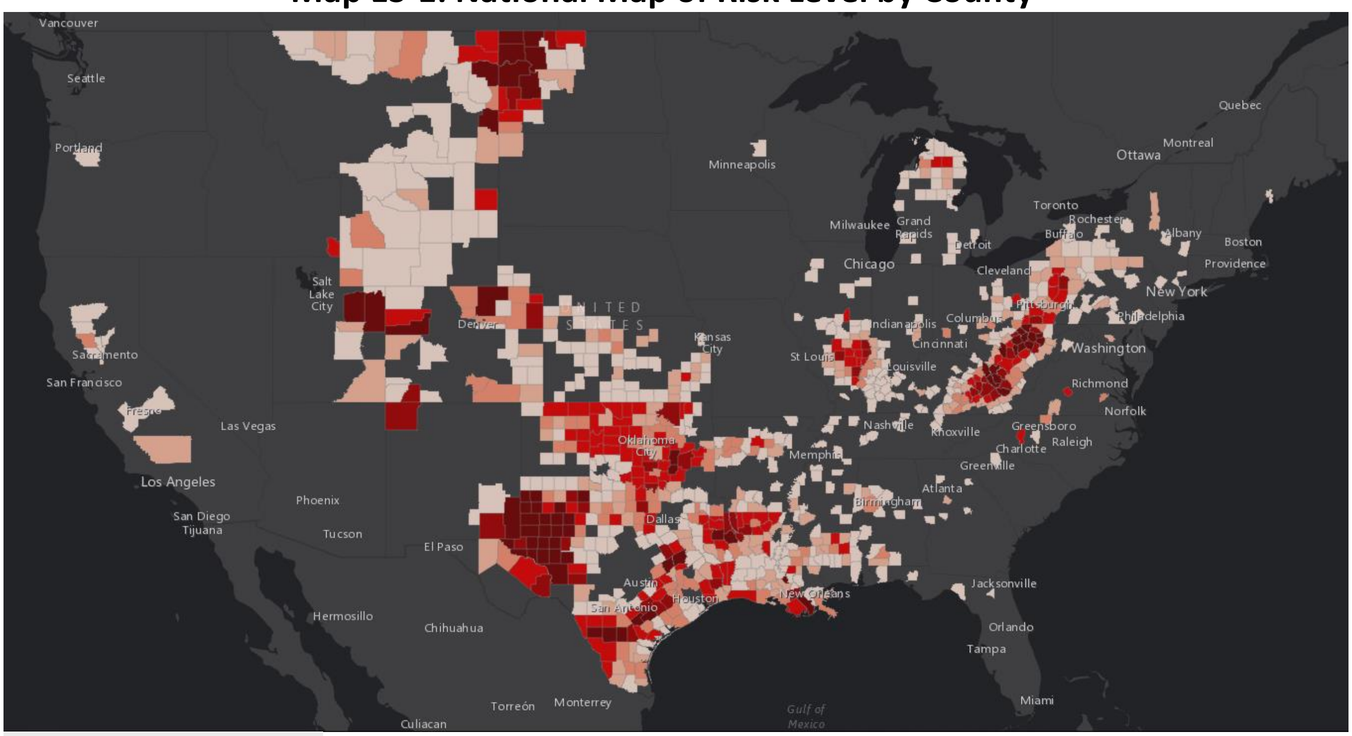
HAP	Hazardous Air Pollutant
LDAR	Leak Detection and Repair
NATA	National Air Toxics Assessment
NEI	National Emissions Inventory
PM	Particulate Matter
RfC	Reference Concentration
URE	Unit Risk Estimate
VOC	Volatile Organic Compound

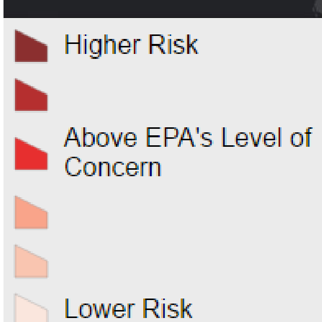
Executive Summary

As the United States works toward implementing ambitious climate goals, methane pollution from the oil and gas supply chain has received increased attention, and for good reason — methane is a greenhouse gas 87 times more potent than carbon dioxide in the near term, and the oil and gas industry is the largest U.S. source of methane pollution. But methane is just one harmful air pollutant from the oil and gas industry. This report sheds light on the health impacts of hazardous and toxic air pollutants that are often emitted from oil and gas sites alongside methane, including benzene, formaldehyde, and ethylbenzene. These hazardous toxic air pollutants harm the health of people living near oil and gas facilities such as oil and gas wells, compressor stations, and processing plants.

This report presents estimates, based on recent analysis carried out by EPA, of the cancer risk and respiratory health risk to residents of every county in the United States that can be traced back to air toxics from the oil and gas industry. Specifically, the analysis here is based on EPA's most recent National Air Toxics Assessment (NATA) analysis updated to reflect the latest emissions data from EPA's National Emissions Inventory (NEI).

Map ES-1: National Map of Risk Level by County





The 238 counties that face cancer risk above EPA's 1-in-a-million level of concern are red or dark red.

The analysis finds:

- 238 counties in 21 states face cancer risk that exceeds EPA's one-in-a-million threshold level of concern;
- These counties have a population of over 9 million people;
- 43 counties face a risk that exceeds one in 250,000 and 2 counties face a cancer risk that exceeds one in 100,000;
- 32 counties also face a respiratory health risk from toxic air emissions that exceeds EPA's level of concern (hazard index > 1); and
- The areas with the greatest health risk are generally located in states with the greatest amount of oil and gas infrastructure including Texas, Louisiana, Oklahoma, North Dakota, Pennsylvania, and Colorado.

The NATA assessment only takes into account the health impacts related to *toxic air* emissions from the oil and gas industry, i.e. it does not account for the health impacts from particulate matter and ozone-related air emissions, and it does not account for the health impacts of water contamination caused by oil and gas development. As such, NATA is an underestimate of the full health impact of oil and gas operations.

Table ES-1: List of Oil and Gas Hazardous Air Pollutants

Hazardous Air Pollutant	Tons Emitted Per Year from Oil and Gas Industry	Health Impacts
Formaldehyde	22,082	Cancer and respiratory symptoms
Benzene	20,221	Cancer, anemia, brain damage and birth defects, and respiratory tract irritation
Acetaldehyde	3,863	Cancer and respiratory irritant
Ethyl Benzene	2,235	Respiratory and eye irritation, and blood and neurological disorders

Hazardous air pollution is emitted from dozens of types of equipment and processes throughout the oil and gas sector, such as wells, completion operations, storage tanks, compressors, and valves. Many proven, low-cost technologies and practices are available to reduce these emissions, while also reducing emissions of methane, the main constituent of natural gas. Thus, policies that aim to reduce pollution from the oil and gas industry will help protect the health of local communities while addressing global climate change. In their *Waste Not* report, CATF, the Natural Resources Defense Council, and the Sierra Club called for EPA regulations to cut methane emissions from the oil and gas industry by 50 percent. These methane standards would also significantly cut toxic hazardous air pollution. In addition, stringent standards specifically for toxic pollutants emitted throughout the oil and gas supply chain are also needed to ensure compliance with the Clean Air Act and to protect public health.

Table ES-2: List of High Risk Counties

*: Also above EPA level of concern for Respiratory Hazard Risk (county-wide average respiratory hazard index is equal to or greater than 1).

Counties with Cancer Risk Above 1 in 100,000	
TX, Gaines*	TX, Yoakum*

Counties with Cancer Risk Above 1 in 250,000					
CO, Weld	ND, Mountrail	TX, Crane*	TX, La Salle	TX, Ward*	WV, Lewis*
LA, De Soto	ND, Williams	TX, Crockett*	TX, Martin*	UT, Duchesne*	WV, Lincoln
LA, Lafourche	NM, Lea	TX, Dawson*	TX, Midland*	UT, Uintah*	WV, Mingo*
LA, West Baton Rouge	OK, Coal*	TX, Ector*	TX, Mitchell	WV, Calhoun*	WV, Ritchie*
ND, Divide	TX, Andrews*	TX, Glasscock*	TX, Reagan*	WV, Doddridge*	WV, Tyler
ND, Dunn	TX, Borden*	TX, Hockley*	TX, Scurry	WV, Gilmer*	WV, Wetzel
ND, McKenzie	TX, Cochran*	TX, Karnes	TX, Upton*	WV, Harrison	

Counties above EPA Level of Concern for Cancer Risk (County-wide average cancer risk is equal to or greater than 1 in 1 million)					
AR, Van Buren	LA, Cameron	OK, Beaver	OK, Texas	TX, Johnson	TX, Upshur
CO, Garfield	LA, Claiborne	OK, Beckham	OK, Washington	TX, Kent	TX, Webb
CO, La Plata	LA, East Feliciana	OK, Blaine	OK, Washita	TX, King	TX, Wheeler
CO, Phillips	LA, Jackson	OK, Caddo	OK, Woods	TX, Lavaca	TX, Wilson
CO, Rio Blanco	LA, La Salle	OK, Carter	PA, Armstrong	TX, Lee	TX, Winkler*
CO, Yuma	LA, Morehouse	OK, Cotton	PA, Clarion	TX, Leon	TX, Wise*
ID, Bear Lake	LA, Ouachita	OK, Custer	PA, Fayette	TX, Liberty	TX, Zapata
IL, Clay	LA, Red River	OK, Dewey	PA, Forest	TX, Limestone	TX, Zavala
IL, Crawford	LA, St. James	OK, Ellis	PA, Greene	TX, Live Oak	VA, Appomattox
IL, Edwards	LA, Terrebonne	OK, Garvin	PA, Indiana	TX, Loving	VA, Buchanan
IL, Fayette	LA, Union	OK, Grady	PA, Jefferson	TX, Lynn	VA, Dickenson
IL, Gallatin	LA, Webster	OK, Grant	PA, Washington*	TX, Madison	WV, Barbour
IL, Jasper	MI, Montmorency	OK, Harper	TX, Bee	TX, Marion	WV, Boone
IL, Lawrence	MI, Otsego	OK, Haskell	TX, Burleson	TX, Maverick	WV, Braxton
IL, Marion	MS, Jasper	OK, Hughes*	TX, Caldwell	TX, McMullen	WV, Clay
IL, Piatt	MS, Wayne	OK, Jefferson	TX, Chambers	TX, Montague	WV, Jackson
IL, Richland	MT, Fallon	OK, Johnston	TX, Colorado	TX, Newton	WV, Kanawha
IL, Wabash	MT, Richland	OK, Kingfisher	TX, DeWitt	TX, Panola	WV, Logan
IL, Wayne	MT, Roosevelt	OK, Latimer	TX, Dickens	TX, Pecos	WV, Marion
IL, White	MT, Sheridan	OK, Lincoln	TX, Dimmit	TX, Refugio	WV, Marshall
KS, Woodson	NC, Iredell	OK, Love	TX, Fayette	TX, Roberts	WV, McDowell
KY, Floyd	ND, Billings	OK, Major	TX, Fisher	TX, Robertson	WV, Pleasants
KY, Johnson	ND, Bottineau	OK, Marshall	TX, Freestone	TX, Rusk	WV, Putnam
KY, Knott	ND, Burke	OK, McClain	TX, Frio	TX, Schleicher	WV, Roane
KY, Letcher	ND, Golden Valley	OK, McIntosh	TX, Garza	TX, Shelby	WV, Taylor
KY, Magoffin	ND, Renville	OK, Nowata	TX, Gonzales	TX, Stephens	WV, Upshur
KY, Martin	ND, Slope	OK, Okfuskee	TX, Gregg	TX, Sterling	WV, Wayne
KY, Perry	ND, Stark	OK, Osage	TX, Hardin	TX, Stonewall	WV, Wirt
KY, Pike	NM, Eddy	OK, Pittsburg*	TX, Harrison	TX, Sutton*	WV, Wyoming
LA, Assumption	NM, San Juan*	OK, Pontotoc	TX, Hemphill	TX, Tarrant	WY, Weston
LA, Bienville	OH, Carroll	OK, Roger Mills	TX, Howard	TX, Terrell	
LA, Bossier	OK, Alfalfa	OK, Seminole	TX, Irion	TX, Terry	
LA, Caddo	OK, Atoka	OK, Stephens	TX, Jasper	TX, Tyler	

Introduction

The National Air Toxics Assessment (NATA)

In December 2015, the U.S. Environmental Protection Agency (EPA) released the results of its National Air Toxics Assessment (NATA) for 2011, based on air pollution estimates collected through the National Emissions Inventory (NEI).[1] The purpose of NATA is to identify and prioritize air toxics, emission source types, and locations that are of greatest potential concern when looking at overall health risk in populations. NATA calculates risk estimates for two types of health impacts that can result from toxic air emissions: cancer risk and respiratory health risk. The metric for cancer risk is the number of cancer cases per million people exposed; areas with cancer risk above 1-in-a-million are considered to be above EPA's level of concern. For respiratory health risk, the metric is the hazard index; areas with a respiratory hazard index above 1 are above EPA's level of concern for potential harm to the respiratory system, including breathing problems, harm to the lungs, or other respiratory diseases.

Details of the National Air Toxics Assessment

The 2011 NATA represents the fifth installment of the national assessment, building on earlier years of 2005, 2002, 1999 and 1996. Each update included improved modeling protocols and expanded coverage of hazardous air pollutants (HAPs). The 2011 NATA modeled 180 air toxic compounds from dozens of separate emissions sources, including point sources (large, distinct facilities such as power plants), non-point (the large number of dispersed smaller facilities), various classes of vehicles, non-road mobile sources (such as construction equipment), fires, and biogenic sources, including species formed in the atmosphere and transported from distant emissions regions. These emission data were collected as part of the NEI. Then, NATA estimated both the cancer and non-cancer effects of 138 air toxics (for which health data based on chronic exposure exists).

The 2011 NATA relies on two air quality models, AMS/EPA Regulatory Model and Community Model for Air Quality, to determine the ambient distribution of air toxics. The models incorporate emissions information with meteorological data to determine the dispersion of pollution and chemical transformations that result in estimated annual concentrations at the census tract level across the United States. The modeled ambient concentrations are then used in an exposure model to estimate population exposure to the pollutants.

The EPA developed NATA to inform national and local data collection and policy efforts. However, the agency emphasizes that because of data quality issues and uncertainties in the model, the data should be used cautiously—it should be used to screen for geographic areas with high risk, not as a measure of actual risk in specific locations.[2] In addition, there are other limitations including incomplete assessment of emissions, limited ability to evaluate threats to vulnerable populations, and reliance on potentially outdated health thresholds.[3]

In this study, we focus on toxic air pollution sources in the oil and gas industry, and we explore the health impacts of these emissions in the latter sections of this report. This assessment characterizes potential public health risk due to inhalation of air toxics including both cancer risk and respiratory health risk. This report focuses on toxic air emissions from the oil and gas industry: oil and natural gas production and natural gas processing, transmission, and storage, including major sources like large compressor stations and gas processing plants, and dispersed sources like wells.[*] The results presented here are

[*] Throughout this report, we refer to 2 types of oil and gas sources: major sources and dispersed sources. Major sources are also known as "point" sources; these sources have the potential to emit 10 or more tons per year of one HAP or 25 or more

estimates for the health risk from oil and gas that communities will face in 2017, based on the NATA report for 2011 and EPA's predictions of the changes in the level of HAPs released by oil and gas sources between 2011 and 2017 (see Appendix for a discussion of our methodology).

Toxic Emissions Sources in the Oil and Gas Industry

Raw natural gas (i.e., gas as it is produced from underground formations, before significant processing is done) usually contains significant amounts of volatile organic compounds (VOCs) and toxic hazardous air pollutants (HAPs), though gas varies in composition from source to source.[4] The HAPs in raw gas include hexane, benzene, and other aromatic chemicals; poisonous gases like hydrogen sulfide can also be present.[†] These pollutants are also emitted from crude oil production operations. Recent work indicates that emissions from oil and gas operations are resulting in concentrations of toxic HAPs that could harm the health of people living and working in and near oil and gas production areas.[5]

While natural gas processing plants separate much of the toxic components from raw natural gas, some of those pollutants remain in the gas even after processing. As such, emissions from facilities further downstream in the natural gas supply chain, like transmission compressor stations and local distribution equipment, still include some toxic pollutants.

There are four segments of the oil and gas industry, and hazardous toxic air pollutants are emitted from each one, though in varying amounts:

Oil and Gas Production: The oil and gas production segment includes many diverse activities, such as production of hydrocarbons from underground geologic formations; separation of natural gas, oil, and, water; and collection of gas from multiple wells through natural gas gathering pipeline and compressor systems. These activities in turn involve processes such as well drilling, hydraulic fracturing or other well stimulation, and well workovers; and they require equipment such as tanks, piping, valves, meters, separators, dehydrators, pipelines, and gathering compressors.

Natural Gas Processing: Gas processing plants separate raw natural gas into natural gas liquids and processed natural gas that meets specifications for transport in high-pressure pipelines and consumption in furnaces and power plants. Natural gas liquids are hydrocarbons such as propane, butane, etc., which are valuable products of gas processing. The processing removes most of the toxic components from the gas, but some toxics still remain.

Transmission and Storage: Natural gas transmission pipelines carry gas from production regions to markets. This segment also includes facilities where gas is stored, either underground or in tanks. Compressor stations along pipelines maintain pressure and provide the energy to move the gas.

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tons per year of some combination of HAPs. Dispersed sources are also known as "non-point" sources; these sources are expected to emit less HAPs than sources emitting above these thresholds. See https://www3.epa.gov/region1/eco/airtox/glossary.html.

† Hydrogen sulfide is not included in EPA's list of Hazardous Air Pollutants due to a directive from Congress. See https://www3.epa.gov/airtoxics/pollutants/atwsmod.html. This does not reflect a determination that hydrogen sulfide does not have toxic properties.

Natural Gas Distribution: Finally, natural gas is delivered to customers (residential, commercial, and light industrial) via low-pressure underground distribution pipelines.

Pollutants

Natural gas development and transmission release a host of pollutants—toxics, smog forming pollutants, and greenhouse gases—that take a toll on our environment and our health. In this analysis, we focus specifically on toxic air pollutants, i.e. those pollutants that are known or probable carcinogens or that cause other serious health problems through either short-term or long-term exposure.[6] More specifically, we focus on the toxic air pollutants that are responsible for elevated cancer risk and increased respiratory hazard. The pollutants of greatest concern are benzene, ethylbenzene, and formaldehyde.

Benzene: Benzene has been linked to cancer, anemia, brain damage, and birth defects, and it is associated with respiratory tract irritation.[7] Over time, benzene exposure can also lead to reproductive, developmental, blood, and neurological disorders. A 2012 study estimated a 10 in a million cancer risk for residents near a well pad, attributable primarily to benzene.[8] According to the NEI, over 20,000 tons of benzene was emitted by oil and gas sources, accounting for 32 percent of the elevated cancer risk and 19 percent of the increased respiratory health risk from the oil and gas industry (see Appendix C). Benzene is a constituent of raw natural gas, so leaks and deliberate releases of gas (venting) are the primary source of benzene pollution from the oil and gas industry.

Ethylbenzene: Exposure to ethylbenzene has been associated with respiratory and eye irritation, as well as blood and neurological disorders.[9] Over 2,000 tons of ethylbenzene was emitted by oil and gas sources, accounting for 71 percent of the increased respiratory health risk from oil and gas. Like benzene, ethylbenzene is a constituent of raw natural gas and leaks and venting sources are the primary sources of ethylbenzene.

Formaldehyde: Formaldehyde has been linked to certain types of cancer, and chronic exposure to it is known to cause respiratory symptoms.[10] Nearly 22,000 tons of formaldehyde was emitted by oil and gas sources, accounting for 59 percent of the elevated cancer risk and 7 percent of the increased respiratory health risk from oil and gas. Formaldehyde is primarily emitted from combustion sources such as flares and compressor engines.[‡]

Other oil and gas industry toxic pollutants were also emitted in lower amounts, including acetaldehyde (a probable carcinogen and respiratory irritant[11]), 1,3-butadiene (increases risk of cancer and cardiovascular diseases[12]), and polycyclic organic matter (a carcinogen[13]).

‡ In addition to being directly emitted from oil and gas engines and flares, a much larger amount of formaldehyde is formed when other pollutants from oil and gas (VOCs) are broken down in the atmosphere. However, the NATA process does not attribute this second, larger quantity of formaldehyde to oil and gas. Therefore, NATA underestimates the impacts from oil and gas formaldehyde.

Some of this pollution is emitted from major facilities like gas processing plants and large compressor stations.[§] But the majority of this pollution comes from the large number of dispersed smaller facilities located, such as well sites, tank batteries, and small compressor stations, in communities throughout the country.

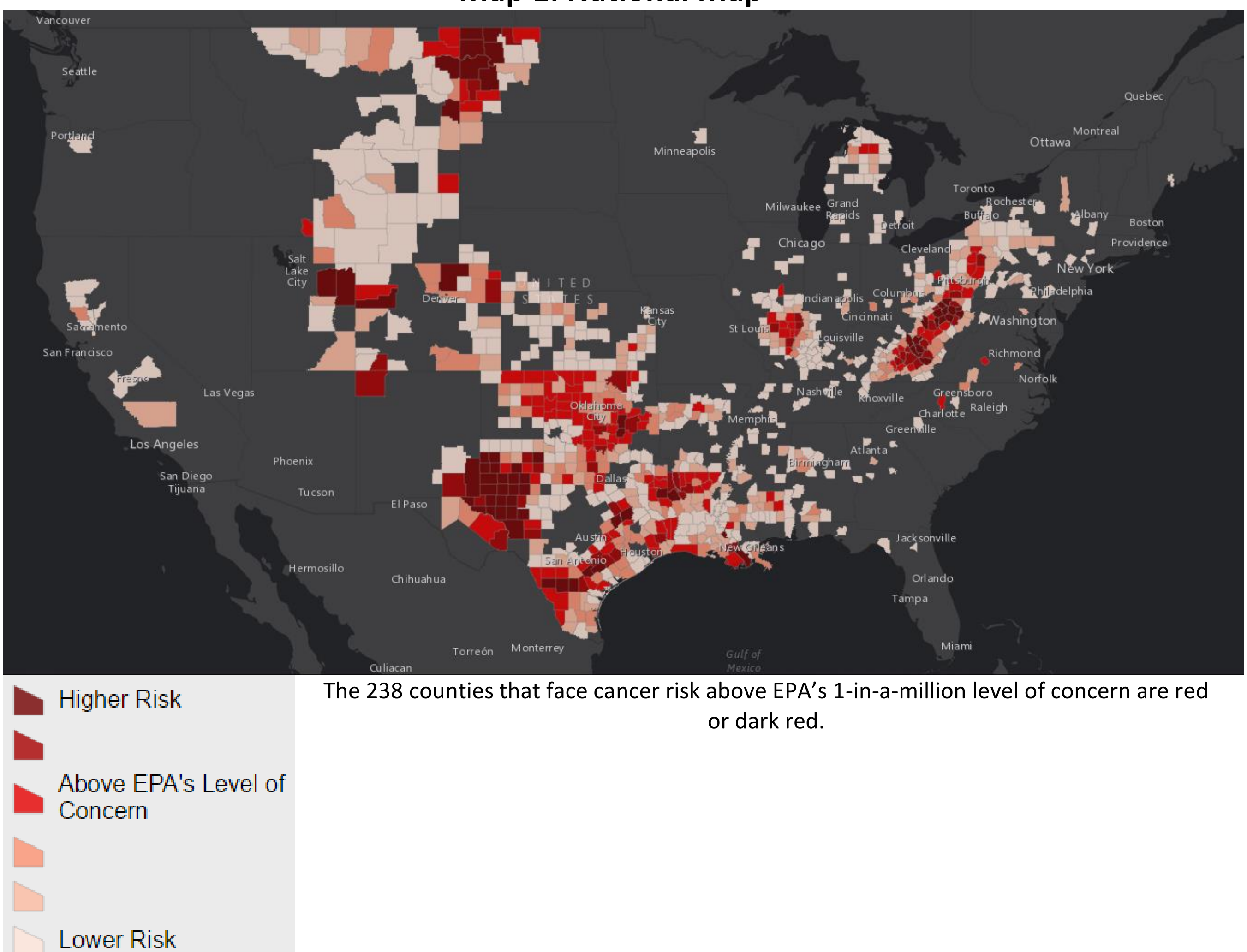
[§] In 2011, on a toxicity weighted basis, cancer risk from oil and gas is 41% from major facilities and 59% dispersed facilities. Respiratory health risk is 13% from major facilities and 87% from dispersed facilities.

Results

National

Using projections of toxic air emissions from EPA's National Emissions Inventory (NEI) for 2017, we estimate that 238 counties in 21 states face cancer risk above EPA's 1-in-a-million level of concern due to toxic emissions from oil and gas operations (National Map). Of these counties, 43 counties face a risk that exceeds one in 250,000 and 2 counties face a cancer risk that exceeds one in 100,000. In addition, 32 of these counties will also face an elevated respiratory health risk from toxic air emissions.** The total population of the counties above EPA's level of concern is over 9 million (see Appendix A). The areas with the greatest health risk are generally located in states with the largest amount of oil and gas infrastructure including Texas, Louisiana, Oklahoma, North Dakota, Pennsylvania, and Colorado, and they include cities such as Fort Worth, Texas; Shreveport, Louisiana; Greeley, Colorado; and Charleston, West Virginia.

Map 1: National Map



The 238 counties that face cancer risk above EPA's 1-in-a-million level of concern are red or dark red.

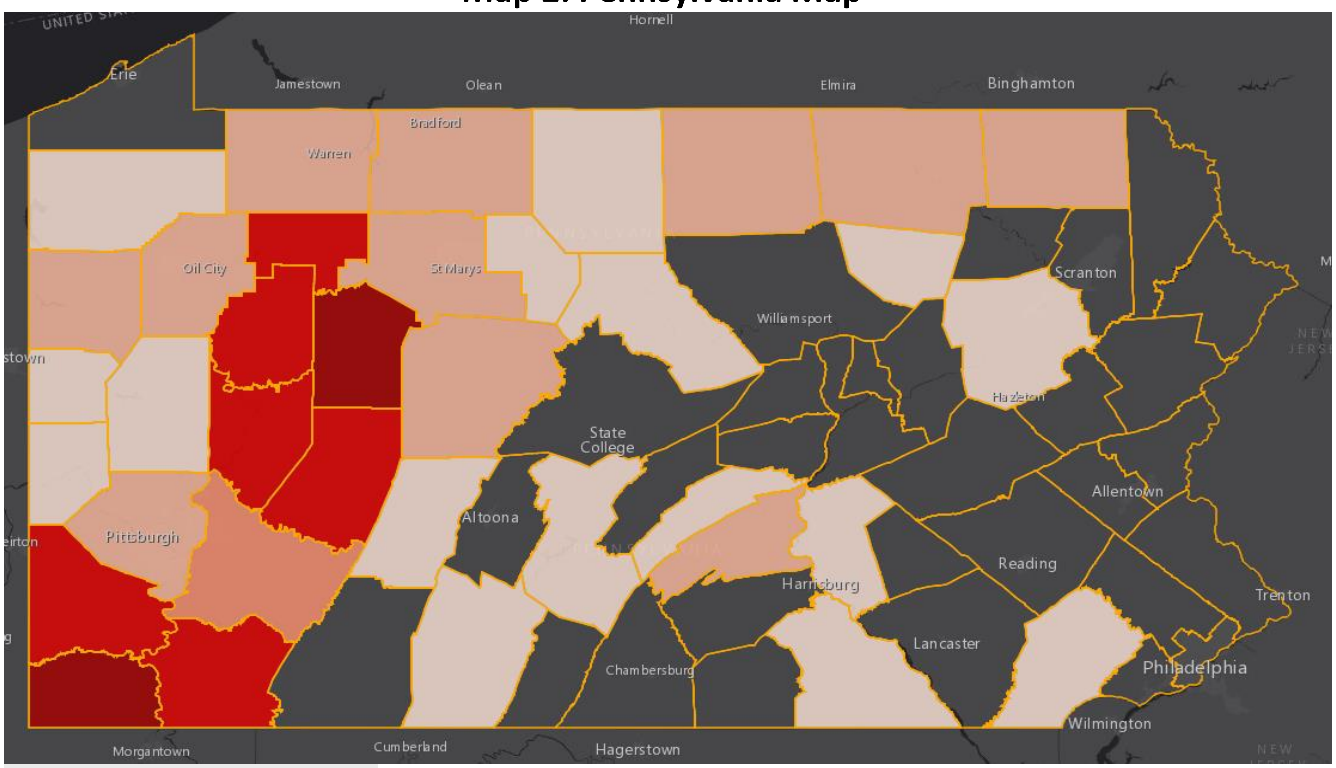
** The U.S. EPA considers cancer risks over one-in-a-million, or a respiratory hazard index greater than 1, to be above its level of concern.

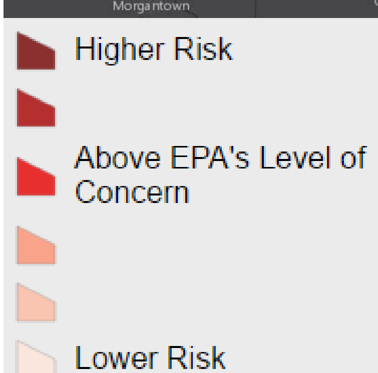
Pennsylvania

According to the NEI, over 1,300 tons of hazardous toxic air pollution—benzene, formaldehyde, and acetaldehyde—were emitted by oil and gas facilities in Pennsylvania. Furthermore, oil and gas production has increased significantly in Pennsylvania since 2011; oil production increased by 112 percent between 2011 and 2015, and natural gas production increased by 264 percent.[14] As a result, toxic air pollution from the oil and gas industry is becoming a greater and greater concern, and it is important to incorporate EPA's projections of emissions growth between 2011 and 2017 emissions into the analysis.

Based on EPA's projection of 2017 emissions, eight counties in Pennsylvania will face a high cancer risk due to toxic emissions from oil and gas operations—Armstrong, Clarion, Fayette, Forest, Greene, Indiana, Jefferson, and Washington counties. The counties above EPA's level of concern have a population of over 625,000. (Pennsylvania Map).

Map 2: Pennsylvania Map





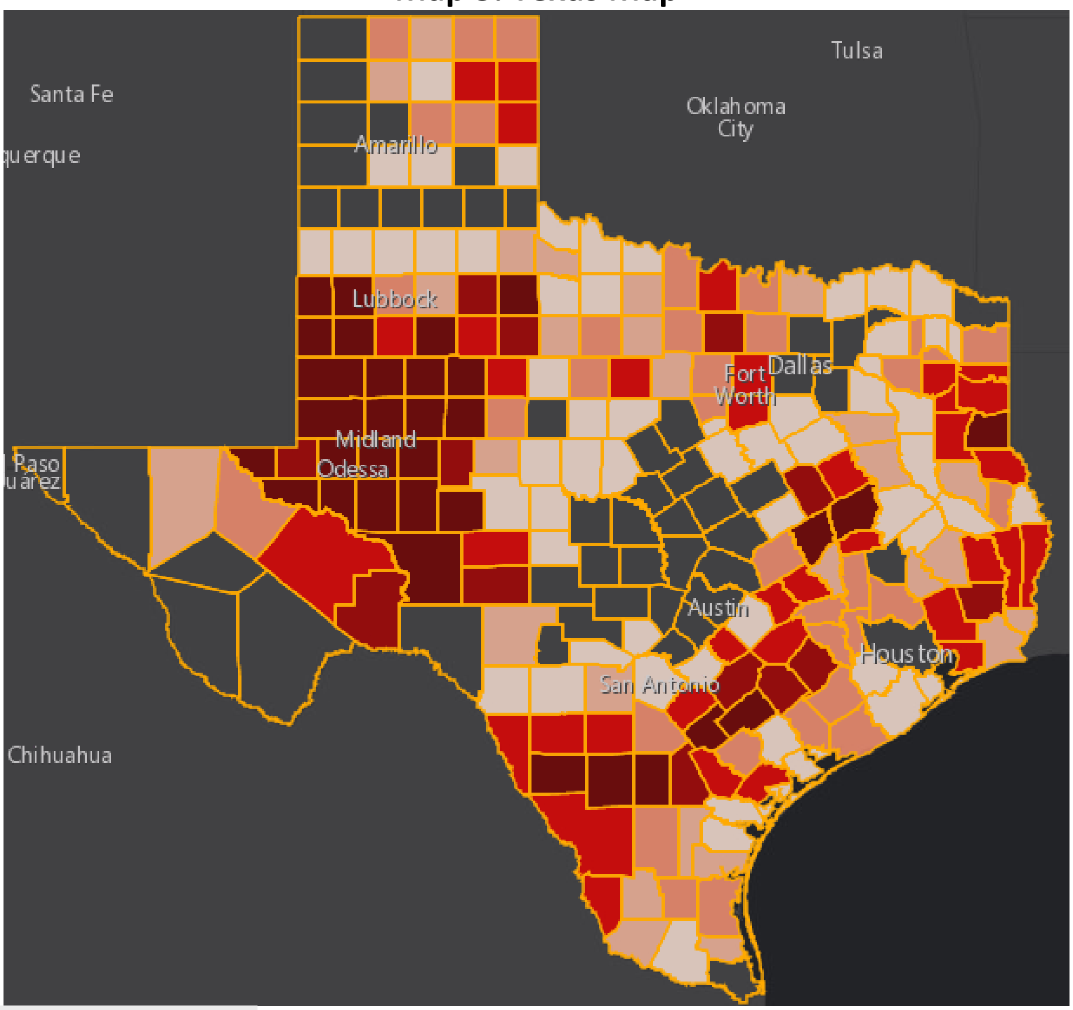
The 8 counties that face cancer risk above EPA's 1-in-a-million level of concern are red or dark red.

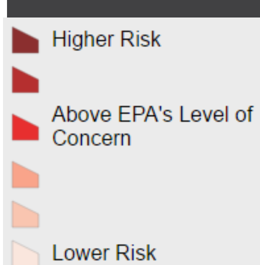
Texas

According to the NEI, over 8,500 tons of hazardous toxic air pollution—benzene, formaldehyde, and acetaldehyde—were emitted by oil and gas facilities in Texas. Oil production has increased significantly in Texas—by 139 percent between 2011 and 2015, and natural gas production has grown moderately—by 11 percent.[15] Accordingly, EPA projects that the volume of benzene, formaldehyde, and acetaldehyde emissions from oil and gas operations in Texas will grow 136% between 2011 and 2017.

Based on that projection, 82 counties in Texas will face elevated cancer risk due to toxic emissions from oil and gas operations (up from 50 counties in 2011). The 82 counties above EPA's level of concern have a population of over 4.1 million (Texas Map).

Map 3: Texas Map





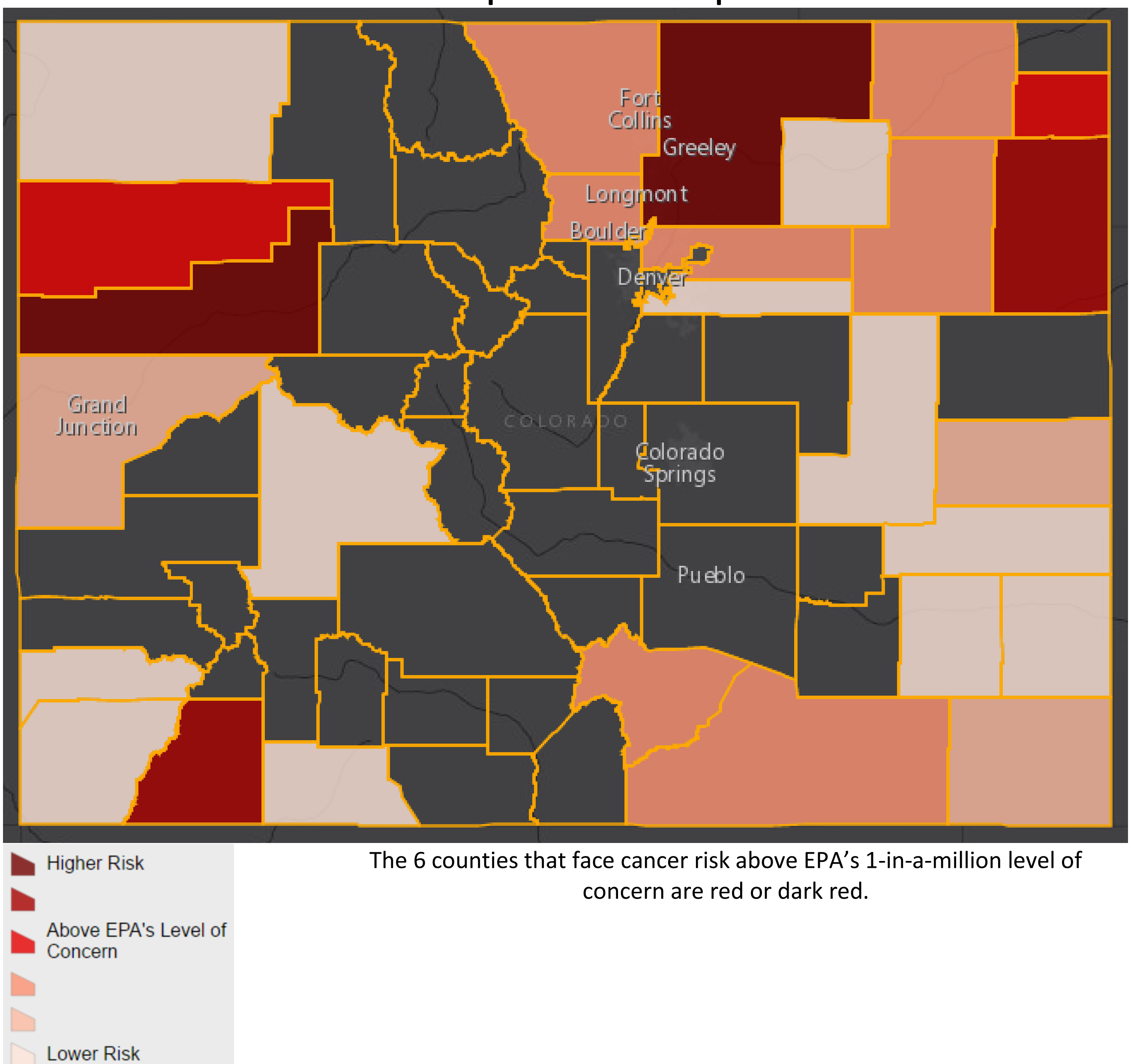
The 82 counties that face cancer risk above EPA's 1-in-a-million level of concern are red or dark red.

Colorado

According to the National Emissions Inventory, over 3,300 tons of hazardous toxic air pollution—benzene, formaldehyde, and acetaldehyde—were emitted by oil and gas facilities in Colorado. Oil production has increased significantly in Colorado—by 202 percent between 2011 and 2015, and natural gas production has stayed approximately level.[16]

Based on EPA's projection of 2017 emissions, six counties in Colorado will face elevated cancer risk due to toxic emissions from oil and gas operations—Garfield, La Plata, Phillips, Rio Blanco, Weld, and Yuma. The counties above EPA's level of concern have a population of over 410,000 (Colorado Map).

Map 4: Colorado Map



The 6 counties that face cancer risk above EPA's 1-in-a-million level of concern are red or dark red.

Further Considerations for NATA Results

NATA is an underestimate of overall health impact from oil and gas for a variety of reasons:

- First, the results represent just a portion of the full impact of oil and gas operations on respiratory health: it only accounts for the respiratory health risk from toxic hazardous air emissions. Oil and gas infrastructure is also responsible for particulate matter (PM) emissions and emissions of chemicals that create ozone. Both PM and ozone exacerbate respiratory diseases, including asthma and chronic lung disease, but these risks are not included in the current analysis. Silica dust from hydraulic fracturing and sand mining operations can also cause lung diseases.
- Second, NATA only accounts only for risk associated with inhalation of these pollutants—the exposure risks from water contamination may also be relevant for communities living near oil and gas facilities.
- Third, we only included health impacts directly associated with oil and gas facilities. Oil and gas development may also entail increased truck traffic and changes in land use, neither of these are accounted for in the present analysis.
- Finally, NATA and the inventories it relies on may underestimate the total emissions of toxics from oil and gas.[17]

The geographic distribution of health impacts changed between 2011 and 2017, while the total number of counties with elevated cancer risk grew from 206 in 2011 to 238 in 2017. These changes follow the growth or decline of the oil and gas industry in different geographical areas, but the industry grew in many more locations than it shrank, as it grew nationwide. For example, the 2011 data indicates that 50 counties in Texas had elevated cancer risk, while 82 Texas counties will face elevated risk in 2017.

In addition, there are many communities affected by oil and gas toxic air pollution that are missed when we look only at county-level risk results. In many places, the county-level average impact may be moderate, but individuals living in close proximity to oil and gas infrastructure will face elevated risk of both cancer and respiratory hazard.[††] NATA did present data on health impacts for geographical units smaller than counties (census tracts), but because of data limitations, we were not able to produce estimates of health impacts at the census tract level for 2017 (see Appendix C).

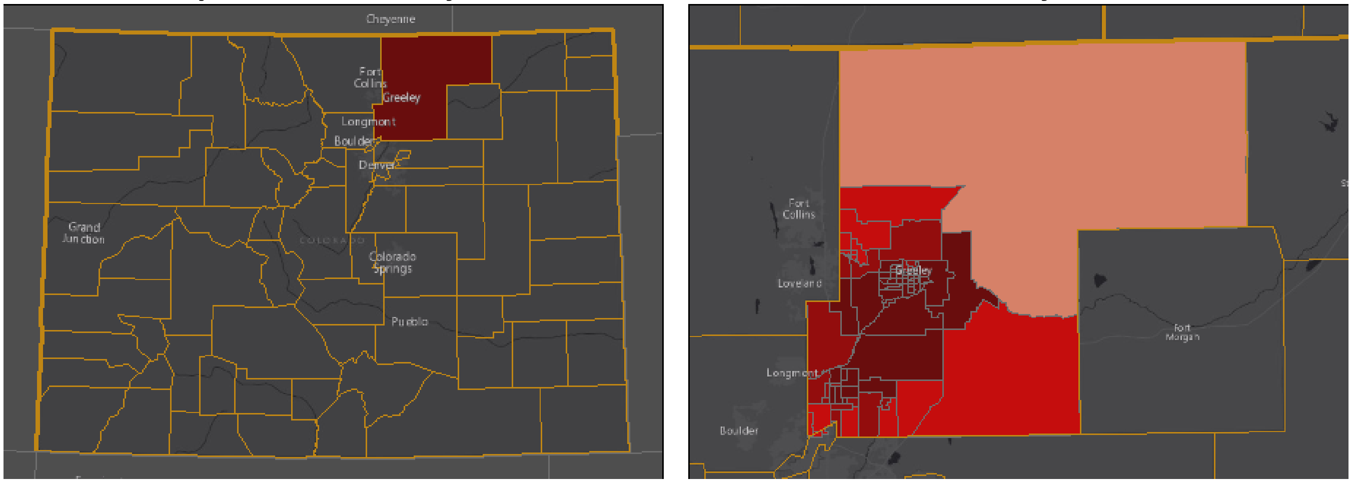
However, census tract level data does demonstrate that some areas within counties experience higher impacts than the county as a whole. Two counties illustrate this:

- In Weld County, Colorado, there is a high overall county-wide cancer risk from oil and gas sources. Within the county, there are 77 individual census tracts, and the cancer risks calculated in those tracts range from 1/5th of the county average to over 3 times the county average—22 census tracts have a risk above the county average and 55 have a risk that is lower than the county

[††] See Oil and Gas Threat Map for more on population living in close proximity to oil and gas infrastructure. Available at: http://oilandgasthreatmap.com/.

average. However, even among the tracts below the county average, all but one still have a cancer risk above EPA's level of concern. (Weld County Map)

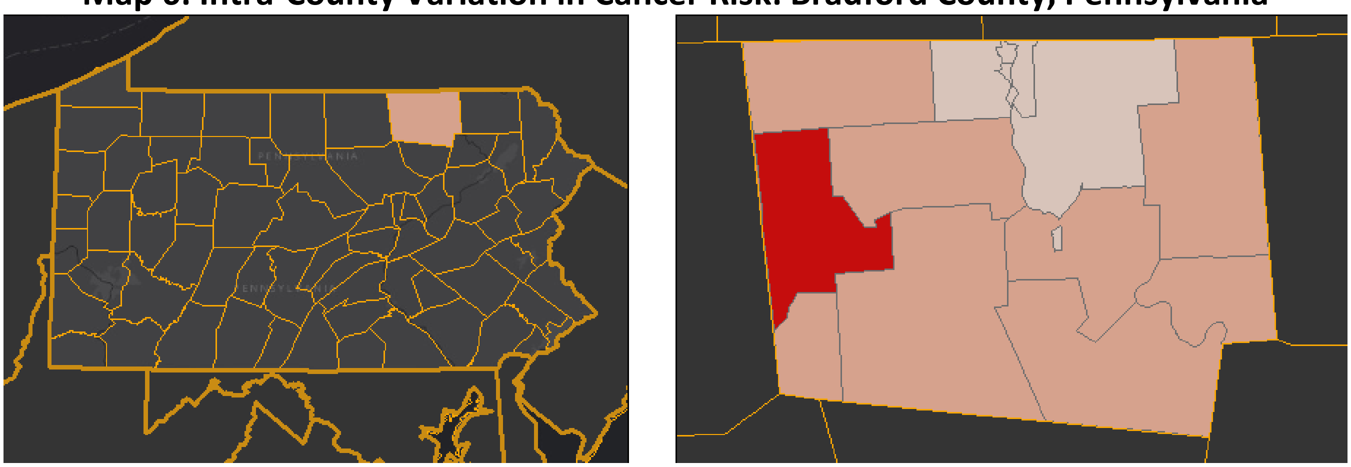
Map 5: Intra-County Variation in Cancer Risk: Weld County, Colorado



Note: Tract level assessments based solely on 2011 data for non-point source emissions, and do not include point sources and growth of emissions from 2011 to 2017.

- In Bradford County, Pennsylvania, the average county-wide cancer risk from oil and gas sources is below EPA's level of concern. However, one census tract in the western part of the county does have a cancer risk above EPA's level of concern, and other tracts may also have a higher risk if major sources and the 2017 emissions projections were taken into account. (Bradford County Map)

Map 6: Intra-County Variation in Cancer Risk: Bradford County, Pennsylvania



Note: tract level assessments based solely on 2011 data for non-point source emissions, and do not include point sources and growth of emissions from 2011 to 2017.

Technologies and Practices to Reduce Toxic Pollution

As outlined in the 2014 report *Waste Not*, readily-available technologies and practices can cut methane emissions dramatically in just a few years.[18] These technologies and practices will reduce the total amount of natural gas that leaks and is released from facilities throughout the oil and gas supply chain. Thus, these policy recommendations will also reduce emissions of hazardous toxic air pollutants from the oil and gas industry. As such, these measures would have important benefits for air quality and public health in and downwind of oil and gas producing areas.

- *Finding and Fixing Leaks*: Unintentional leaks of natural gas from static components such as connectors, valves, regulators, and hatches throughout the oil and natural gas sector are widespread. Leaks will eventually occur at all oil and gas facilities; failing to fix them in a timely manner is a wasteful and harmful practice that leads to clearly avoidable emissions. Leak emissions can be reduced with rigorous leak detection and repair (LDAR) programs. These programs require frequent, regular surveying of facilities for leaks using instruments that detect methane and other hydrocarbons in natural gas.

- *Reducing or eliminating venting from natural gas-driven pneumatic equipment*: Gas-driven pneumatic equipment uses the pressure energy of natural gas in pipelines to do work, such as control, open, and shut valves, or operate pumps. This equipment is ubiquitous at oil and gas facilities, and emits natural gas to the atmosphere by design. Replacing high-emitting pneumatic equipment with low- or zero-emitting equipment will greatly reduce toxic emissions.

- *Controlling Emissions from Oil and Condensate Storage Tanks*: Storage tanks are used to hold oil, condensate, and produced water from oil and gas wells. During normal operations, toxic pollutants such as benzene, methane, and other light hydrocarbons separate from the liquids and, if not controlled, vent into the atmosphere. Tanks are a very large source of toxic air pollutants – we estimate that tanks are emitting over a quarter of the toxic pollutants from the oil and gas industry.[‡‡] Control measures such as vapor recovery units (small compressors which capture these vapors and inject them into natural gas pipelines) can greatly reduce emissions of these toxic pollutants.

- *Reducing Compressor Seal Emissions*: Seals on the moving parts of natural gas compressors are a significant source of preventable toxic emissions. These emissions can be very large when the seals are not regularly maintained or replaced, and when operators use older designs for certain compressors. Fortunately, these emissions can easily be reduced or eliminated by employing a mix of modern seal design, capture of gas that escapes from seals so it can be utilized, and proper maintenance practices.

- *Reducing Dehydrator Venting*: Dehydrators remove water from the natural gas stream. When their emissions are not controlled, dehydrators vent large amounts of pollution alongside the

[‡‡] Calculations based on the US GHG Inventory and ratios of VOC to methane and toxic air pollutants to methane from various emission streams from US EPA Regulatory Impact Statement.

water they are intended to remove. They are very large source of toxic air pollutants – dehydrators are the source of about a third of the entire oil and gas industry's toxic air emissions.[§§] There are a number of approaches to reducing emissions from dehydrator venting, such as adjusting circulation rates of the glycol fluid; routing the vent gas to a burner used to heat the glycol, so toxics are combusted; and routing emissions to a flare or incinerator.

- *Reducing venting from oil wells*: Venting of gas during completion of oil wells, following hydraulic fracturing, can be a significant source of toxics. In 2012, EPA established standards to address emissions from gas wells during flowback after hydraulic fracturing or re-fracturing requiring operators to flare or capture the gas,[***] and in 2016, EPA issued standards that will extend this requirement to hydraulically fractured oil wells.[19] Some oil well operators also vent off the "casinghead" natural gas, which they may consider to be an unwanted by-product of oil production; this venting is another significant source of toxics.

- *Reducing venting from gas wells during liquids unloading*: When water from the underground formations that produce gas accumulates in a mature gas well, it can slow or stop gas production from that well. In order to maintain production, operators remove, or "unload", liquids through a variety of methods, some of which vent natural gas to varying degrees. While a variety of technologies and practices can reduce or eliminate this venting and the resulting pollution, some operators forego these proven, affordable approaches and crudely "blow down" the well by opening it to the atmosphere. This approach is inefficient, as it vents large quantities of gas, including toxics, while only removing a small portion of the liquids in the well.[20]

[§§] Calculations based on the US GHG Inventory and the ratio of toxic air pollutants to methane from various emission streams from US EPA Regulatory Impact Statement

[***] When a well (gas or oil) is hydraulically fractured, large volumes of water and other substances are pumped down the well to break up (fracture) the rock holding the gas / oil. After fracturing is completed, the water is allowed to flow back to the surface during the "flowback" phase of well completion. Natural gas, including toxic species like benzene, from the fractured rock mixes in with this water, and if not controlled, will be vented into the air.

Appendix

A. Counties with Cancer and/or Respiratory Health Risk above EPA's Level of Concern: *In order of population from most populous to least populous*[21]

State	County	2014 population
TX	Tarrant	1,945,360
CO	Weld	277,670
TX	Webb	266,673
LA	Caddo	252,603
PA	Washington	208,187
WV	Kanawha	190,223
NC	Iredell	166,675
TX	Johnson	157,456
LA	Ouachita	156,325
TX	Midland	155,830
TX	Ector	153,904
PA	Fayette	134,086
LA	Bossier	125,064
NM	San Juan	123,785
TX	Gregg	123,204
LA	Terrebonne	113,328
LA	Lafourche	98,020
PA	Indiana	87,706
TX	Liberty	78,117
NM	Lea	69,999
WV	Harrison	68,761
PA	Armstrong	67,785
TX	Harrison	67,336
KY	Pike	63,034
TX	Wise	61,638
CO	Garfield	57,461
TX	Maverick	57,023
WV	Marion	56,803
WV	Putnam	56,770
NM	Eddy	56,395
TX	Hardin	55,621
CO	La Plata	53,989
TX	Rusk	53,923
OK	Grady	53,854
OK	Washington	51,937
OK	Carter	48,821
OK	Osage	47,981
TX	Wilson	46,402
PA	Jefferson	44,638
OK	Pittsburg	44,626
OK	Stephens	44,493
WV	Wayne	41,122
TX	Upshur	40,354
LA	Webster	40,333
TX	Caldwell	39,810
PA	Clarion	38,821
IL	Marion	38,571
TX	Chambers	38,145
KY	Floyd	38,108
OK	Pontotoc	38,005

State	County	2014 population
PA	Greene	37,843
OK	McClain	37,313
UT	Uintah	36,867
TX	Howard	36,651
TX	Jasper	35,552
WV	Logan	35,348
OK	Lincoln	34,619
TX	Bee	32,863
WV	Marshall	32,416
ND	Williams	32,130
ND	Stark	30,372
OK	Custer	29,500
OK	Caddo	29,317
WV	Jackson	29,126
OH	Carroll	28,187
KY	Perry	27,597
OK	Garvin	27,561
LA	De Soto	27,142
LA	Morehouse	26,760
WV	Mingo	25,716
TX	Shelby	25,515
OK	Seminole	25,421
LA	West Baton Rouge	25,085
TX	Fayette	24,833
WV	Upshur	24,731
MI	Otsego	24,158
TX	Panola	23,769
WV	Boone	23,714
OK	Beckham	23,691
TX	Hockley	23,577
TX	Limestone	23,524
KY	Letcher	23,359
KY	Johnson	23,262
VA	Buchanan	23,106
LA	Assumption	23,034
WV	Wyoming	22,598
LA	Union	22,539
IL	Fayette	21,870
OK	Texas	21,853
LA	St. James	21,638
WV	Lincoln	21,561
TX	Tyler	21,418
TX	Colorado	20,719
TX	DeWitt	20,684
MS	Wayne	20,490
TX	Gonzales	20,462
WV	McDowell	20,448
UT	Duchesne	20,380
OK	McIntosh	20,088

State	County	2014 population
LA	East Feliciana	19,813
TX	Freestone	19,762
TX	Lavaca	19,721
TX	Gaines	19,425
TX	Montague	19,416
IL	Crawford	19,393
TX	Frio	18,531
TX	Andrews	17,477
TX	Scurry	17,328
TX	Burleson	17,253
WV	Taylor	17,069
TX	Leon	16,861
AR	Van Buren	16,851
WV	Barbour	16,766
TX	Lee	16,742
MS	Jasper	16,601
IL	Wayne	16,543
IL	Lawrence	16,519
TX	Robertson	16,500
IL	Piatt	16,431
WV	Lewis	16,414
LA	Claiborne	16,412
OK	Marshall	16,182
IL	Richland	16,061
LA	Jackson	15,994
WV	Wetzel	15,988
TX	Pecos	15,893
KY	Knott	15,892
OK	Kingfisher	15,532
VA	Dickenson	15,308
VA	Appomattox	15,279
TX	Karnes	14,906
LA	La Salle	14,839
WV	Roane	14,664
WV	Braxton	14,463
IL	White	14,374
TX	Zapata	14,319
TX	Newton	14,138
LA	Bienville	13,885
TX	Madison	13,861
OK	Hughes	13,806
OK	Atoka	13,796
IL	Clay	13,520
TX	Dawson	13,372
KY	Magoffin	12,913
OK	Haskell	12,896
TX	Terry	12,739
KY	Martin	12,537
TX	Zavala	12,267
OK	Okfuskee	12,186

State	County	2014 population
TX	Live Oak	12,091
TX	Ward	11,625
MT	Richland	11,576
IL	Wabash	11,549
OK	Washita	11,547
MT	Roosevelt	11,332
OK	Johnston	11,103
TX	Dimmit	11,089
ND	McKenzie	10,996
OK	Latimer	10,693
OK	Nowata	10,524
CO	Yuma	10,202
TX	Marion	10,149
WV	Ritchie	10,011
OK	Blaine	9,917
ND	Mountrail	9,782
OK	Love	9,773
IL	Jasper	9,623
TX	Stephens	9,405
MI	Montmorency	9,300
OK	Woods	9,288
WV	Tyler	9,098
TX	Mitchell	9,076
WV	Clay	8,941
LA	Red River	8,669
WV	Gilmer	8,618
WV	Doddridge	8,391
TX	Yoakum	8,286
TX	Winkler	7,821
OK	Major	7,750

State	County	2014 population
WV	Pleasants	7,634
PA	Forest	7,518
WV	Calhoun	7,513
TX	La Salle	7,474
TX	Refugio	7,302
WY	Weston	7,201
CO	Rio Blanco	6,707
LA	Cameron	6,679
ND	Bottineau	6,650
IL	Edwards	6,617
TX	Garza	6,435
OK	Jefferson	6,292
OK	Cotton	6,150
ID	Bear Lake	5,957
WV	Wirt	5,845
OK	Coal	5,807
OK	Alfalfa	5,790
TX	Lynn	5,771
TX	Wheeler	5,714
OK	Beaver	5,486
TX	Martin	5,460
IL	Gallatin	5,291
TX	Crane	4,950
OK	Dewey	4,914
OK	Grant	4,501
ND	Dunn	4,399
CO	Phillips	4,363
TX	Hemphill	4,180
OK	Ellis	4,150
TX	Sutton	3,972

State	County	2014 population
TX	Fisher	3,831
TX	Crockett	3,812
OK	Harper	3,812
OK	Roger Mills	3,761
TX	Reagan	3,755
MT	Sheridan	3,696
TX	Upton	3,454
TX	Schleicher	3,162
KS	Woodson	3,157
MT	Fallon	3,108
TX	Cochran	2,935
ND	Renville	2,587
ND	Divide	2,432
ND	Burke	2,245
TX	Dickens	2,218
ND	Golden Valley	1,825
TX	Irion	1,574
TX	Stonewall	1,403
TX	Sterling	1,339
TX	Glasscock	1,291
TX	Roberts	928
TX	Terrell	927
ND	Billings	901
TX	McMullen	805
TX	Kent	785
ND	Slope	765
TX	Borden	652
TX	King	262
TX	Loving	86
TOTAL POPULATION		**9,013,075**

B. Counties with Cancer and/or Respiratory Health Risk above EPA's Level of Concern: *By State*

Arkansas
Van Buren
Colorado
Garfield
La Plata
Phillips
Rio Blanco
Weld
Yuma
Idaho
Bear Lake
Illinois
Clay
Crawford
Edwards
Fayette
Gallatin
Jasper
Lawrence
Marion
Piatt
Richland
Wabash
Wayne
White
Kansas
Woodson
Kentucky
Floyd
Johnson
Knott
Letcher
Magoffin
Martin
Perry
Pike
Louisiana
Assumption Parish
Bienville Parish
Bossier Parish
Caddo Parish
Cameron Parish
Claiborne Parish
De Soto Parish
East Feliciana Parish
Jackson Parish
La Salle Parish
Lafourche Parish
Morehouse Parish
Ouachita Parish
Red River Parish
St. James Parish
Terrebonne Parish

Louisiana (cont.)
Union Parish
Webster Parish
West Baton Rouge Parish
Michigan
Montmorency
Otsego
Mississippi
Jasper
Wayne
Montana
Fallon
Richland
Roosevelt
Sheridan
North Carolina
Iredell
North Dakota
Billings
Bottineau
Burke
Divide
Dunn
Golden Valley
McKenzie
Mountrail
Renville
Slope
Stark
Williams
New Mexico
Eddy
Lea
San Juan
Ohio
Carroll
Oklahoma
Alfalfa
Atoka
Beaver
Beckham
Blaine
Caddo
Carter
Coal
Cotton
Custer
Dewey
Ellis
Garvin
Grady
Grant

Oklahoma (cont.)
Harper
Haskell
Hughes
Jefferson
Johnston
Kingfisher
Latimer
Lincoln
Love
Major
Marshall
McClain
McIntosh
Nowata
Okfuskee
Osage
Pittsburg
Pontotoc
Roger Mills
Seminole
Stephens
Texas
Washington
Washita
Woods
Pennsylvania
Armstrong
Clarion
Fayette
Forest
Greene
Indiana
Jefferson
Washington
Texas
Andrews
Bee
Borden
Burleson
Caldwell
Chambers
Cochran
Colorado
Crane
Crockett
Dawson
DeWitt
Dickens
Dimmit
Ector
Fayette
Fisher

Texas (cont.)
Freestone
Frio
Gaines
Garza
Glasscock
Gonzales
Gregg
Hardin
Harrison
Hemphill
Hockley
Howard
Irion
Jasper
Johnson
Karnes
Kent
King
La Salle
Lavaca
Lee
Leon
Liberty
Limestone
Live Oak
Loving
Lynn
Madison
Marion
Martin
Maverick
McMullen
Midland
Mitchell
Montague
Newton
Panola
Pecos
Reagan
Refugio
Roberts
Robertson
Rusk
Schleicher
Scurry
Shelby
Stephens
Sterling
Stonewall
Sutton
Tarrant
Terrell

Texas (cont.)
Terry
Tyler
Upshur
Upton
Ward
Webb
Wheeler
Wilson
Winkler
Wise
Yoakum
Zapata
Zavala
Utah
Duchesne
Uintah
Virginia
Appomattox
Buchanan
Dickenson
West Virginia
Barbour
Boone
Braxton
Calhoun
Clay
Doddridge
Gilmer
Harrison
Jackson
Kanawha
Lewis
Lincoln
Logan
Marion
Marshall
McDowell
Mingo
Pleasants
Putnam
Ritchie
Roane
Taylor
Tyler
Upshur
Wayne
Wetzel
Wirt
Wyoming
Wyoming
Weston

C. Calculating 2017 Cancer and Respiratory Health Risk

The results of our analysis are based on the modeled cancer and respiratory health risk presented by NATA in its 2011 risk assessment. We made two adjustments to this data to more fully reflect the true impact of the oil and gas industry: we incorporated EPA's data on toxic emissions from Oil and Gas "point" sources, and we updated the results using EPA's 2017 emissions inventory projection to estimate 2017 health impacts.

The NATA results as presented only include non-point emissions sources in the oil and gas industry—these are the large number of relatively small and dispersed facilities and oil and gas activities, such as oil and gas well pads and smaller compressor stations. The cancer and respiratory health risk figures by tract, county, and state can be downloaded directly from the EPA website.[22] These results represent the impact from non-point sources, which make up the majority of toxic emissions from the oil and gas industry.

However, emissions from the less numerous but larger point sources are also significant. To determine the full impact of the oil and gas industry, we estimated the impact of emissions from oil and gas point sources and added that to the impacts from non-point sources. Since the NATA calculation of point source cancer and respiratory health risk lumps all industry segments together, we used the following methodology to estimate the cancer and respiratory health risk specifically from oil and gas point sources:

- Download data from the National Emissions Inventory by pollutant for Oil and Gas Point sources and All Point sources by county.[23]
    - Point source emissions are not available at the census tract level, so we could not do this analysis at the tract level.
    - As downloaded, the Oil and Gas Point Source data includes a number of facilities that we do not consider to be part of the natural gas supply chain. We removed a total of 11 facilities with the following "facility source descriptions":
        - Coke Battery
        - Electricity Generating via Combustion
        - Hot Mix Asphalt Plant
        - Landfill
        - Coal Gasification Plant
        - Gasoline/Diesel Service Station
        - Petroleum Refinery
        - Petroleum Storage Facility
            - (Note: we made similar adjustments to emissions in our 2017 inventory to keep the inventories consistent.)
- For each point source data set (Oil and Gas, All) we multiply pollutant tonnage by pollutant toxicity to get the weighted sum of toxicity for each pollutant from each county. For cancer, we

used Unit Risk Estimate[†††] (URE) as an estimate of pollutant toxicity, and for respiratory health risk we used Reference Concentration[‡‡‡] (RfC) as an estimate of pollutant toxicity. The EPA uses the URE and RfC concepts in its dose-response assessments for chronic exposure to toxic air pollutants, and it periodically re-examines and updates the values for individual substances as knowledge improves.[24] The same pollutant has a different impact on cancer and respiratory health, so we calculate two weighted toxicities, one for cancer and one for respiratory health risk.

- For cancer risk, subtract out risk from Coke Ovens from All Point source risk, because EPA modeled emissions and impacts from coke ovens as a distinct source type.[25]
- We can calculate the percent of point source cancer and respiratory toxicity in each county that are from oil and gas facilities by taking the ratio of weighted oil and gas emissions toxicity to weighted toxicity of emissions from all point sources.
- Multiply this percentage by the total respiratory health risk or the total cancer risk minus risk from coke ovens. This is the estimate of cancer and respiratory health risk from oil and gas point sources.
- Add the estimate of risk from oil and gas point sources to the cancer or respiratory health risk for oil and gas non-point sources that was presented directly by NATA.
- This is the total estimate of 2011 oil and gas cancer or respiratory health risk.

The total estimate of 2011 oil and gas cancer risk, as calculated using this methodology at the countywide level, averaged 24% higher than the risk from non-point sources alone. As a result of adding in oil and gas point sources, the number of counties exceeding the threshold of EPA's level of concern for cancer risk for 2011 increased from 106 to 206.

Next, we know that the oil and gas industry has changed substantially between 2011 and today, both in terms of the volume of oil and gas being produced and the geographic distribution of oil and gas production. For example, oil production has increased 67 percent, from 2,058 million barrels in 2011 to 3,442 million barrels in 2015.[26] Gas production has increased 16 percent, from 38.48 trillion cubic feet in 2011 to 32.96 trillion cubic feet in 2015.[27] Thus, a risk assessment based on 2011 emissions does not accurately reflect the current realities of emissions from the oil and gas industry. We used NEI's 2017 projection of air toxic emissions to estimate cancer and respiratory health risk in 2017, and NEI's inventory of emissions in 2011, to estimate the change in risk between 2011 and 2017.

- We downloaded EPA's 2017 projection of toxic emissions by county for both oil and gas point and non-point sources.[§§§]

†††††† "The upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of 1 µg/m3 in air." See: https://www.epa.gov/national-air-toxics-assessment/nata-glossary-terms.

‡‡‡ "The reference concentration is an estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups that include children, asthmatics, and the elderly) that is likely to be without an appreciable risk of deleterious effects during a lifetime." See: https://www.epa.gov/national-air-toxics-assessment/nata-glossary-terms.

§§§ Using the 2011 NEI v2 as a starting point, the U.S. EPA developed a 2017 future case by projecting population and production growth as well as the impact of federal emissions regulations promulgated by December 2014. The emissions model used for this platform is the Sparse Matrix Operator Kernel Emissions (SMOKE) model version 3.7 commonly used by

- 2017 projected toxic emissions are not available at the tract level, so this analysis cannot be done at the tract level.

- We calculated weighted toxicity for oil and gas in each county for both point and non-point sources (using same URE and RfC factors and method as above). To simplify analysis, we focused on only the most consequential pollutant species: benzene, formaldehyde, and acetaldehyde. These three pollutants account for 93% of national cancer risk and 27% of national respiratory hazard risk in the oil and gas sector (Note: ethyl benzene accounts for 71% of national respiratory hazard risk in the oil and gas sector, but it was not reported as a separate pollutant species in NEI's 2017 projections, so we did not include it in our analysis. However, ethyl benzene emissions will closely track benzene emissions, and benzene, which is reported separately in NEI's projection, makes up most of the remainder of the national respiratory hazard risk.)
- For each county we compared total 2011 toxicity for the 3 pollutants (benzene, formaldehyde, acetaldehyde) to total 2017 toxicity for the 3 pollutants, and calculated percent increase or decrease for cancer and respiratory toxicity.
- We multiplied this percent increase (or decrease) by the 2011 oil and gas risk estimate for both cancer and respiratory health risk. This is the 2017 risk estimate.

As a result of the 2017 update, the number of counties exceeding the threshold of EPA's level of concern for cancer risk increased from 206 in 2011 to 238 in 2017. (60 counties shifted from below to above the threshold, while 28 counties fell from above to below the threshold as a result of the 2017 adjustment, for a net increase of 32.)

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the EPA for emissions processing. EPA, 2015. Technical Support Document (TSD), Preparation of Emissions Inventories for the Version 6.2, 2011 Emissions Modeling Platform. Office of Air Quality Planning and Standards, Air Quality Assessment Division. See: http://www3.epa.gov/ttn/chief/emch/index.html#2011.

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[16] US EIA. Colorado Field Production of Crude Oil. Available at: https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=mcrfpco1&f=a.

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[17] Many peer-reviewed studies based on independent measurements conducted in both oil and gas producing basins and urban areas consuming natural gas have concluded that official emissions inventories such as NEI underestimate actual emissions from oil and gas. See *Waste Not*, pp. 9 – 11. More recent work, including work carried out in cooperation with the industry, has come to similar conclusions. See Harriss, R., et al., (2015) "Using Multi-Scale Measurements to Improve Methane Emission Estimates from Oil and Gas Operations in the Barnett Shale Region, Texas," *Environ. Sci. Technol.* 49, 7524−7526, and references therein. Recent work to update and improve emissions inventories, particularly for methane, is improving this situation. EPA Office of Inspector General (2013), "Report: EPA Needs to Improve Air Emissions Data for the Oil and Natural Gas Production Sector." Available at: https://www.epa.gov/office-inspector-general/report-epa-needs-improve-air-emissions-data-oil-and-natural-gas-production. Although the methane inventory and the NEI, which NATA and our analysis are based on, are developed separately, it is likely that the NEI underestimates HAP from oil and gas just as the GHG inventory underestimates methane from oil and gas, for similar reasons (underestimated emissions factors and undercounts of equipment).

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