FRACTRACKER ALLIANCE

A Hazy Future: Pennsylvania's Energy Landscape in 2045

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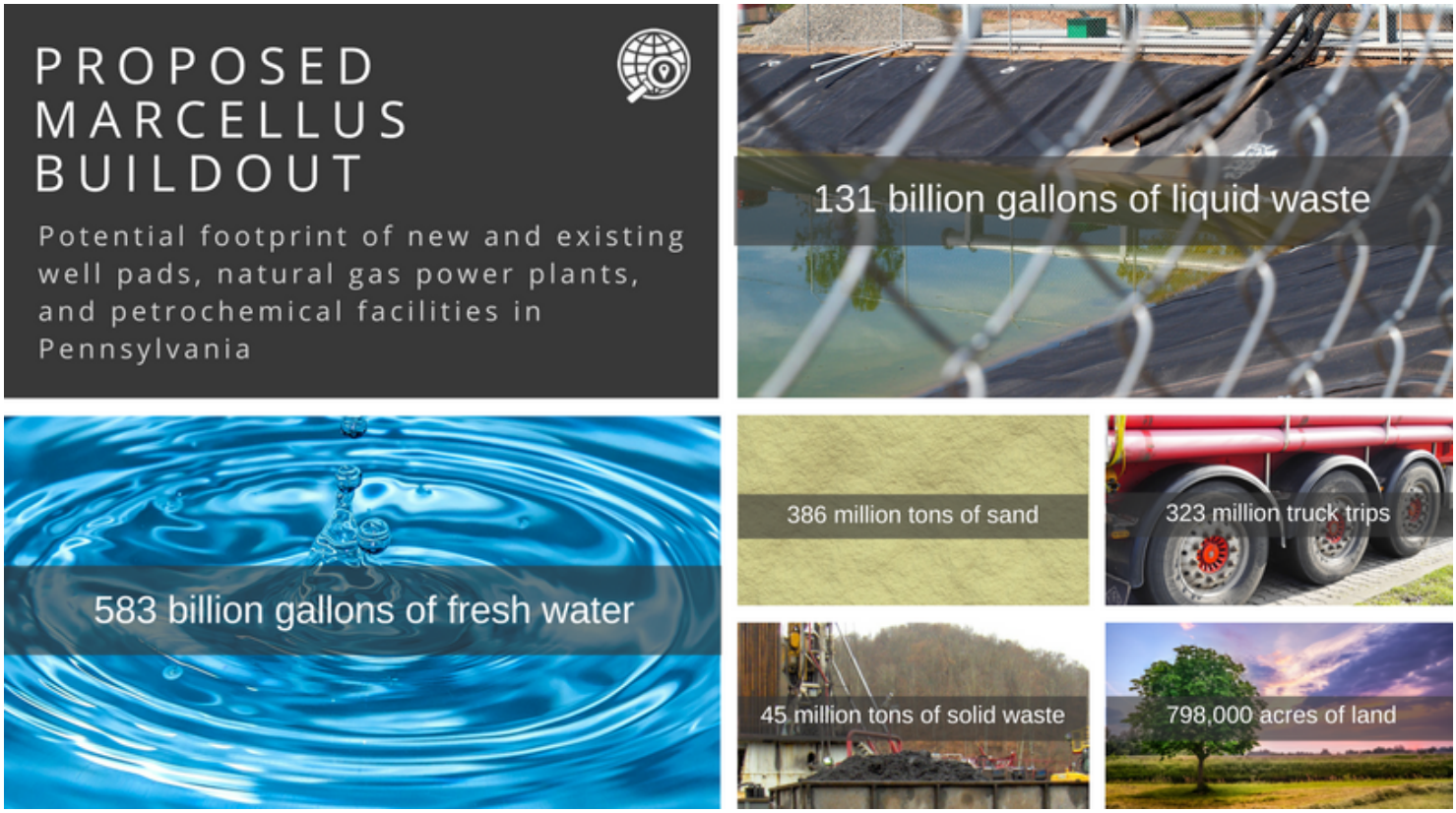
EARTHWORKS



Executive Summary

Industry analysts forecast 47,600 more Marcellus Shale oil and gas (O&G) wells may be drilled in Pennsylvania by 2045, fueling new natural gas power plants and petrochemical facilities in the state and beyond. A buildout of this size will bring enormous impacts on air, land, and water and the communities proximate to these activities. Based on industry projections and current rates of consumption, the cumulative impact of the O&G buildout would require 583 billion gallons of fresh water, 386 million tons of sand, 798,000 acres of land, and more than 323 million truck trips to drilling sites. All of this activity will generate at least 131 billion gallons of liquid waste and 45 million tons of solid waste.

Is all the gas really needed? Increasingly, other states and countries are meeting their own energy needs through cleaner renewable energy options. The nation's energy demands are leveling off, energy efficiency is on the rise, and renewable energy options are becoming much less expensive. So why is Pennsylvania increasing its fossil-fuel portfolio especially when it comes with such a heavy toll on communities and natural resources?

In this issue paper, FracTracker reviews the current state of energy demand and use in Pennsylvania, calculates the footprint of industry projections of the proposed buildout, and assesses what that would look like for residents of the Commonwealth.

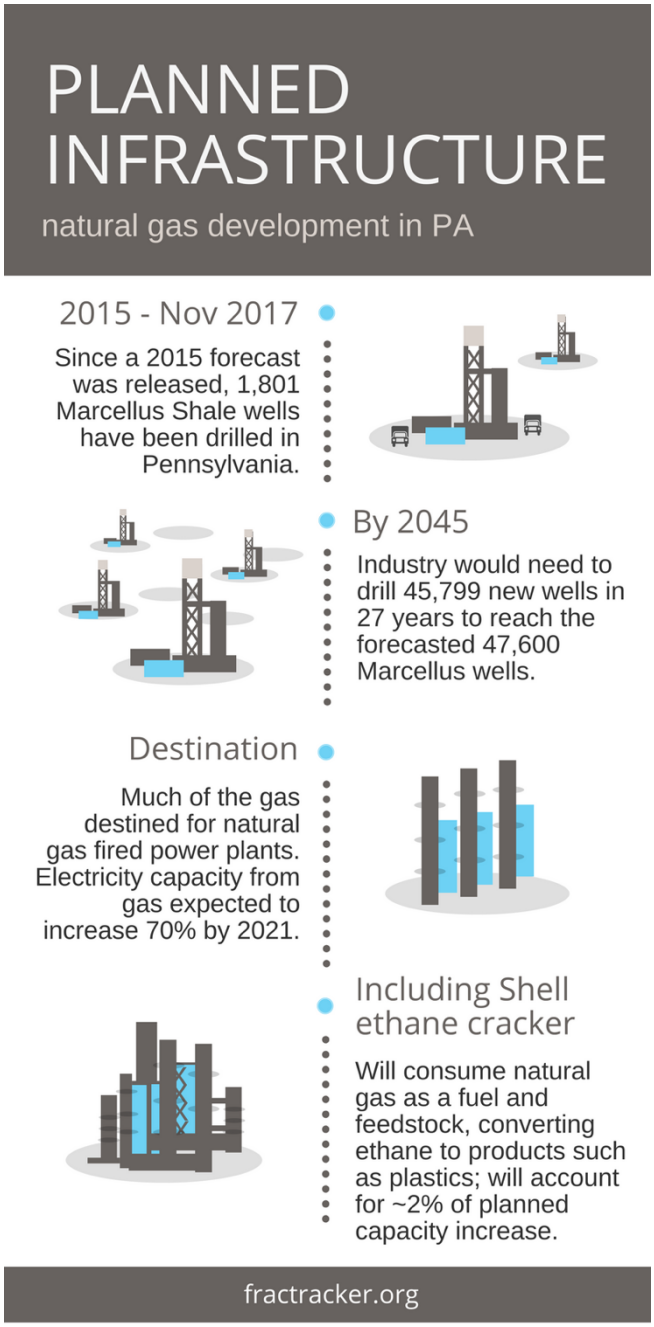
Planned Infrastructure

The Marcellus Shale boom has transformed Pennsylvania into the second leading producer of natural gas in the nation[1] behind Texas, with production levels roughly twice that of third place Alaska in 2017.

The oil and gas industry projects this trend will continue in the future, with a 2015 analysis forecasting up to 47,600 new unconventional wells from the Marcellus Shale in the Commonwealth by 2045.[2] Only 1,801 of the 10,851 unconventional wells already drilled as of November 28, 2017 count as a part of this projection, meaning we could see an additional 45,799 such wells in the coming decades.

Much of this gas is slated to be sent to natural gas fired power plants, delivering electricity to consumers throughout the state and beyond. According to the U.S. Energy Information Administration (EIA), Pennsylvania's electricity capacity from natural gas is scheduled to increase by 70% by 2021,[3] to a total nameplate capacity of 30,595 megawatts of grid-connected power[4] (See Figure 1 below).

This figure includes grid-connected industrial facilities, which are authorized to sell excess energy capacity to the grid. One of the most significant such facilities to be proposed in recent years is Shell Chemical Appalachia's ethane cracker, currently under construction in Beaver County.



[1] Energy Information Administration (EIA). (2017). Natural Gas Gross Withdrawals and Production (tables) https://www.eia.gov/dnav/ng/ng_prod_sum_a_EPG0_FGW_mmcf_m.htm

[2] CNA (2016). The Potential Environmental Impacts of Full Development of the Marcellus Shale in Pennsylvania. https://www.cna.org/cna_files/pdf/Maps1_WellProjections.pdf

[3] EIA. (2017). Electricity: Detailed State Data (File name: july_generator2017_EIA.xls) https://www.eia.gov/electricity/data/state/

[4] Industrial facilities that are permitted to sell excess capacity to the grid are included in this report.

The ethane cracker will consume natural gas both as a fuel and as a feedstock, converting the high ethane content of the region's natural gas to ethylene, which will then be used to create numerous industrial and commercial products, chiefly plastics. While the feedstock consumption will be high, the hydrocarbons consumed as fuel at the plant will be relatively modest compared to electricity generating plants; five grid-connected units will have a total nameplate capacity of 273 megawatts, accounting for about 2% of Pennsylvania's planned increase of capacity in the next few years.[5]

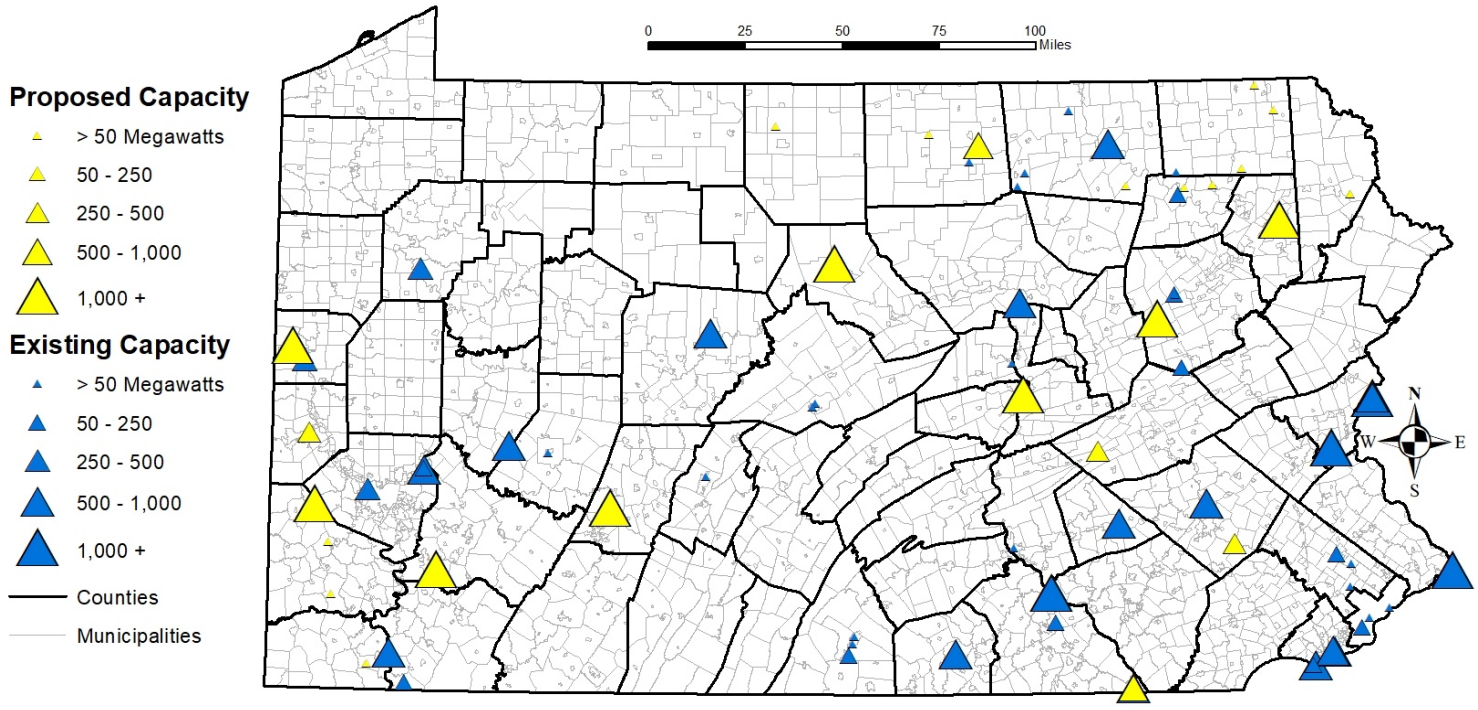


Figure 1. Current and proposed PA gas-fired power plants and generating capacity

Resource Consumption Trends

Ethane

Ethane consumption as a feedstock for Shell's ethane cracker will be very significant, as the plant will be able to process 107,000 barrels of ethane per day (bpd) – or 4.5 million gallons. There are also a number of ethane pipelines to get the product to market, including the Mariner East, which can carry 70,000 bpd (2.9 million gallons per day) of ethane and other natural gas liquids (NGL) to the Philadelphia area. The Mariner West

[5] Frazier R. (2012). Frequently Asked Questions about Ethane Crackers. Allegheny Front. https://www.alleghenyfront.org/frequently-asked-questions-about-ethane-crackers/

carries 50,000 bpd (2.1 million gpd) to the Canadian border. The Mariner East 2 pipeline, which is largely adjacent to the original Mariner East, is scheduled to move 450,000 bpd (18.9 million gpd), and a third adjacent pipeline to be known as the Mariner East 2X will carry an additional 250,000 bpd (10.5 million gpd) when it is built. These projects, when operating at full capacity, add up to 927,000 bpd (38.9 million gpd) of NGL.

Electricity

Pennsylvania generated 48,091 megawatts (MW) of electricity in 2015.[6] Thirty percent (30%) of this figure is from burning natural gas, from plants with a combined nameplate capacity of 18,017 MW (See Figure 2).

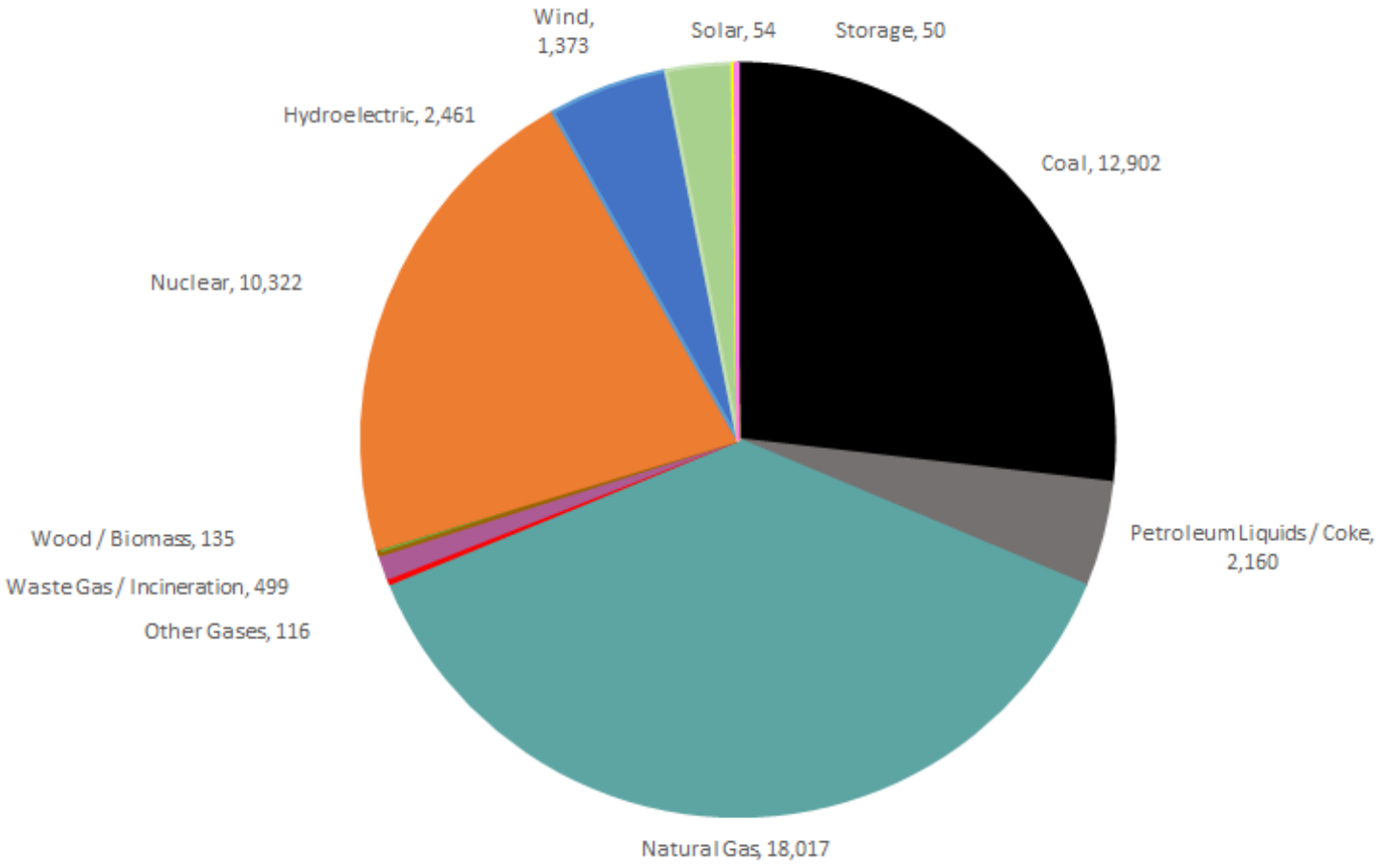


Figure 2. Electricity generation capacity in PA (MW)

[6] EIA. (2017). Electricity: Preliminary Monthly Electric Generator Inventory (based on Form EIA-860M as a supplement to Form EIA-860). https://www.eia.gov/electricity/data/eia860M/

In the coming years, there are plans to expand electrical capacity by 12,627 MW, 98.6% of which is scheduled to burn natural gas (See Figure 3).

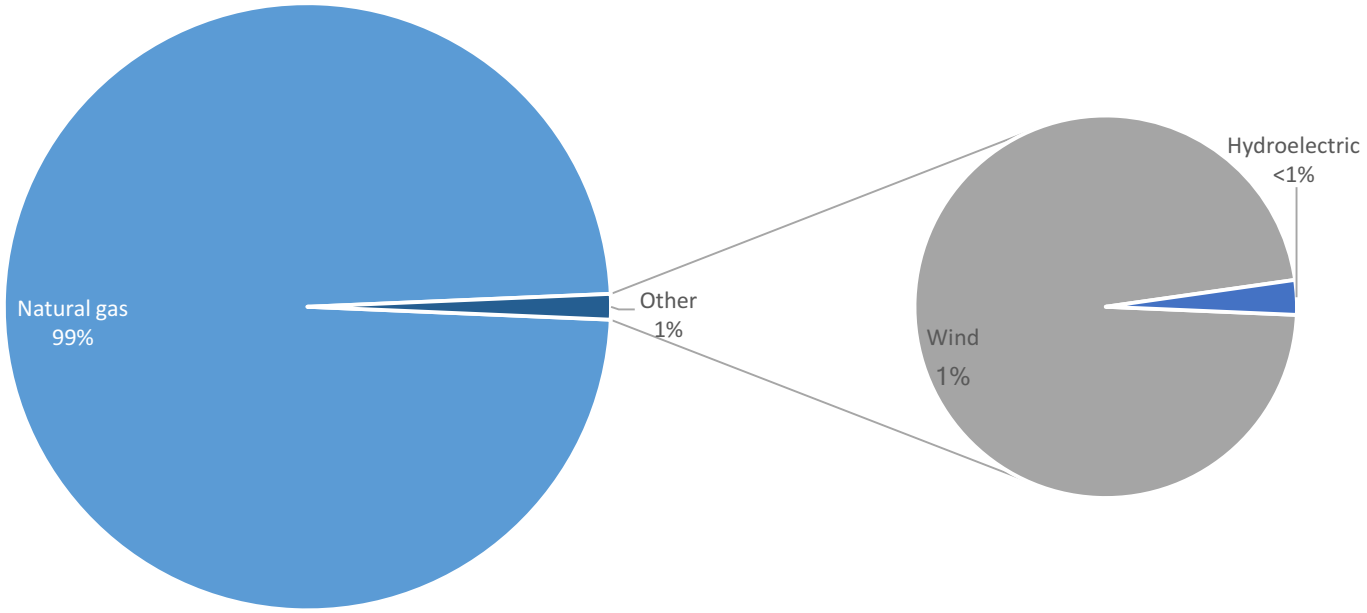


Figure 3. Planned additional electricity generation sources in PA (Percent of 12,627 MW)

But is there a demand for all of this added electrical capacity?

According to EIA documents, Pennsylvania's actual production from natural gas in 2015 was 59.4 million megawatt hours,[7] which is only 38% of the combined listed capacity. If electricity demand remains flat but the new proposed generation is built, this figure would fall to just 22.2% of capacity.

There is no reason to think that there will be an added demand for electricity in the coming years. Nationally, electricity demand has been flat for over a decade across all sectors (See Figure 4), with increases in efficiency offsetting any demand required for a growing population.[8] Even if new generation were required, it is hard to imagine that this would outpace the capability of existing infrastructure.

[7] EIA. File download: https://www.eia.gov/electricity/data/eia923/
[8] EIA. File download: https://www.eia.gov/electricity/annual/xls/epa_02_02.xlsx

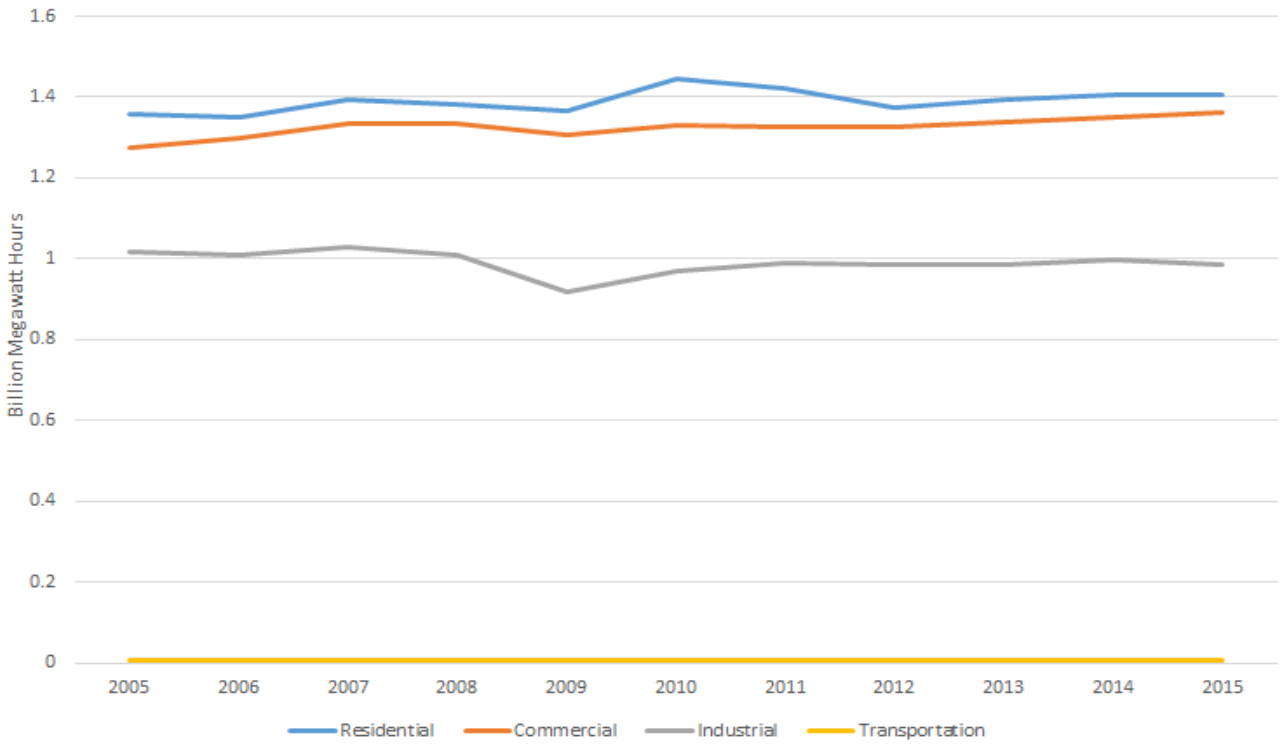


Figure 4. Electricity sale by sector in U.S.[9]

Exports

EIA keeps track of gas exports for some states,[10] but Pennsylvania is not included on the list. We do know that Pennsylvania produced 5,128 trillion BTUs from gas in 2015, while consuming 1,345 trillion BTUs,[11] leaving a surplus of 3,783 trillion BTUs, or nearly three quarters of the total production. While some of this surplus undoubtedly went into storage, we know that a large portion was exported to other states through Pennsylvania's 10,000-mile transmission pipeline system.[12] Increasingly, this product is being exported to international markets, although EIA export records do not indicate from which state exports are derived.[13]

[9] EIA. (2017). Retail sales of electricity to ultimate consumers - By sector, by provider. https://www.eia.gov/electricity/data.php#sales. Data download: https://www.eia.gov/electricity/annual/xls/epa_02_02.xlsx
[10] EIA. (2017). Natural Gas: U.S. Natural Gas Imports & Exports by State. https://www.eia.gov/dnav/ng/ng_move_state_a_EPG0_EEX_Mmcf_a.htm
[11] EIA. (2015). Pennsylvania Energy Consumption Estimates, 2015. https://www.eia.gov/state/?sid=PA#tabs-1
[12] Pipeline and Hazardous Materials Safety Administration (PHMSA). (2017). Pipeline Mileage and Facilities. https://www.phmsa.dot.gov/data-and-statistics/pipeline/pipeline-mileage-and-facilities
[13] EIA. (2017). U.S. Natural Gas Exports and Re-Exports by Country (Table). https://www.eia.gov/dnav/ng/ng_move_expc_s1_a.htm

Trends in PA Natural Gas Production

As of November 28, 2017, Pennsylvania has 108,539 active and shut-in oil and gas wells, of which 11,446 are classified as *unconventional*.[14],[15] Despite their recent appearance and smaller number, the industrial-scaled unconventional wells now dominate the industry, accounting for 5.1 trillion cubic feet of gas production in 2016,[16] compared to 124 billion cubic feet for the conventional O&G wells. These hydrocarbons came from 7,706 producing unconventional wells, putting the average annual production at 661 million cubic feet per well.

Partially due to the large production figures per well, the trend for drilling new unconventional wells in Pennsylvania has fallen off dramatically since its peak in the early part of this decade (See Figure 5).

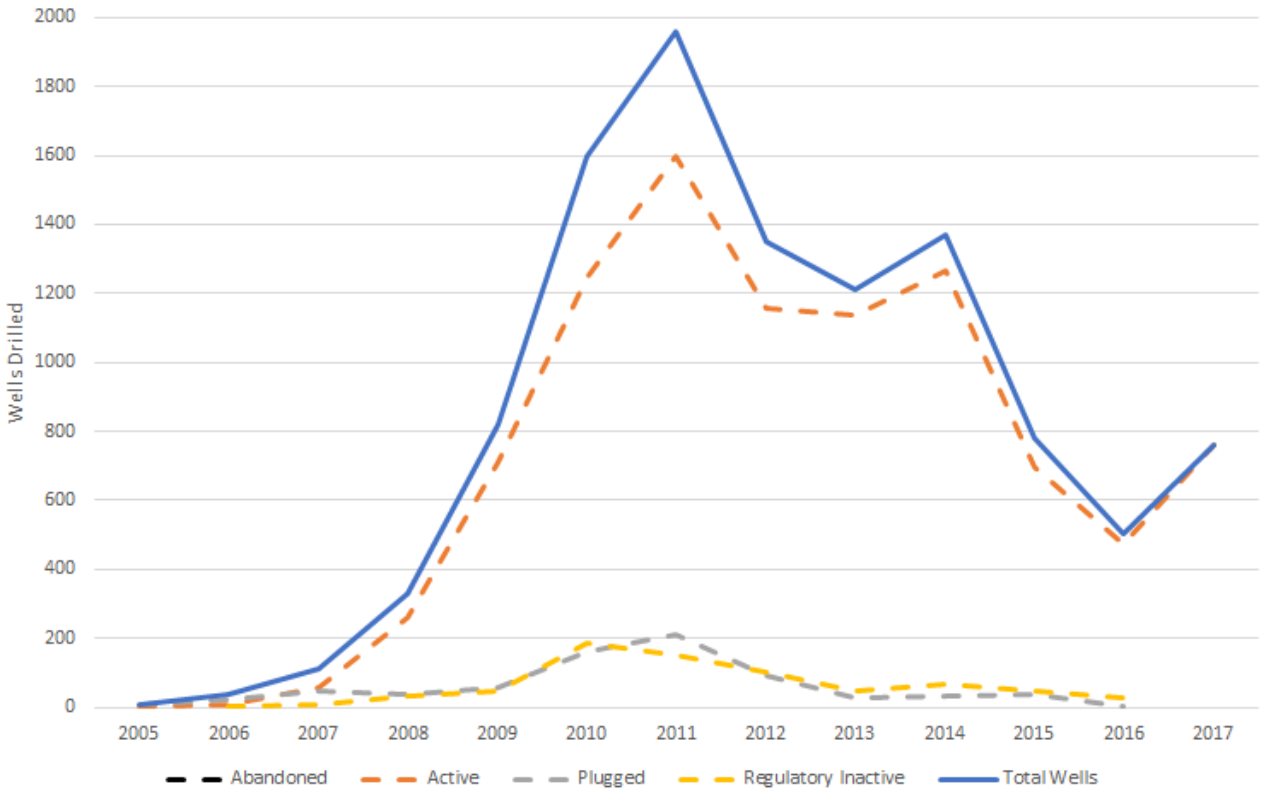


Figure 5. Current status of unconventional wells drilled in PA, January 1, 2005 – October 2, 2017

[14] Pennsylvania Spatial Data Access (PASDA) (2017). Oil Gas Locations - Conventional Unconventional http://www.pasda.psu.edu/uci/DataSummary.aspx?dataset=1088

[15] Almost 95% of all of the unconventional wells in Pennsylvania are drilled into the Marcellus Shale.

[16] Pennsylvania Department of Environmental Protection (PA DEP). (2017). Oil and Gas Electronic Reporting website. https://www.paoilandgasreporting.state.pa.us/publicreports/Modules/Welcome/Agreement.aspx

The 504 unconventional wells drilled in 2016 represent just a quarter of the 1,959 wells drilled in 2011, and nearly half of the unconventional wells in the state were drilled in the three-year period between 2010 and 2012.[17] The large amount of gas that these wells produced has created an oversupply, thus reducing the profitability of new drilling in the region. In response to this, a recent spate of pipeline development[18] has begun to move more of the product from the region, and industry activity is once again increasing, albeit nowhere close to 2011 levels.

While production per well remains high, the longevity of the wells is questionable. Some industry sources claim that Marcellus Shale wells might produce for more than 50 years,[19] but as the formation was first drilled in the early 2000s, such a forecast is mere conjecture. Actual data from 144 wells drilled just 10 years ago show that 39%[17] have already been plugged and abandoned. This figure increases sharply to 77% of the wells drilled 12 years ago, although the sample size is small (n=9). These trends indicate that unconventional wells in Pennsylvania are not nearly as durable as first suggested by industry.

Drilling Impacts

Resource extraction requires a good deal of resource investment, and unconventional gas development is particularly heavy in this regard.

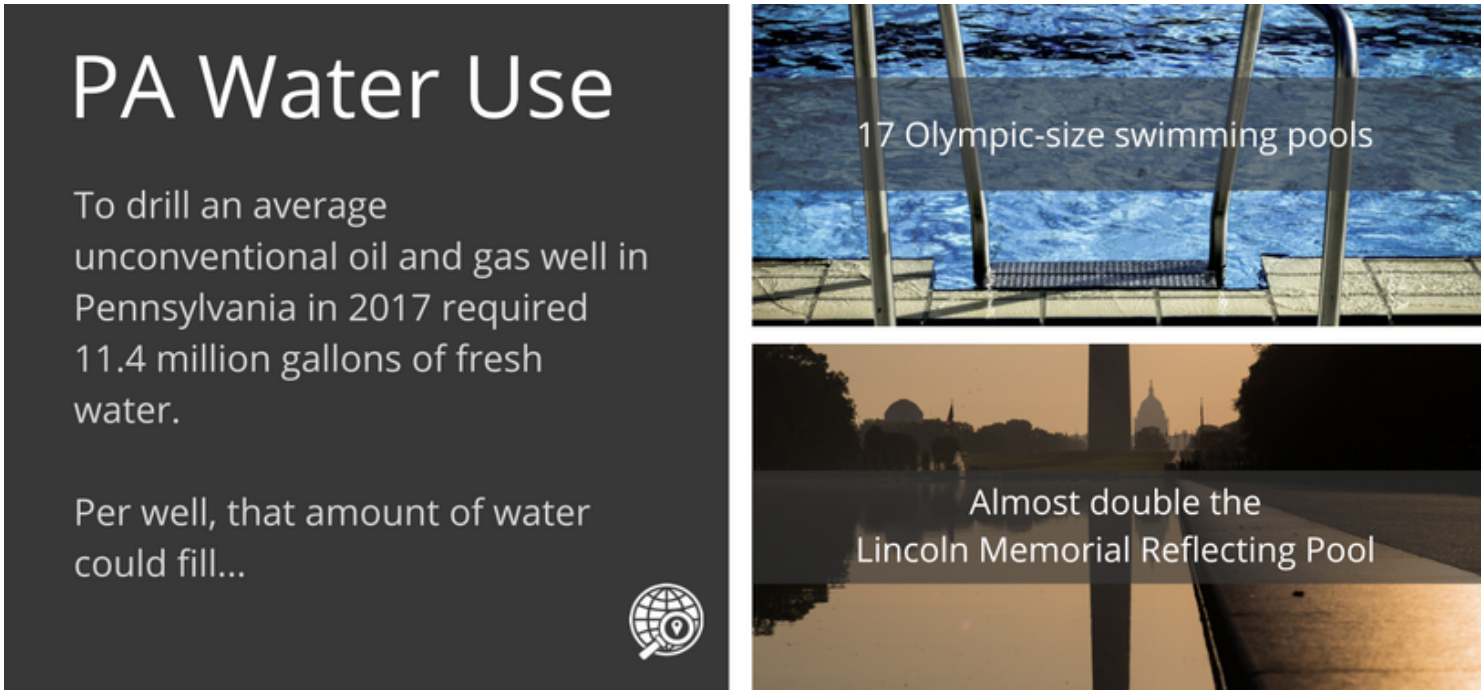
Water and Sand Use

According to self-reported data from FracFocus[20] – the industry's chemical registry – the average unconventional well in Pennsylvania required 11.4 million gallons of water in 2017, a 14% increase from the 10.0 million gallons used per well the year before. That much water could fill 17 Olympic-sized swimming pools. The cumulative impact of the O&G buildout would require 583 billion gallons of fresh water. In addition to the water needed, the sand required to prop open the hydraulically fractured fissures in the shale averaged 7,857 tons per well (for operators who reported their sand use) in 2017. One well reported using over 30,000 tons, easily eclipsing the previous record of 25,000 tons from a 2016 Haynesville Shale well in Louisiana. The LA well used so much proppant that the operator dubbed the well "propageddon," declaring, "What we're

[17] Kelso M. (2017). What is the Life Expectancy of the Marcellus Shale? FracTracker Alliance. https://www.fractracker.org/2017/10/life-expectancy-marcellus-shale/
[18] Cusick M. (2017). As pipelines alleviate natural gas glut, prices rise for producers in Northeast. StateImpact Pennsylvania. https://stateimpact.npr.org/pennsylvania/2017/08/17/as-pipelines-alleviate-natural-gas-glut-prices-rise-for-producers-in-northeast/
[19] Muhlenkamp & Company, Inc. (2013). The Financial Aspects of Marcellus Shale Drilling for the Landowner. http://www.freetochoosemedia.org/broadcasts/power_people/explore/shale_gas_and_landowner.pdf
[20] FracFocus. (2017). Data Downloads: http://fracfocus.org/data-download

doing is unleashing hell on every gas molecule downhole."[21] Cumulatively, 386 million tons of sand would be required for this industry into 2045.

The notable increase in water and sand quantities needed to stimulate unconventional drilling efforts in Pennsylvania corresponds with industry trends of drilling longer laterals (the portion of the well that extends horizontally from the mostly vertical portion of the well bore where the operator reaches the target formation). In 2017, one Marcellus Shale well in Washington County was drilled where the lateral portion reached 15,000 feet (2.8 miles) in length.[22] In neighboring Ohio, a Utica Shale well drilled the same year had a 19,500 foot (3.7 mile) long lateral portion.[23] If the trend of extra-long well bores continues, we can expect correspondingly increased demand on water and sand resources, even beyond the massive figures represented in the per-well figure below.



All of this sand and water, along with a variety of heavy machinery, pipes, chemicals, and fuel must be shipped to the drill site on trucks, while the brine, flowback fluid, drill cuttings, and other waste products must be hauled offsite, along with equipment that is no longer needed onsite. Even before the expansion in water and sand demands for longer well bores, the number of truck trips required per well is truly staggering. A 2012

[21] Carroll J, and Wethe D. (2016). Chesapeake declares 'propageddon' with record frac job. World Oil. http://www.worldoil.com/news/2016/10/21/chesapeake-declares-propageddon-with-record-frac-job
[22] Marcellus Drilling News. (2017). Range Resources Drills Longest Marcellus Well Ever – in Washington Co. http://marcellusdrilling.com/2017/06/range-resources-drills-longest-marcellus-well-ever-in-washington-co/
[23] Marcellus Drilling News. (2017). Eclipse Breaks Record Again – New Longest Shale Well in World! http://marcellusdrilling.com/2017/06/eclipse-breaks-record-again-new-longest-shale-well-in-world/

analysis estimated that 6,790 truck trips were required for a single well's development,[24] when lateral lengths averaged just 3,300 feet.[25] In our projection, then, this trend would calculate out to more than 323 million truck trips to drilling sites.

These figures represent the requirements for a single well, but unconventional O&G drilling in Pennsylvania typically uses multi-well pads. The number of wells per pad in the region is also increasing, including the 36-well Prentice pad being developed in Forward Township,[26] near the southern tip of Allegheny County. There could be some efficiencies with equipment on multi-well pads, but not always. It is common practice for operators to drill some but not all of their planned wells upon the development of the pad, for example, returning to the site as gas supplies and other economic variables dictate. For example, the R. Smith well pad in Washington County has had wells drilled on it in six different years since 2010, with a few of the wells still undeveloped as of November 2017.

Air Pollution

The tendency to return to develop wells means that the impacts of trucks on communities from a single pad can last for many years and may be larger than refineries on a macro level. These impacts transcend the nuisance of noise and traffic congestion, as particulates and volatile organic compounds from the diesel engines contribute both to short-term, high-intensity local and regional air pollution in the communities in which they operate.[27,28,29]

Truck traffic is only the starting point for the discussion of pollution generated by oil and gas development. We looked at national summaries of pollutants[30] that are often identified with oil and gas extraction and combustion from 12 related sectors (See Table 1):

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[24] Elected Officials to Protect New York. (2012). http://www.nyelectedofficials.org/wp-content/uploads/2012/11/Elected-Officials-Accompanying-Release-Documents.pdf

[25] Marcellus Shale. (2012). CONSOL Energy Reports Marcellus Shale Gusher. http://shale.typepad.com/marcellusshale/lateral-length/

[26] PA Department of Environmental Protection, Office of Oil and Gas Management. Well Pads Report Viewer (Database, searched for 2012). http://www.depreportingservices.state.pa.us/ReportServer?/Oil_Gas/Well_Pads

[27] Swarthout RF, Russo RS, Zhou Y, et al. (2015). Impact of Marcellus Shale Natural Gas Development in Southwest Pennsylvania on Volatile Organic Compound Emissions and Regional Air Quality, *ES&T*, *49* (5), 3175-3184.

[28] McCawley M. (2015). Air contaminants associated with potential respiratory effects from unconventional resource development activities. In *Seminars in respiratory and critical care medicine* (Vol. 36, No. 03, pp. 379-387). Thieme Medical Publishers.

[29] Goodman PS, Galatioto F, Thorpe N, Namdeo AK, Davies RJ, and Bird RN. (2016). Investigating the traffic-related environmental impacts of hydraulic-fracturing (fracking) operations. *Environment international, 89*, 248-260.

[30] Data source: National Emissions Inventory. NEI is a comprehensive and detailed estimate of air emissions of criteria pollutants, criteria precursors, and hazardous air pollutants from air emissions sources.

Table 1. 2014 National Emissions Inventory pollutants from natural gas sectors

Sector	Carbon Monoxide (Tons)	Benzene (Lbs)	Ethyl Benzene (Lbs)	Toluene (Lbs)	Xylenes (Lbs)	Formal-dehyde (Lbs)	PM_{10} (Tons)	$PM_{2.5}$ (Tons)	VOCs (Tons)
Bulk Gasoline Terminals Total	898	1,272,090	173,404	3,335,488	1,477,177	236	44	31	126,857
Fuel Combined Totals:									
Comm/Institutional - Natural Gas	120,916	182,731	6,248	109,057	28,155	1,040,116	6,312	6,086	10,628
Comm/Institutional - Oil	12,830	18,556	85	6,851	3,724	202,101	5,156	4,834	3,161
Electric Generation - Natural Gas	81,530	85,208	180,845	692,679	343,043	3,245,024	24,381	23,734	9,281
Electric Generation - Oil	9,656	12,611	3,095	22,979	7,132	96,250	8,212	6,991	1,718
Industrial Boilers, ICEs - Natural Gas	320,604	1,057,122	82,750	713,774	292,007	22,145,137	23,929	23,102	61,301
Industrial Boilers, ICEs - Oil	21,803	44,631	5,651	36,825	32,971	391,813	6,759	5,776	4,567
Residential - Natural Gas	95,101	124,376		58,780		581,960	3,848	3,597	13,330
Residential - Oil	9,185	1,670	29	881		123,762	4,285	3,732	1,170
Gas Stations Total	43	2,901,153	5,087,274	46,609,766	20,514,485	18	1	1	425,889
Industrial Processes - Oil & Gas Production Total	846,431	60,524,636	5,718,017	47,024,173	67,840,861	37,150,013	22,861	22,333	3,180,324
Industrial Processes - Petroleum Refineries Total	48,118	677,008	232,492	1,320,061	1,017,281	589,666	18,820	16,324	50,374
Percentage of O&G Production to Listed Sectors	**54.0%**	**90.5%**	**49.8%**	**47.1%**	**74.1%**	**56.7%**	**18.3%**	**19.2%**	**81.8%**
Production/Refinery Emission Ratio	**17.6 : 1**	**89.4 : 1**	**24.6 : 1**	**35.6 : 1**	**66.7 : 1**	**63.0 : 1**	**1.2 : 1**	**1.4 : 1**	**63.1 : 1**

This table includes: Gas stations (commercial and bulk terminal), electricity generation (O&G), residential use (O&G), industrial and commercial combustion (O&G), industrial boilers (O&G), oil and gas production, and refineries. Pollutants we assessed include carbon monoxide, particulate matter (PM_{10} and $PM_{2.5}$), the BTEX aromatics (benzene, toluene, ethylbenzene, and xylenes), and formaldehyde. The 2014 NEI does not contain values for carbon dioxide or methane for any of these sectors.

The oil and gas production sector topped the list nationally for each of these pollutants except for particulate matter (PM_{10} and $PM_{2.5}$), in which the sector ranked third behind electricity generation from natural gas and natural gas industrial boilers. The O&G production process accounted for over 90% of the benzene, almost 82% of volatile organic compounds (VOCs), 74% of xylenes, and more than half of all carbon monoxide and formaldehyde generated from these 12 sectors.

Emissions from oil and gas production were greater than emissions from refineries in every case, and dozens of times more for the BTEX aromatics and total VOCs.

These activities also contribute substantially to climate change, primarily through the addition of the greenhouse gasses carbon dioxide and methane to the atmosphere. The US Environmental Protection Agency's (EPA) greenhouse gas inventory[31] estimates that petroleum systems emitted 1,595 kilotonnes (kt, or 84 billion BTUs) of methane in 2015, and that natural gas systems account for an additional 6,497 kt (342 billion BTUs). These figures largely represent leaks, venting, flaring, fugitive emissions from wells, and engine emissions from equipment at the production site for petroleum systems. Natural gas systems are similar, but also produce significant emissions from processing, transmission and storage, and distribution processes.

Land Disturbance

Another factor to consider with the industrial-scaled unconventional gas extraction in Pennsylvania is the amount of land that is disturbed in the extraction and transmission processes. A 2014 report by the Nature Conservancy[32] suggests that the average amount of land that needs to be cleared for the average well pad is 28 acres, including 3 acres for the pad itself, 19 acres of gathering pipelines to connect the gas wells into the existing gas transmission network, and the remaining 6 acres for access roads, equipment, and storage for supplies and waste streams. For Pennsylvania's 3,733 unconventional well pads as of November 28, 2017, this adds up to about 104,500 acres impacted by wells statewide.

[31] US Environmental Protection Agency (EPA). (2017). Inventory of U.S. Greenhouse Gas and Emissions Sinks (1990-2015). Report. https://www.epa.gov/sites/production/files/2017-02/documents/2017_complete_report.pdf

[32] The Nature Conservancy (2014). Land Use and Ecological Impacts From Shale Development in the Appalachians, Summary Statement for DOE Quadrennial Energy Review Public Stakeholder Meeting Pittsburgh, PA July 21, 2014 https://energy.gov/sites/prod/files/2014/07/f17/pittsburg_qermeeting_minney_statement.pdf

Since natural gas must be connected with a pipeline network, we should also factor in the rights-of-way for 87,125 miles of existing transmission and distribution lines.[33] A typical permanent pipeline right of way is 50 feet wide, meaning 6.06 acres of land must be permanently cleared per linear mile, for a total of 527,978 acres statewide (larger than the acreage of Allegheny County, PA). Additional pipelines will be required to get the natural gas and associated liquids to market. FracTracker is aware of 1,112 miles of these projects to be completed in the near term, accounting for 6,739 additional acres of impact, a number that is likely to grow substantially in the coming years.

Between the existing and proposed pipelines and well pads, we estimate the total permanent land disturbance for the oil and gas industry in Pennsylvania would be 797,529 acres. This is an area greater than the combined size of Allegheny, Delaware, Montour, and Philadelphia counties.[34]

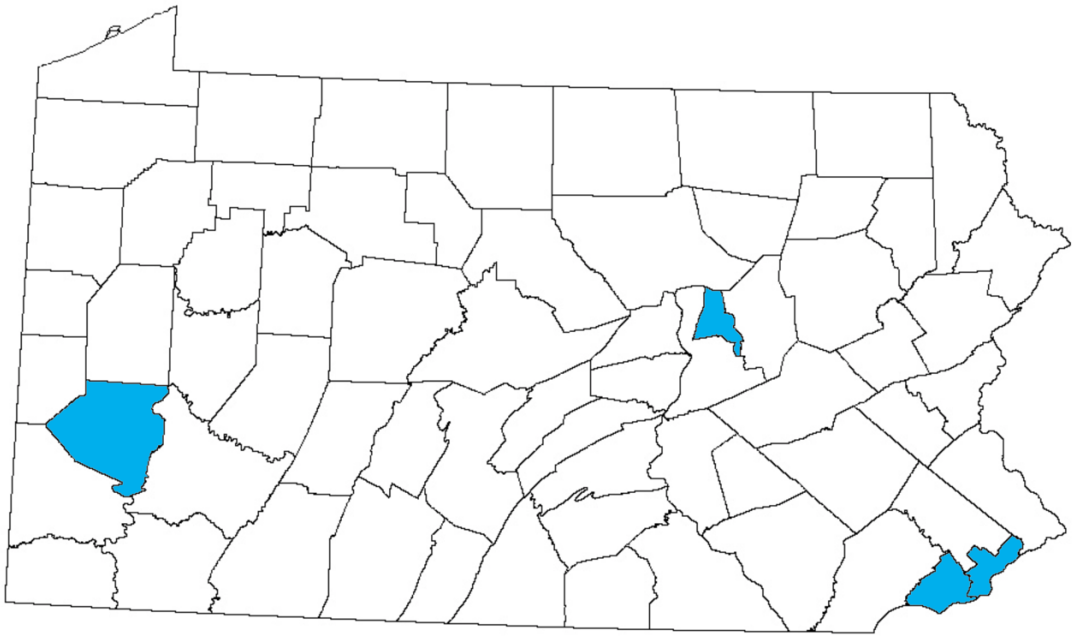

Figure 6. Portrayal of permanent land disturbance from Marcellus Shale gas drilling and O&G pipelines in PA by 2045 – Equates to ~800,000 acres, combined size of Allegheny, Montour, Delaware, and Philadelphia counties (left to right).

[33] Pipeline and Hazardous Materials Safety Administration (PHMSA). (2017). Pipeline Mileage and Facilities. https://www.phmsa.dot.gov/data-and-statistics/pipeline/pipeline-mileage-and-facilities

[34] National Association of Counties. "NACo - Find a county". Archived from the original on October 25, 2007. Retrieved 2008-04-30. (via Wikipedia) https://web.archive.org/web/20071025112341/http://www.naco.org/Template.cfm?Section=Find_a_County&Template=%2Fcffiles%2Fcounties%2Fstate.cfm&state.cfm&statecode=PA

Waste Production

In 2016, unconventional wells in Pennsylvania generated more than 1.7 billion gallons of liquid waste and 588,000 tons of solid waste.[16] These numbers work out to 216,000 gallons of liquids and 54 tons of solids per well, per year. By 2045, Pennsylvania's 55,082 total Marcellus Shale wells[2] will have generated about 131 billion gallons of liquid waste and 45 million tons of solid waste.[35]

To put these numbers into perspective, 131 billion gallons exceeds ten days' worth of average flow in the Allegheny River.[36] Comparatively, 45 million tons is equivalent to the weight of 200,000 Statues of Liberty.[37]

A Better Path Forward: Renewables Potential

Projections based on what the industry is capable of producing is not the same as predicting what is likely to be consumed in the future. To reach the target of 47,600 new unconventional wells by 2045, the drilling industry would have to drill an average of 1,636 wells per year, a feat accomplished only once so far, in the peak year of 2011. Nonetheless, if we use the industry estimate of 47,600 new wells and assume a lifetime well production between 4 and 8 bcf,[38] the average annual production from the Marcellus in Pennsylvania would be between 6.3 and 12.6 trillion cubic feet per year through 2045, not counting wells drilled prior to 2015 or unconventional wells from other formations, such as the Utica.

We must ask, however, is there a need for all of this gas? What about the potential for renewable energy in Pennsylvania?

We know Pennsylvania consumed 1,344 trillion Btu's of natural gas in 2015,[11] or about 1.3 trillion cubic feet. Even if the industry were able to extract these lofty sums of gas in the coming decades, finding a demand for the tremendous supply would require a sustained industry effort, through new

[35] Assuming a conservative 11-year life cycle for unconventional wells
[36] US Geological Survey (USGS). (2009). https://wdr.water.usgs.gov/wy2009/pdfs/03049500.2009.pdf - 19,750 ft^3/s at the village of Natrona, PA
[37] The Statue of Liberty - Ellis Island Foundation. (n.d.). Statue facts. Retrieved Jan. 3, 2018. https://www.libertyellisfoundation.org/statue-facts
[38] Penn State Extension (2017). Natural Gas Production Decline Curve and Royalty Estimation https://extension.psu.edu/natural-gas-production-decline-curve-and-royalty-estimation

petrochemical and gas fired power plants, as well as a seemingly endless network of pipelines to move the product to different markets. An oversupply from Pennsylvania would compete with other hydrocarbon-producing areas, both locally within the Appalachian basin, as well other major supply centers like Texas.

All of this infrastructure buildout is happening at a time when renewable energy is flourishing. Both wind and utility-scale solar power are already cheaper per unit of power than natural gas after removing all energy subsidies.[39] On an even brighter note, these renewables don't contribute air or water pollution beyond the manufacture of the components. And while Pennsylvania doesn't have the solar potential of Arizona, it still has great promise. The state is sunnier than Germany,[40] for example, which generated 6.9% of its power from solar in 2014, compared to less than 1% for Pennsylvania.

The National Renewable Energy Laboratory (NREL) estimated that every 2.8-acre array of fixed-axis photovoltaic solar energy panels can power 1,000 homes.[41] If the existing and proposed cleared land for well pads and pipelines (797,529 acres) in Pennsylvania were instead used for industrial-scaled solar power plants, the land could provide enough electricity for 285 million homes per year!

If all land to be used for oil and gas infrastructure in PA was used for solar energy instead, each year enough electricity would be produced to power all 136 million homes in the U.S. for more than two years.

We could do a similar exercise with wind power, although many areas with drilling and pipelines would not be suitable location for wind development. Still, the US Department of Energy has calculated that Pennsylvania could produce 184,000 gigawatt hours from wind power,[42] enough to

[39] Shahan, Z. (2016). Low Costs of Solar Power & Wind Power Crush Coal, Crush Nuclear, & Beat Natural Gas. Clean Technica. https://cleantechnica.com/2016/12/25/cost-of-solar-power-vs-cost-of-wind-power-coal-nuclear-natural-gas/
[40] World Bank Group (2016). Global Solar Atlas. http://globalsolaratlas.info/?c=35.675147,-24.257813,3
[41] Montgomery J. (2013). Calculating Solar Energy's Land-Use Footprint. Renewable Energy World. http://www.renewableenergyworld.com/articles/2013/08/calculating-solar-energys-land-use-footprint.html
[42] U.S. Department of Energy. (2017). WINDExchange initiative. https://windexchange.energy.gov/maps-data/321

provide electricity for 17.7 million Pennsylvania homes,[43] or more than three times the number of homes that actually exist in the Commonwealth as of 2016.[44]

Realistically, we are not going to get all of our energy from solar and wind power in the near future, and there are some industrial applications where renewables cannot yet compete with hydrocarbon consumption, such as the production of plastics. There are still challenges with energy storage and inconsistent supply from renewables, as well.

However, it is unfortunate that while other states and countries are focusing on making their energy portfolios as clean as possible, Pennsylvania is planning to double down on fossil fuel combustion for the foreseeable future. While the economics of modern energy production makes renewable choices more affordable, Pennsylvania's policy decisions are not keeping up, granting huge subsidies to drillers and petrochemical plants, which will continue to impact the water we drink and the air we breathe. Pennsylvania has been an energy leader in the United States for centuries, but will find itself entrenched in fossil fuels while our neighbors move forward with cleaner, healthier options.

[43] EIA (2009). Household Energy Use in Pennsylvania. https://www.eia.gov/consumption/residential/reports/2009/state_briefs/pdf/PA.pdf
[44] U.S. Census Bureau. (2016). QuickFacts Database. https://www.census.gov/quickfacts/PA

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1845 Market St, Ste. 204,
Camp Hill, PA 17011
(717) 303-0403
info@fractracker.org
www.fractracker.org
@FracTracker

FracTracker Alliance studies, maps, and communicates the risks of oil and gas development to protect our planet and support the renewable energy transformation. For more information on this work and others by FracTracker Alliance go to: www.fractracker.org.

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Analysis: Matt Kelso
Edits: Brook Lenker, Samantha Rubright, and Kirk Jalbert
Layout/Graphics: Samantha Rubright
Cover Image: Ted Auch
FracTracker Alliance