Natural Gas Pipeline Methane Leaks

Air Sampling and Technology Review Findings

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Accufacts Inc.
"Clear Knowledge in the Over Information Age"

Drexel University

CLEAN AIR COUNCIL

Introduction

Since 2008, Pennsylvanians have witnessed a large expansion in Marcellus Shale gas drilling, processing, and transportation. As the second largest producer of natural gas in the nation, Pennsylvania has been at the forefront of the natural gas rush. While there was a drop in new wells in Pennsylvania last year, mostly due to low gas prices, there continues to be a steady number of proposals for large-scale transmission pipeline projects designed to transport shale gas and byproducts, such as natural gas liquids.

To transport the gas and byproducts, many companies have focused on constructing or upgrading interstate and intrastate pipelines. Constructing pipelines results in extensive tree clear-cutting, the taking of private property through eminent domain, air pollution, and impacts on wetlands and rivers.[1] With pipelines come compressor stations and pumping stations, facilities which are needed to pressurize and filter the transported gas and byproducts. These facilities themselves can be significant sources of air pollution.

When natural gas transmission pipelines or expansion projects are proposed, it is crucial that the public have access to the technical information they need to meaningfully participate in opportunities for public comment. Public participation can help ensure that safety, health and environmental protections are prioritized and being adequately considered. Providing data and information about pipeline technology can strengthen the quality of public participation in public meetings, public hearings, and commenting opportunities which will result in a more critical regulatory review of a project.

Once operating, natural gas pipelines, and related infrastructure, produce fugitive emissions of methane and other hydrocarbons, but the number and amount of leaks occurring along various parts of the natural gas sector, including transmission pipelines, is largely unknown.

Multiple studies, including Environmental Protection Agency ("EPA") publications, have concluded that oil and gas leak rates are often higher than the federal government estimates that

[1] CAN, *Cumulative Land Cover Impacts of Proposed Transmission Pipelines in the Delaware River Basin* (2016), available at https://www.cna.org/news/releases/2016-06-01.

rely on "sparse data, incorrect assumptions, or both."[2] A study from the University of Texas found that updated data and simulations calculated emission rates 1.5 times greater than the EPA Greenhouse Gas ("GHG") Inventory, 2.7 times greater than the EPA GHG Reporting Program, and 4.3 times greater than the Emissions Database for Global Atmospheric research.[3] Many of the new data and simulations included equipment leaks and super-emitter sites; those sites that emit the highest amounts of methane compared to the amount the site produces.[4] Other studies have stated that "effective national and state greenhouse gas reduction strategies may be difficult to develop without appropriate estimates of methane emissions."[5] U.S. natural gas infrastructure is also aging, providing new potential avenues for leaks if not properly maintained. Some pipelines and compressor stations are operating using 30 to 50 year old equipment.[6] Having more reliable data on natural gas infrastructure emissions and leaks would be beneficial for industry in terms of leak detection and repair, but would also inform local and state decision-makers when assessing a proposed natural gas pipeline project.

Meanwhile, state and federal regulations are playing catchup. There are no mandatory leak detection and repair ("LDAR") requirements for natural gas and byproducts pipelines. For compressor stations, recently published EPA regulations require quarterly LDAR at new facilities. In Pennsylvania, state regulators are currently revising air permitting requirements to — in part — extend improved air pollution requirements to new transmission sector compressor stations. However, at compressor stations already in operation, LDAR is generally not required. In addition, pumping stations are not subject to a uniform set of air regulatory standards, leaving them similarly under-regulated.

Air pollution from gas transmission has the potential to impact air quality and, consequently, public health. When methane is leaked from gas infrastructure, it can be accompanied by toxic air pollutants that pose a risk to the health and safety of nearby residents. As regulatory

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[2] U.S. Environmental Protection Agency, *Estimate of Methane Emissions from the U.S. Natural Gas Industry*, available at http://www3.epa.gov/ttnchie1/ap42/ch14/related/methane.pdf .
[3] David R. Lyon, et al., *Constructing a Spatially Resolve Methane Emission Inventory for the Barnett Shale Region*, Environ. Sci. Technol. 2015, 49, 8147−8157, available at http://pubs.acs.org/doi/pdf/10.1021/es506359c .
[4] Id.
[5] Scott M. Miller, et al., *Anthropogenic Emissions of Methane in the United States*, PNAS December 10, 2013 vol. 110 no. 50 20018-20022, available at http://www.pnas.org/content/110/50/20018.abstract
[6] Interstate Natural Gas Association of America, *Interstate Natural Gas Pipeline Efficiency* (2010), available at http://www.ingaa.org/file.aspx?id=10929 .

requirements continue to evolve, it is crucial to better monitor and quantify methane emissions, and to evaluate the technology and practices used for emission reduction.

Executive Summary

In 2015, Clean Air Council (the "Council") contracted experts, Accufacts Inc. and Drexel University, to sample air quality near natural gas pipelines and also to assess the adequacy of the U.S. Environmental Protection Agency-recommended pipeline and compressor station technologies**.** Accufacts and Drexel's reports can be found in full in the following sections.

Drexel University conducted ground-based mobile methane measurements for five days. These continuous measurements targeted compressor stations, metering stations, and road crossings along the Transcontinental Pipeline and Tennessee Gas Pipeline in Northeastern Pennsylvania. Leak rates were assessed using EPA OTM33a method. Leak rates were found to be consistent with results observed by other studies for compressor and metering stations. Well pads were observed to have larger emissions than previously measured, up to ten times as much as found in other studies. The local background methane levels were found to have increased significantly since a similar analysis was completed by Drexel in 2012. Within 100 meters from pipelines, nearly 18% of methane measurements above current background concentration were due to pipeline related infrastructure.

In its Natural Gas STAR Analysis for the Council, Accufacts Inc. found that various methods of leak detection and repair are available to natural gas companies in order to further reduce fugitive methane and hydrocarbon emissions from leaks in natural gas infrastructure. Accufacts' recommended Aerial and Ground-Level Laser Methane Assessment ("[A]LMA") as the preferred method of methane leak detection and repair. This method has been well-established and is currently used by industry and academia for leak detection. However, the Natural Gas STAR Program does not mention ALMA as an effective means of leak reduction and, as a result, EPA did not perform a cost analysis for this method, nor explain how it could be effectively implemented. In its report, Accufacts also scrutinized the effectiveness of a voluntary program, especially due to the volatility of energy markets and the recent downward trend in natural gas pricing.

The reports separately illustrate both the problem of methane leakages, but also the potential opportunities for quickly reducing methane from natural gas transmission pipelines. While background levels of methane in northeast Pennsylvania have risen in recent years, with notable increases near pipelines, there are also best practices and technologies to detect and prevent future methane leaks from occurring and reduce leaks in older infrastructure. However, due to the fluctuating price of natural gas, it is unclear if these technologies will be implemented in a timely manner without further requirements to do so.

Results from the Drexel University 2015 measurements: methane emission rates from natural gas transmission sites in Northeastern Pennsylvania and other observations

Goetz, J. D., Werden, B., Avery A., DeCarlo, P.F.*

*Contact: pfd33@drexel.edu

Department of Civil, Architectural, and Environmental Engineering and Department of Chemistry at Drexel University

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Dr. Peter DeCarlo is an Assistant Professor with a joint appointment in the Department of Civil, Architectural, and Environmental Engineering, and the Department of Chemistry at Drexel University. Dr. DeCarlo has a Ph.D. in Atmospheric Science from the University of Colorado, and a BS in Biochemistry from the University of Notre Dame. He uses state-of-the-art instrumentation to measure the chemical composition of particulates and gases in the atmosphere to better understand air quality and climate impacts of human emissions. He has made air quality and climate-related measurements from planes, trucks, and stationary sites all over the world to better understand emissions, sources, and subsequent chemical reactions of pollutants in the atmosphere. Dr. DeCarlo also is interested in the intersection of science and policy, and was an AAAS Science Policy Fellow at the US EPA prior to starting his faculty position at Drexel. Recently, Dr. DeCarlo has been identified as a highly cited researcher by Thompson Reuters (2014, 2015).

Overview

Natural gas is a globally important fossil fuel. In the United States, natural gas comprised a 27% share of the total primary energy consumption in 2013 with large demand from the electric power industry, chemical industry, and residential use (EIA, 2015). The recent development of unconventional natural gas resources like gas rich tight sandstone, coal, or shale has dramatically increased the domestic production potential due to advances in extraction technology (Kargbo et al., 2010). The extraction of unconventional natural gas resources has raised both air quality and climate concerns due to the emissions of air pollutants (i.e. volatile organic compounds, particulate matter, carbon monoxide, nitrogen oxides) and climate forcing compounds (i.e. methane and carbon dioxide) (Field et al., 2014). With the increase in domestic production and subsequent decrease in price of natural gas coupled with changes in environmental regulations the demand for natural gas by the electrical power sector has increased over the past decade and is projected to increase with the decline of coal-fired power generation (EIA, 2015). Additionally, the Energy Information Administration (2015a) projects that the use of compressed and liquefied natural gas in the transportation sector will increase 10% annually in the coming decades. Natural gas is known to be cleaner burning than other fossil fuels (de Gouw et al., 2014), and therefore generate less air pollutants and climate forcing compounds per unit of fuel burned. However, the air quality and climate impacts of natural gas production and transmission are not well understood. Because of the high global warming potential of methane (the largest component of natural gas), the clean emission benefits of natural gas combustion can be minimized by leaks throughout the natural gas system. Additionally, uncertainty in natural gas leak rates has generated underestimations in "bottom-up" emission inventories compared to "top-down" approaches (Brandt et al., 2014). The uncertainty in natural gas leak rates demonstrates the need for methane emission rate measurements throughout all natural gas sectors in the United States.

In the Appalachian region, the development of the Marcellus Shale, the most productive unconventional natural gas resource in the United States (EIA, 2016), coupled with increased demand throughout the United States has necessitated improvements and upgrades to the natural gas gathering and transmission infrastructure in the region. The transmission infrastructure includes high pressure pipeline, metering facilities, and large compressor station facilities used to transmit natural gas long distances from production areas to end-use distribution networks (US Environmental Protection Agency, 2015). Emissions of methane, the primary constituent of natural gas, from fugitive leaks or venting from pneumatic controllers have been reported from pipelines and its associated infrastructure (US Environmental Protection Agency, 2015). Methane emissions have also been attributed to uncombusted engine exhaust and other sources at compressor stations (Subramanian et al., 2015). Additionally, compressor stations have been reported to emit EPA regulated criteria pollutants such as carbon monoxide (CO) and nitrogen dioxide (NO_2) (Goetz et al., 2015).

The addition of pipelines and increased compressor power to transmission infrastructure in the Appalachian region, as proposed by several pipeline expansion plans such as the Leidy Southeast Expansion, Leidy South Project, the Atlantic Sunrise Project, and Constitution pipeline, is expected to increase the emissions of methane and other pollutants in the region. In the summer of 2015 ground-based mobile measurements of methane were conducted to investigate atmospheric emissions from transmission infrastructure located in the Marcellus Shale dense region of Northeastern Pennsylvania. The measurements were conducted to fulfill the following objectives:

- Estimate the emission rates from sources in the natural gas transmission sector in the Marcellus region with an underlying goal of investigating sites that have undergone or will undergo upgrades due to expansion projects
- Quantify leaks from transmission pipelines at opportunity road crossings in the Marcellus shale region
- Understand background concentration levels throughout the Marcellus Shale region
- Estimate emission rates at opportunity sites[1] associated with Marcellus Shale production and gathering

[1] These are sites that meet or exceed the minimum requirements for emission rate

Another objective of the study was to identify differences in methane emissions between transmission sites with new technology (recently upgraded) and old technology (not upgraded or soon to be upgraded). However, it was determined that the objective could not be adequately achieved because of the difficulty of isolating the influence of upgrades at transmission stations when significant differences in other factors like natural gas throughput and site operation exist between the sites. Because the objective could not be achieved the methane emission rate results provided in this work should be considered baseline values that can be used in future work to characterize changes in emissions at individual sites after upgrades are complete or used to understand how emission rates change as the natural gas infrastructure ages. The methodology used to complete the above objectives, the sampling plan, and results from the measurements will be presented in the following sections.

August 2015 Sampling Plan

To complete the above objectives the Drexel Mobile Lab conducted ground-based mobile measurements of methane at targeted transmission related sites and throughout Northeastern Pennsylvania within the Marcellus Shale basin. Measurements took place for 5 days in August 2015 and continuous measurements were made throughout each day. Figure 1 displays the sampling track of the DML and location of the sites investigated.

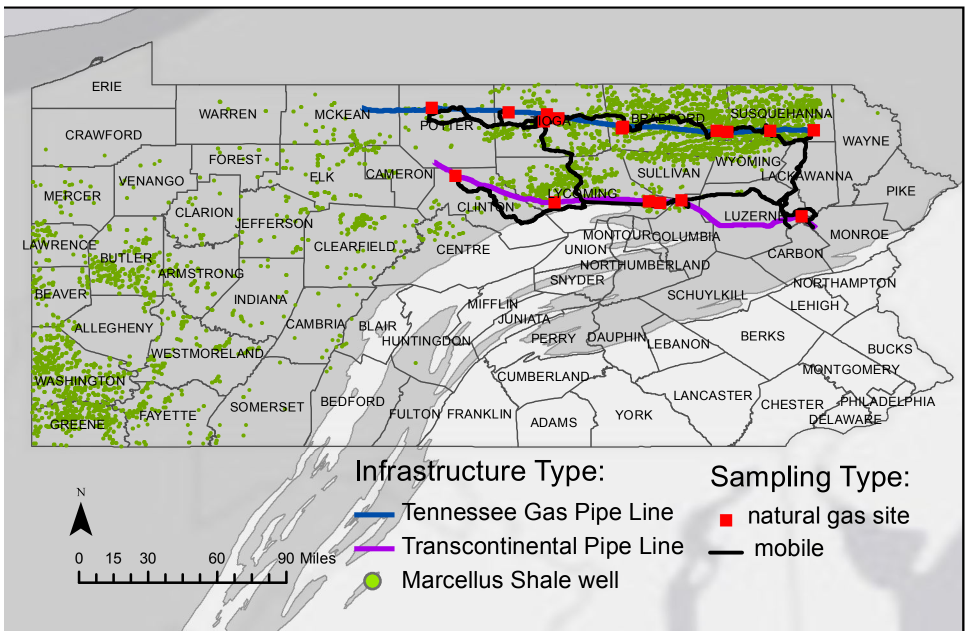

Figure 1. Map of Pennsylvania overlaid with the Marcellus Shale basin (gray), permitted unconventional wells in Pennsylvania (green), transmission pipelines within sampling area, mobile sampling track (black), and the location of sites sampled for methane emissions testing (red)

Natural gas transmission-related sites located on the Transcontinental Pipe Line (Transco) and the Tennessee Gas Pipe Line (TGP) were the primary focus of the sampling plan. Compressor stations, meter stations, and pipeline road crossing were the major types of infrastructure investigated. Facilities on the Transco and TGP were studied for the following reasons:

- Both pipelines are the major transmission lines found in Northeastern PA within the Marcellus region
- Both pipelines transport Marcellus Shale produced gas and service distribution networks along the East coast of the United States
- The Transco Pipeline was part of the Leidy Southeast expansion project, which included plans for new pipeline loops, upgrades to the compressor power at several compressor facilities (stations 515, 517, 520), and modifications to metering stations within Northeastern PA with a projected in-service date of December 1, 2015 (Transcontinental Gas Pipe Line Company, 2013)
- The TGP was proposed to be part of the Kinder Morgan Northeast Direct Energy Project that included the addition of new compressor stations in Northeastern PA, modifications to an existing station (TGP 319) and additional pipeline loops (Dominion Transmission, 2015)
- Methane emission estimates will be made prior to the projected start date for these projects and other future projects providing an emission baseline that represents lower capacity facilities or older infrastructure.

Another natural gas transmission site investigated was a large site in Clinton County, which contained the newly built Dominion Frinnefrock compressor station and the Dominion Leidy natural gas storage facility. The Frinnefrock station is part of the Dominion Leidy South project; however, based on contact with operators at the time of sampling the Frinnefrock facility was not operational (on standby) while sampling took place (Dominion Transmission, 2015).

In addition to sampling at facilities associated with natural gas transmission the DML was also used to estimate emission rates at sites associated with Marcellus Shale natural gas production and gathering. The Marcellus Shale sites were considered "opportunity sites" because they were not part of the pre-defined sampling plan and instead were sampled if encountered while in transit to transmission sites and the topographical and meteorological conditions were conducive to downwind sampling. Table 1 provides information on the name (if known), location, site type, operator, and associated pipeline of the transmission and Marcellus Shale sites investigated in August of 2015.

Table 1. Name, Operator, and location of sites investigated.

site type	name	operator	county	latitude (DD)	longitude (DD)
compressor station	515	Transco	Luzerne	41.1724	-75.6725
	517	Transco	Columbia	41.2719	-76.4300
	520	Transco	Lycoming	41.2599	-77.2291
	Leidy*	Dominion	Clinton	41.4284	-77.8515
	313	TGP	Potter	41.8532	-78.0008
	315	TGP	Tioga	41.8137	-77.2789
	317	TGP	Bradford	41.7388	-76.7976
	319	TGP	Bradford	41.7067	-76.2087
	321	TGP	Susquehanna	41.7116	-75.5990
	Tuesa-Thomas	Talisman	Bradford	41.7255	-76.8051
	Teel	Williams	Susquehanna	41.7107	-75.8716
meter station	unknown -1	Transco	Lycoming	41.2656	-76.6384
	unknown -2	TGP	Tioga	41.8273	-77.5201
	unknown -3	TGP	Bradford	41.7035	-76.1422
well pad	Buck	XTO	Lycoming	41.2595	-76.5659
	Nestor	SWEPI	Tioga	41.7688	-77.2981
	Sampson	SWEPI	Tioga	41.7893	-77.2050

* The Leidy facility includes Dominion Leidy Storage and the Frinnefrock compressor station

Methodology

The Drexel Mobile Lab (DML) was used for stationary ambient monitoring of methane downwind of the investigated sites and to perform mobile surveying around the sites to locate emission plumes and determine background concentrations. When applicable, the data collected at each site were used to estimate point source emissions by the method described in the EPA Other Test Method 33a (OTM-33a) (Thoma, 2014). In addition to ambient monitoring at the listed natural gas sites, mobile measurements were made between sites to evaluate leaks from pipelines and other natural gas infrastructure, and to characterize local-background concentrations of methane within the sampling track found in Figure 1. The following sections provide information about the instrumentation utilized on the DML and a brief description of OTM-33a.

Instrumentation

The DML is a late 1990s Ford cargo van that is equipped for gas-phase and particle-phase ambient mobile monitoring. The platform is modular in design and allows for the installation of any combination of instrumentation using a shock-mounted military grade 19-inch rack. When mobile, the instrumentation is powered through the vehicles alternator and a 2000-watt DC to AC power inverter. When stationary, the instrumentation is powered by a 1000-watt gasoline powered generator placed >100 feet downwind of the DML. The inlet system is adaptable to the instrumentation and for this study non-reactive PTFE tubing was used. The inlet was attached to PTFE gooseneck positioned in front of the vehicle and at a height of ~2 meters. The inlet was positioned to be outside the boundary layer of the vehicle. The gas-phase inlet was equipped with inline Teflon disc filters to remove particulate contamination. The inlet flow rate is adjustable based on excess flow and for this study was set to a fixed flow rate that provided an inlet residence time of ~1 second.

Data collection focused on methane measurements made using a Picarro Inc. Cavity Ring Down Spectrometer (CRDS) model G2401. The CRDS has a sampling rate of ~1 Hz and the mobile detection limit for methane was estimated to be <1 ppbv. The CRDS was factory calibrated prior to the measurement campaign and dilution calibrations were performed at the end of the campaign. The multi-point dilution calibrations were completed by using zero air and a custom calibration standard of methane, CO, and CO_2 balanced with N_2 produced by Airgas Inc. (Radnor, PA). The calibrations determined that the CRDS measured ~6.5% low for the campaign compared to the calibration standard for a span up to 5 ppmv for methane. All campaign measurements were adjusted to reflect the calibration results.

Ancillary instrumentation included a 1 Hz GPS, providing geopostioning with <5m precision, and a Davis Vantage Vue weather station. The weather station was fixed on the DML when conducting stationary sampling at a height of ~2.5 meters and within a meter of the inlet opening. The weather station provided wind speed, wind direction, temperature, and relative humidity data at each site at sampling rate of ~1 Hz.

Emission Rate Calculation

Methane emission rates were calculated using the EPA OTM-33a (Thoma, 2014). The method utilizes fast-response instrumentation and Gaussian dispersion principles to estimate emissions rates of a point source from a roadside sampling location. At each site, the sampling location was chosen based on several survey loops in which elevated methane concentrations found in the bearing of the prevailing wind were assumed to be part of the emission plume from the site. Each survey loop utilized the closest accessible up-wind and down-wind roads around the tested site to find the position of the emission plume, to determine if interferences exist from other sources, and to establish the background concentration outside of the emission plume. Once the location of the emission plume was determined the DML was positioned on the nearest downwind road within the plume and remained stationary within the plume for 20 to 60 minutes. Sampling locations ranged between 80 to 400 meters of the emission source at the tested sites based on estimates from satellite imagery, though at large sites with multiple emission sources the downwind distance was approximated to the center of the site.

The data collected from within each plume was used in conjunction with collocated wind measurements to determine the average peak concentration within the plume based on a Gaussian distribution (Brantley, 2014). Methane concentrations were binned by the wind direction data in ten degree increments, which was converted into polar coordinates based on the prevailing wind direction (Figure 2). A Gaussian function was fit to the results for each site plume and the average peak concentration was used to calculate the emission rate using a simplified 2-dimension Gaussian dispersion equation (eq. 1) (no reflection). In equation 1 Q is the emission rate in grams per second (g/s), μ is the mean wind speed during stationary sampling (m/s), C is the peak average concentration, σ_z is the vertical dispersion coefficient (m), and σ_y is the horizontal dispersion coefficient (m) (Thoma, 2014, Brantley, 2014).

$$Q = 2\pi\sigma_y\sigma_x\mu C \quad (1)$$

The horizontal and vertical dispersion coefficients were calculated using equation 2 for rural dispersion, which is a function of the downwind distance (x) and constants I, J, and K that are derived from a look-up table that corresponds to the estimated Pasquill stability class (Beychock, 2005).

$$\sigma = \exp\left[I + J(\ln x) + K(\ln x)^2\right] \quad (2)$$

The Pasquill stability class for each plume was estimated using the wind speed, standard deviation of the wind direction, and degree of solar insolation. Generally, because measurements were made during the day, and each sampling day had strong solar insolation, the Pasquill stability class was typically estimated to be B or C.

For each plume, error was calculated based on the propagation error from the Gaussian function fit of the binned concentrations, uncertainty in downwind distance determined by the site radius, and variability in wind speed. All data processing and analysis was performed using Igor Pro 6.37 (Wavemetrics, Lake Oswego, OR). A more detailed discussion of the methods used can be found in Brantley et al. (2014) and Thoma and Squier (2014).

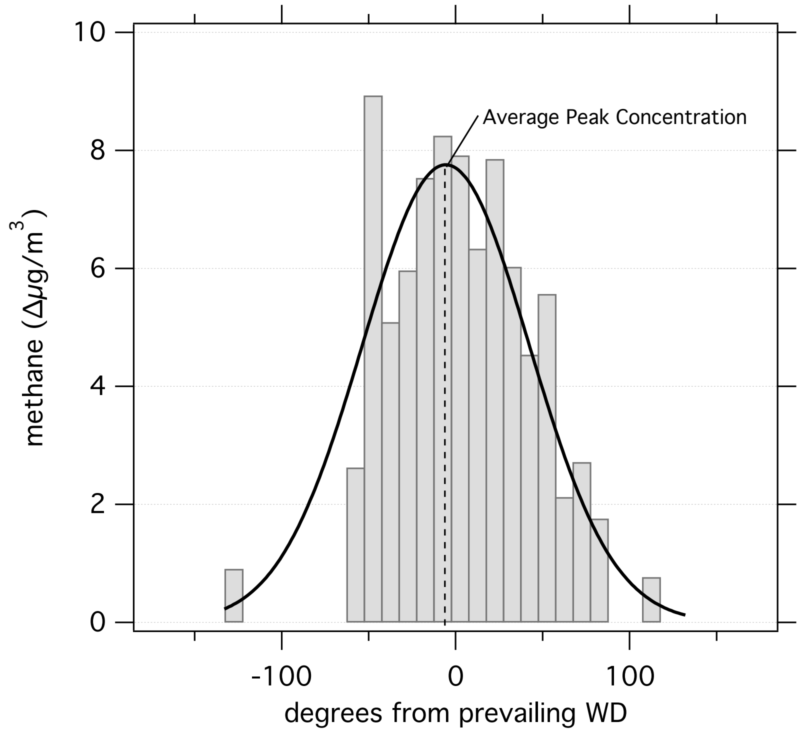

Figure 2. Excess methane concentrations observed at the Buck Well Pad after 25 minutes of sampling binned by degrees from prevailing wind direction and fit with a Gaussian function.

Methane Emission Rates

The calculated methane emission rates from the investigated sites can be found in Table 2. The downwind distance, average wind speed, and average peak concentration observed at each site can also be found in Table 2. Emission rate estimates are not available for several of the sites investigated including Transco 515, Transco 517, Teel compressor station, and meter station 2. Generally, emission rates at these sites could not be calculated because the topography or the road network at the site was not compatible for plume measurements because of unfavorable wind direction. Transco 515 and 517 for example had few available downwind roads given the prevailing wind direction on that sampling day and no methane plumes were encountered near the site. A site-type based discussion and overview of results can be found in the following sections. It should be noted that the uncertainty in all of the emission rate estimates is substantial primarily due to the propagated error from uncertainty in the exact location of the major methane emission source at each site. Because site radius was used to approximate uncertainty in downwind distance at each site, distinguishing the location of the largest on-site emission source (by FLIR camera or other method) would significantly reduce any spatial uncertainty in future measurements by removing the need to include a large range of downwind distances in the final emission rate uncertainty calculation.

Compressor Stations

The transmission compressor stations investigated were found to have a large range of methane emission rates with the lowest rates observed at TGP 319 (0.18 g/s) and the largest emission rate at TGP 313 (23.22 g/s) and a mean emission rate of 7.5 g/s. All transmission compressor stations except for TGP 319 were estimated to have methane emission rates within the range of emissions observed by Subramanian et al. (2015) of 0.544-281 g/s, though generally skewed to the lower range of the study. The low emission rate at TGP 319 is significantly lower than previous measurements at the site by Goetz et al. (2015), which estimated a methane emission rate of 4.75 ±1.69 g/s in 2012 using different methods. The inconsistency between this study and Goetz et al. (2015) could be due to different operational states, fixed leaks, or due to differences of methods. Additionally, the very low wind speeds and long downwind distance at TGP 319 could have added additional error to the 2015 measurement. The Leidy Storage facility was found to have the second highest emissions of the study at 16.24 ±19.09 g/s. Operation of the proximal Frinnefrock facility is expected to increase methane in the area. An analysis of the type and quantity of infrastructure at each site could highlight why differences in emissions exist between many of the transmission sites.

Table 2. Site type, name, downwind distance, average wind speed, average peak height and methane emission rates calculated for the investigated sites.

site type	name	downwind distance ±site radius (m)	average wind speed ±1σ (m/s)	Average peak concentration ±1σ (Δμg/m³)	methane emission rate ±1σ (g/s)
Compressor Station	515	N/A	N/A	N/A	N/A
	517	N/A	N/A	N/A	N/A
	520	280 ±100	3.10 ±0.41	283.59 ±200.0[1]	7.88 ±6.79
	Leidy	300 ±150	0.41 ±0.47	755.57 ±12.98	16.24 ±19.09
	313	370 ±200	2.17 ±1.50	691.33 ±727.70[1]	23.22 ±33.91
	315	240 ±100	1.51 ±0.78	86.75 ±3.11	0.84 ±0.66
	317	400 ±100	2.08 ±0.75	88.22 ±3.48	3.29 ±1.66
	319	390 ±150	0.34 ±0.42	31.41 ±8.08	0.18 ±0.25
	321	340 ±100	0.47 ±0.49	100.52 ±1.55	0.630 ±0.70
	Tuesa-Thomas	220 ±80	1.01 ±0.67	304.44 ±12.46	1.66 ±1.38
	Teel	80 ±40	N/A	N/A	N/A
Meter Station	unknown -1	320 ±20	1.44 ±0.57	10.01 ±0.20	0.07 ±0.03
	unknown -2	250 ±20	N/A	N/A	N/A
	unknown -3	290 ±20	0.09 ±0.17	107.75 ±1.28	0.04 ±0.08
Well Pad	Buck	170 ±50	1.46 ±0.80	7.76 ±0.40	0.04 ±0.02
	Nestor	160 ±30	0.30 ±0.45	1011.5 ±85.2	0.95 ±1.44
	Sampson	90 ±40	2.45 ±1.56	325.8 ±13.9	0.76 ±0.68

1. Due to technical difficulties wind measurements were not available while sampling in the emission plume. To calculate the methane emission rate the average wind speed was instead estimated from other time periods while sampling at the site. The average peak concentration and standard deviation was estimated by using summary statistics from the stationary sampling at the site, no Gaussian function was used.

Of the two Marcellus Shale natural gas gather compressor stations only measurements at the Tuesa-Thomas compressor station were applicable for methane emission rate calculations. However it should be noted although emission rates could not be calculated at the Teel compressor station, the largest methane enhancements observed during the study of >50 ppm were observed downwind of the site. The large methane enhancements are thought to be due to on-site construction and modifications that were taking place while sampling. The calculated methane emission rate at the Tuesa-Thomas station was determined to be 1.66 ±1.38 g/s and was found to be 34 times lower than measurements made by Goetz et al. (2015). Employing the same parameters used to calculate the original emission rate, downwind methane enhancements of ~15 ppm would be required to reach the observations made in 2012, whereas a max enhancement of 2.3 ppm was observed downwind of the site in 2015. The large difference between the observations suggests site operations may have changed since 2012, though differences due to measurement techniques cannot be discounted.

Meter Stations

Little information in known about the investigated meter stations except that they service the Transco and TGP transmission lines. Based on satellite imagery it is assumed that the tested meter stations are receipt stations, or stations that meter the natural gas volumes from supply pipelines. Compared to the compressor stations in the transmission sector the investigated meter stations were found to have low methane emissions with rates of 0.04 and 0.07 g/s. The most recent study that also investigated emission from meter stations found mean methane emission rates of 0.067 g/s from facilities servicing pipelines at an inlet pressure of >300 psi and 0.031 g/s from facilities servicing pipelines at 100-300 psi (Lamb et al., 2015). Although the inlet pressure at the tested facilities is not known, there is generally good agreement between this study and Lamb et al. (2015).

Well Pads

The tested well pads were generally found to have lower methane emissions than the compressor station and larger emissions than the meter stations (Table 2). The Nestor well pad has the most wells with 5, followed by the Buck well pad with 4, and the Sampson well pad that contains 3. Of the well pads tested, Nestor, the site with the most wells, was found to have the largest methane emissions (0.95 ±1.44 g/s), but also had the most uncertainty compared to the other two well pads. The Buck well pad was estimated to emit 0.04 ±0.02 g/s of methane and the Sampson well pad was estimated to emit at a rate of 0.76 ±0.68 g/s. The methane emission rates estimated in this study were found to be similar to findings from one well pad in Goetz et al. (2015) (0.937 ±0.92 g/s) and were

2-4 g/s less than emissions from the other wells investigated. Another recent study estimated that equipment leaks from natural gas production sites emit an average of 0.02 g/s of methane per well (Allen et al., 2013). Given the number of wells on each site, the Nestor and Sampson pads where found to have 13 and 9.5 times emissions compared to the findings by Allen et al. (2013).

Local-background concentrations

Ambient concentrations of methane throughout Northeastern PA were recorded during the day while driving from site to site (Figure 1) to understand the regional concentration and make comparisons to other studies. The mobile ambient observations, while useful for finding emission sources or areas with high concentrations, are not useful for comparison with other ambient studies because of the contribution of unmixed emission and changes in concentration due to topography or other factors which are unique to the time and space where the measurement was made. For example, direct emissions from Marcellus Shale infrastructure encountered while sampling could skew the average concentration to a value that is not representative of the regional concentration. To correct for unmixed emissions the mobile dataset was transformed using a percentile interval smoothing technique to isolate the "local"-background concentration of methane in Northeastern PA (Goetz et al., 2016). The 35th percentile over a 20-minute interval was used to transform the dataset. More on the percentile interval smoothing used for this work can be found in Goetz et al. (2016). An example of the transformed data can be found in Figure 3, which provides the 1-Hz time series and the transformed data for one sampling day. It should be noted that any time period in which stationary sampling took place was not included in the local-scale background analysis.

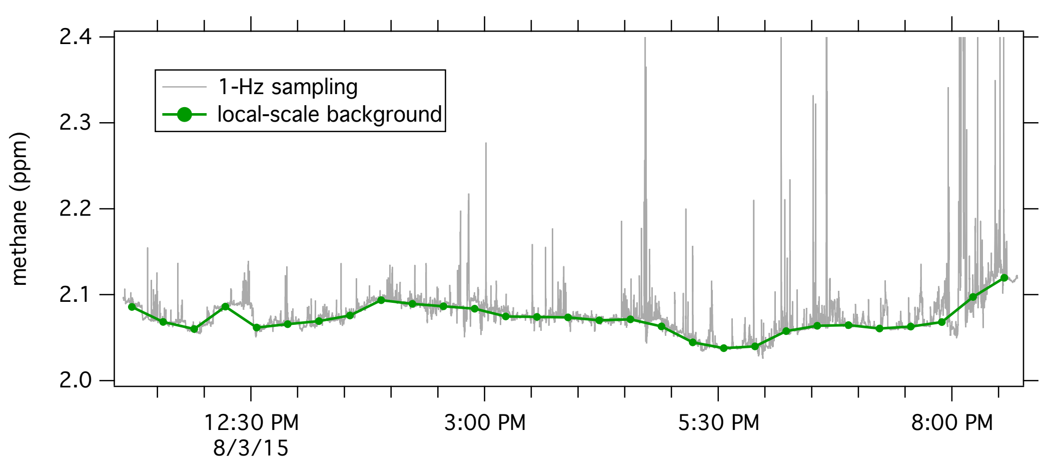

Figure 3. Time series of the mobile 1-Hz methane data from the 8/3/15 sampling day and the transformed 20-minute local-scale background.

The results from the 2015 local-scale background analysis can be found in Figure 4. The figure shows a box and whisker plot that represents the 5th, 25th, 50th, 75th, and 90th percentiles of transformed data set from 111 20-minute data points. The 25th percentile was determined to be 2.054 ppm, the median was 2.065 ppm and the 75th percentile was 2.086 ppm (Figure 4). In addition to the 2015 local background methane concentrations, Figure 4 also shows the 2012 local-scale background from mobile measurements made by Goetz et al. (2016) in Bradford and Sullivan counties in August of that year. A comparison of the two sampling campaigns shows that the median local-background methane in 2015 was elevated by 0.1 ppm compared to 2012 and that there were no overlapping concentrations between the campaigns. Although the 2015 measurements investigated a larger area than 2012, some of the same roads were sampled in Bradford County and an analysis of those roads found the same trend as the complete datasets. The elevated methane observed in 2015 compared to 2012 during the same time of year, suggests that emissions of methane in the region increased over the time period, possibly from natural gas production. The impact of increased natural gas production and infrastructure development on methane background concentrations in the region should be further scrutinized.

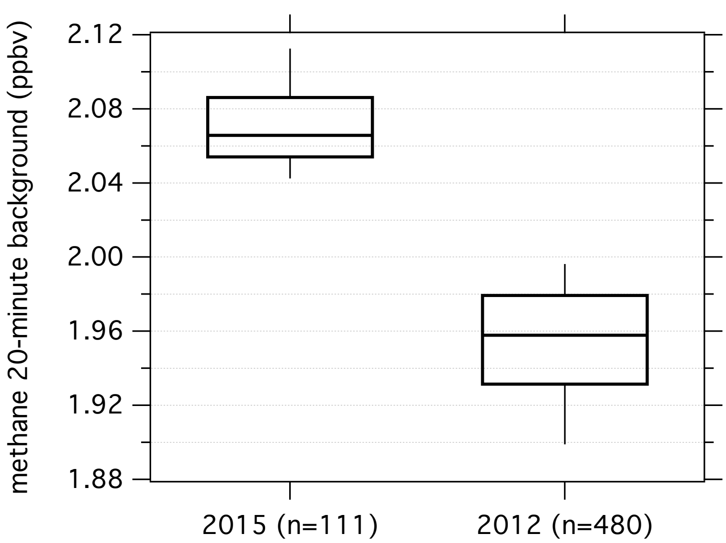

Figure 4. Box and whisker plots of the 20-minute local-background concentrations observed by this study in 2015 and by Goetz et al. in 2012. The boxes represent the 25th, 50th, and 75th percentiles. The whiskers represent the 10th and 90th percentiles of the data.

Assessment of Pipeline Leaks

The local background assessment was used as a baseline to determine the magnitude of enhancements in the 1-Hz mobile dataset while near pipeline road crossings. The analysis is limited to crossings of the Transco or TGP pipelines and only investigated enhancements within 100 meters of the pipelines. Figure 5 shows a cumulative distribution plot of the observed enhancements at the pipeline crossings. Because pipeline road crossings are rare and often outside of the planned route, only ~2 hours of data from the 5 days were within 100 meters of the studied pipelines. A mobile detection limit of 9 ppb (0.009 ppm) for methane was estimated as 3 times the standard deviation of a 30-minute period of data from outside the Marcellus Shale region where there are fewer point sources of methane. In this assessment any pipeline enhancements above 9 ppb are considered to be enhancements due to natural gas emissions or other sources and not from instrument noise. Based on Figure 5, nearly 18% of the measurements within 100 meters of the studied pipelines observed methane enhancements above the mobile detection limit. Additionally, approximately 8% of the measurements were 50 ppb above the local background concentrations and enhancements as large as 0.5 ppm were observed. The observation of enhancements above the detection limit and local background suggests that methane emissions were observed near pipeline road crossings. However, since some of the crossings were also near other types of transmission infrastructure (e.g. compressor and meter stations) it is not clear whether some of the observed emissions were also from sources other than the pipelines.

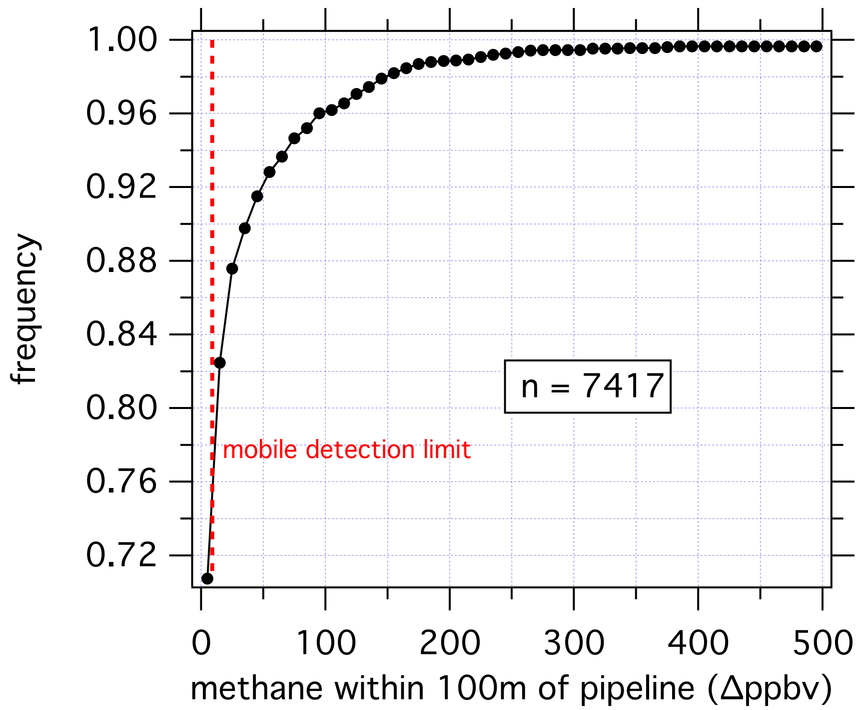

Figure 5. Cumulative probability distribution of methane enhancements within 100 meters of pipelines. Mobile detection limit is shown as the vertical red line and measurements to the right of the line indicate enhancements above that value. 8% of the measurements were 50 pbbv higher than the background value, and 4% were 100 ppbv higher than the background.

Conclusions

The DML was used in August 2015 to make ground-based mobile measurements in the Marcellus region with the goals of estimating methane emission rates from sources in the natural gas transmission sector (mainly the Transco and TGP pipelines), quantify pipeline leaks, and characterize background concentrations in the region. An additional goal was to estimate emissions from Marcellus Shale production and gathering sites if found along the sampling route and conducive to sampling. Methane emission rates from the studied sites were estimated using the EPA OTM33a method, also known as the Point Source Gaussian method. Emission rates were calculated for 8 of the 11 compressor stations investigated and were within the range observed by other studies, but mostly found in the lower emissions range of findings by Subramanian et al. (2015). Methane emissions at the TGP 319 and Tuesa-Thomas compressor stations were found to be significantly lower than previous observations by the authors in 2012 using tracer release methods. The metering stations studied were observed to have emissions consistent and within the same order of magnitude as observations by a recent study that generated a larger dataset (Lamb et al., 2015). The methane emission estimates from the transmission sites that have proposed modifications due to pipeline expansion projects can now serve as a pre-modification baseline for a number of sites or serve as a baseline to determine the effect of aging infrastructure. The Marcellus shale well pads were observed to have emissions ~10 times greater than the well-based leak rate estimated by Allen et al. (2013). The local background analysis demonstrated that methane concentrations in 2015 have increased significantly from a similar analysis conducted by the authors in 2012. The increase in background methane is possibly from increased natural gas production in the region, but the contribution of other sources is unknown. Finally, methane leaks from the Transco and TGP pipeline were assessed using the local background values as a baseline. It was estimated that nearly 18% of the methane enhancements above the local background observed within 100 meters of the pipelines were due to emissions from pipelines, pipeline infrastructure, or other sources of methane.

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Accufacts Review of EPA Natural Gas STAR Program: Possible Best Technologies and Practices for Natural Gas Transmission Compressor Stations and Pipelines

Richard B. Kuprewicz, President

Produced for the Clean Air Council

December 2015

Richard B. Kuprewicz is President of Accufacts, Incorporated. He has over 40 years of experience in the energy industry, including gas and liquid pipeline operation, design, siting, engineering, regulatory compliance, emergency response, safety and risk management. His special focus is on proper design and operation in areas of unique population density or of an environmentally sensitive nature. He is a certified safety management engineer and he has developed and performed safety and risk management and assessment analysis for various clients representing chemical plants, LNG facilities, refineries and pipelines. He served 8 years on the Washington State Citizens Committee on Pipeline Safety.

Accufacts Inc.
"Clear Knowledge in the Over Information Age"

8040 161st Ave NE, #435
Redmond, WA 98052
Ph (425) 802-1200
kuprewicz@comcast.net

December 29, 2015

To: Matt Walker
Clean Air Council
135 S. 19th Street, Ste #300
Philadelphia, PA 19103-0600
Via email mwalker@cleanair.org

Re: Accufacts' Review of EPA Natural Gas STAR Program Possible Best Technologies and Practices for Natural Gas Transmission Compressor Stations and Pipelines

I. Executive Summary

Accufacts has reviewed the EPA Natural Gas STAR Program ("Program") concerning attempts to voluntarily reduce oil and natural gas industry methane emissions. I find no technical applications that are not already well known by the oil and gas industry for many years, if not decades, to reduce methane releases into the atmosphere. While I can appreciate the EPA's efforts to quantify various methane emission reducing approaches, I find that EPA's volunteer approach, what I would identify as a "bottom-up" attempt, as overly optimistic. The economic inducements presented are most likely overstated as to their ability to introduce cultural changes to actually reduce oil and gas industry methane releases.

Based on our extensive investigations and experience, I conclude that in much of the gas transmission pipeline infrastructure the majority of methane releases are associated with:

1. a small percentage of methane super-emitter equipment/activities such as at certain compressor stations that are not designed, operated, or maintained to reduce such major methane emitters, and

2. blowdowns, either scheduled or unscheduled, to deinventory a compressor station or the considerable tonnage of gas held as mainline pipeline inventory, that must be removed for various reasons from time to time.

Accufacts recommends that a top down approach focused on independent system measurement be utilized to identify methane super-emitters that in all probability are emitting much more tonnage of methane than conventional "leaks." It has been our experience that for transmission systems, optical or laser remote monitoring, usually by aerial or fixed sites, can efficiently cover the vast distances of transmission pipelines, and are ideally suited for methane release system monitoring. Such approaches do not have the limitations of FLIR (forward-looking infrared radar) or other detection approaches that tend to be more focused on leak identification and leak survey methods that can easily miss emission incidents/releases at super-emitters such as periodic blowdowns.

II. A Simple Perspective on the EPA Natural Gas STAR Program

The EPA Natural Gas STAR Program is an attempt by the agency to encourage methane gas releasers in the oil and gas industry to reduce methane gas emissions. My comments primarily focus on gas transmission pipelines, but the following general observations are also relevant to oil and gas production and gas distribution systems as explained in more detail later in this report.

The EPA Natural Gas STAR Program, by its nature, is "volunteer" and it is important to recognize that no regulation to date, including gas pipeline safety regulations, prevent nor require the reduction of methane emissions such as those that occur through "leaks" including venting and blowdowns at existing facilities. Methane, being lighter than air, is a potent greenhouse gas contributor with a shorter duration life than carbon dioxide. Federal pipeline safety regulations, for example, leave the decision as to system leak survey timing and associated leak grading up to the pipeline operator.[1] While Accufacts supports a more collaborative effort toward reducing methane emissions, various factors work against a volunteer, so-called "bottom-up" economic-based approach, which is the underpinning of the EPA Natural Gas STAR Program approach.

The wide historical swings associated with natural gas prices and the fundamental structure of pipeline tariff mechanisms can provide little economic incentive for the oil and gas industry to reduce methane emissions. For example, a gas transmission pipeline operator may not realize an economic penalty for "lost gas" or operating inefficiency associated with methane emissions. The recent decline in energy and natural gas prices illustrates how economic efforts to prevent venting or release of natural gas in pipeline operations can be undermined. In addition, the focus on increasing production as well as pipeline operation/throughputs for various reasons, can lead to methane super-emitters that can release high quantities of methane for extensive periods of time, that may not be captured in volunteer accounting efforts such as the EPA Natural Gas STAR Program.

III. The Natural Gas Industry

The natural gas industry is generally divided into three major categories or segments:

1) gas production – facilities that are utilized to drill and produce gas out of the ground via gas wells with associated gas treatment equipment depending on the gas/oil production field to meet transportation quality pipeline specifications,
2) gas transportation or gas transmission pipelines - involved in moving large volumes of natural gas, usually over long distances, to consumers via larger diameter higher pressure steel pipelines, and

[1] Even the most severe "Hazardous Leaks" as defined in federal pipeline safety regulation, 49§CFR192.1001 for gas distribution systems, do not have to be immediately repaired to eliminate the leak. Federal regulation for Distribution Integrity Management Programs, or DIMP, since 2010 requires a distribution pipeline operator to report Hazardous Leaks (i.e., by cause and by material) that are repaired, in annual reports to PHMSA.

3) gas distribution systems – a network of lower pressure smaller diameter pipes that receive gas from transmission pipelines via metering and pressure reducing stations that decrease the gas pressure to the lower pressure gas distribution networks servicing industrial plants, electric power plants, and the network of smaller pipes consisting of mains and service lines leading to consumer homes.

Production and gas treatment and processing facilities (sometimes utilized to remove via refining natural gas liquids and other impurities from natural gas streams) are not under the jurisdiction of the Pipeline and Hazardous Material Safety Administration, or "PHMSA," the federal office responsible for development and enforcement of minimum federal pipeline safety regulations for pipelines involved in the transportation of certain hazardous fluids such as natural gas. A somewhat confusing category of pipelines defined as "gathering" is also under the limited jurisdiction of PHMSA. Gas distribution systems up to the low-pressure regulators to/within buildings/homes, fall under the jurisdiction of PHMSA. These distribution system low-pressure regulators reduce distribution gas pressures to the much lower pressure gas pipe network servicing appliances within buildings/homes. The lower pressure gas network within buildings downstream of the distribution system low-pressure regulator is not under the jurisdiction of PHMSA.

As a general rule, the greater the complexity of the natural gas system and equipment, the more likely that such complexity creates potential opportunities for methane releases, either through leakage or venting (either intentional or unintentional). Of the above three categories, the transmission pipelines will tend to be the least complex, but even transmission pipelines, as discussed further, can be serious emitters of methane to the atmosphere (i.e., super-emitters) as some of these transmission systems are moving vast quantities of gas and may have little or no economic or business incentive to reduce methane emissions. Given over 40 years of experience and investigations across the industry, I would generally rank (based on the likelihood or presence of methane super-emitters) gas production/treating/gathering as the most likely contributors of methane emissions, followed by gas distribution networks depending on the distribution system, and finally gas transmission pipelines. Note that this does not mean that natural gas transmission systems should be ignored as super-emitters can be present and will vary by transmission pipeline.

IV. Voluntary Economic Programs Will Not Effectively Reduce Methane Emissions

The history of extreme price swings for natural gas (prices in many parts of the country are currently well below $3.00/MMBtu) can render methane release reduction economics moot by company decision makers. Future projections by the Energy Information Administration, or EIA, indicate that natural gas production will continue to grow, even with a slight downward trend through 2020 with a slow rise in natural gas pricing from 2020 through 2040.[2] Even with this increase in natural gas production, the economics of preventing methane leaks may not make sense for many years. The Henry Hub spot price (2013 dollars) predicts a fall from $3.14/MMBTU in 2015 to $3.12 in 2020, and then only about a one dollar increase from 2020 to 2040 to $4.38/MMBTU.[3] Should higher gas prices eventually occur, given the longer term

[2] "Annual Energy Outlook 2015 with projections to 2040," http://www.eia.gov/forecasts/aeo/pdf/0383(2015).pdf
[3] Ibid.

economic uncertainties, the historical gas price fluctuations, and the fundamental shortcomings in many tariff structures that don't provide incentive for the reduction of gas leaks or losses, volunteer efforts are an illusion and will not be effective at seriously reducing methane emissions. Such voluntary efforts can take much too long on actually capturing significant methane emitters, or what has been called methane super-emitters.

Accufacts has also observed that the rush to build multibillion dollar natural gas transmission pipelines as quickly as possible can place pipeline and project management emphasis on cutting corners to get a pipeline up and running as quickly as possible, overriding or negating voluntary methane reduction attempts. This is especially true if there is no real regulatory requirement or economic penalty <u>in not reducing</u> methane emissions. Such project acceleration can wreak havoc on volunteer efforts to reduce methane "leakage" no matter their good intentions. Multiple studies, including EPA publications, have determined that oil and gas leak rates are often greater than the federal government estimates that rely on "sparse data, incorrect assumptions, or both."[4] A study from the University of Texas found that updated data and simulations produced emission factors 1.5 times greater than the EPA GHG Inventory, 2.7 times greater than the EPA GHG Reporting Program, and 4.3 times greater than the Emissions Database for Global Atmospheric research.[5] Many of these emissions differences were due to equipment leaks, and exclusion of emissions from fat-tail (also known as super-emitter) sites.[6] Other studies have stated that "effective national and state greenhouse gas reduction strategies may be difficult to develop without appropriate estimates of methane emissions."[7] Having more reliable data on natural gas infrastructure emissions would be beneficial for industry in terms of methane release reduction effectiveness, but would also inform U.S. policy decisions and provide a new potential source of emission and leak data.

U.S. natural gas infrastructure is also aging, providing new potential avenues for leaks if not properly maintained. Some pipelines and compressor stations operate using 30 to 50 year old equipment. Lack of data and aging infrastructure also comes at a time when the U.S. is in the middle of a natural gas boom. EIA estimates lower 48 shale gas production will increase by 73% in the Reference case by 2040, which will result in a 45% increase in nationwide dry natural gas production. Without a way of detecting sources of methane pollution, new and old infrastructure alike will be emitting unknown quantities of methane. Given the unannounced or unpredictable nature of many major pipeline methane releases in natural gas transmission facilities, I believe that more remote monitoring that efficiently covers large areas such as aerial surveys are warranted on gas transmission pipelines. My experience over the past couple of decades is that laser methane assessment (LMA) monitoring of methane release facilities is the technology currently ideally suited for field identification and measuring methane super-emitters along gas transmission pipeline systems. LMA uses laser technology to remotely determine methane emissions. This laser technology was originally developed for aerial surveillance of pipelines in

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[4] "Estimate of Methane Emissions from the U.S. Natural Gas Industry," http://www3.epa.gov/ttnchie1/ap42/ch14/related/methane.pdf.
[5] "Constructing a Spatially Resolve Methane Emission Inventory for the Barnett Shale Region" http://pubs.acs.org/doi/pdf/10.1021/es506359c
[6] Ibid.
[7] "Anthropogenic Emissions of Methane in the United States" http://www.pnas.org/content/110/50/20018.abstract

Europe, but has been commercially utilized in the U.S. for at least a decade with advancements incorporating GPS software technology to quickly benchmark emitters along pipelines. LMA can utilize either periodic (aerial, vehicle, or individual carried) or fixed monitoring station sites for problematic equipment that might be super-emitters, either scheduled or unscheduled. There are various optical or laser approaches, but our experience to date is that the laser technology doesn't have the field limitations associated with other remote detection monitoring. Standoff optical or laser approaches have proven well suited for such remote methane coverage and do not have the limitation associated with infrared measurement which can be sensitive to vegetation, for example.

While there are many other different technologies and approaches that can be utilized for leak survey/leak detection, such as those utilized or touted for Direct Inspection and Maintenance, or DI&M, it is my experience that such micro-focused "leak" tracking and elimination efforts fail, or can be too easily manipulated to avoid capturing methane super-emitters.[8] Quite simply, it can take a great number of leak repairs to compensate for one-super-emitter of methane. A standoff methane release measurement detection approach that can be independently measured unannounced to identify major methane releases is what is needed to capture gas systems that can span many miles, such as transmission systems. Efforts overly focused on volunteer leak elimination will, I believe, miss the vast preponderance of true methane emissions associated not only with gas transmission, but also gas production and gas distribution system super-emitters. Again to be fair, one must keep in perspective that it is still not illegal to emit methane in the U.S., either as a multitude of leaks, or as a super-emitter. Regulations should first focus on independent identification and elimination of methane super-emitters and then decide if further efforts are warranted to address equipment leaks.

I must conclude that, in all probability, the voluntary "bottom-up" EPA Program for methane release reduction seriously understates the amount of methane actually released, especially if such efforts fail to capture super-emitter activities along natural gas transmission pipelines, as well as other oil and gas industry facilities. It is also most likely that claimed methane release reduction progress in the STAR Program within the oil and gas industry is overly optimistic. Proper 24/7 monitoring for the earlier identified two types of transmission pipeline releases, I believe, would quickly identify super-emitters of methane on many natural gas transmission systems that contribute the bulk of methane releases from this type of infrastructure. Efforts to identify and target super-emitters are best approached by mandatory regulatory requirements demonstrated by independent field system-wide measurement, not voluntary illusionary efforts demonstrated by calculated piecemeal assumptions or approaches. I must stress that a transmission pipeline operator required to make investments in equipment to deal with methane super-emitters should be allowed to capture the additional expenses and equipment investments in their pipeline tariffs, provided the pipeline operator has adequately identified and justified these additional expenditures that should be also independently and transparently reviewed and approved to assure they are appropriate and justified.

[8] http://www3.epa.gov/gasstar/tools/recommended.html

V. Focusing on Natural Gas Transmission Systems

Gas transmission pipeline systems are comprised of one or more large diameter pipes (mainlines) designed to operate at higher Maximum Allowable Operating Pressures, or MAOP, depending on various steel pipe properties, usually intended to move large volumes of natural gas long distances.[9] Because transmission pipelines operate at higher pressures, even small leak sites such as at valve packings or at compressor seals, can leak gas at high rates, though even these high pressure leaks are not likely to become super-emitters. In general, however, gas transmission systems are composed of mainline pipes dispersed between compressor stations located approximately every 40 to 75 miles along the pipeline to re-pressure and move gas along the mainline. The mainline pipe segment is fairly simple, usually comprised of the pipe valving (and sometimes valve actuation) depending on various factors such as pipe class location, and incorporates minor monitoring equipment utilized to observe and possibly control the pipeline system.

While mainline piping and its associated equipment (such as mainline blowdown venting stacks) can be sources of methane super-emitters, on gas transmission systems it is usually the compressor stations and their associated complexity that are most likely to introduce various sources of major potential methane releases, both continuous and intermittent. Compressor station sources of methane emissions are compressor seals, the additional equipment associated with stations such as piping, inline inspection launcher and/or receivers, valving filters/strainers, blowdown vent stacks, monitoring connections, and auxiliary equipment such as relief valves. This equipment can be the source of methane release via periodic maintenance/inspection activities, but leakage releases tend to be from minor emission sources. By the nature of their design, compressor mechanical seals can release continuously and can easily become super-emitters of methane. Compressor stations can vary in their design, but are usually the greatest possible source of methane super-emitters (either continuous or periodic) to the atmosphere from natural gas transmission systems. A possible exception to this general observation would be if the mainline piping is poorly designed, or if there was a high frequency of the mainline gas inventory released to the atmosphere.

VI. EPA's "Bottom-Up" Volunteer Approach Will Not Address Methane Super-emitters in a Timely Manner

Accufacts has reviewed the various approaches on the EPA's Natural Gas STAR Program website regarding the identification and inventorying of possible equipment that could generate methane releases in the oil and gas industry. Particular attention was paid to a review of equipment inventory identified as possible release sources, methane detection tools, methods and approaches suggested for gas facilities to address methane release sources. I would characterize the EPA Natural Gas STAR Program approach as a "bottom-up" effort to address methane emissions. A bottom-up approach has serious weaknesses in that it may not focus proper resources on the greatest sources of methane releases, such as intermittent blowdowns, especially if such release sources are not captured in a volunteer program. Also, as a volunteer program, considerable time may be required before real detectable methane reduction is actually realized.

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[9] MAOP is defined in federal minimum pipeline safety regulations 49CFR§192.3 as "the maximum pressure at which a pipeline or segment of a pipeline may be operated under this part."

While I find EPA's approach meticulous, thorough, and up to date, and EPA's approach utilizes technology well known in the oil and gas industry for many years, the question remains whether this Program is actually effective in reducing methane super-emitter emissions.[10]

One major problem is that there has been no real incentive to apply many of these technologies and it can be several decades before real methane reduction occurs in the overall industry. While the EPA tries to capture a possible economic incentive by utilizing various gas costs in outlining possible economics in support of methane reduction, the history of gas pricing, especially the recent energy pricing downturn, can seriously hamper economics and can delay meaningful methane release reduction from the oil and gas industry. The simple fact is that volunteer efforts may not be adequately capturing or quick enough to reduce the super-emitters that are most likely contributing to the majority of methane releases from the oil and gas industry.

VII. Conclusions - A "Top-Down" Methane Independent Field Measurement/Audit Approach Is Needed

While I can appreciate the time and energy spent to date on the volunteer EPA Program efforts to reduce methane releases, the simple fact is that no volunteer approach replaces actual independent field measurement, what I call unannounced monitoring or auditing of oil and gas industry facilities as they relate to methane releases. Of the three segments of the gas industry, natural gas transmission pipelines should be the least complex to remotely field measure actual methane release over a period of time. Such measurement should embrace independent remote monitoring such as LMA unannounced verification (able to cover large segments of a pipeline very efficiently), and will most likely show that gas transmission compressor stations are likely a significant super-emitter for the gas transmission industry. Independent field measurement will help demonstrate whether EPA's bottom-up approach was reasonable, and if stated EPA Natural Gas STAR Program claims are true.

In addition, Program claims of methane emissions reduction carry little merit if unidentified super-emitters are not properly captured, identified, addressed, or mitigated in a timely manner. A more independent and scientific approach is warranted to assure prudent efforts at methane emissions reduction are instituted in this industry with primary efforts focused on field surveys to identify and address methane super-emitters. Real field unannounced measurement, what I call "top-down" field verification and measurement, is the true gauge of methane reduction performance and impact in the atmosphere. I believe the EPA Program bottom-up approach is seriously overstating actual methane reductions. The underestimate of possible methane releases across the oil and gas industry, given the 24/7 nature of these operations and the long history of various mechanisms not preventing, even encouraging, methane release to the atmosphere (especially super-emitters), will show a wide discrepancy in bottom-up versus top-down methane release approaches. A serious and scientific discussion involving more transparent and independently obtained methane release field measurement information, especially as it relates to possible super-emitters, is warranted. I believe LMA field measurement is ideally suited for these field verification efforts, but to avoid confusion, such field survey results should be made public and subject to independent review.

[10] www3epa.gov/gasstar/index.html

Richard B. Kuprewicz,
President,
Accufacts Inc.