Statistical Analysis of Methane Emissions from Marcellus Shale Region from 2015 to 2016

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Motivation

- Natural gas is considered the bridge to clean energy. Methane(CH_4), a gas with 28 to 34 times the global warming potential of CO_2 is released into the atmosphere during the harvest of natural gas.[1]
- Quantify the rate of gas emission from wells to evaluate whether natural gas sufficiently serves as a better alternative to fossil fuel. [2]
- Analyze the statistical accuracy of the data collected in summer of 2016 and compare with both previous samples and to the population as a whole.

Methods

- A LICOR 7500(CO_2) and 7700 (CH_4) were mounted horizontally to the roof of a Honda CRV. An AIRMAR sensor was used to monitor wind direction and speed. Custom built Ammonia and Ethane sensors were also mounted to the mobile lab.
- If a methane plume was detected, 10 transects were made at the well site downwind of prevailing wind direction.

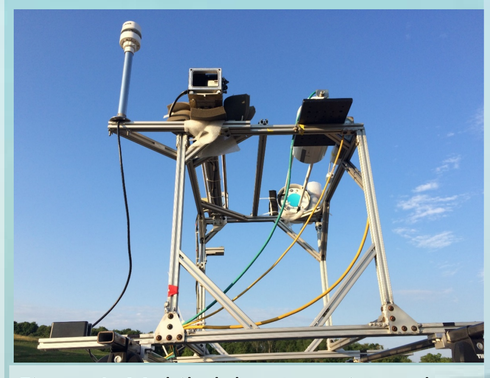

Figure 1: Mobile lab set up pictured. From left to right, AIRMAR, Ethane, Methane, CO2

- Time of day, weather conditions, surrounding area, and characteristics of the well were noted.
- Statistical analysis was performed using MATLAB and excel.
  - One-sample t-tests were run to compare the subsamples with the population using charachteristics from the most recent database from PA DEP (2016).[3]
  - Two-sample t-test were run to compare the 2015 and 2016 subsamples

Results

2015 Subsample vs 2016 Subsample			
Ho=0	AGE	EMISSIONS	PRODUCTION
p-value	0.015	0.221	0.705
alpha	0.05	0.05	0.05
Reject?	yes	no	no

Table 1: Shows the results of statistical comparison (2-sample z) test between subsamples from 2015 to 2016 for age and production. Emission rate and production are statistically similar while age is different. Emission was assigned a binary 1 if there was a measured methane plume and 0 if there wasn't. A 2-proportion z-test was performed.

Sample vs. Population				
Ho≠0	2015		2016	
	AGE	PRODUCTION	AGE	PRODUCTION
p-value	0.004	0.103	0.004	< 0.0001
alpha	0.05	0.05	0.05	0.05
reject?	Yes	no	yes	yes

Table 2: Shows statistical comparison using 2-sample z test of age and production between the wells sampled during the campaign and the total population of wells in Pennsylvania in 2015 and 2016. Ho=sample is not the same as the population.

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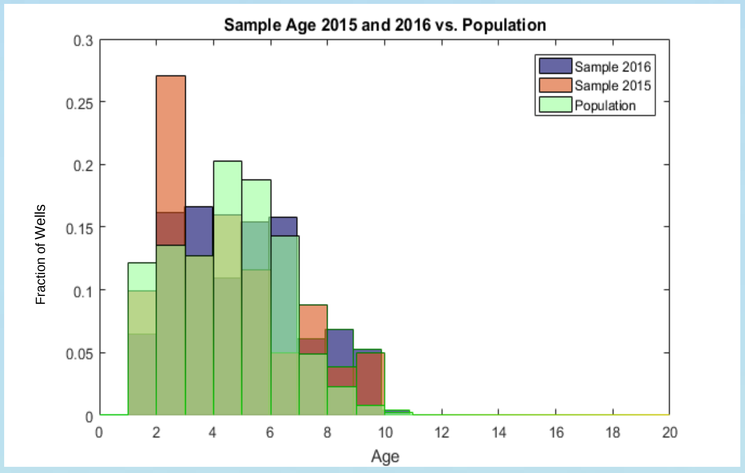

Figure 2 compares age across the 2015 and 2016 (340 and 499 wells respectably) sampled wells and the entire population (3618 wells)

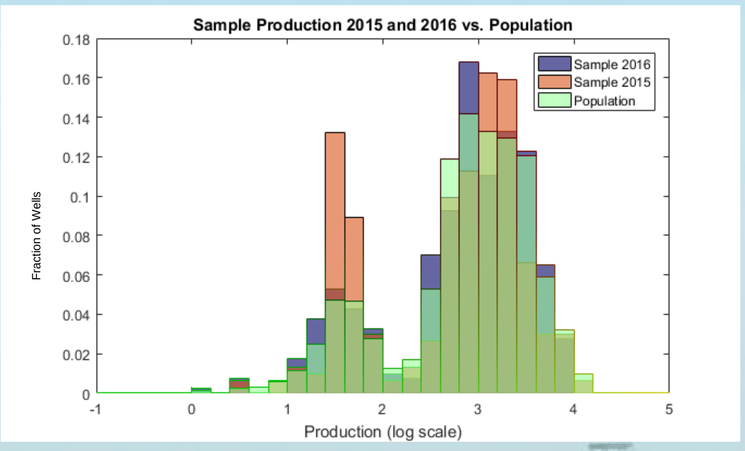

Figure 3 compares production per day of individual wells for 2015 and 2016 sampled wells (340 and 499 wells respectably) and the population (3618 wells).

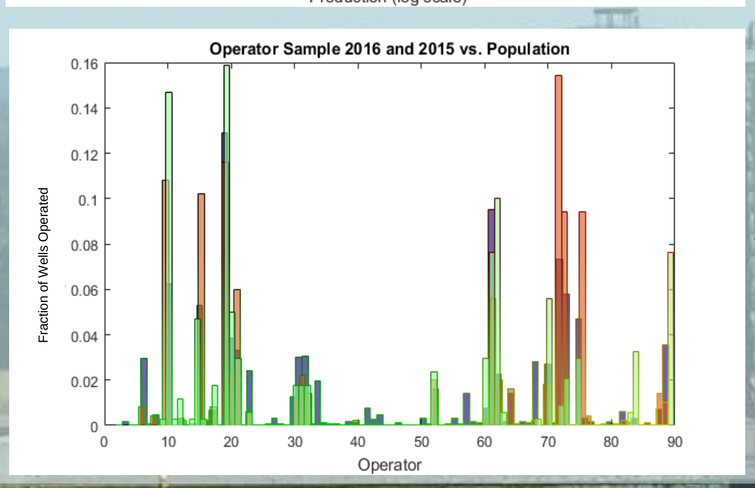

Figure 4 shows operator distribution across the 2015 and 2016 sampled wells and entire well population. X-axis displays number correlated to a well operator company. (Total of 89 companies)

Discussion

- In comparing random samples from both 2015 and 2016:
  - There is no statistically significant difference in the fraction of wells that emitted methane.
  - There is a statistically significant difference in age, but not in production.
- In comparing the 2015 and 2016 samples to the population(based on 2016 database):
  - The 2016 wells are statistically representative of the population as a whole.
  - However, the 2015 wells are statistically representative of the population as a whole in age but not in production.
- Recommendations for future work:
  - A large sample size with wells from many different regions could contain variation in age similar to the entire population.
  - Increasing the sample size and combining the current samples will create a more statistically representative sample.

[1]Alvarez, R. A., S. W. Pacala, J. J. Winebrake, W. L. Chameides, and S. P. Hamburg. "Greater Focus Needed on Methane Leakage from Natural Gas Infrastructure." PNAS 109, no. 17 (2012): 6435-440.
[2]Myhre, G. et al. "Anthropogenic and Natural Radiative Forcing." In Climate Change 2013: The Physical Science Basis, edited by T. F. Stocker et al. Contribution of Working Group I to the Fifth Assessment Report of the IPCC. Cambridge: Cambridge University Press, 2013.
[3] PA Department of Environmental Protection