

Overview of Air Emissions from Unconventional Oil and Gas Operations

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Outline of Presentation

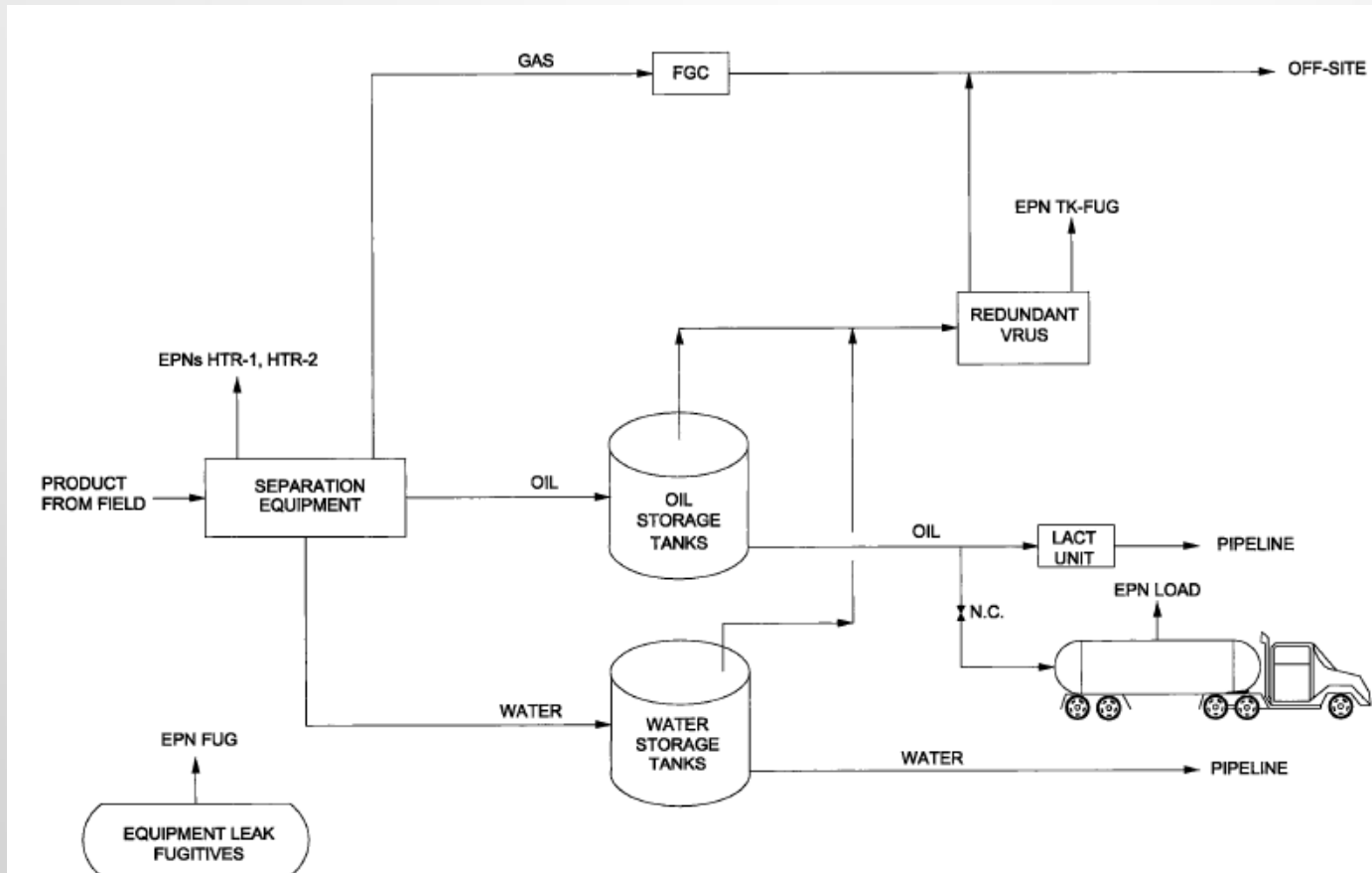
- Overview of major equipment on-site and regulatory developments
- Intro to specific sources and control technologies
 - Guided by regional ozone planning inventories
 - NO_x and VOC emissions as surrogates for combustion and non-combustion sources
- Perspective on how methane studies could inform HEI Research



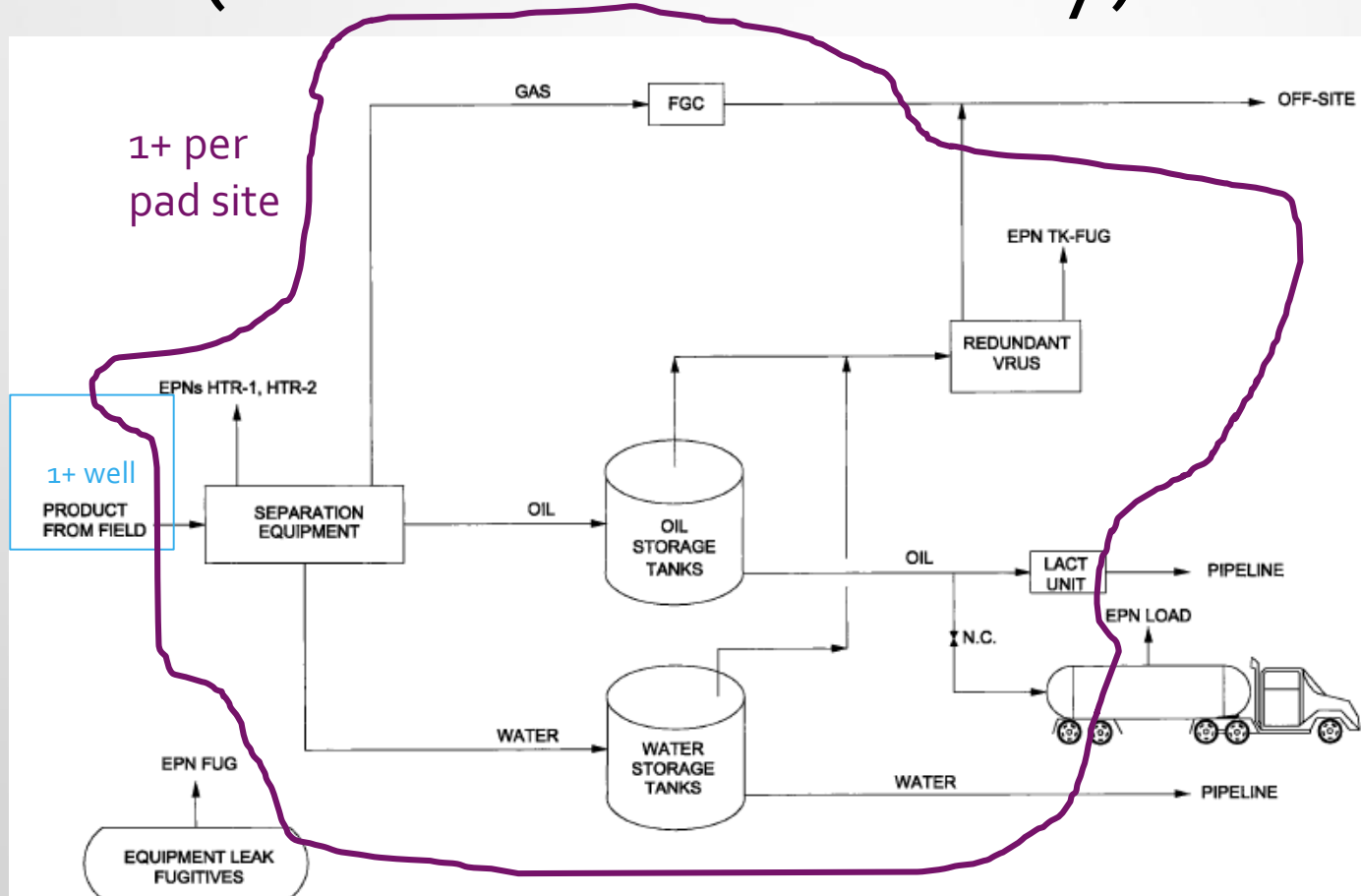


Overview of Site Operations and Regulatory Basics

Simple Process Flow Diagram (Central Tank Battery)



Simple Process Flow Diagram (Central Tank Battery)



US EPA Regulations for Upstream

- Applicable to constructed, modified, or reconstructed facilities after compliance dates
- Controls and operational practices for volatile organic compound (VOC) emissions

NSPS OOOO (2012)

HF Gas Wells

Pneumatic Controllers

Storage Tanks

Compressors

NSPS OOOOa (2016)

HF Oil Wells

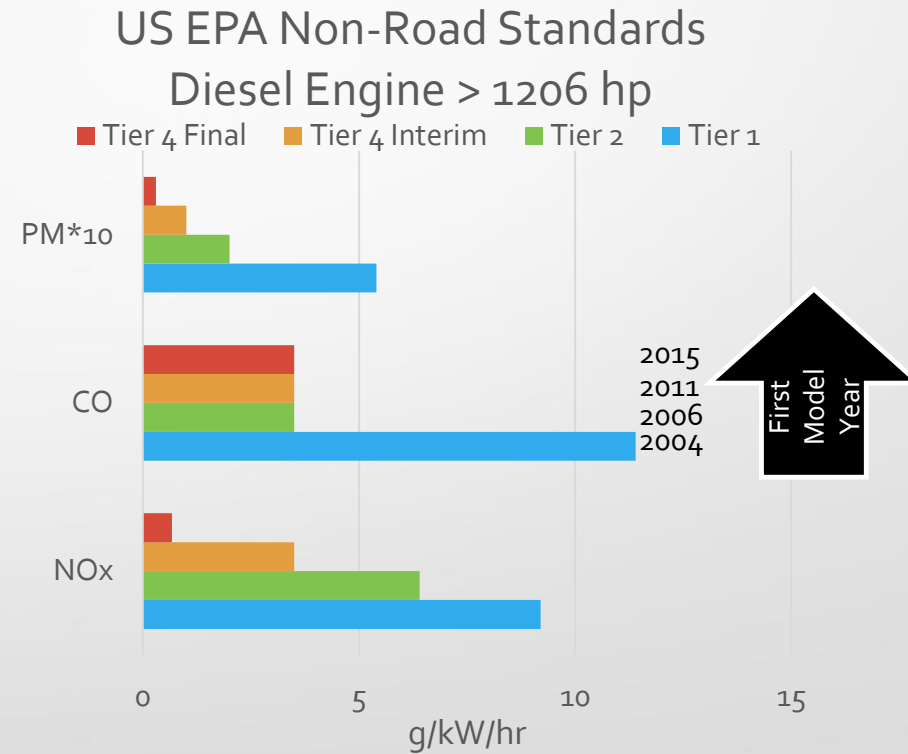
Equipment Leaks/Fugitives

Pneumatic Pumps

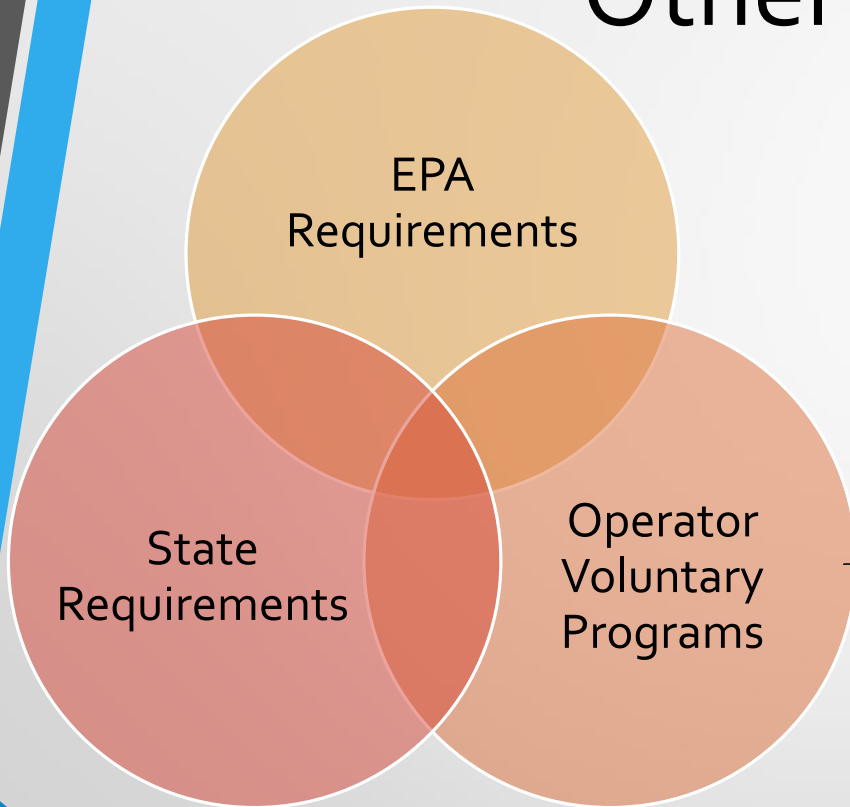
- Chart above is a simple overview. There are a myriad of complex requirements for compliance that would go beyond an overview.

US EPA Engine Emission Regulations

- Performance requirements (Tiers) on new engines for a model year
- Retirement of older engines over time and replacement with lower emitting models
- May be local requirements for additional controls or which engines can be permitted



Other Programs



- The Environmental Partnership (2017)
 - Pneumatic Controller
 - Manual Liquid Unloading
 - Leak Detection and Repair
- Center for Responsible Shale Development (2013)
 - Surface and Groundwater Performance Standards
 - Air and Climate Performance Standards
 - Flaring Limits
 - Green Completions
 - Engine Emissions
 - Storage Tank Controls



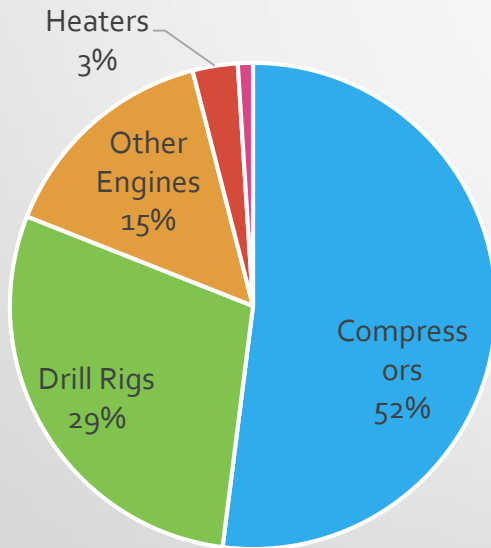
Sources of Air Emissions and Control Technologies

Why Draw on Emission Inventories for Ozone Planning?

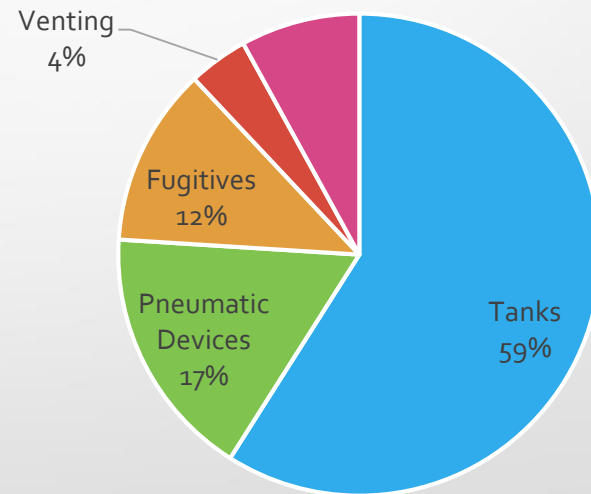
- Cover both combustion (~NO_x) and non-combustion (~VOC) sources
- Publicly available from regulatory agencies
- Introduction to sources
- Limitations:
 - Level of granularity for a dispersed area source
 - Average operating conditions in a basin

Example: 2010 Ramboll Environ Inventory for the Denver Julesburg (DJ) Basin

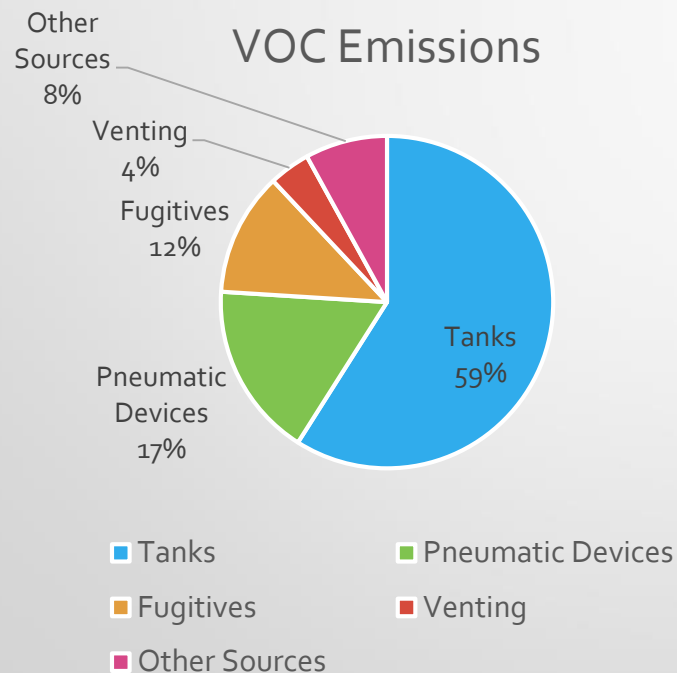
NOx Emissions



VOC Emissions



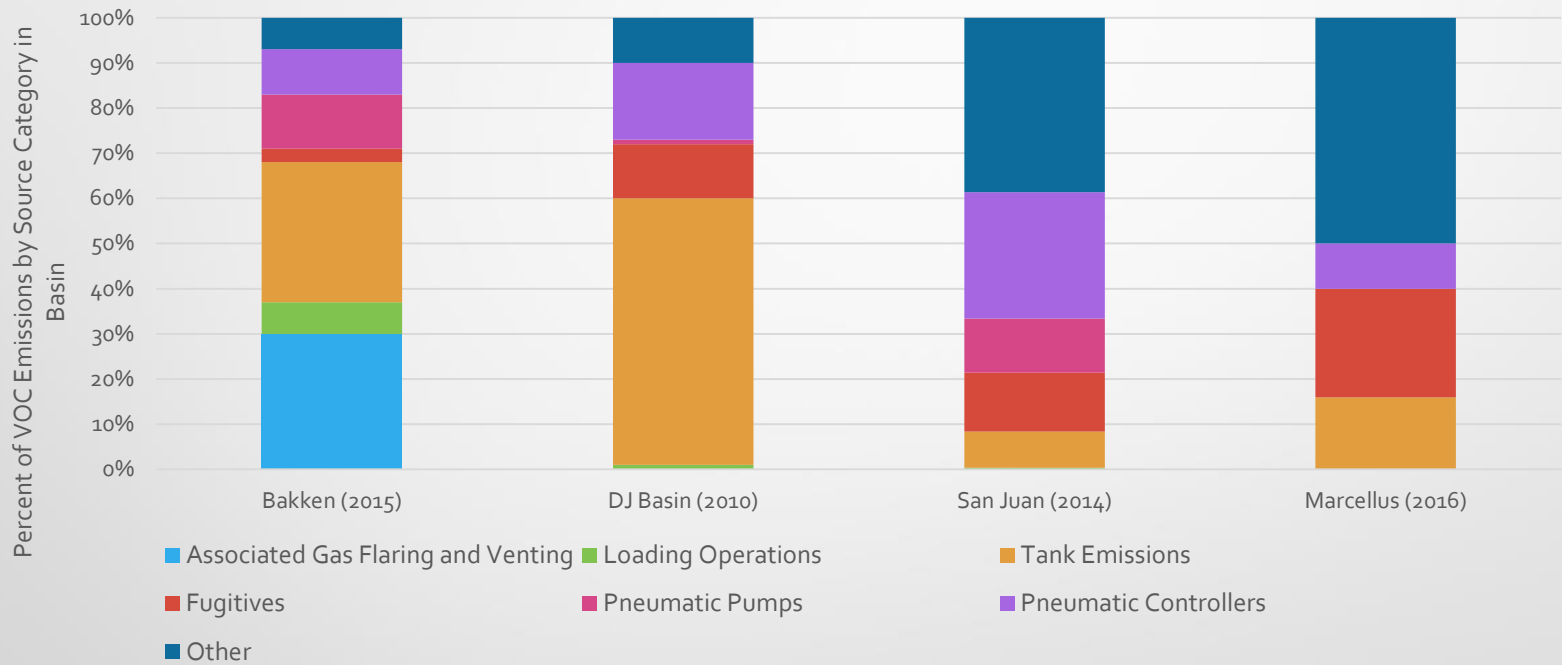
What efforts is industry taking to control VOC emissions?



Data: 2010 Ramboll-Environ DJ
Basin Inventory

- Tank Emissions:
 - Vapor Recovery Systems
 - Flaring
- Venting
 - Reduced emission completions
- Pneumatic Controllers
 - High bleed changeouts
- Leak detection and repair programs

Basin-to-Basin Variation in VOC Emission Sources

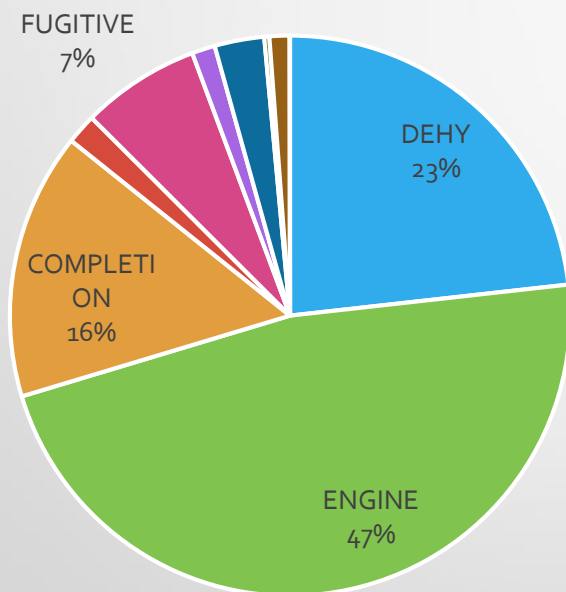


- Bakken, DJ Basin, and San Juan – Ramboll Environ Inventories
- Marcellus – PA DEP reported data

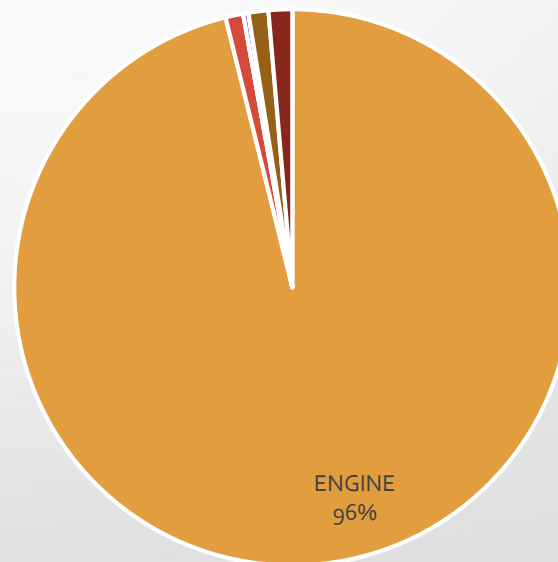
Hazardous Air Pollutant (HAP) Emission Inventories

- Pennsylvania Department of Environmental Protection (PA DEP) requires annual reporting of HAP emissions from unconventional oil and gas operations
- Barnett Shale Special Emission Inventory by TCEQ
- Individual site estimates are included in many state permits

PA DEP Inventory in 2016



Reported Benzene Emissions



Reported Formaldehyde Emissions

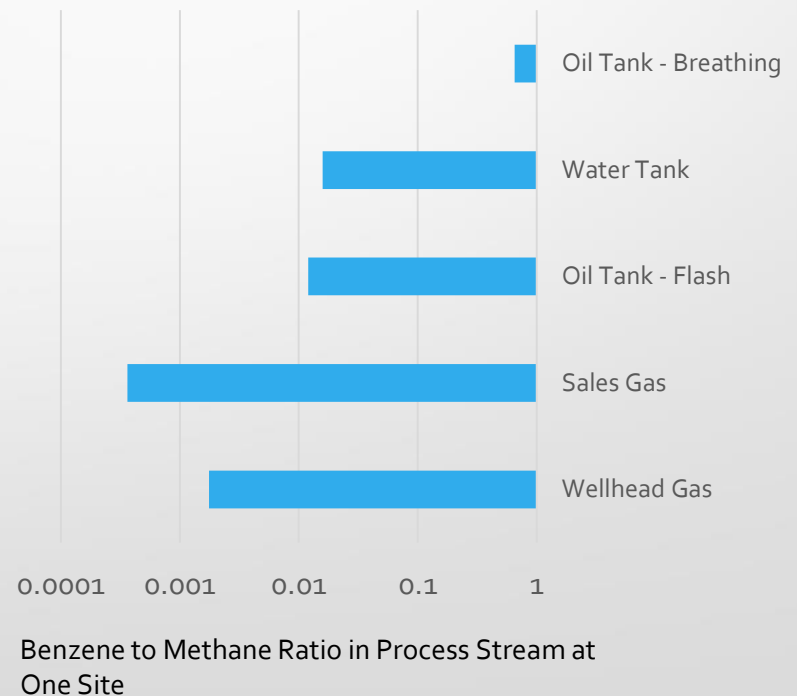


Methane Emission Studies

Methane as a Surrogate for Other Emissions from Unconventional Operations

- Confounding sources possible with ambient methane measurements
- Ratios to other chemical species is highly variable
- Simple scaling of off-site methane concentration measurements is not likely to be meaningful.
- Methane is not necessarily a good proxy for HAPs and other air emissions.

Gas Analyses from a Single Unconventional Site



Applicable Lessons Learned from Methane Emission Research

- Early planning on scaling/contextualizing results
- Recent studies show a "fat tail" (small number of sources responsible for a large portion of emissions) for methane emissions.
- Multiple measurement methods and inter-comparison studies are vital.
- Spatial and temporal variations in emissions and activities are key.
- Operational insights are key for understanding results.



Thank You