Oil and Gas 101: An Overview of Emissions from Upstream Oil and Gas Exploration and Production Sources

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Training Overview

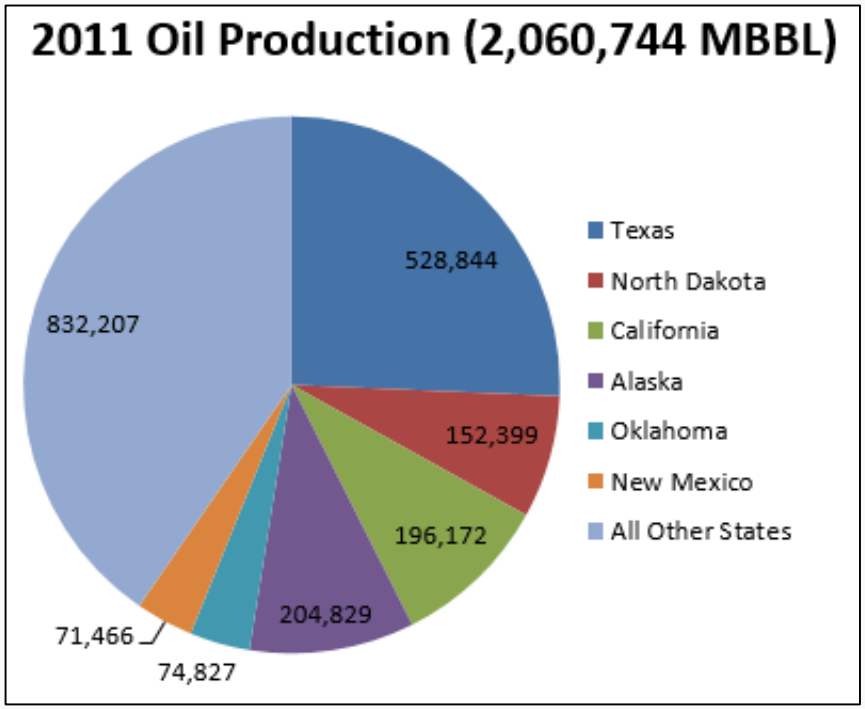
- Oil and gas production in the United States
- Upstream oil and gas emission sources
- EPA Nonpoint Emission Estimation Tool
- Data resources

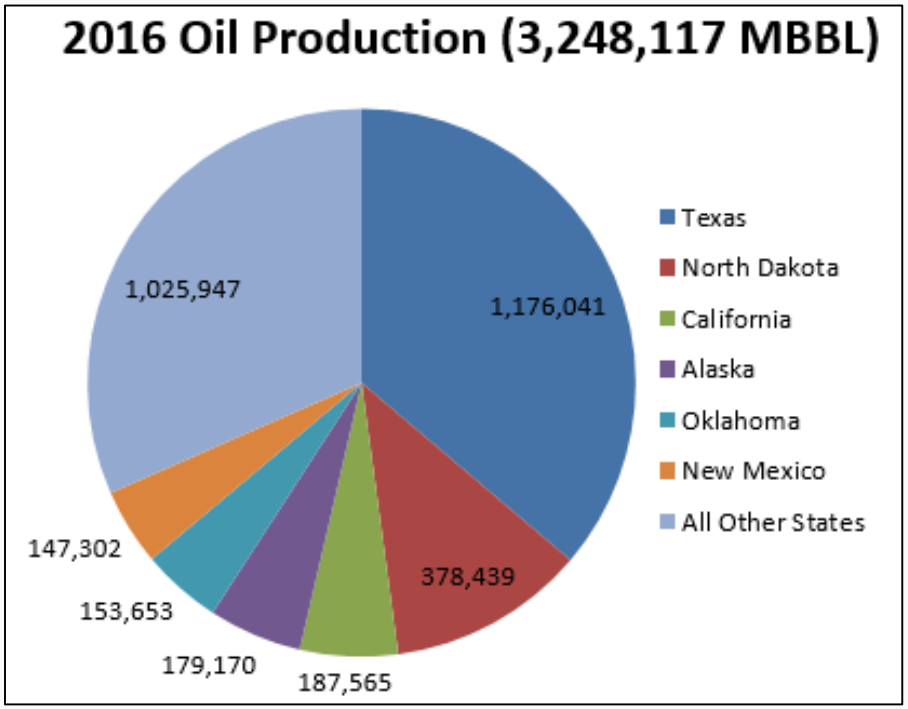
Oil and Gas Production in the US

- Over 3 billion barrels of crude oil produced in 2016
  - ~50% increase since 2011
  - Down slightly from 2015
  - ~18% of production offshore (was 30% in 2010)
  - Texas, North Dakota, California
- Over 28 trillion cubic feet of gas produced in 2016
  - ~30% increase since 2009
  - ~5% of production offshore
  - Texas, Pennsylvania, Oklahoma

Source: U.S. Energy Information Administration

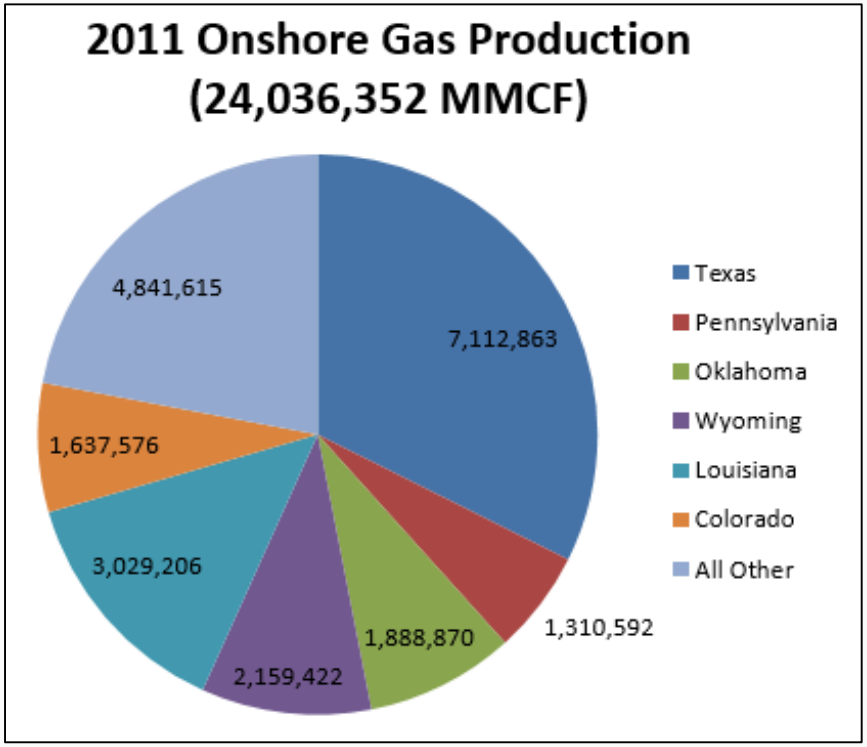
US Onshore Crude Oil Production

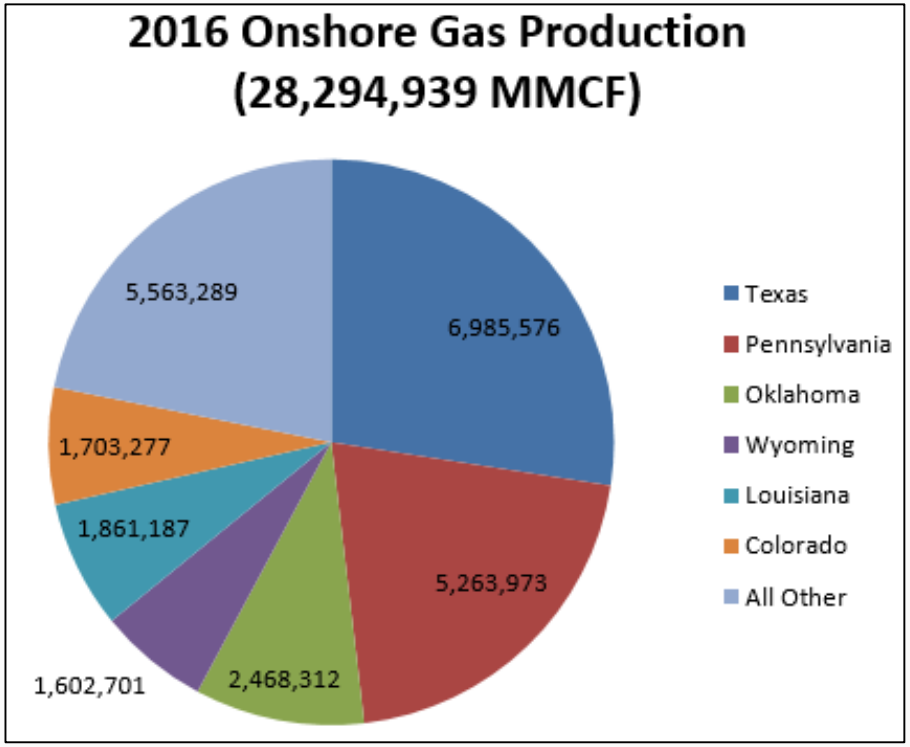




Source: U.S. Energy Information Administration

US Onshore Natural Gas Production



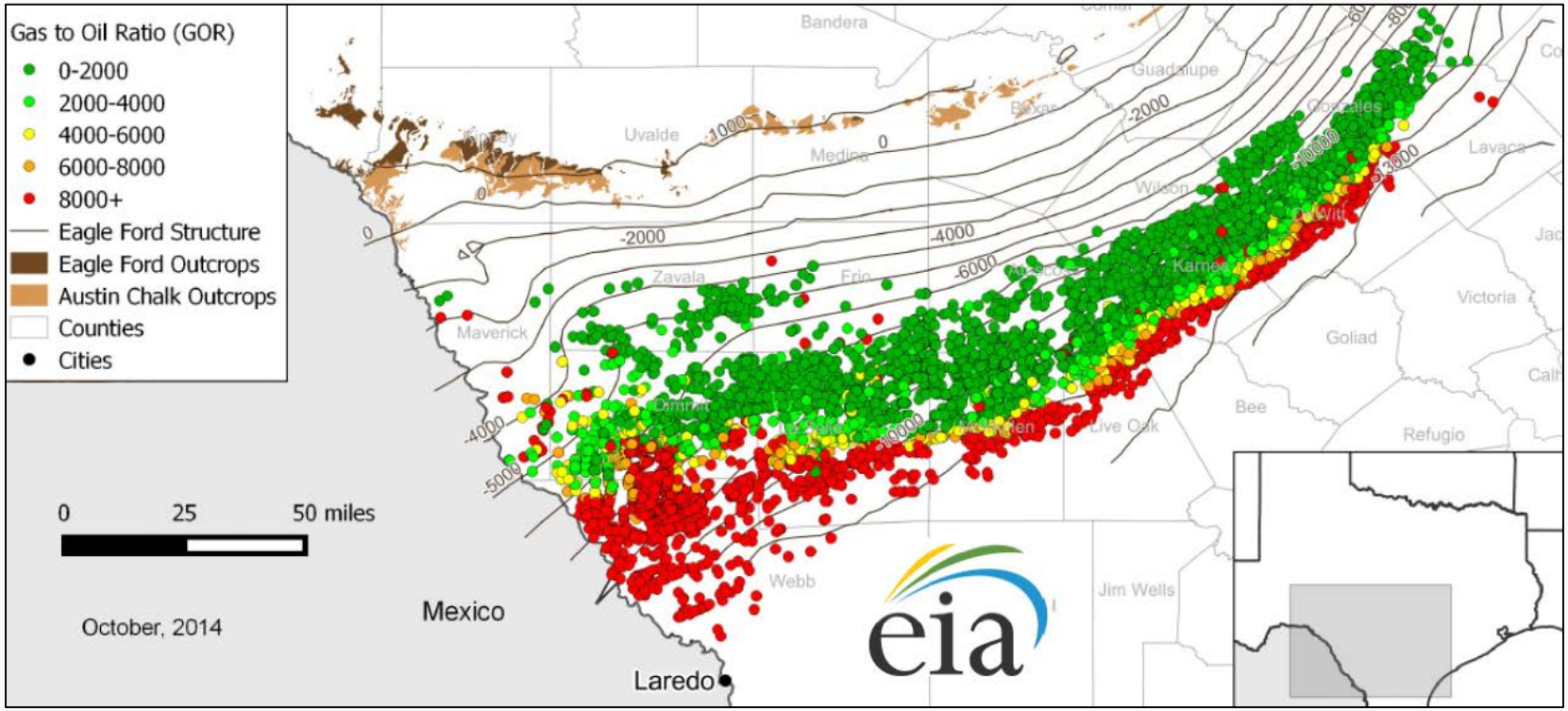


Source: U.S. Energy Information Administration

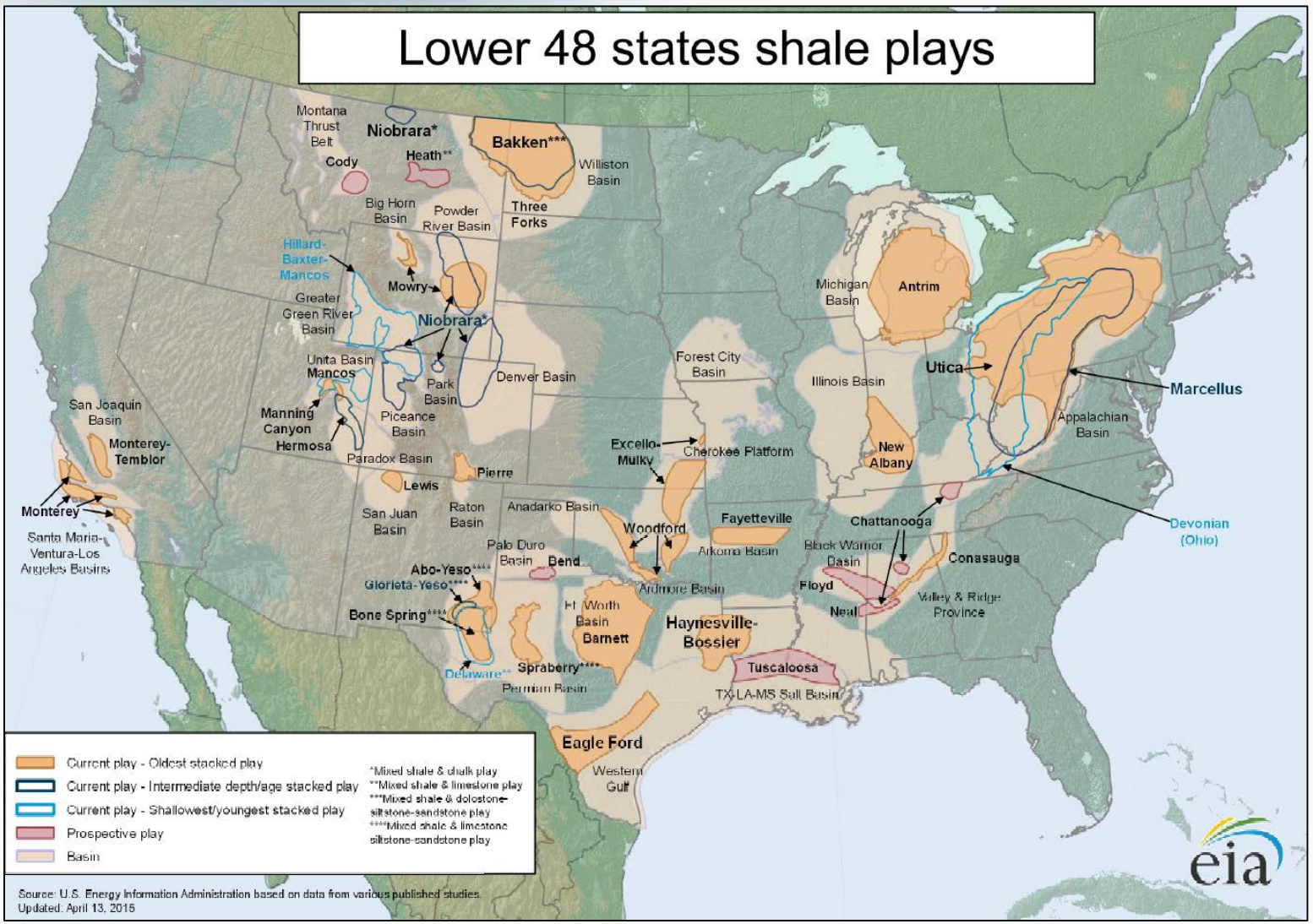
Natural Gas, NGLs, Condensate, Oil

- Natural Gas (C1 – primarily Methane)
- Natural Gas Liquids (C2 – C4)
  - Ethane, Propane, Butane
  - Extracted at gas processing plants
  - “Wet gas”
- Condensate (~C5+)
  - Condenses out of gas stream at surface
- Crude Oil (mixture of heavier hydrocarbons)
  - Distilled into gasoline, kerosene, diesel, jet fuel

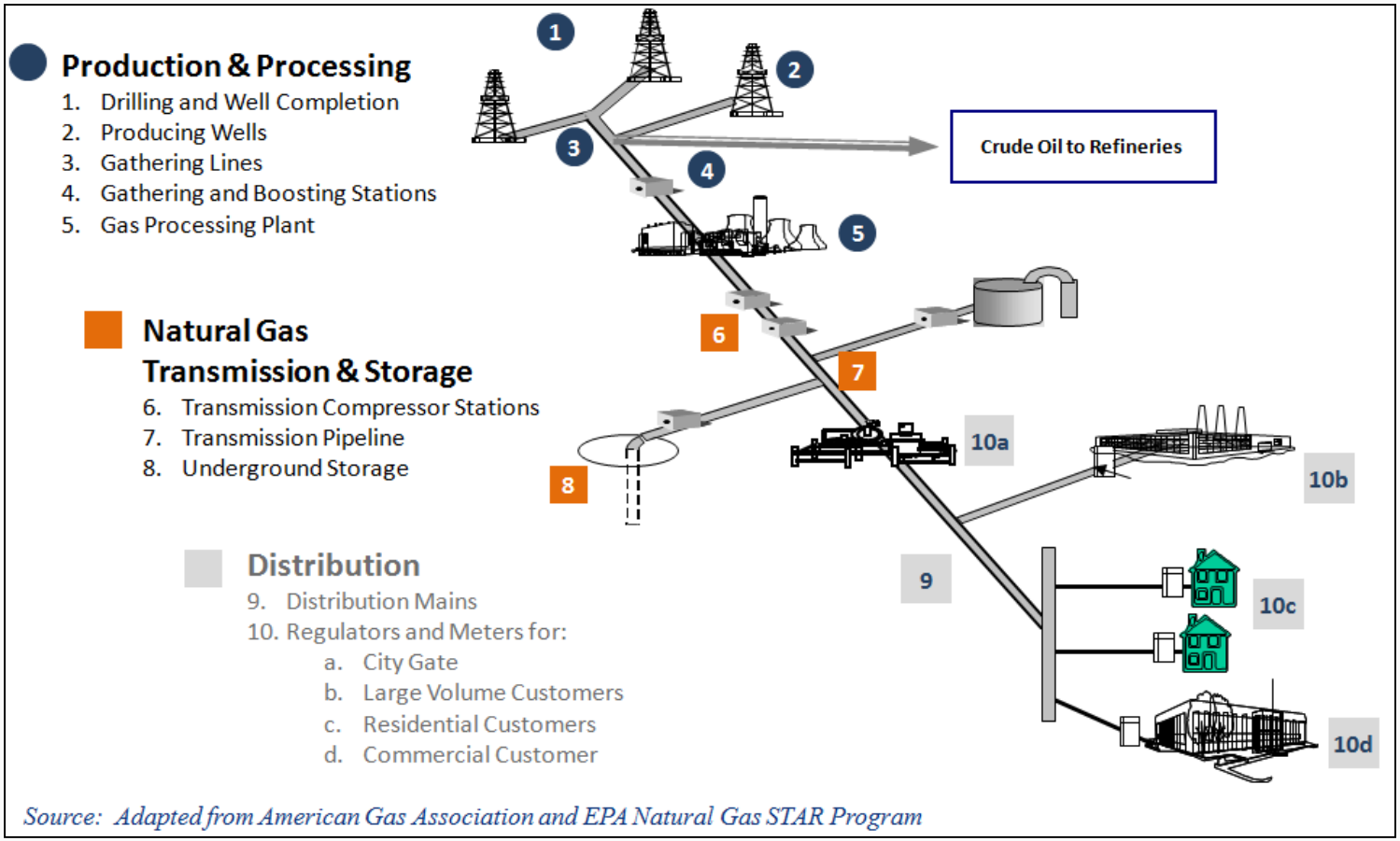
Eagle Ford Shale Oil and Gas Well Map



Source: U.S. Energy Information Administration


Lower 48 states shale plays
Montana Thrust Belt
Niobrara*
Cody
Heath**
Bakken***
Williston Basin
Big Horn Basin
Powder River Basin
Three Forks
Hillard-Baxter-Mancos
Mowry
Greater Green River Basin
Niobrara*
Unita Basin
Mancos
Park Basin
Denver Basin
Piceance Basin
Manning Canyon
Hermosa
Paradox Basin
San Joaquin Basin
Monterey-Temblor
Monterey
Santa Maria-Ventura-Los Angeles Basins
Pierre
Lewis
San Juan Basin
Raton Basin
Anadarko Basin
Palo Duro Basin
Bend
Abo-Yeso****
Glorieta-Yeso****
Bone Spring****
Delaware**
Spraberry****
Permian Basin
Ft Worth Basin
Barnett
Forest City Basin
Excello-Mulky
Cherokee Platform
Woodford
Fayetteville
Arkoma Basin
Ardmore Basin
Haynesville-Bossier
Tuscaloosa
TX-LA-MS Salt Basin
Eagle Ford
Western Gulf
Michigan Basin
Antrim
Illinois Basin
Utica
Marcellus
Appalachian Basin
New Albany
Chattanooga
Black Warrior Basin
Conasauga
Floyd
Neal
Valley & Ridge Province
Devonian (Ohio)
Current play - Oldest stacked play
Current play - Intermediate depth/age stacked play
Current play - Shallowest/youngest stacked play
Prospective play
Basin
*Mixed shale & chalk play
**Mixed shale & limestone play
***Mixed shale & dolostone-siltstone-sandstone play
****Mixed shale & limestone siltstone-sandstone play
Source: U.S. Energy Information Administration based on data from various published studies.
Updated: April 13, 2015
eia

Upstream Oil and Gas Emission Sources



Upstream Oil and Gas Emission Sources

Exploration Sources

- Drilling Rigs
- Hydraulic Fracturing Pumps
- Mud Degassing
- Well Completion Venting

Production Sources

- Artificial Lift Engines
- Associated Gas Venting
- Coalbed Methane Dewatering Pump Engines
- Condensate Tanks
- Crude Oil Tanks

Production Sources (continued)

- Dehydrators
- Fugitive Leaks
- Gas-Actuated Pneumatic Pumps
- Heaters
- Lateral Compressor Engines
- Liquids Unloading
- Hydrocarbon Liquids Loading
- Pneumatic Devices
- Produced Water Tanks
- Wellhead Compressor Engines

EPA Tool Estimation Methodologies

- Area (nonpoint) source methodologies
- Based on point source methodologies averaged over the population
- Scaled to the county level using activity factors (well counts, oil production, gas production)
- Refer to "*2014 Nonpoint Oil and Gas Emission Estimation Tool Version 2.2*" (June, 2017) for details

Exploration - Drilling Rigs

- Used to drill wellbore to target formation
- 2 primary rig types
  - Mechanical
  - Diesel-electric
- Powered by large, diesel engines (~1,000 – 1,500 HP)
- ~2 – 4 weeks

Drilling Rigs

- Emissions based on cumulative feet drilled
- Process characteristics needed to estimate emissions
  - Engine size and type (HP)
  - Operating hours (hr/spud)
- Emission factors from EPA's NONROAD model
- Methodology accounts for different types of rig configurations (mechanical and diesel-electric)

Mud Degassing

- Mud degassing refers to the process of “off-gassing” of entrained gas in the drilling mud once it is outside of the wellbore
- Drilling mud used to keep the drill bit cool, carry out drill cuttings, and maintain wellbore pressure to prevent formation fluids from entering wellbore
- Emissions based on total drilling days
- Emission factor derived from 1977 EPA report “*Atmospheric Emissions from Offshore Oil and Gas Development and Production*”

Hydraulic Fracturing Pumps

Hydraulic Fracturing Pumps

- Emissions based on number of fracture events
- Process characteristics needed to estimate emissions
  - Engine size (HP)
  - Number of engines
  - Operating hours (hr/event)
- Emission factors from EPA's NONROAD model

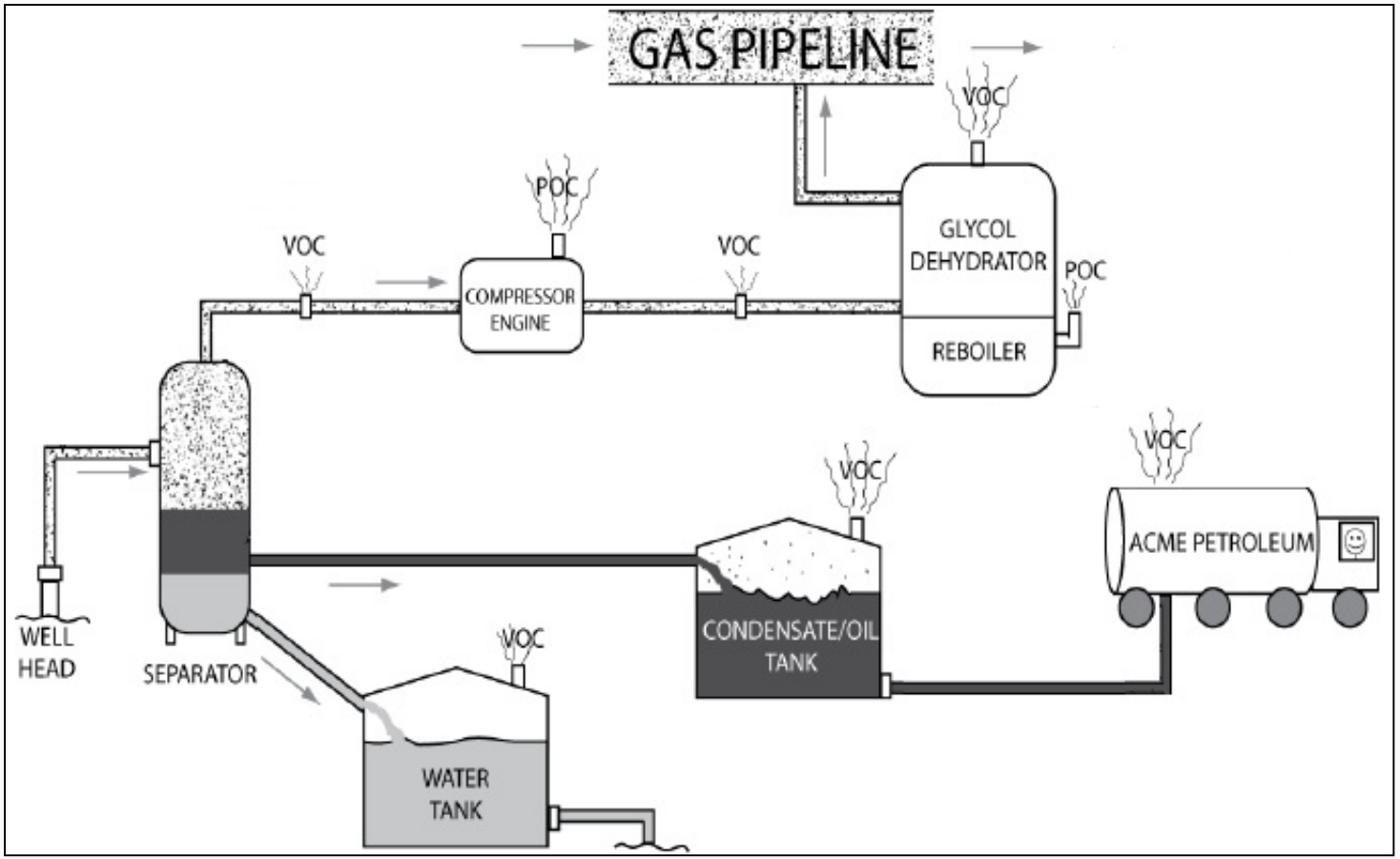
Well Completion Venting

- Emissions generated as gas is vented prior to well being brought into production
- For fractured wells, emissions are generated as gas entrained in the flowback fluid is emitted through open vents at the top of flowback tanks
- Emissions from fractured wells regulated under NSPS OOOO and OOOOa

Well Completion Venting

- Emissions based on number of completion events
- Process characteristics needed to estimate emissions
  - Volume of gas released per completion (MCF/event)
    - Oil and gas
    - Conventional and unconventional
  - Gas composition
  - Controls

Production Sources



Source : Texas Commission on Environmental Quality Air Permit Reference Guide APDG 5942

Artificial Lift Engines

- “Pumpjack” engines
- Engines used to lift oil out of the well if there is not enough bottom hole pressure for the oil to flow to the surface
- Generally use casinghead gas if electricity not available

Artificial Lift Engines

- Emissions based on number of oil wells
- Process characteristics needed to estimate emissions
  - Engine size (HP)
  - Engine operating schedule (hr/yr)
  - Fraction of oil wells with engines
- Emission factors from AP-42
- Electric engines are common, accounted for in methodology

Associated Gas Venting

- Refers to the practice of venting gas produced at oil wells where the well is not connected to a gas sales pipeline
- May be flared (e.g. Bakken Shale)
- Emissions estimated based on
  - Quantity of gas vented per barrel of oil production (MCF/bbl)
  - Fraction of gas flared
  - Composition of the vented gas

Coalbed Methane Dewatering Pump Engines

Coalbed Methane Dewatering Pump Engines

- New category added for 2017
- “Pumpjack” engines similar to Artificial Lift
- Engines used to lift water out of the well
- Electric engines are common, otherwise use CBM gas
- No current default factors

Coalbed Methane Dewatering Pump Engines

- Emissions based on number of CBM wells
- Process characteristics needed to estimate emissions
  - Engine size (HP)
  - Engine operating schedule (hr/yr)
  - Fraction of CBM wells with engines
- Emission factors from AP-42
- Electric engines accounted for in methodology

Condensate Tanks

Condensate Tanks

- Emissions based on condensate production
- Emissions occur from flashing, working, and breathing losses
- Flashing losses are generally the largest component and occur when gases entrained in a liquid “flash off” as the pressure drops
- Emissions per barrel of condensate needed to estimate total county-level emissions (lb/bbl)
- Regulated under NSPS OOOO and OOOOa

Crude Oil Tanks

- Used to store crude oil at a well pad or central tank battery prior to transfer to a refinery
- Some oil fields pipe oil directly downstream and do not have tanks in the field
  - accounted for in Tool
- Largest VOC source as calculated by the Tool

Permian Basin Tank Battery
Source: Google Earth

Crude Oil Tanks

- Emissions based on oil production
- Emissions occur from flashing, working, and breathing losses
- Emissions per barrel of crude oil needed to estimate total county-level emissions (lb/bbl)
- Regulated under NSPS OOOO and OOOOa

Dehydrators

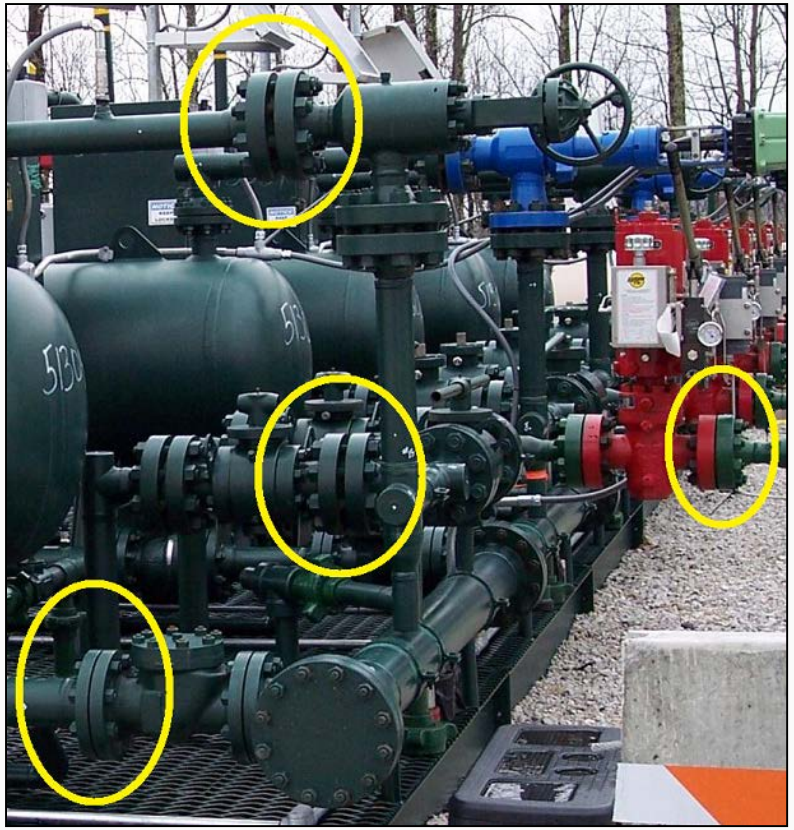
- Use glycol to remove water from gas stream to prevent corrosion or freezing issues downstream
- Small reboiler used to regenerate the glycol
- May be located at well pad, or at centrally located gathering station

Dehydrators

- Emissions generated from the still vent and the reboiler
- Emissions from the still vent based on gas production
  - Emissions per throughput (lb/MMSCF)
- Emissions from the reboiler based on gas well count
  - Number of dehydrators per well
  - Reboiler size (MMBtu/hr) and operating schedule (hr/yr)
- NESHAP HH and HHH may require controls

Fugitive Leaks

- Emissions of gas that escape through well site components such as connectors, flanges, and valves
- Source category only covers components located at the well pad
- Regulated under NSPS OOOOa

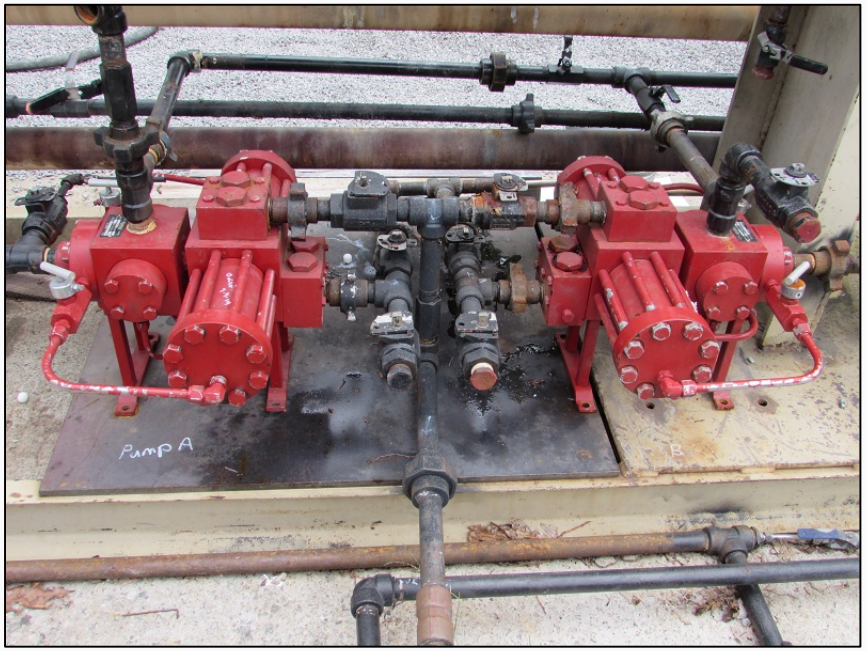


Fugitive Leaks

- Emissions based on well count
- Process characteristics needed to estimate emissions
  - Counts of fugitive components by type per well
  - Operating schedule (hr/yr)
  - Composition of leaked gas
- Emission factors from “Protocol for Equipment Leak Emission Estimates” (EPA, 1995)

Gas-Actuated Pneumatic Pumps

- Small gas-driven plunger pumps used to provide a constant supply of chemicals or lubricants
- Commonly used in sites where electric power is unavailable
- Gas-actuated pumps vent by design



Gas-Actuated Pneumatic Pumps

- Emissions based on well counts
- Kimray pumps
- Chemical injection pumps (CIP)
- Certain pumps regulated under NSPS OOOOa
- Process characteristics needed to estimate emissions
  - Count of pumps per well (oil, gas, CBM)
  - Pump vent rate (SCF per throughput or day)
  - Composition of vented gas

Heaters

- Line heaters - used to maintain temperatures as pressure decreases to prevent formation of hydrates (Marcellus Shale)
- Heater treaters – used to heat oil/water emulsions to aid in separation (Bakken Shale, Permian Basin)

Heaters

- Emissions based on the number of wells
- Heaters used as control devices regulated under NSPS OOOO and OOOOa
- Process characteristics needed to estimate emissions
  - Number of heaters per well
  - Heater size (MMBtu/hr)
  - Operating schedule (hr/yr)
  - H_2S content (to estimate SO_2)

Lateral Compressor Engines

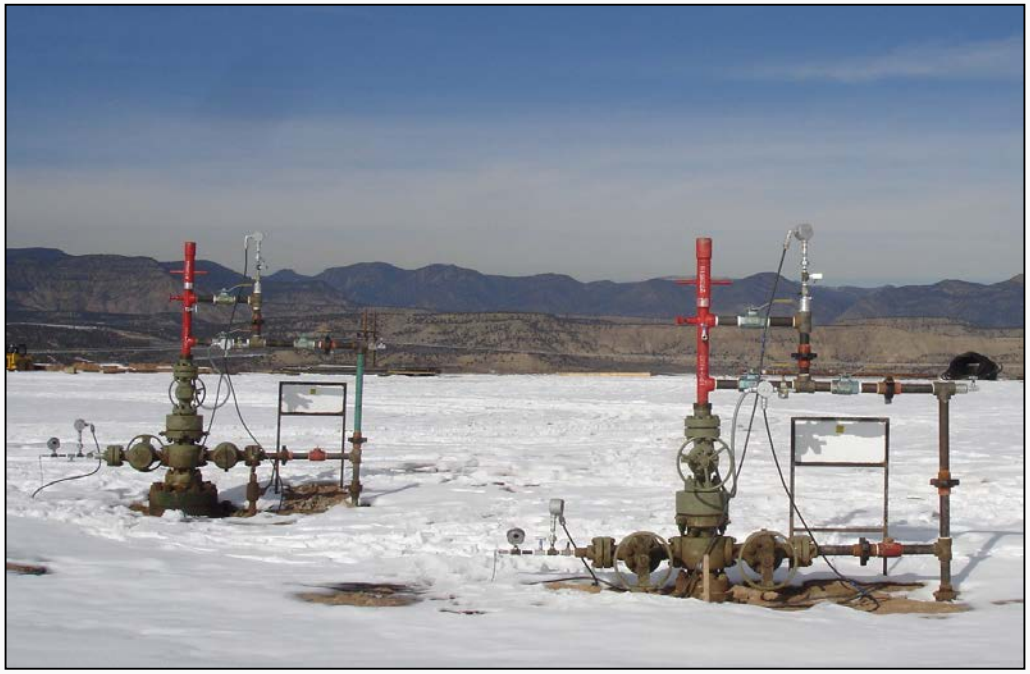
- Large “line” engines
- May serve ~10 to 100 wells
- Used at gathering or booster stations (mid-stream)
- Natural gas-fired
- Rich-burn or lean-burn

Lateral Compressor Engines

- Emissions based on the number of gas wells
- Compressors regulated under NSPS OOOO and OOOOa
- Process characteristics needed to estimate emissions
  - Number of gas wells served by a lateral engine
  - Engine size (HP)
  - Operating schedule (hr/yr)
  - Control information

Liquids Unloading

- Used to remove accumulation of fluids in the wellbore
- Also known as “well blowdowns”
- May be controlled (flaring or plunger lifts)



Liquids Unloading

- Emissions based on the number of gas wells
- Process characteristics needed to estimate emissions
  - Number of unloading events per well
  - Volume of vented gas per liquids unloading event (MCF/event)
  - Composition of vented gas
  - Control information

Hydrocarbon Liquids Loading

- Emissions generated during transfer of liquids from tanks to trucks
- As with storage tank emissions, where liquids are piped directly downstream, no emissions from this category
  - Accounted for in Tool

Hydrocarbon Liquids Loading

- Emissions based on oil and condensate production
- AP-42 loading loss equation used to estimate emissions
- Tank vapor composition needed to estimate VOC and HAP emissions

$$L = 12.46 \times \left(\frac{S \times V \times MW_{gas}}{T} \right)$$

Pneumatic Devices

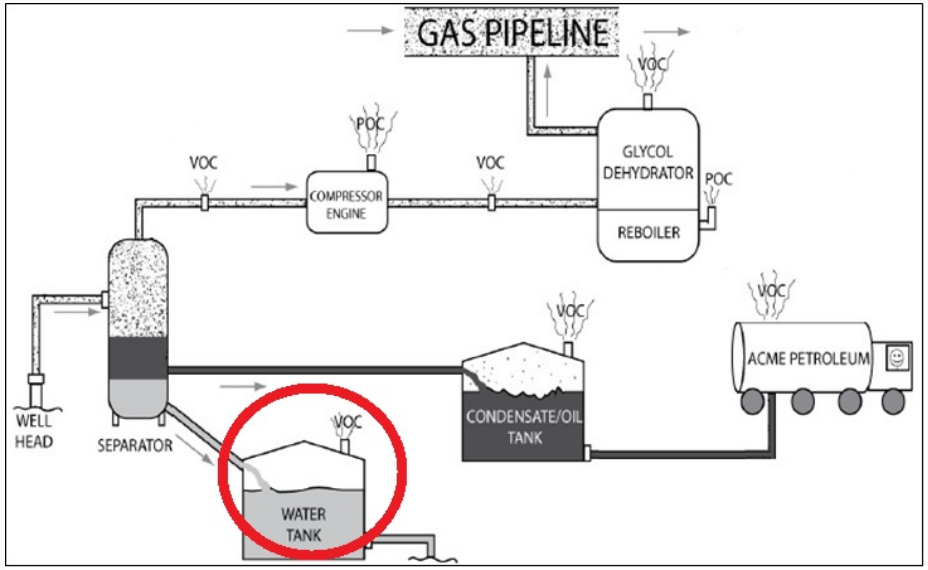
- Use high-pressure gas to produce mechanical motion (levers, switches)
- Largest CH_4 source under Subpart W and in the GHG EI (production sector)
- 2nd largest VOC source as calculated by the Tool

Pneumatic Devices

- Emissions based on the number of wells
- Process characteristics needed to estimate emissions
  - Number of devices per well
  - Type of devices (high, low, and intermittent-bleed)
  - Volume of vented gas per device (SCF/hr/device)
  - Operating schedule (hr/yr)
  - Composition of vented gas
- Regulated under NSPS OOOO and OOOOa

Produced Water Tanks

- Store water separated at the wellhead
- Emissions generated from working and breathing losses
- Water may be injected underground to maintain pressure (waterflooding) or for disposal



Source : Texas Commission on Environmental Quality Air Permit Reference Guide APDG 5942

Produced Water Tanks

- Emissions based on produced water production
- Emissions occur from working and breathing losses
- Process characteristics needed to estimate emissions
  - Emissions per barrel of production (lb/bbl)
  - Fraction of produced water directed to tanks
  - Composition of the tank vapors

Wellhead Compressor Engines

- Provide energy to move produced gas downstream to gathering or boosting station
- Brought onsite as well pressure drops
- Utilize produced gas as fuel
- Largest NO_x source as calculated by the Tool

Wellhead Compressor Engines

- Compressors regulated under NSPS OOOO and OOOOa
- Emissions based on the number of gas wells
- Process characteristics needed to estimate emissions
  - Fraction of gas wells requiring compression
  - Engine size (HP)
  - Operating schedule (hr/yr)
  - Control information

QUESTIONS?

Data Resources

- National Oil & Gas Committee Information Repository
- Existing Studies
- EPA Natural Gas STAR Program
  - https://www.epa.gov/natural-gas-star-program/natural-gas-star-program
- Industry Surveys
- State Permitting/Inventory Data

Existing Studies

- National Oil & Gas Committee Information Repository
  - http://vibe.cira.colostate.edu/ogec/home.htm
- Texas Commission on Environmental Quality (TCEQ)
  - https://www.tceq.texas.gov/airquality/airmod/project/pj_report_ei.html
- Western Regional Air Partnership (WRAP)
  - https://www.wrapair2.org/emissions.aspx

Industry Surveys

- Send directly to industry, focused or broad
- Recent Industry Surveys/Examples
  - CenSARA
  - TCEQ
  - WRAP

State Permitting/Inventory Data

- Permit Applications
- Annual Emissions Inventory Submittals
- Dehydrator Simulation Software
  - Gas Research Institute (GRI) GLYCalc Model
  - ProMax®, Aspen HYSYS®, etc.
- Storage Tank Simulation Software
  - American Petroleum Institute (API) E&P TANKS
  - ProMax®, Aspen HYSYS®, etc.

State Permitting/Inventory Data

- EPA (Cindy Beeler) Presentation
  - GRI-GLYCalc and E&P TANK Example Applications
  - http://vibe.cira.colostate.edu/ogec/docs/meetings/2015-03-12/NationalOGEmissionWorkGroup_031215_GLYCalc_EPTank4.pdf
- Data may be used to develop “nonpoint” factors
  - GRI-GLYCalc - fugitive gas composition and dehydrator emission factors
  - E&P TANK – VOC and HAP emission factors

GRI-GLYCalc Gas Composition

WET GAS STREAM

Temperature: 95.00 deg. F
Pressure: 994.70 psia
Flow Rate: 2.48e+005 scfh

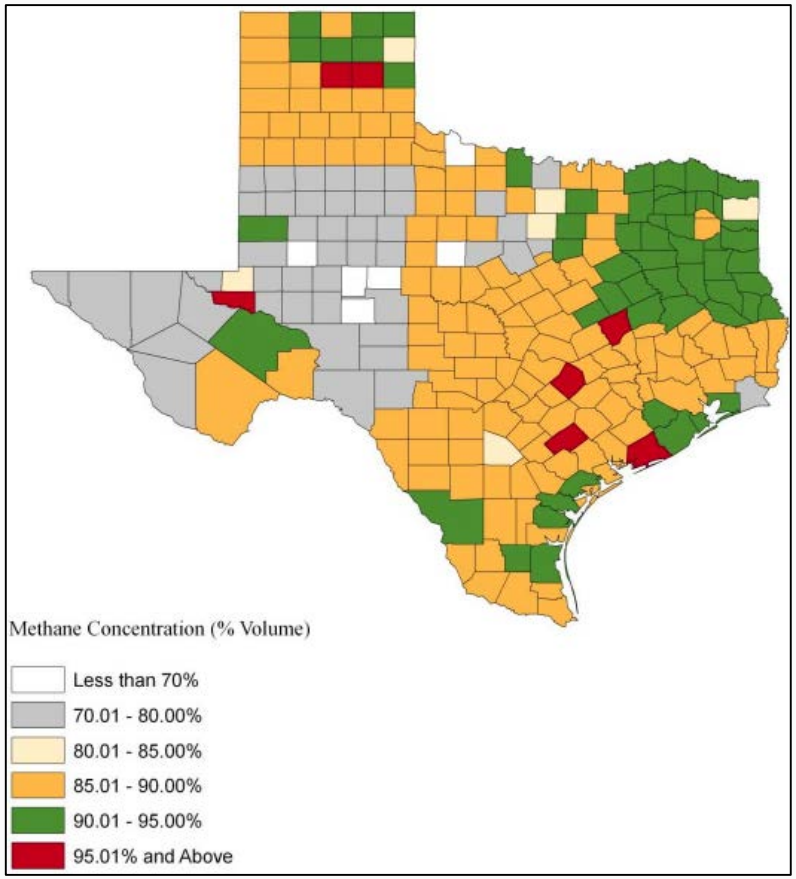
Component	Conc. (vol%)	Loading (lb/hr)
Water	1.08e-001	1.27e+001
Carbon Dioxide	1.90e-001	5.46e+001
Hydrogen Sulfide	9.99e-005	2.22e-002
Nitrogen	1.02e-001	1.86e+001
Methane	8.96e+001	9.39e+003
Ethane	5.67e+000	1.12e+003
Propane	2.33e+000	6.71e+002
Isobutane	5.93e-001	2.25e+002
n-Butane	5.95e-001	2.26e+002
Isopentane	2.33e-001	1.10e+002
n-Pentane	1.62e-001	7.63e+001
Cyclopentane	9.99e-003	4.58e+000
n-Hexane	5.59e-002	3.15e+001
Cyclohexane	4.29e-002	2.36e+001
Other Hexanes	6.99e-002	3.94e+001
Heptanes	4.10e-002	2.68e+001
Methylcyclohexane	3.60e-002	2.31e+001
Benzene	1.60e-002	8.16e+000
Toluene	1.30e-002	7.82e+000
Ethylbenzene	9.99e-004	6.93e-001
Xylenes	4.00e-003	2.77e+000
C8+ Heavies	1.21e-001	1.35e+002

DRY GAS STREAM

Temperature: 95.00 deg. F
Pressure: 994.70 psia
Flow Rate: 2.48e+005 scfh

Component	Conc. (vol%)	Loading (lb/hr)
Water	4.17e-003	4.90e-001
Carbon Dioxide	1.89e-001	5.42e+001
Hydrogen Sulfide	9.59e-005	2.13e-002
Nitrogen	1.02e-001	1.86e+001
Methane	8.97e+001	9.39e+003
Ethane	5.68e+000	1.11e+003
Propane	2.33e+000	6.69e+002
Isobutane	5.93e-001	2.25e+002
n-Butane	5.94e-001	2.25e+002
Isopentane	2.32e-001	1.09e+002
n-Pentane	1.61e-001	7.59e+001
Cyclopentane	9.79e-003	4.48e+000
n-Hexane	5.56e-002	3.13e+001
Cyclohexane	4.15e-002	2.28e+001
Other Hexanes	6.96e-002	3.91e+001
Heptanes	4.05e-002	2.65e+001
Methylcyclohexane	3.47e-002	2.22e+001
Benzene	1.18e-002	5.99e+000
Toluene	8.47e-003	5.09e+000
Ethylbenzene	5.94e-004	4.12e-001
Xylenes	2.00e-003	1.38e+000
C8+ Heavies	1.17e-001	1.30e+002

GRI-GLYCalc Gas Composition



GRI-GLYCalc Dehydrator Emissions

CONTROLLED REGENERATOR EMISSIONS

Component	lbs/hr
Hydrogen Sulfide	<0.0001
Methane	0.0088
Ethane	0.0096
Propane	0.0123
Isobutane	0.0061
n-Butane	0.0081
Isopentane	0.0027
n-Pentane	0.0025
Cyclopentane	0.0006
n-Hexane	0.0009
Cyclohexane	0.0025
Other Hexanes	0.0011
Heptanes	0.0006
Methylcyclohexane	0.0014
Benzene	0.0065
Toluene	0.0027
Ethylbenzene	0.0001
Xylenes	0.0004
C8+ Heavies	<0.0001
Total Emissions	0.0668
Total Hydrocarbon Emissions	0.0668
Total VOC Emissions	0.0484
Total HAP Emissions	0.0106
Total BTEX Emissions	0.0097

FLASH TANK OFF GAS

Component	lbs/hr
Hydrogen Sulfide	0.0001
Methane	4.5066
Ethane	1.2750
Propane	0.8493
Isobutane	0.2991
n-Butane	0.3260
Isopentane	0.1343
n-Pentane	0.1012
Cyclopentane	0.0081
n-Hexane	0.0389
Cyclohexane	0.0362
Other Hexanes	0.0479
Heptanes	0.0287
Methylcyclohexane	0.0277
Benzene	0.0127
Toluene	0.0096
Ethylbenzene	0.0005
Xylenes	0.0018
C8+ Heavies	0.0356
Total Emissions	7.7396
Total Hydrocarbon Emissions	7.7395
Total VOC Emissions	1.9579
Total HAP Emissions	0.0635
Total BTEX Emissions	0.0246

E&P TANKS

Project Setup Information

Project File	: C:\Program Files\API\E&P TANK Version
Flowsheet Selection	: Oil Tank with Separator
Calculation Method	: AP42
Control Efficiency	: 95.0%
Known Separator Stream	: Low Pressure Oil
Entering Air Composition	: No
Production Rate	: 301.2[bbl/day]
Days of Annual Operation	: [illegible]

-- Emission Summary

Item	Uncontrolled [ton/yr]	Uncontrolled [lb/hr]	Controlled [ton/yr]	Controlled [lb/hr]
Total HAPs	14.210	3.244	0.711	0.162
Total HC	566.994	129.451	28.350	6.473
VOCs, C2+	500.099	114.178	25.005	5.709

-- Emission Composition

No	Component	Uncontrolled [ton/yr]	Uncontrolled [lb/hr]	Controlled [ton/yr]	Controlled [lb/hr]
1	H2S	0.000	0.000	0.000	0.000
2	O2	0.000	0.000	0.000	0.000
3	CO2	3.783	0.864	3.783	0.864
4	N2	1.607	0.367	1.607	0.367
5	C1	66.895	15.273	3.345	0.764
6	C2	113.476	25.908	5.674	1.295
7	C3	141.081	32.210	7.054	1.611
14	C8	8.178	1.867	0.409	0.093
15	[illegible]	1.717	0.392	0.086	0.020
16	C10+	0.023	0.005	0.001	0.000
17	Benzene	0.489	0.112	0.024	0.006
18	Toluene	1.242	0.284	0.062	0.014
19	E-Benzene	0.147	0.034	0.007	0.002
20	Xylenes	1.259	0.287	0.063	0.014
21	n-C6	11.006	2.513	0.550	0.126
22	22[illegible]Methylp	0.064	0.015	0.003	0.001

EPA Gas Composition Calculator

- Gas composition data used in the Tool for the following source categories:
  - Associated gas
  - Condensate tanks
  - Crude oil tanks
  - Dehydrators
  - Fugitives
  - Gas-actuated pumps
  - Liquids unloading
  - Loading operations
  - Mud degassing
  - Pneumatic devices
  - Produced water tanks
  - Well completions

EPA Gas Composition Calculator

- Excel-based workbook
  - README sheet with description/instructions
  - Calculator sheets for each source category
- User provides gas composition
  - Weight % or
  - Volume %
- Calculator generates Tool basin factors

Questions?

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