Natural Gas & Petroleum Systems: Updates Under Consideration for 2021 GHGI

Stakeholder Webinar

November 12, 2020

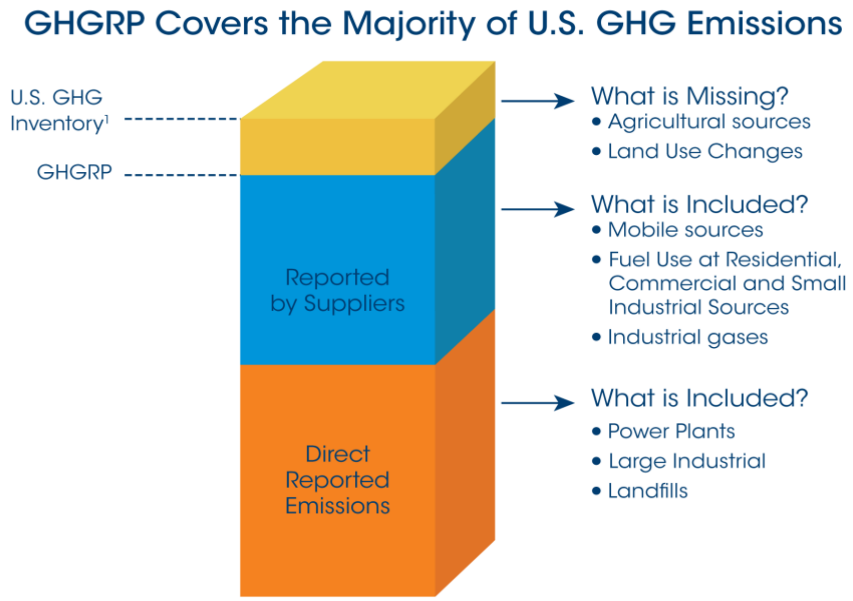
11/12 Stakeholder Webinar Agenda

- Overview of GHGI and GHGRP, **EPA**
- GHGRP Reporting Year 2019 Data, **EPA**
- CO_2 Uncertainty Update, **EPA**
- Closing the gap: Explaining persistent underestimation of US oil and natural gas production methane inventories, **Stanford University**
- Mud Degassing and Produced Water Updates, **EPA**
- Quantifying Intermittent Device Emissions by Actuation Count, **EQT**
- Customer Meters Update, **EPA**
- Temporal variability of emissions at an underground natural gas storage facility revealed by long-term continuous monitoring, **University of Colorado**
- Storage Well Update, **EPA**
- Wrap Up

Overview of GHGI and GHGRP

GHG Reporting Program and U.S. GHG Inventory

- Inventory of U.S. Greenhouse Gas Emissions and Sinks (GHG Inventory) tracks total annual U.S. emissions across all sectors of the economy using national-level data
- GHGRP collects detailed emissions data from large greenhouse gas emitting facilities in the United States, as directed by the Clean Air Act
  - GHGRP covers most, but not all, U.S. GHG emissions
  - GHGRP does not include agriculture, land use, and small sources



Task	Inventory of U.S. GHG Emissions and Sinks	Greenhouse Gas Reporting Program
Find total U.S. emissions	✓	
Review trend data for the past 20 years	✓	
Browse a map to find largest emitters in your area		✓
Compare facility emissions across an industrial sector		✓
Find reported emissions by state		✓

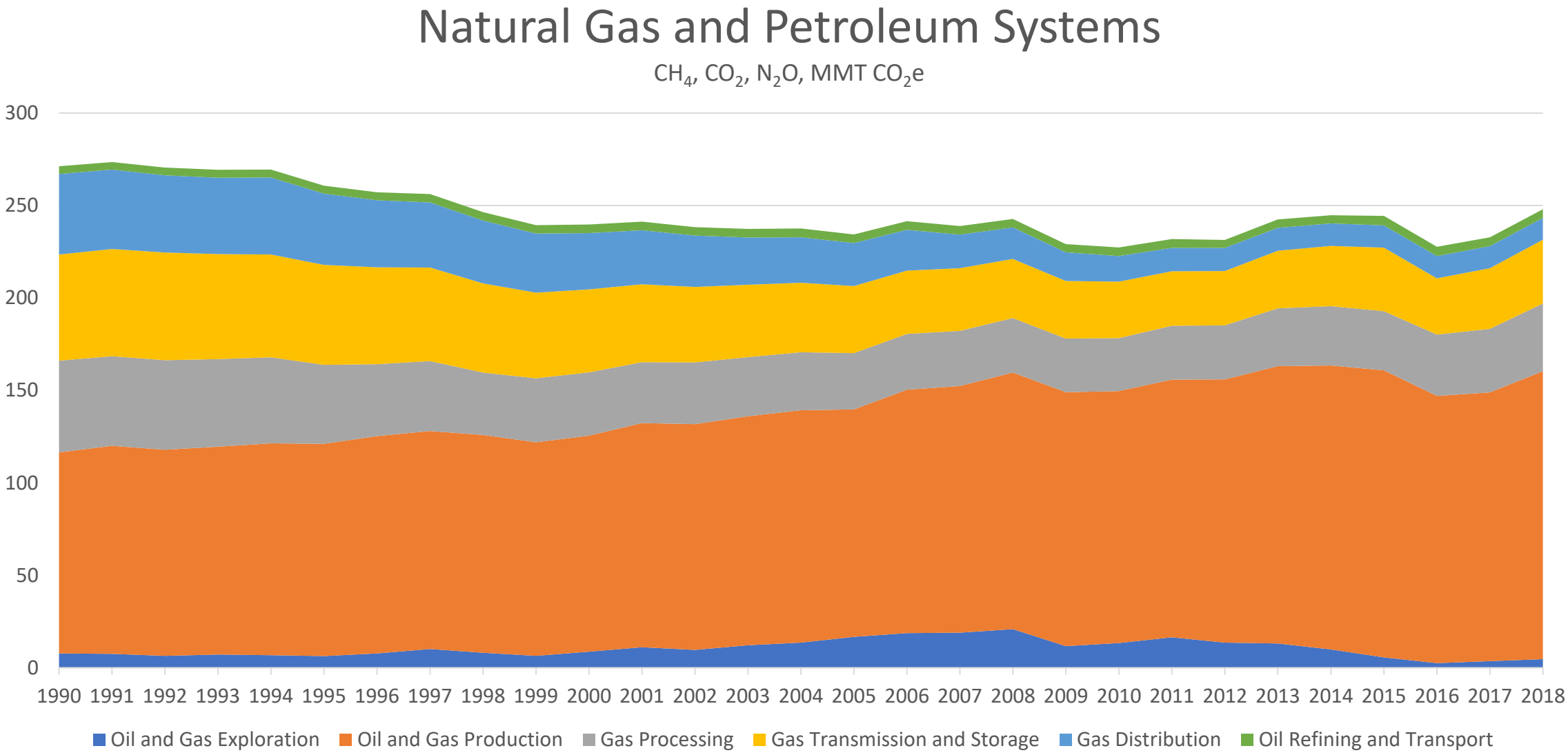
U.S. Greenhouse Gas Inventory Background

- Official U.S. estimate of greenhouse gas emissions for reporting to United Nations Framework Convention on Climate Change (UNFCCC)
  - Annual national-level inventory submissions to the UNFCCC since 1994
  - Emission estimates begin in 1990; most current inventory covers 1990-2018
- EPA leads Inventory development, working with several other agencies (e.g., agriculture, energy) to prepare estimates and provide activity data
- Sectors Covered
  - Energy, Industrial Processes, Agriculture, Land-Use Change and Forestry, and Waste
- Gases Covered
  - CO_2, CH_4, N_2O, HFCs, PFCs, NF_3, SF_6
  - Reported in mass of each gas, and as global warming potential (GWP)-weighted CO_2e emissions
- Record of emissions trends over time
- Each year, Inventory undergoes expert review, public review, and UNFCCC review

Calculating U.S. GHG Emissions from Oil and Gas

- Inventory is stratified into natural gas and petroleum pathways of the industry
  - Natural gas - offshore production, onshore production, gas processing, gas transmission, underground gas storage, LNG storage, LNG import and export terminals, and gas distribution
  - Petroleum – offshore production, onshore production, oil transportation, and refineries
- Oil and gas in inventory covers hundreds of types of sources
- Basic approach is to multiply national activity data by emission factors, e.g.:
  - Miles cast iron pipeline x CH4 per mile cast iron pipeline
  - # residential meters x CH4 per residential meter

Oil and Gas GHG Trends



Updating Oil and Gas Estimates in the GHGI

- Large amount of data and information newly available
- Opportunity to re-evaluate and make updates to GHG Inventory
- Stakeholder process
  - Webinar
  - Memos
- Public review draft and memo comments

CO_2 Uncertainty

CO_2 Uncertainty – Background

- For the 2018 GHGI, EPA updated its approach to estimate uncertainty for CH_4 emissions. At that time, uncertainty calculations focused on CH_4 because of its large contribution to CO_2e
- CH_4 used the IPCC Approach 2 methodology (i.e., Monte Carlo simulations)
- Due to number of sources, EPA calculates uncertainty for the highest-emitting sources that contribute at least 75% of gross emissions (modeled sources) and applies their results to the other low emission (unmodeled sources).
- Currently, CO_2 uncertainty is not calculated, but instead CH_4 bounds are applied to CO_2
- GHGRP data have been more fully incorporated, improving estimates of CO_2 from flaring
- EPA is considering developing uncertainty estimates specific to CO_2

CO_2 Uncertainty – Emission Sources

Top 10 Natural Gas Systems CO_2 Emission Sources in the 2020 GHGI

Emission Source (segment)	Year 2018 Gross Emissions (MMT CO_2)	% of Source Category Emissions
AGR Vents (processing)	**17.5**	**50%**
Flares (processing)	**7.0**	**20%**
G&B Stations – Flare Stacks (production)	**4.2**	**12%**
Misc. Onshore Production Flaring (production)	1.4	3.9%
G&B Station – Tanks (production)	1.3	3.7%
Condensate Tanks (production)	0.8	2.4%
G&B Station – Dehydrators (production)	0.8	2.3%
G&B Station – AGR (production)	0.6	1.8%
HF Completions (exploration)	0.4	1.1%
LNG Export Terminals (LNG export)	0.3	0.8%
Subtotal, Top Three Sources	**28.6**	**82%**
Natural Gas Systems Total	**35.0**	**100%**

Top 10 Petroleum Systems CO_2 Emission Sources in the 2020 GHGI

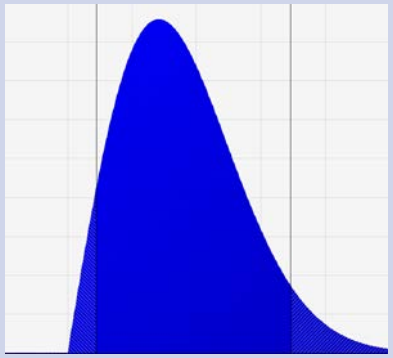
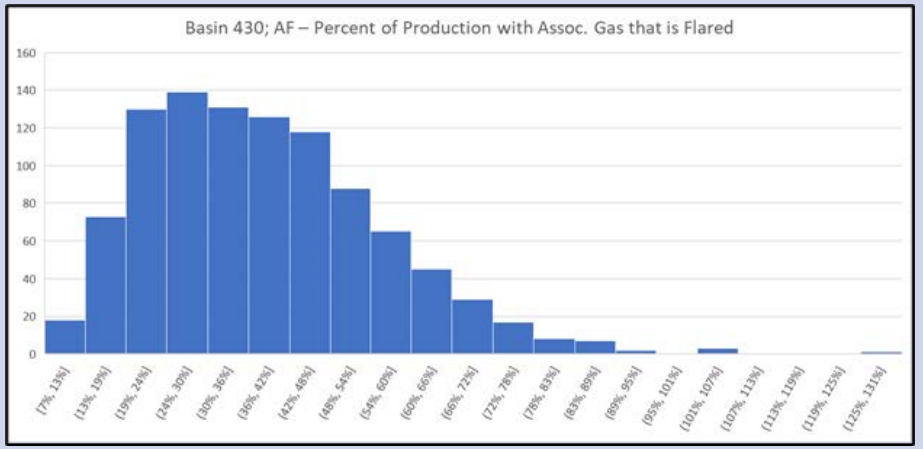
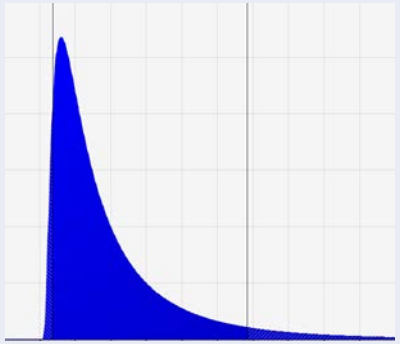
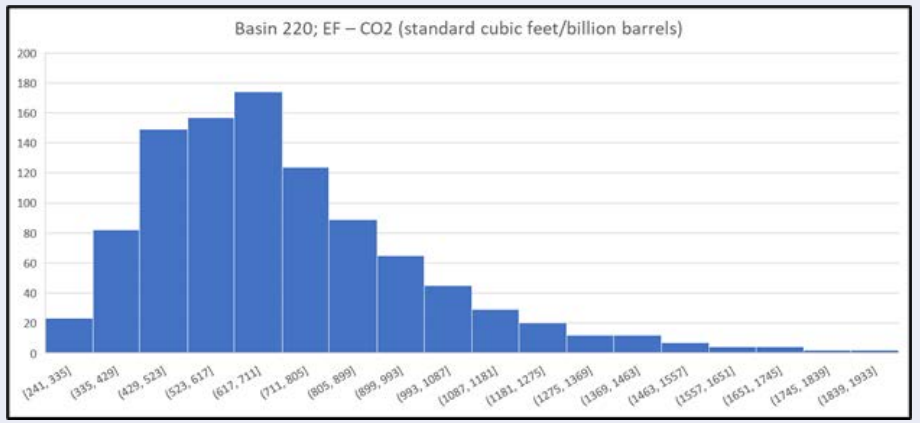
Emission Source (segment)	Year 2018 Gross Emissions (MMT CO_2)	% of Source Category Emissions
Associated Gas Flaring (production)	**19.0**	**52%**
Oil Tanks (production)	**6.4**	**17%**
Misc. Production Flaring (production)	**4.2**	**12%**
Flaring (refinery)	3.6	10%
HF Well Completions (exploration)	2.7	7.4%
Offshore Facilities – Gulf of Mexico (production)	0.4	1.1%
Offshore Facilities – Alaska (production)	0.1	0.3%
HF Workovers (production)	0.1	0.3%
Pneumatic Controllers (production)	0.1	0.2%
Process Vents (refinery)	<0.1	0.1%
Subtotal, Top Three Sources	**29.6**	**80%**
Petroleum Systems Total	**36.8**	**100%**

CO_2 Uncertainty – Background Cont.

Per IPCC Guidelines, EPA calculates a 95% confidence interval to estimate uncertainty. Confidence interval calculations require the following:

- Characterization of the probability density function (PDF). The PDF (e.g., normal, lognormal) describes the range and likelihood of possible values for the average emissions and average activity factors.
- Activity and Emission Factor data for all modeled CO_2 sources is from GHGRP. Therefore, EPA employs bootstrapping to determine the PDF and the applicable statistical parameters (e.g., mean, standard deviation, maximum, minimum).

CO_2 Uncertainty – Microsoft Excel's @RISK

PDF Type	PDF Pictorial Representation	Example, GHGRP Calculation Input	GHGRP Input
Weibull			Petroleum Activity factor Basin 430 (Anadarko); Percent of Production with Associated Gas that is Flared.
Invgauss			Petroleum CO_2 Emission factor Basin 220 (Gulf Coast); standard cubic ft per billion barrels of oil produced.

CO_2 Uncertainty – Petroleum Findings

Emission Source	2018 Mean Emissions	2.5% Lower Bound of Mean	97.5% Upper Bound of Mean
Associated Gas Flaring - 220 Gulf Coast	686,281	-76%	170%
Associated Gas Flaring - 360 Anadarko	37,482	-83%	161%
Associated Gas Flaring - 395 Williston	10,131,704	-45%	64%
Associated Gas Flaring - 430 Permian	7,248,710	-79%	181%
Associated Gas Flaring - Other	876,292	-77%	154%
Production - Large Oil Tanks with Flares	6,369,067	-33%	41%
Miscellaneous Production Flaring - 220 Gulf Coast	686,842	-56%	78%
Miscellaneous Production Flaring - 395 Williston	1,653,170	-96%	208%
Miscellaneous Production Flaring - 430 Permian	1,182,863	-61%	78%
Miscellaneous Production Flaring - Other	703,446	-52%	71%
Modeled Sources Total	**29,575,857**	**-30%**	**49%**
Not-modeled Sources Total	**7,238,515**	**-30%**	**49%**
Grand Total	**36,814,372**	**-23%**	**34%**
GHGI 1990 – 2018 (from Methane)	**-**	**-31%**	**34%**

CO_2 Uncertainty – Stakeholder Questions

1. EPA seeks feedback on calculating uncertainty bounds for CO_2 emissions separately from CH_4 emissions.
2. EPA seeks feedback on applying the CH_4 emissions uncertainty methodology to CO_2 emissions.
3. EPA seeks feedback on if the PDFs incorporated into the uncertainty analysis should be limited (i.e., normal, lognormal, uniform, triangular, and beta) or if other distributions should be considered (e.g., Weibull, Kumaraswamy, Pearson5).

Exploration and Production

a. Mud Degassing

b. Produced Water

Mud Degassing – Background

- Emissions from onshore mud degassing are not included in the current GHGI
- Preliminary approach
  - EF – EPA publication (1977); THC EFs for water-based and oil-based muds
  - Activity – Drilling duration and number of wells drilled (Enverus DrillingInfo)
  - Mud usage – Fraction of water-based muds versus oil-based muds

Mud Degassing – Preliminary estimates

Year	Case 1 – 80% Water-Based Muds		Case 2 – 100% Water-Based Muds	
	Natural Gas – CH_4 (metric tons)	Oil – CH_4 (metric tons)	Natural Gas – CH_4 (metric tons)	Oil – CH_4 (metric tons)
Preliminary Estimate (from memo)				
1990	95,133	105,862	111,922	124,543
2018	19,301	101,179	22,707	119,035

Mud Degassing – Stakeholder Comments

- Water-based EF assumptions on borehole size and porosity
- Oil-based EF
- Mud type usage for horizontal/lateral drilling versus vertical drilling
- Total drilling duration and total drilling days versus drilling days in the producing formation
- Regional versus national CH_4 content
- Effect of balanced and over-balanced systems

Mud Degassing – Comment Considerations

- Calculated water-based mud EF could be adjusted (e.g. for different borehole diameter or porosity) but data are limited
- EPA is evaluating the use of Enverus DrillingInfo to estimate drilling days
- EPA could evaluate HF vs non-HF completions data to estimate mud type distribution

Mud Degassing – Stakeholder Questions

1. EPA requests additional information on the diameter of a typical borehole
2. EPA requests additional information on the typical porosity
3. EPA requests additional data on drilling duration
4. EPA requests information on usage proportions of water-based muds and oil-based muds

Produced Water – Current GHGI

Produced water emissions are estimated for two CBM formations in GHGI

Emission Factors

Basin	Base EF
Powder River	2.0522 metric tons CH_4/million gallons water drainage
Black Warrior	2.0694 metric tons CH_4/well

Activity Data

- Powder River – produced water volumes from the Wyoming Oil and Gas Conservation Commission (WOGCC)
- Black Warrior – producing well counts from Alabama Oil and Gas Board (AOGB)
- 2013 data have been held constant for last five inventory years (i.e., 2014-2018)

Produced Water – Activity Data Update

- Produced water production (bbl/year) at gas (including CBM) and oil wells
- Data used in the U.S. EPA Oil and Gas Tool
  - Enverus DrillingInfo – 27 states
  - State oil and gas commissions – 3 states
  - State environmental agencies – 1 state
  - Multiple sources (Enverus DrillingInfo, EIA, and state environmental agencies) – 3 states
- Data available for nearly entire time series

Produced Water – EF Update

- GHGI EFs under consideration are from Production Module of 2017 NEI Oil and Gas Tool
  - Based on 1996 GRI/EPA Study; also used in API Compendium, The Climate Registry guidance document, and 2011 CenSARA inventory
  - Key assumption: 30% of produced water in tanks; remaining 70% is reinjected.
- Low pressure oil wells (i.e., wells using artificial lift) assumed to be 73% of oil well population; regular pressure oil wells (i.e., wells not using artificial lift) are remaining 27% of oil well population – from CenSARA

Well Type	CH_4 EF (lb/bbl)
Low Pressure Oil Wells	0.0033
Regular Pressure Oil Wells	0.0313
Gas and CBM Wells	0.112

Produced Water – Preliminary National CH_4 Emissions Estimates

Well Type	Produced Water Volume (bbl)	EF (lb/bbl)	2017 CH_4 Emissions (metric tons)
Oil Wells – Low Pressure	11,577,008,380	0.0033	17,329
Oil Wells – Regular Pressure	4,281,302,580	0.0313	60,793
Gas and CBM Wells	1,492,302,580	0.112	75,813
Preliminary Total			**153,936**
Powder River (CBM)	490,393,575	0.22	48,877
Black Warrior (CBM)	131,591,163	0.21	12,796
Current GHGI			**61,674**

Produced Water – Stakeholder Comments

- Produced water often routed to tanks
- Tanks can have controls
- Use same EF for gas and CBM wells

Produced Water – Stakeholder Questions

1. EPA seeks feedback on how frequently produced water tanks are controlled.
2. EPA seeks feedback on the percent of produced water that releases emissions (e.g., through tank flashing or evaporation in a pond), including whether the assumption that 30 percent of produced water undergoes tank flashing is reasonable.
3. EPA seeks feedback on updating the current GHGI EF for gas wells, currently applied to only certain CBM formations, to instead use the updated EF for all gas well produced water.
4. EPA seeks feedback on the fraction of oil wells that are low pressure, including whether it is reasonable to apply an average of 73 percent of oil wells using artificial lifts.

Customer Meters

Customer Meters – Current GHGI Methodology

Industrial and Commercial Meters

- Activity Data – EIA meter counts for commercial and industrial meters for each year in the time series
- Emission Factor – 9.7 kg/meter/yr EF is applied to both commercial and industrial meter counts
- The current EF is from a GTI 2009 study and was based solely on commercial meter data
  - Industrial EF from GTI 2009 study not used in GHGI due to limitations of industrial meter data and stakeholder feedback

Customer Meters – Available Data

GTI 2009 Study

- Sampled leak and vented emissions at 836 commercial meters and 46 industrial meters
- Calculated population EFs for each type of meter

GTI 2019 Study

- Sampled leak emissions at 337 commercial meters and 186 industrial meters
  - Found a leak at 43% of commercial meters and 42% of industrial meters
- Calculated population EFs for each type of meter

Customer Meters – Preliminary Estimates

Emissions Type	EF Basis	EF (kg/meter/year)	2018 Activity (# Meters)	2018 Emissions (MT CH_4)
Commercial Meters				
Leak	GTI 2019	57.4	5,515,841	316,609
Leak + Vented	Weighted – GTI 2009 and 2019	23.43	5,515,841	129,277
Current GHGI - Leak and Vented	*GTI 2009 Commercial EF*	*9.7*	*5,515,841*	*53,692*
Industrial Meters				
Leak	GTI 2019	117.8	184,943	21,786
Leak	Weighted – GTI 2009 and 2019	105	184,943	19,419
Vented	GTI 2009	3,487	184,943	711,489
Vented	Weighted – GTI 2009 and 2019	763	184,943	141,112
Current GHGI – Leak + Vented	*GTI 2009 Commercial EF*	*9.7*	*184,943*	*1,800*

Customer Meters – Stakeholder Comments

- Size of data set
- Averaging GTI 2009 and 2019 study data
- Use of leaker versus population EFs
- Inclusion of venting emissions
- Regional versus national EFs
- Component-specific EFs

Customer Meters – Comment Considerations

- EPA evaluated population EFs vs leaker EFs vs regional EFs
  - Leaker EFs: data on leaking meters are not available across the time series
  - Regional EFs: limited data are available to develop accurate regional EFs
- Following slides compare different approaches for leak EFs, based on GTI 2019 data

Customer Meters – Commercial Leak EF Comment Considerations

Commercial Meter EF Options

1. GTI 2019 Population EF
2. GTI 2019 Leaker EF
3. GTI 2019 Regional Population EFs
4. GTI 2009 Population EF
5. Weighted Average EF from GTI 2009 and 2019 Studies

EF Basis	Meters Sampled	CH_4 EF (kg/meter/year)
GTI 2019 – Population	337	57.4
GTI 2019 – Leaker	146	132.4
GTI 2019 – Regional		
Midwest	99	28.4
Northeast	75	20
Pacific	63	4
Rocky Mountain	12	108.4
Southeast	5	139.3
Southwest	83	153.9
GTI 2009 – Population	836	9.7
GTI 2009 and 2019 Weighted Average	1,173	23.43

Customer Meters – Preliminary National Emissions for Commercial Meters

- Using GTI 2019 population EFs, leaker EFs, or regional EFs leads to similar results

EF Basis	CH_4 EF (kg/meter/year)	2018 Activity (# Meters)	2018 Emissions (MT CH_4)
GTI 2019 - Population	57.4	5,515,841	316,609
GTI 2019 - Leaker	132.4	2,371,812	316,390
GTI 2019 - Regional	varies	5,515,841	335,795
Weighted Average - GTI 2009 and 2019	23.43	5,515,841	129,277
Current GHGI (GTI 2009)	*9.7*	*5,515,841*	*53,692*

Customer Meters – Industrial Leak EF Update Considerations

Industrial Meter Leak EF options

1. GTI 2019 Population EF
2. GTI 2019 Leaker EF
3. GTI 2019 Regional Population EFs
4. GTI 2009 Population EF
5. Weighted Average EF from GTI 2009 and 2019 leak data

*EFs only include leak emissions, vented emissions are excluded

EF Basis	Meters Sampled	CH_4 EF (kg/meter/year)
GTI 2019 – Population	186	117.8
GTI 2019 – Leaker	79	277.4
GTI 2019 – Regional		
Midwest	77	52.3
Northeast	13	172.5
Pacific	52	17.4
Rocky Mountain	9	322.5
Southeast	15	291.7
Southwest	20	372.9
GTI 2009 – Population	46	55
GTI 2009 and 2019 Weighted Average	232	105

Customer Meters – Preliminary National Leak Emissions for Industrial Meters

- Using GTI 2019 population EFs, leaker EFs, or regional EFs leads to similar results

EF Basis	CH_4 EF (kg/meter/year)	2018 Activity (# Meters)	2018 Emissions (MT CH_4)
GTI 2019 - Population	117.8	184,943	21,786
GTI 2019 - Leaker	277.4	77,676	21,790
GTI 2019 - Regional	varies	184,943	23,471
Weighted – GTI 2009 and 2019	105	184,943	19,419
Current GHGI (GTI 2009 for commercial meters)	*9.7*	184,943	*1,800*

Customer Meters – Stakeholder Questions

1. EPA seeks feedback on leak EF approaches
2. EPA seeks feedback on national versus regional EFs
3. EPA seeks additional data on venting emissions at commercial and industrial meters

Underground Natural Gas Storage Wells

Storage Wells – Current GHGI Methodology

Emission Factor

- 115 scfd/well from 1996 GRI/EPA report
- Well-level EF calculated by GRI/EPA using average number of components per wellhead and component-specific EFs
  - Component EFs based on measurements taken at onshore gas production wellhead components in the western U.S.

Activity Data

- Well count estimated as 17,999 in year 1992 from 1996 GRI/EPA report
- 1992 well counts scaled to all other years using residential gas consumption

Storage Wells – Available Data

GSI 2019 Study

- Performed wellhead component measurements at three storage stations (one depleted field, two salt domes) and developed component-specific EFs
- Estimated average number of components per wellhead for depleted field and salt dome wellheads

Subpart W

- Facilities report total number of wellhead components
- Methodology uses component-specific EFs, based on GRI/EPA study

Storage Wells – EF Update Considerations

- EPA is considering shifting from "per wellhead" EFs to "per station" EFs
  - This is a simplified approach, as compared to that presented during the September webinar, and minimizes assumptions
- Subpart W facilities report total component counts. EPA calculated average component counts per station (see table)
- Assigned each subpart W facility to a field type by matching against EIA data

GHGRP RY2015 – RY2018 Average Component Counts Per Station, by Field Type[a]

Component Type	Depleted Field		Salt Dome		Aquifer	
	Count	% of Total	Count	% of Total	Count	% of Total
Valve	1,030	23%	198	27%	2,786	20%
Connector	3,199	72%	523	71%	10,887	77%
Open-Ended Line	188	4%	5	1%	326	2%
Pressure Relief Valve	12	<1%	7	1%	195	1%
Total	**4,430**	-	**733**	-	**14,194**	-
Station Count in 2018[a]	27		8		5	

a - It is assumed that each GHGRP facility is a single storage station.

Storage Wells – EF Update Considerations (cont.)

- Table compares component EFs from GRI/EPA and GSI studies
- Valves and connectors account for >95% of total subpart W components
- Valve EFs are similar between GSI and GRI/EPA studies
- GSI study connector EF is lower than GRI/EPA EF

Underground Storage Wellhead Component CH_4 EF Comparison (scf/hr/component)

Component Type	1996 GRI/EPA	GSI 2019 Study
Valves	0.10	0.10
Connectors	0.01	0.0023
Open-Ended Lines	0.03	0.0053
Pressure Relief Valves	0.17	0.10

Storage Wells – EF Update Considerations (cont.)

- EPA calculated "per station" EFs using average subpart W component counts per station and GSI component EFs
- Field type distribution has little variation in EIA dataset; applied average percentage of each field type to calculate weighted average EF

Storage Field Type	EIA Average % of Field Type, for 2005-2018	Station CH_4 EF (scf/day/station)
Depleted Field	80%	2,702
Salt Dome	9%	521
Aquifer	11%	7,796
Weighted Average CH_4 EF		**3,085**

Storage Wells – Activity Data Update Considerations

- EPA is considering using storage station counts (station counts are already in GHGI)

- Alternatively, EPA is also considering an approach that would retain "per well" EFs and scale well counts using total gas consumption

Storage Wells – Preliminary National CH_4 Emissions (metric tons)

EF Approach	Activity Approach	1992 CH_4	2018 CH_4
Station-Based Approaches			
GSI all years	Station counts from GHGI	8,371	7,431
GRI (1990-92) → Interpolation → GSI (2017+)		14,488	7,431
Well-Based Approaches			
Current GHGI - GRI all years	Residential gas consumption scaling	14,488	15,365
GSI all years	Station count scaling	9,616	7,139
GRI (1990-92) → Interpolation → GSI (2017+)		14,488	7,139
GSI all years	Total gas consumption scaling	9,616	14,241
GRI (1990-92) → Interpolation → GSI (2017+)		14,488	14,241

Storage Wells – Stakeholder Questions

1. EPA seeks feedback on the most appropriate approach to apply. This includes (1) using EFs based on the GSI 2019 data or retaining the current GHGI EFs and (2) whether a "per station" or "per well" approach is appropriate
2. For "per well" EFs, EPA seeks feedback on whether the wellhead component counts for depleted fields or salt domes from the GSI 2019 study are most applicable to aquifer wellheads. Alternatively, EPA seeks average component counts for aquifer wellheads
3. For "per well" EFs, EPA seeks feedback on three options to estimate well counts over the time series: (1) applying an average of 39 wellheads per storage station, based on subpart W and GSI data, (2) relying on residential gas consumption to scale the 1992 estimate of wells, or (3) relying on total gas consumption to scale the 1992 estimate of wells

Wrap-Up

Providing Stakeholder Feedback

- EPA memos for mud degassing, produced water, and customer meters updates are posted online and include additional details and specific stakeholder feedback requests
- EPA memos for underground storage wells and CO_2 uncertainty will be posted online with additional details and specific stakeholder feedback requests
- https://www.epa.gov/ghgemissions/stakeholder-process-natural-gas-and-petroleum-systems-1990-2019-inventory

- Submit feedback via email: GHGInventory@epa.gov

- Public Review draft available in early 2020
  - 30 day public comment period