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

Stakeholder Webinar

September 15, 2020

AGENDA

1. Onshore Exploration and Production
   a. Mud Degassing
   b. Produced Water
2. Underground Storage Wells
3. Distribution and Post-Meter
   a. Customer Meters
      i. GTI and EPA Presentations
   b. Post-Meter Emissions
4. CO_2 Uncertainty
5. Wrap-Up and Next Steps

1. Exploration and Production

a. Mud Degassing

b. Produced Water

Mud Degassing – Background

- Mud degassing – natural gas entrained in the drilling mud is removed in a mud separator and vented
- 3 types of drilling muds:
  - water-based
  - oil-based
  - synthetic-based
- Market analysis reports – water-based muds dominate the drilling muds industry
- Emissions from onshore mud degassing are not included in the current GHGI

Mud Degassing – Emission Factors

- EFs from EPA 1977 publication

Type of Drilling-Mud	THC EF (metric tons/drilling day)
Water-Based	0.4
Oil-Based	0.09

- Used by TCEQ, CenSARA, NYSERDA, and BOEM Inventories
- EFs calculated for consideration in updating GHGI

Type of Drilling-Mud	CH_4 EF (metric tons/drilling day)
Water-Based	0.24
Oil-Based	0.06

Mud Degassing – Activity Data

- Activity data have two components – drilling days/well and wells drilled
- Drilling days/well
  - 2014 Marcellus Shale study default assumption = 26 drilling days/well
  - NYSERDA – 24 days/well (back-calculated); CenSARA states – 22 days/well (back-calculated)
  - For the public review draft, Enverus DrillingInfo (which includes drilling beginning and end dates) will be assessed to determine an average drilling duration
- Current GHGI already includes gas and oil wells drilled per year (from Enverus DrillingInfo)

Mud Degassing – Activity Data

Mud Type Usage (only available for offshore)

- BOEM Gulfwide Emissions Inventory
  - 2011 – 92% of drilling operations were performed using water-based muds and 8% used synthetic-based muds
  - 2017 – 48% of drilling operations were performed using water-based muds, 37% used oil-based muds, and 15% used synthetic-based muds
- Subpart W Offshore Platforms
  - Water-based muds account for an average of 82.7% of total mud degassing emissions for 2015-2018

Mud Degassing – Preliminary Estimates

	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)
1990	95,133	105,862	111,922	124,543
2018	19,301	101,179	22,707	119,035

Mud Degassing – Stakeholder Questions

1. EPA seeks feedback on applying the EFs from the 1977 EPA publication. EPA seeks information on other available data sources on emissions and/or emission factors from mud degassing.
2. EPA seeks feedback on the split between water- and oil-based mud usage, and if there is regional or temporal variability in mud type usage (i.e., water, oil, and synthetic) that should be incorporated into the methodology.
3. EPA seeks feedback on the usage of flares on mud gas separators. Are there other pollution control devices that deserve consideration other than flaring? How should these be accounted for in the estimation methodology?

Produced Water – Background

- Produced water is the water/brine brought to the surface during the extraction of oil and gas – may include formation water, injection water, and any chemicals added downhole or during the oil/water separation process
- Ratio of produced water to recovered hydrocarbon is extremely variable – ranging from less than 1:1 to more than 100:1
- Emissions from produced water are included in the current GHGI – but only for two CBM formations (Powder River Basin in WY and Black Warrior Basin in AL)

Produced Water – Current 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 should be available for nearly all of the 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 Questions

1. 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.
2. 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.
3. 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.

2. Underground Natural Gas Storage Wells

Storage Wells – Current GHGI Methodology

Emission Factor

- 115 scfd/well from 1996 GRI/EPA report
- 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

- Valves and connectors account for >90% of total components
- Valve EFs are similar between GSI and GRI/EPA studies, but GSI found more valves at salt dome wellheads
- GSI study connector EF is lower than GRI/EPA EF, but GSI found more connectors overall

	GSI 2019 Study			1996 GRI/EPA Study	
Component Type	Average Count Per Wellhead		CH_4 EF (scf/hr/component)	Average Count Per Wellhead	CH_4 EF (scf/hr/component)
	Depleted Fields	Salt Domes			
Valve	**26**	**45**	**0.10**	**30**	**0.10**
Connector	**111**	**197**	**0.0023**	**89**	**0.01**
PRV	0	1.1	0.10	1	0.17
Open-Ended Line	4.3	0.1	0.0053	7	0.03
Gauge	6.1	7.7	0.027	-	-
Regulator	2.8	2	0.009	-	-

Storage Wells – EF Update Considerations (cont.)

- EPA calculated "per wellhead" EFs using GSI component counts and GSI EFs for depleted fields and salt domes
- EPA assumed the component makeup of aquifer wellheads resembles that of depleted field wellheads
- 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	GSI Based CH_4 EF (scf/day/wellhead)
Depleted Field	80%	72
Salt Dome	9%	117
Aquifer	11%	72
Weighted Average CH_4 EF		**76**
Current GHGI EF		115

Storage Wells – AF Update Considerations

- Instead of scaling the 1992 estimate of wellhead counts across the time series using residential gas consumption, EPA is considering relating wellhead counts to storage station counts (i.e., wellheads/station)
  - Storage station counts are already in GHGI
- Used subpart W average components/station and GSI average components/wellhead → wellheads/station (subpart W Based Calcs)

Storage Field Type	EIA Average % of Field Type, for 2005-2018	Average Wellheads per Station		
		Subpart W Based Calcs	GSI 2019 Study	Current GHGI (1992 basis)
Depleted Field	80%	34	43	
Salt Dome	9%	3	4.5	
Aquifer	11%	103	-	
Weighted Average		**39**		47

Storage Wells – Preliminary National Emissions

- Applied weighted average EF from GSI study (76 scf/well/day) and weighted average AF based on subpart W data (39 wellheads/station)

Approach	Year	Activity Data (# Wells)	CH_4 EF (scf/well/day)	Emissions (MT CH_4)
Preliminary Update	2018	13,363	76	7,140
Current GHGI	2018	19,089	115	15,365

Storage Wells – Stakeholder Questions

1. EPA seeks feedback on the most appropriate EFs to apply for underground storage wells. This includes whether weighted average EFs using the GSI 2019 data should be applied, or if the current GHGI EFs should be retained.
2. 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. EPA seeks feedback on applying an average of 39 wellheads per storage station, based on subpart W and GSI data, to estimate well counts over the time series instead of relying on residential gas consumption to scale the 1992 estimate of wells.

3. Distribution and Post Meter

A. Customer Meters

- GTI and EPA Presentations

B. Post Meter

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
- Calculated population EFs for each type of meter

Customer Meters – Commercial EF Update Considerations

Commercial Meter EF options

1. Use the GTI 2019 EF
2. Use both datasets to develop weighted average EF

Study	Meters Sampled	CH_4 EF (kg/meter/year)
GTI 2009	836	9.73
GTI 2019	337	57.4
Weighted Average EF		23

Customer Meters – Preliminary National Emissions for Commercial Meters

Emissions Type	EF Basis	EF (kg/meter/year)	2018 Activity (# Meters)	2018 Emissions (MT CH_4)
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*

Customer Meters – Industrial EF Update Considerations

- Vented emissions account for ~99% of total emissions in GTI 2009
- GTI 2019 observed but did not quantify vented emissions

Industrial Meter EF Options

- Leak Emissions EF: GTI 2019 EF OR weighted average EF
- Vented Emissions EF: GTI 2009 EF OR weighted average EF

Study	Meters Sampled	Leak Emissions CH_4 EF (kg/meter/yr)	Vented Emissions CH_4 EF (kg/meter/yr)	Total CH_4 EF (kg/meter/yr)
GTI 2009	46	55	3,847	3,902
GTI 2019	186	117.8	0	117.8
Weighted Average		105	763	868

Customer Meters – Preliminary National Emissions for Industrial Meters

Emissions Type	EF Basis	EF (kg/meter/year)	2018 Activity (# Meters)	2018 Emissions (MT CH_4)
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 Questions

1. EPA seeks feedback on how to incorporate leak and venting emissions for industrial meters, including whether using the GTI 2019 EF or a weighted average EF is most appropriate.
2. EPA seeks feedback on how to incorporate leak and vented emissions for commercial meters, including whether using the GTI 2019 EF or a weighted average EF is most appropriate. EPA also seeks feedback on if commercial meter vented emissions should be supplemented with vented emissions data from industrial meters or if other data are available to address vented emissions from commercial meters.
3. EPA seeks feedback on if different EFs should be applied over the time series. EPA is considering applying the same EFs, but could consider applying one EF to early years of the time series and a different EF to recent years, with linear interpolation between.

Post-Meter Emissions

- GHGI does not currently estimate post-meter fugitive (leakage) emissions
- IPCC 2019 Refinements to the 2006 IPCC guidelines newly included EFs for post-meter
  - Post-meter fugitives were not explicitly included in 2006 IPCC GL
  - Post-meter fugitives were included in 1996 IPCC GL
- IPCC 2019 includes emission factors for these sources; EPA is considering IPCC factors or other data sources for future GHGIs

IPCC Post-meter categories	Emission Source Details
Appliances in Commercial & Residential Sectors	Leakage from house piping and appliances, including home heating, water heating, stoves, barbecues.
Leakage at Industrial Plants and Power Stations	Leakage beyond gas meters including internal piping.
Natural gas-fueled vehicles	Leakage from vehicles with alternative fuels produced from natural gas e.g., LNG, CNG, RNG.

Post-Meter – Residential and Commercial Emissions Data

Author	EF for specific appliance types	Appliance EF (kg/house or kg/appl.)	Study Details
Fischer et al. (ES&T, Aug. 2018)	X	2.93 (per house)	75 single-family CA homes.
Merrin et al. (ES&T, March 2019)	X	0.25 (per house) 0.38 (per tonne NG consumption)	98 sites in U.S. cities (e.g., Boston, Indianapolis)
Lebel et al. (ES&T, April 2020)	X	1.42 (per water heater)	64 single-family CA homes; Only water heaters.
Saint-Vincent et al. (ES&T, Dec.2019)	X	2.41 (per house, calculated from nat'l total presented in study)	Uses data from Fischer, Merrin, + UNFCCC GHGIs
2019 IPCC		4.0 (per appliance)	Applies to both commercial and residential
1996 IPCC		0-192,000 (per PJ consumption)	Applies to both commercial and residential

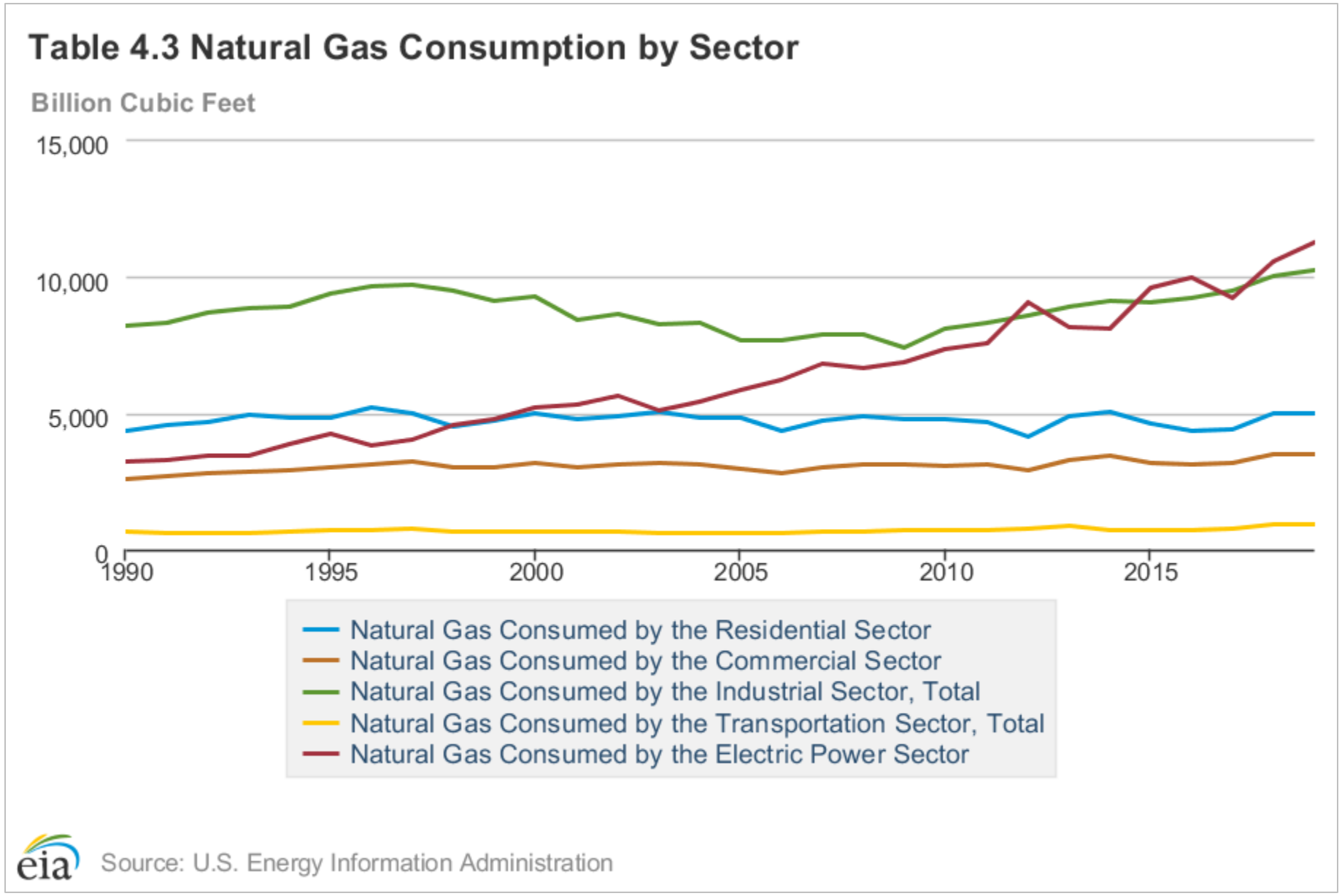
Post-Meter – Industrial and NG Vehicle EFs

Sub-Segment	Emission Factor	Data Source
NG-fueled vehicles	0.30 kg/car	2019 IPCC
	0.33 kg/car	Germany UNFCCC
Leakage at industrial power plants	0-13 mt/million m^3	1996 IPCC
	0.4 mt/million m^3	2019 IPCC
	0.27 mt/million m^3	Germany UNFCCC

Post-Meter – Potential Activity Data Sources

- **All Uses** – Gas Consumption – EIA's Monthly Energy Review (MER) – Annual fuel consumption by sector
- **Residential** – **Housing & Appliance** – U.S. Census Bureau's American Housing Survey (AHS) – Includes counts of housing units by fuel type and appliance usage information. Available once every 2 years from 1991-2017
- **Commercial and Industrial** – Meter counts available from EIA
- **NG Vehicles**
  - EIA-886 Data – Natural gas vehicle data from federal and state government, fuel providers, transit agencies
  - U.S. DOE's Alternate Fuel Data Center (AFDC) – Natural gas vehicle inventory from Clean Cities coalition data annual activity reports

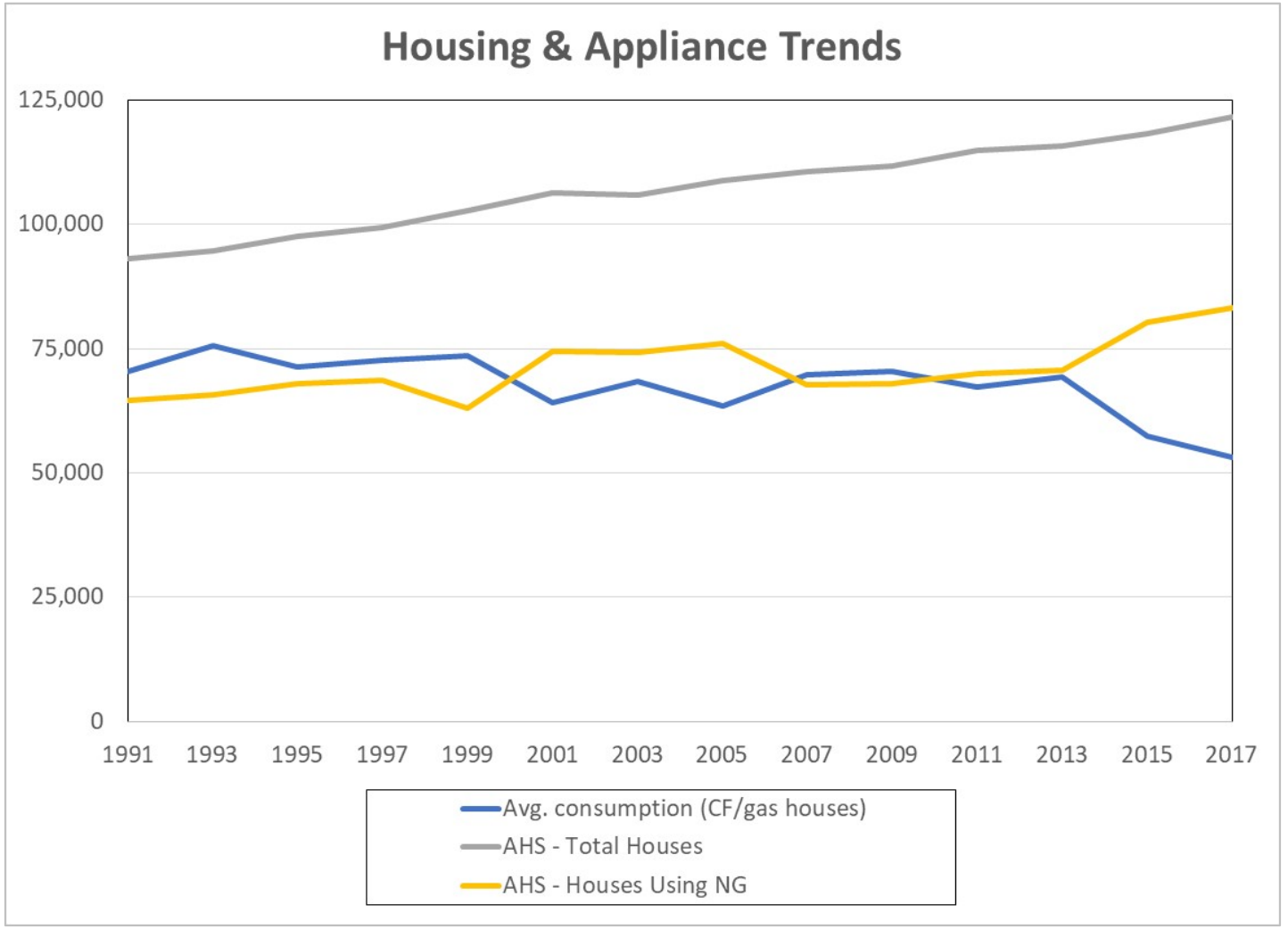
Post-Meter – Gas Consumption



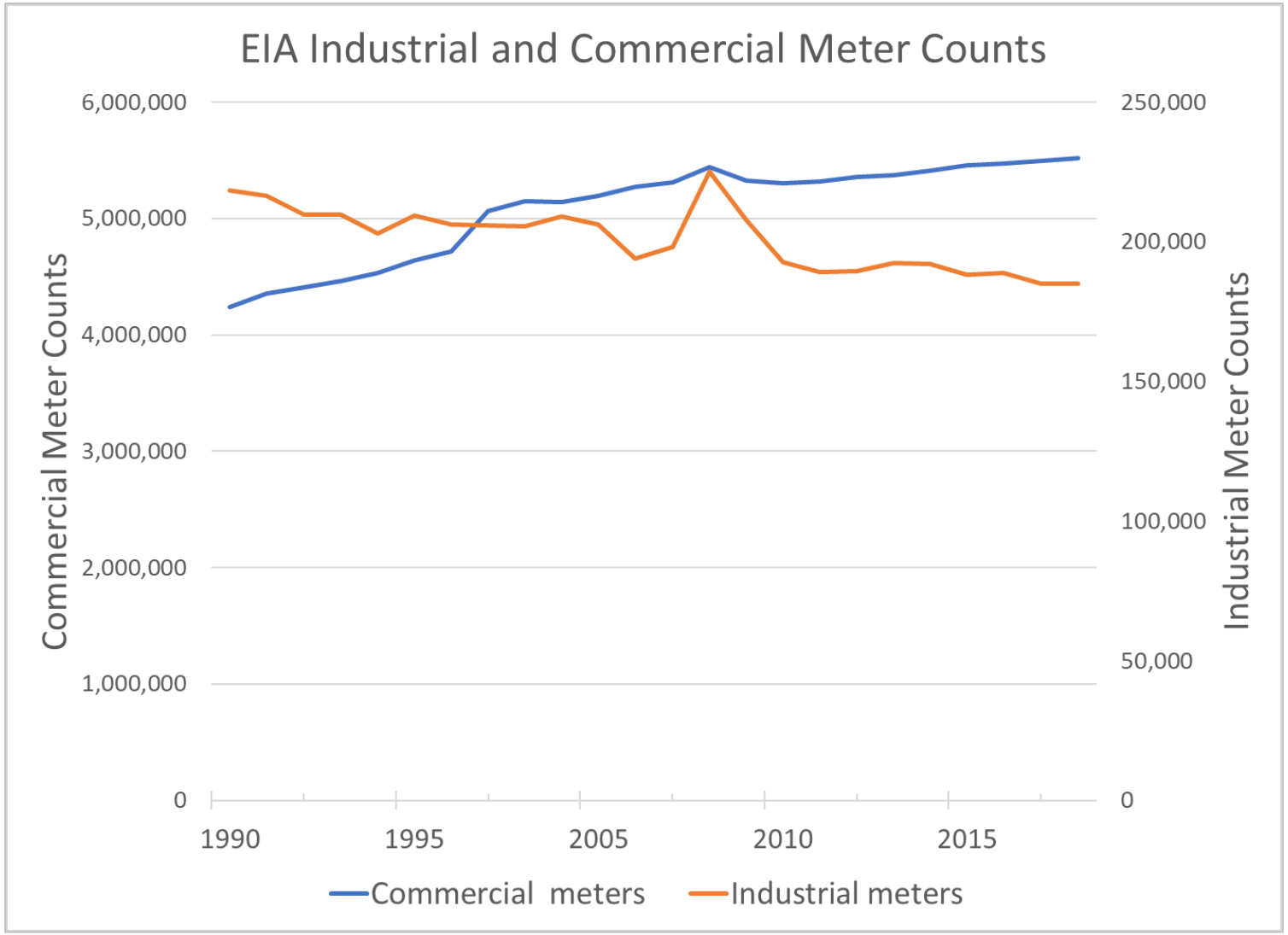
POST-METER – RESIDENTIAL APPLIANCE ACTIVITY DATA

U.S. Census Bureau's American Housing Survey (AHS)

Housing & Appliance Activity	2017
U.S. houses (million)	122
Houses using NG as fuel	68%
Appliances/House using NG	2.2



Post-Meter – Industrial and Commercial Meters



Source: U.S. Energy Information Administration
EIA-176, "Annual Report of Natural and Supplemental Gas Supply and Disposition"

Post-Meter – Stakeholder Questions

1. Are there additional data sources that can be considered for post-meter emissions?
2. Several studies have conducted top-down measurements in urban areas and calculated that inventory-based emissions from distribution and post-meter sources are lower than the top-down methane attributed to those sources. Will the inclusion of post-meter emissions explain some of the difference?
3. Are other bottom-up data sources available that could be used to assess or update estimates in the GHG Inventory?
4. Are other top-down studies available that can provide additional information on distribution and post-meter emissions?

4. 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, including high emitting CO_2 sources (e.g., flaring). It is therefore less reasonable to apply the CH_4 results 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%**

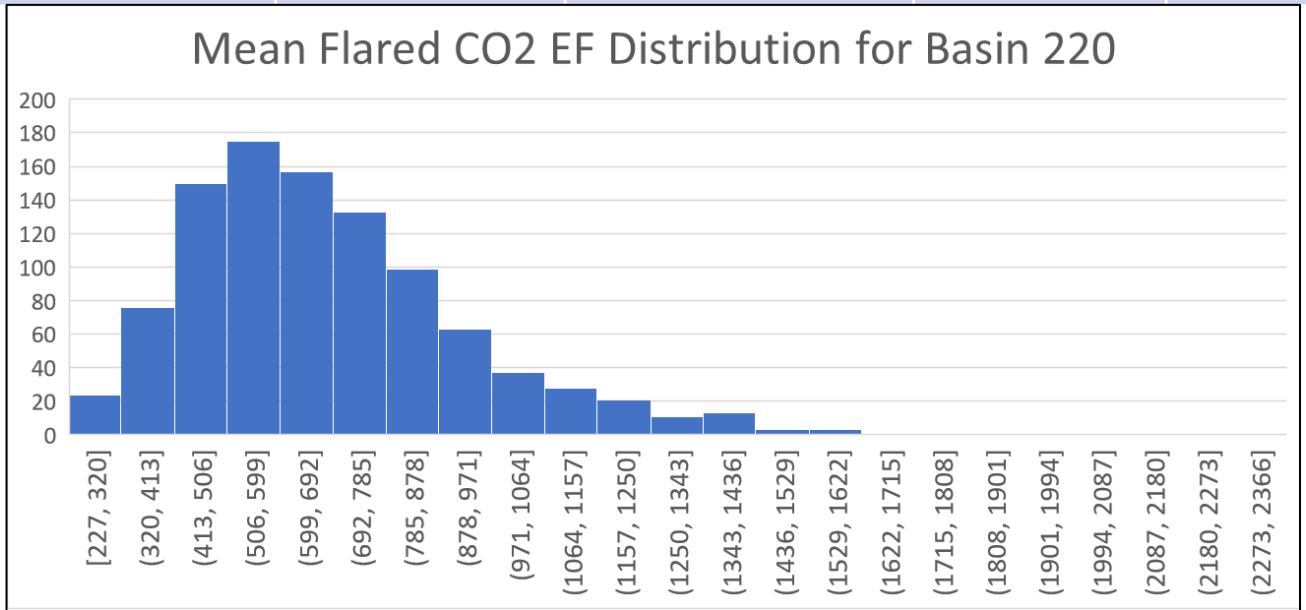
CO_2 Uncertainty – Background Cont.

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 – Modeled Petroleum System Example: Associated Gas Flaring EF Bootstrapping

Basin	PDF	GHGRP Mean, CO_2 EF (scf/bbl)	Simulated Stan. Dev.	2.5% Percentile	97.5% Percentile
Gulf Coast (LA,TX); Basin 220	Lognormal	633	265	322 (-53%)	1,349 (96%)
Anadarko; Basin 360	Lognormal	5,987	2,737	1,575 (-74%)	11,597 (92%)
Williston; Basin 395	Lognormal	683	143	448 (-34%)	1,038 (52%)
Permian; Basin 430	Lognormal	293	164	136 (-61%)	749 (115%)
All Other Basins	Lognormal	450	199	181 (-64%)	956 (90%)



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.

5. Wrap-Up

Providing Stakeholder Feedback

- EPA memos 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

- Next stakeholder webinar will be held in November
  - EPA invites stakeholders to present on data or other information relevant to the EPA GHG data for oil and gas
  - To request or present at the workshop, please contact ghginventory@epa.gov with information on the topic area for the presentation