Synthesis of Natural Gas Methane Emission Data and Prioritization of Emission Reduction Opportunities

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CRC LCA Workshop

October 26, 2017

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Attribution

KeyLogic Systems, Inc.'s contributions to this work were funded by the National Energy Technology Laboratory under the Mission Execution and Strategic Analysis contract (DE-FE0025912) for support services.

NETL's Life Cycle Analysis (LCA) Program

- Supports NETL and Fossil Energy Headquarters
- Supports inter- and intra-DOE initiatives
- Conducts research to improve approaches to energy analysis
- Builds and maintains life cycle models and databases

Importance of Boundary Definition

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Emission rates are often compared without boundary reconciliation or consistent definitions

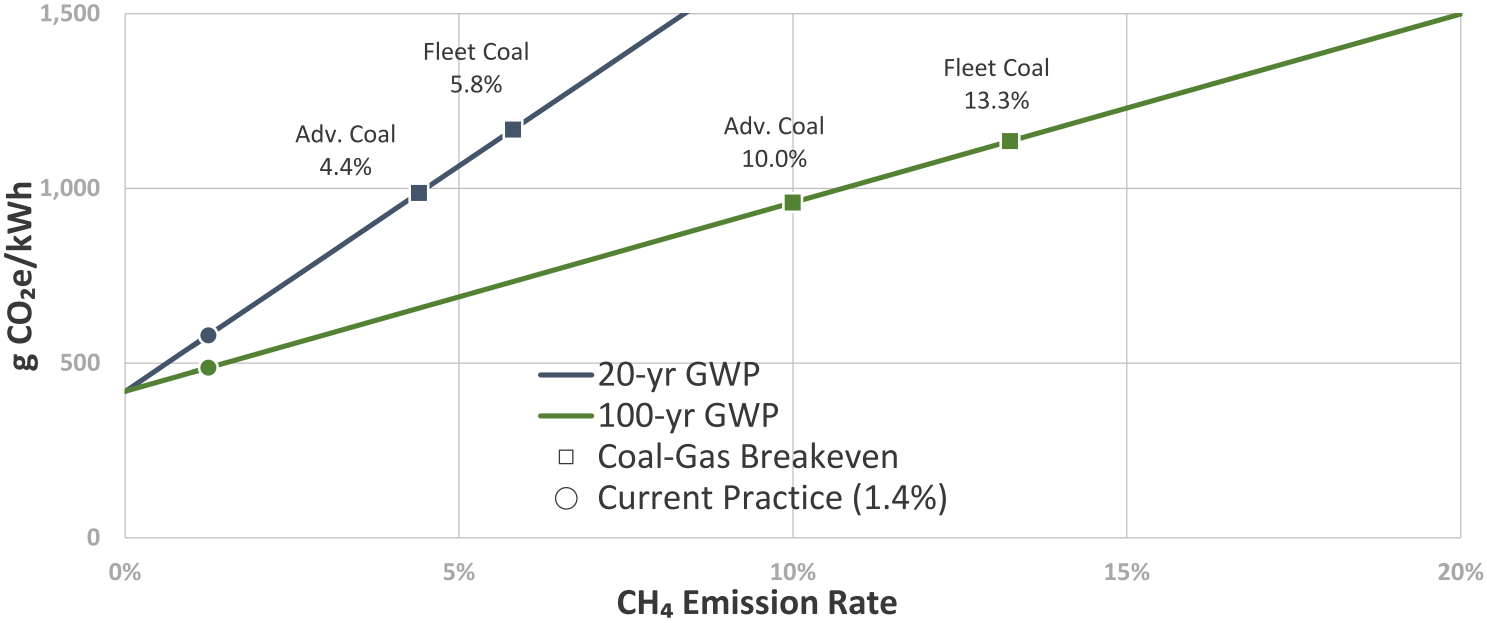
Boundary	Upstream Emissions (g CH) Extraction	—	Processing	—	Transmission	—	Distribution	NG Exiting Boundary (g)	Loss Rate	Emission Rate
Cradle-to-Extraction	4.7							1,086	0.5%	0.43%
Cradle-to-Processing	4.7	+	2.6					1,020	6.6%	0.71%
Cradle-to-Transmission	4.7	+	2.6	+	5.2			1,005	7.9%	1.24%
Cradle-to-Distribution	4.7	+	2.6	+	5.2	+	4.5	1,000	8.4%	1.70%
Processing Only (GtG)			2.6					1,020	6.1%	0.25%
Transmission Only (GtG)					5.2			1,005	1.5%	0.52%
Distribution Only (GtG)							4.5	1,000	0.5%	0.45%

Numerator *Denominator*

- CH_4 emission rates change as stage boundaries change – ranging from 0.43% (production only) to 1.7% (production through distribution
- Loss rate, which includes consumptive losses, is often confounded with emission rates

Boundaries Are Also Temporal

At what point would natural gas power systems have higher GHG emissions than coal power systems?



- **20-year global warming potentials (GWP):** Cradle-through-transmission emission rate must exceed 4.4% before advanced coal power has lower GHG emissions than NG power
- **Technology warming potential (TWP):** Cradle-through-transmission emission rate can be as high as 3.2% before the GHG impacts from natural gas power exceed those from coal power at any point during a 100-year time frame

Bottom-Up Synthesis

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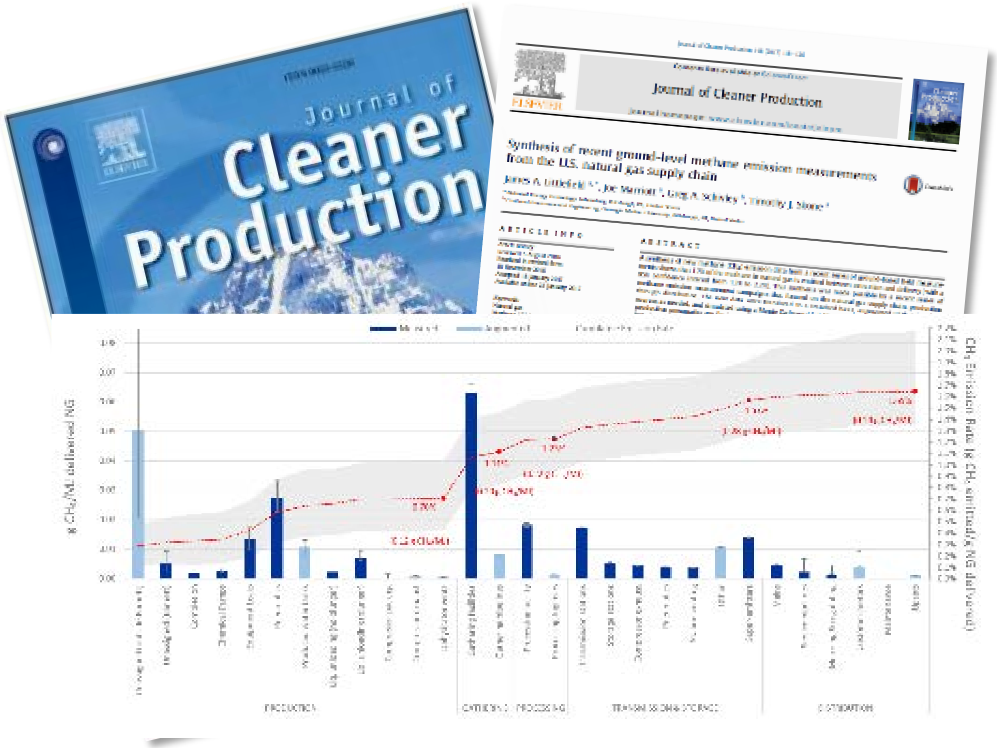


EDF ENVIRONMENTAL DEFENSE FUND
Finding the ways that work

- **Overall Result: 1.7% CH_4 emission rate across the NG life cycle**
- **Emission reduction opportunities**

  Pneumatic devices (widespread use in production and gathering)

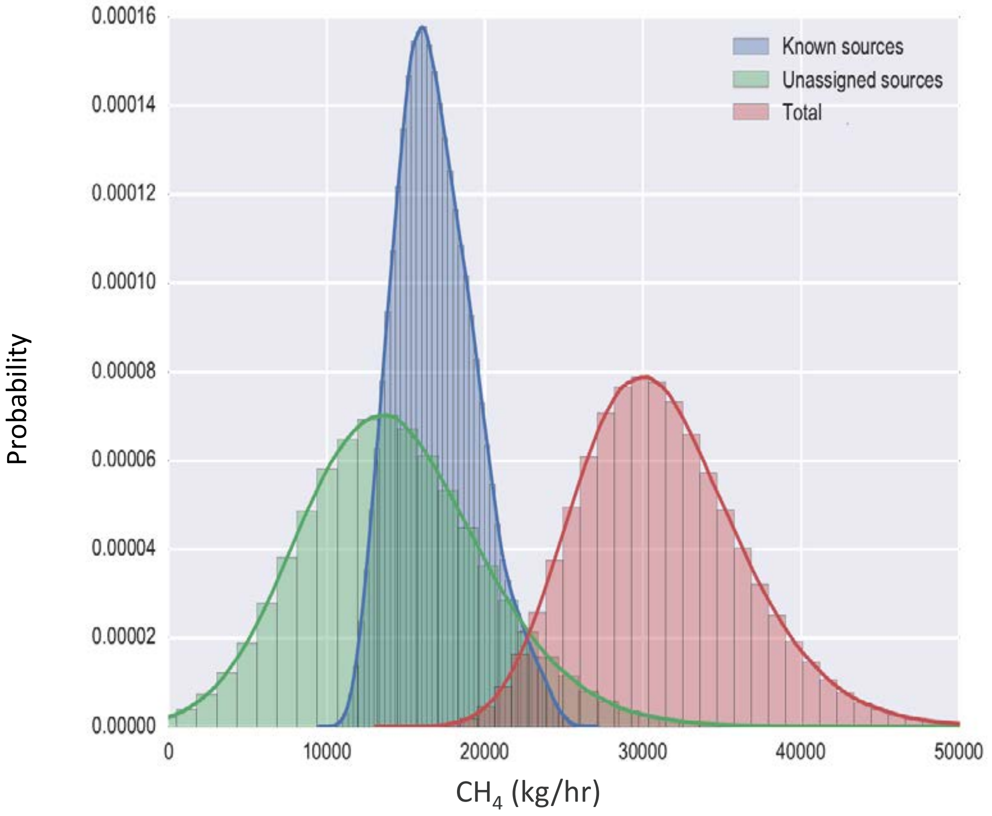
  Gathering Systems (new to emissions inventories, but highly aggregated)

  “Unassigned” emissions (observed, but not fully understood)

Unassigned Methane Emissions

Filling the gap between bottom-up component emissions and basin-level measurements

Unassigned = Total$_{observed}$ – Known$_{component}$



Adapted total emissions from Zavala et al. (2015)

Calculated known emissions using Greenhouse Gas Reporting Program (GHGRP)

Translated to an emission rate using 2.14 Tcf/year (Barnett region)

Extrapolated to other regions, scaling by production rates

Zavala-Araiza, D., Lyon, D.R., Alvarez, R.A., Davis, K.J., Harriss, R., Herndon, S.C., Karion, A., Kort, E.A., Lamb, B.K., Lan, X., 2015. Reconciling divergent estimates of oil and gas methane emissions. Proc. Natl. Acad. Sci. 112, 15597e15602.

GHGI Uncertainty Characteriztion

Collaboration with EPA to improve understanding of uncertainty around key parameters in the natural gas sector

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Emission Source	Supply Chain Segment	Emission Rank (GHGI 2014)	Key Data Source
Gathering stations	production	1	Marchese et al., 2015
Pneumatic controllers	production	2	Subpart W, 2014
Reciprocating compressor fugitives	transmission	4	Zimmerle et al., 2015
Engine combustion	production	6	GRI, 1996
Pipeline venting	transmission	10	GRI, 1996
Pipeline leaks	production	11	GRI, 1996
Station venting	transmission	12	GRI, 1996
Station, including compressor, fugitives	transmission	13	Zimmerle et al., 2015
Chemical injection pumps	production	14	Subpart W, 2014
Centrifugal compressor, wet seals, fugitives	transmission	15	Zimmerle et al., 2015
Centrifugal compressor, dry seals, fugitives	transmission	16	Zimmerle et al., 2015
Separator fugitives	production	17	GRI, 1996
Liquids unloading, manual	production	18	Subpart W, 2014
Liquids unloading, plunger lifts	production	19	Subpart W, 2014
Reciprocating compressor fugitives	storage	20	Zimmerle et al., 2015

Constraints:

- Average values for parameters were already in place
- Documentation for legacy data sources was scant

Causes of Uncertainty

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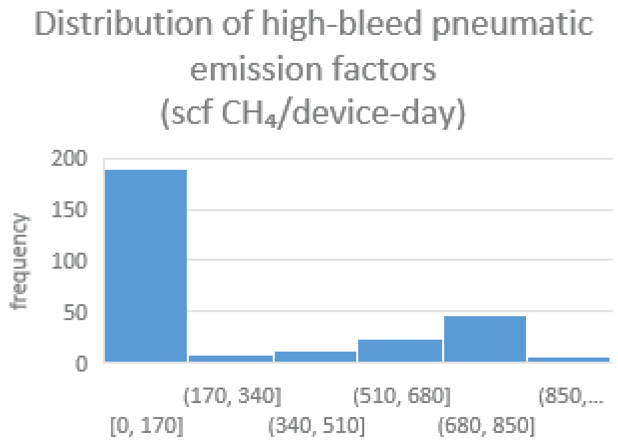
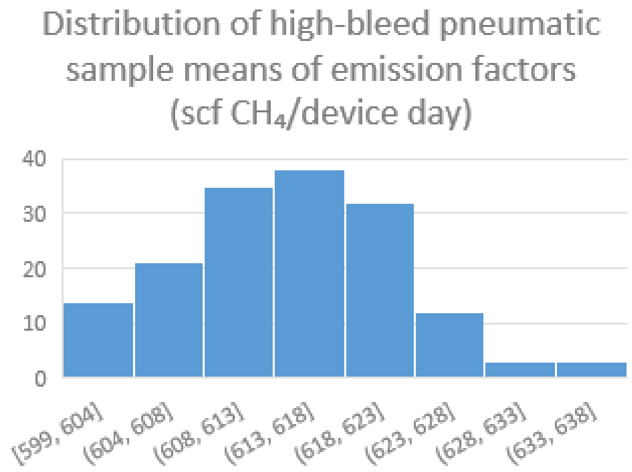
IPCC Uncertainty Guidelines (Annex 1)

- Uncertainties from inconsistent definitions (e.g. unclear or faulty definition of an emission)
- Uncertainties from natural variability of the process that produces an emission or uptake
- Uncertainties resulting from the assessment of the process or quantity, including uncertainty caused by measurement, sampling, or expert judgement.
  - Random sampling error. This source of uncertainty is associated with data that are a random sample of a finite sample size and typically depends on the variance of the population from which the sample is extracted and the size of the sample itself (number of data points).
  - Lack of representativeness. This source of uncertainty is associated with lack of complete correspondence between conditions associated with the available data and the conditions associated with real world emissions or activity. For example, emissions data may be available for situations in which a plant is operating at full load but not for situations involving start-up or load changes. In this case, the data are only partly relevant to the desired emission estimate.

GHGI Requires Average Values, Not Parameters of Entire Distribution

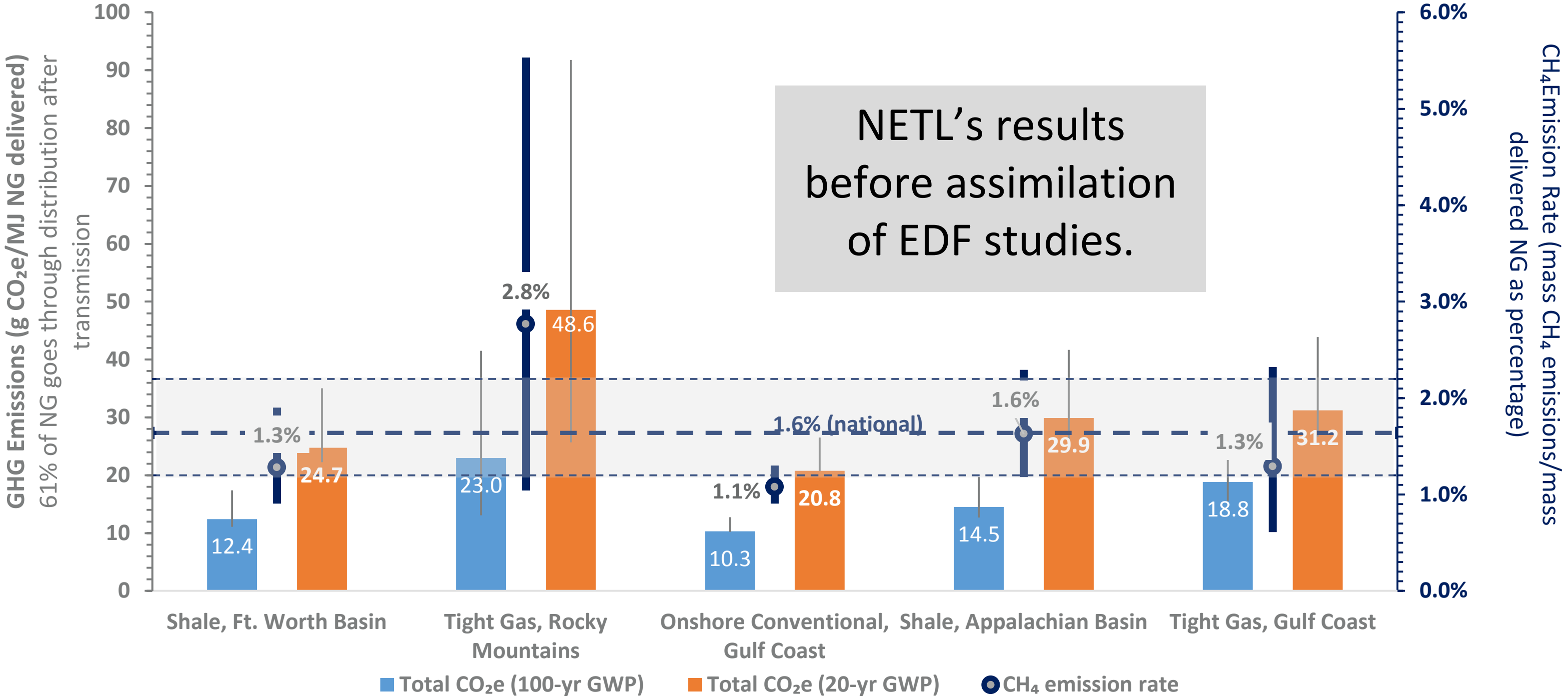




- For national averages, characterizing confidence in mean is more appropriate than characterizing entire distribution
- Sampling from discrete data points reduces random sampling error and gives confidence in average – curve fitting not necessary
- Representativeness is still a problem

NETL "Techno-Regions" and Variability

Understanding technological & regional variability allows focused policy and R&D



- There are scenarios where CH_4 emission rates greater than 5% are likely
- But the national average is lower (1.6% based on NETL's 2016 report)

Reaching common ground

- Resolution of technological, geographical, and temporal boundaries
- Definition of metrics and statistical analysis methods
- Collaboration among government, NGO, and industry

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