Uncertainty Input Development for Natural Gas Systems in the GHG Inventory

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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

15 GHGI emission sources were evaluated

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

Not all emission sources within top 20 GHGI contributors were evaluated, because EPA is revising the corresponding inventory methods.

Same emissions, sorted by key data source

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Reciprocating compressor fugitives	storage	20	Zimmerle et al., 2015
Gathering stations	production	1	Marchese et al., 2015

- Data sources span a broad range of data quality (vintage, transparency, and representativeness)
- This uncertainty analysis constrained by data currently used in GHGI

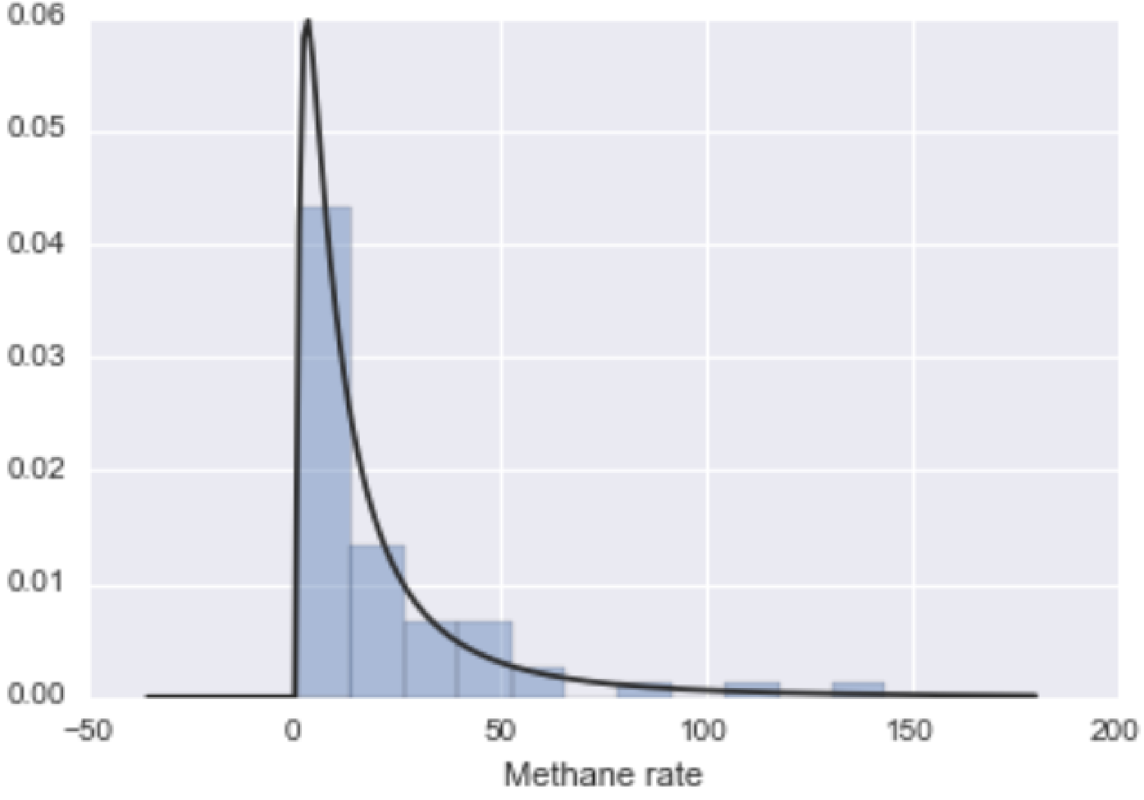
Given the wide array of data quality, we need a unifying definition of uncertainty

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.

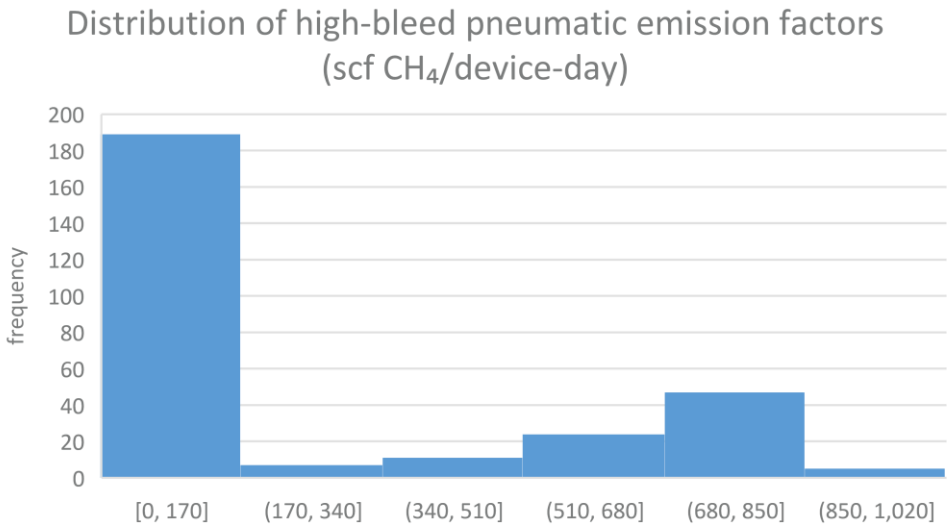
Skewed distributions complicate uncertainty characterization

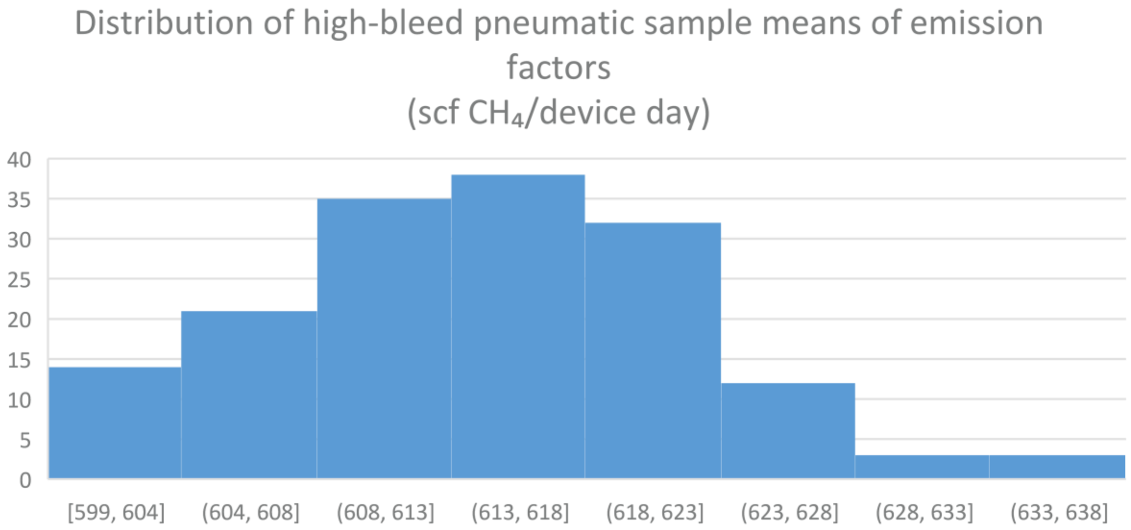
- Curve fitting is unreliable for small data sets
- If handled parametrically, sampling can pull unrealistically high values
- Truncation would prevent sampling of extremely high values, but point of truncation would be arbitrary



GHGI requires average values, not parameters of entire distribution

- Characterizing confidence in mean is more appropriate than characterizing confidence in entire distribution
- Fitting curves is unnecessary
- Sampling from discrete data points allows calculation of <u>distribution of the mean</u>


Distribution of high-bleed pneumatic emission factors (scf CH_4/device-day)


Distribution of high-bleed pneumatic sample means of emission factors (scf CH_4/device day)

Computations were performed both stochastically and analytically

- Monte Carlo and bootstrapping simulations were used to calculate standard deviations in means
- In instances with sufficiently large sample sizes, bootstrapping was validated analytically:

$$\boldsymbol{SD_{\bar{x}} = \frac{\sigma}{\sqrt{n}}}$$

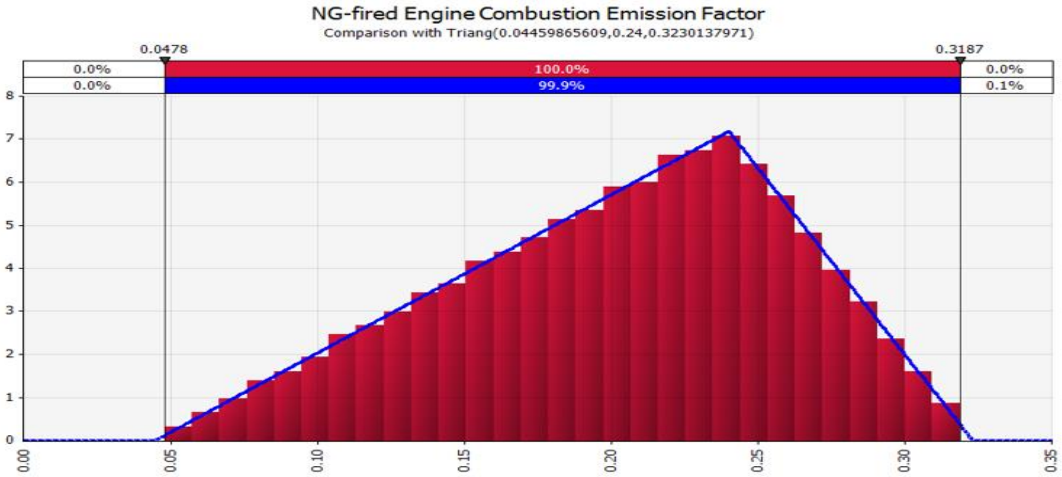
- Relationship between standard deviation and sample size provides a basis for comparing uncertainty among parameters

Our approach reduces random sampling error and gives us a good understanding of the distribution of the mean, <u>but</u> it does not solve problems with representativeness.

In data-limited instances, expert judgement is necessary

- Expert judgement is not merely a “best guess”
- It needs to be informed by literature and engineering principles
- Our goal is to characterize known uncertainty, not mask it with aggressively-bounded assumptions
- Applied in instances where legacy data were used or representativeness was in question (e.g., engine efficiency)

Example: Engine combustion emission factor (*0.240 scf CH_4/hp-hr*) based on literature review and NETL engineering expertise



Summary

- Characterizing uncertainty is a multi-tiered process
- Our goal is to characterize known uncertainty, not introduce more uncertainty
- Our method was simplified given that GHGI represents average emissions
- Effect of skewness is still accounted for, but exact distribution of underlying data remains unknown
- Expert judgement is used to fill data gaps, but is more than best guesses – it needs to be supported by research and engineering principles

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