Measurements of Methane Emissions at Natural Gas Production Sites in the United States

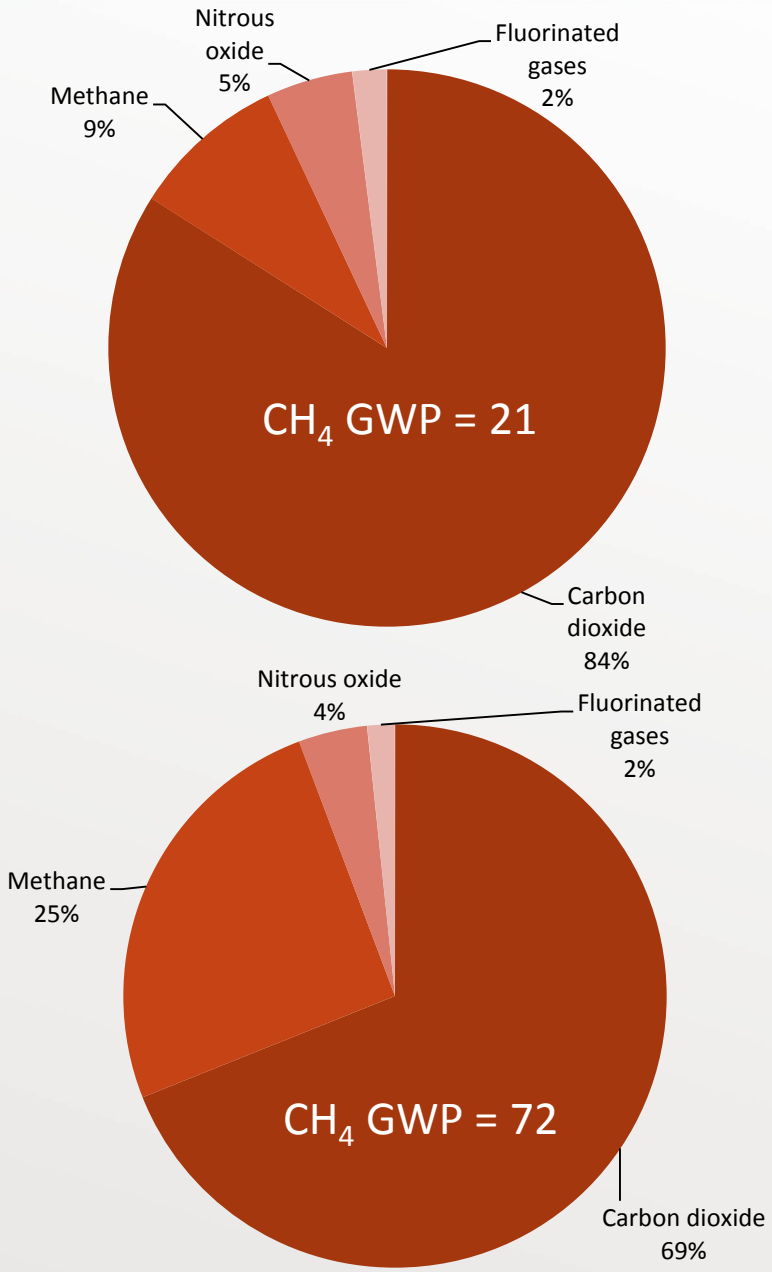
URS

Aerodyne Research

Why is methane important?

The role of methane in the national greenhouse gas inventory

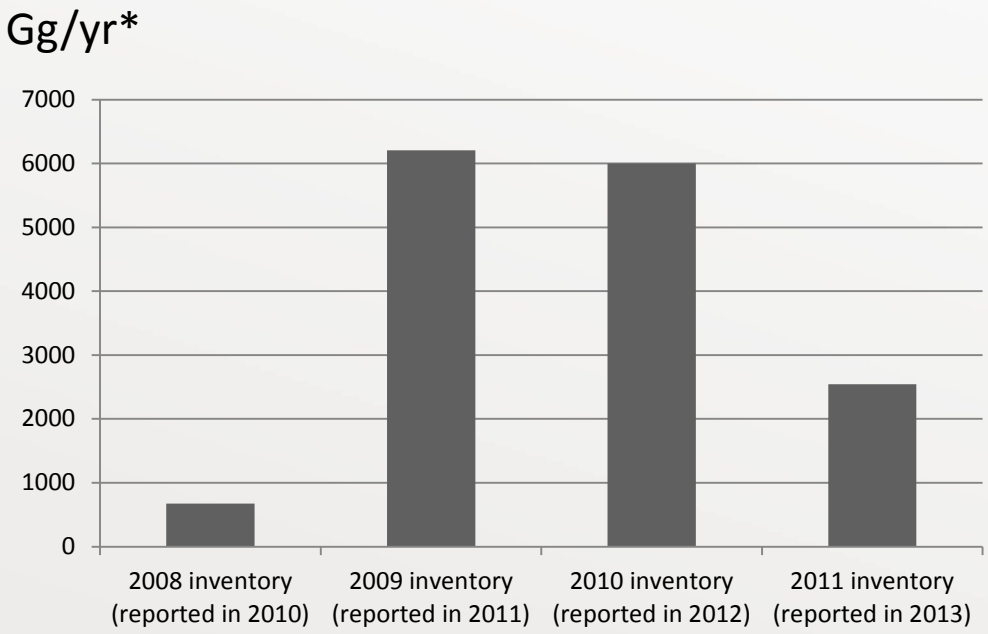
- Most recent national greenhouse gas inventory from EPA assumes a GWP for methane of 21, using a 100 year time horizon; methane accounts for 9% of the carbon dioxide equivalent emissions in the inventory
- The potency of methane is sensitive to our time frame of interest since methane is converted to CO_2, over decadal time scales
- If we change our time frame of interest to 20 years the GWP becomes 72 and methane becomes a quarter of the carbon dioxide equivalent emissions in the inventory



Need for Study

- Estimates of methane emissions from natural gas production , from academic and governmental sources, have varied widely
- In the past several years, methane emission estimates in the EPA national greenhouse gas inventory have varied by an order of magnitude, largely due to changes in assumptions in estimating emissions
- Measured data for some sources of methane emissions during natural gas production are limited
- To better inform policy, scientifically sound and rigorous measurements are needed to quantify the amount of methane emissions that result from natural gas production.

Methane emissions from natural gas production sector
(does not include processing and transmission)



*6000 Gg/yr is 2% of the national greenhouse gas inventory (in carbon dioxide equivalents, GWP=21; 6% if GWP for methane is 72)

A Unique Partnership

- Sponsors were an environmental group and nine natural gas producers
  - Environmental Defense Fund (EDF), Anadarko Petroleum Corporation, BG Group plc, Chevron, Encana Oil & Gas (USA) Inc., Pioneer Natural Resources Company, SWEPI LP (Shell), Southwestern Energy, Talisman Energy USA, and XTO Energy, an ExxonMobil subsidiary
- Study team
  - Led by University of Texas and including URS and Aerodyne Research
- Scientific Advisory Panel
  - Six university faculty with expertise in air quality and natural gas production

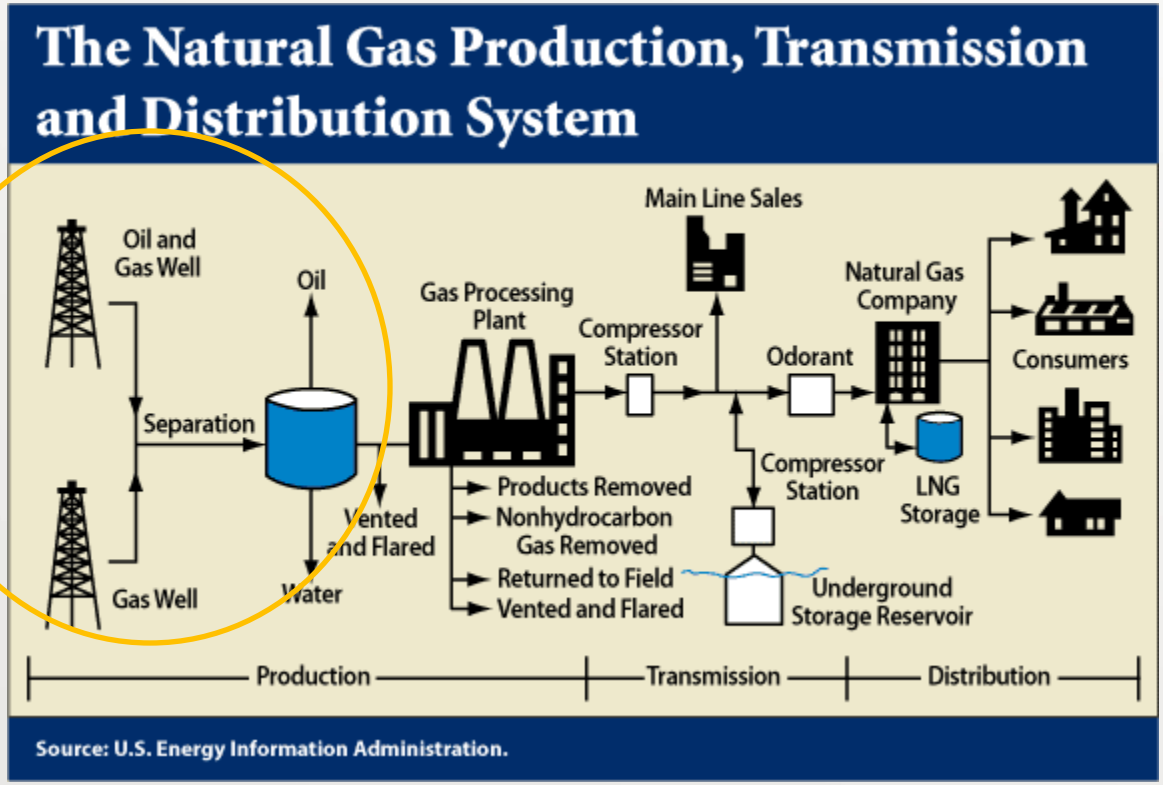
A new approach

- **A unique partnership:** Study design, data, and findings were all reviewed by the study team, Environmental Defense Fund, participating companies, and an independent Scientific Advisory Panel
- **Direct access:** Participating companies provided access to production sites and equipment, and assisted in the design of safe sampling protocols, making possible measurements of methane emissions, directly at the source
- **First measurements:** For several source categories, these data are the first reported direct, on-site measurements of methane emissions
- **Multiple measurement methods:** Downwind measurements at over 20% of the well completion sites and 13% of the production sites were used to confirm that potential sources were accounted for

Technical and Scientific Review

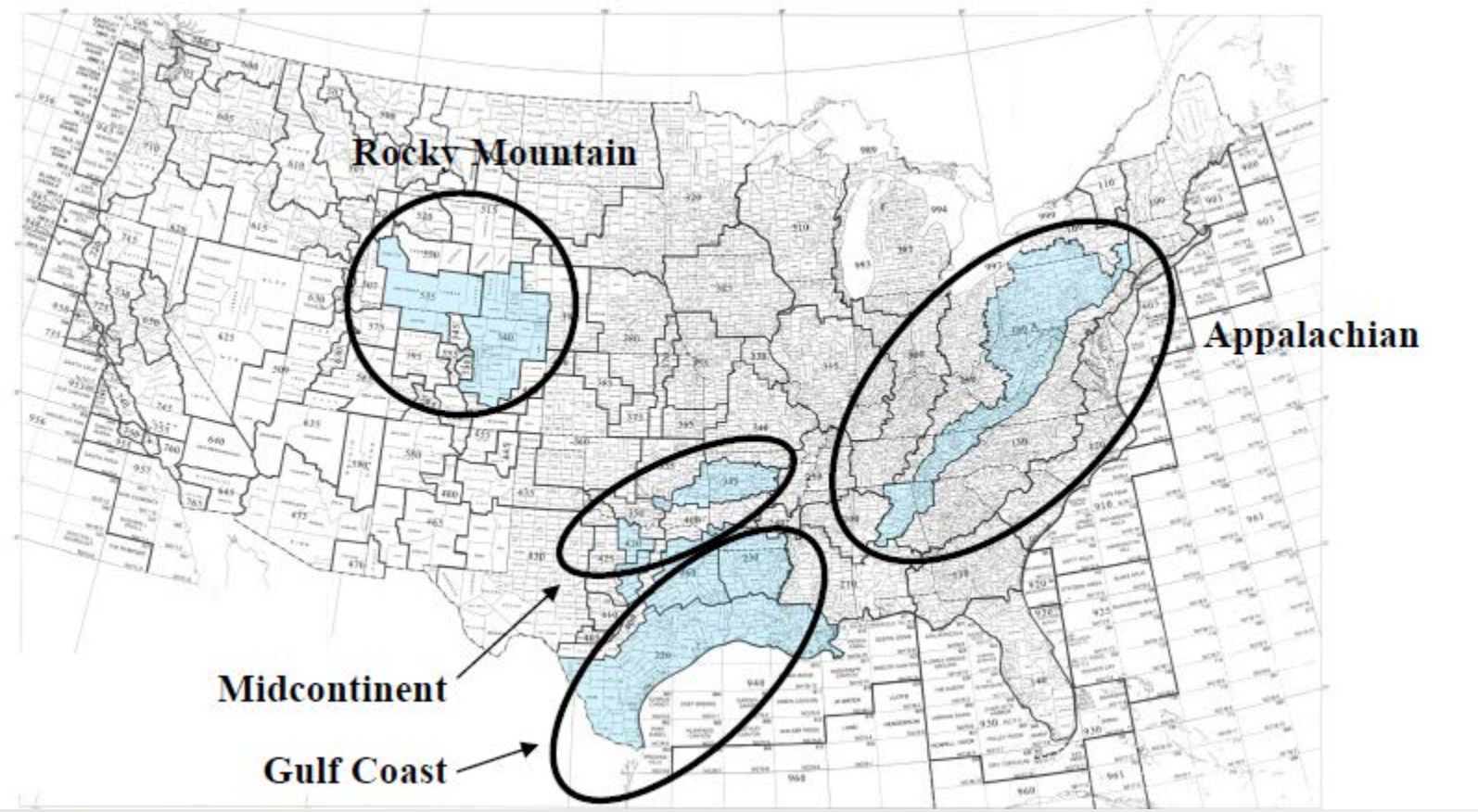
- Scientific Advisory Panel
  - Six independent academic experts
  - Reviewed project plans before data collection and preliminary findings during data collection
  - Reviewed draft final report
- Study findings published in peer-reviewed scientific publication
  - Independent, anonymous peer reviews

Scope of Study



Environmental Defense Fund, with different groups of companies and study teams, are engaged in projects addressing the rest of the supply chain for natural gas

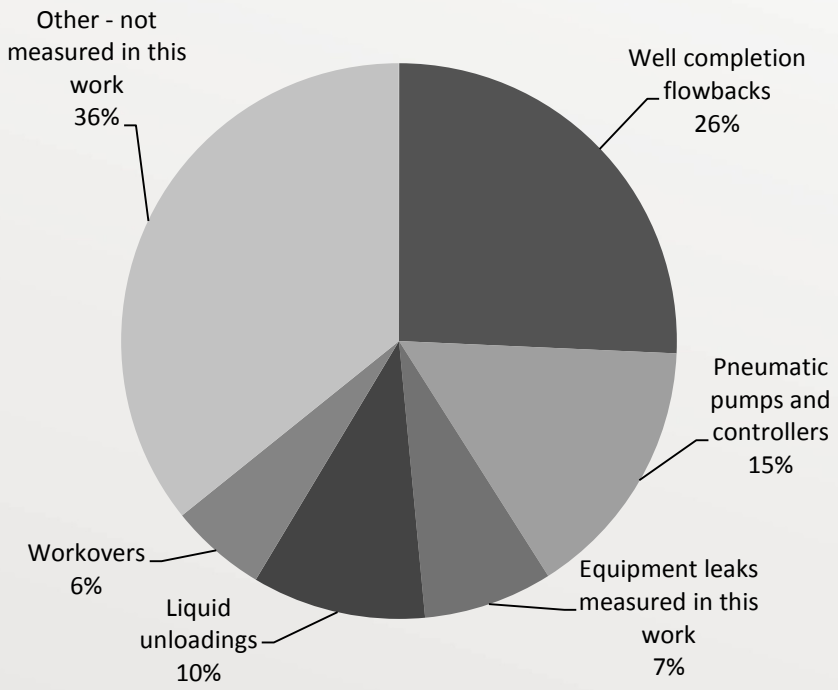
Multiple production regions were sampled



Measurements focused on methane: Types of emission sources sampled

- Sources targeted account for two thirds of the natural gas production emissions in the 2011 EPA national inventory (released in 2013)
- Completion flowbacks
  - 27 wells
- Sites in routine production
  - 150 sites, 489 wells
- Liquid unloadings
  - 9 unloading events
- Well workovers
  - 4 workovers

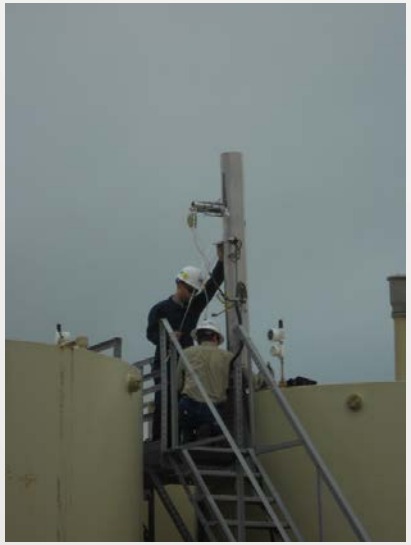
Natural gas production emissions of 2545 Gg reported in 2011 greenhouse gas inventory (annual emissions %, inventory released in 2013)



Direct source measurements

(methane emission measurements were made directly at the emission point, capturing the entire flow)

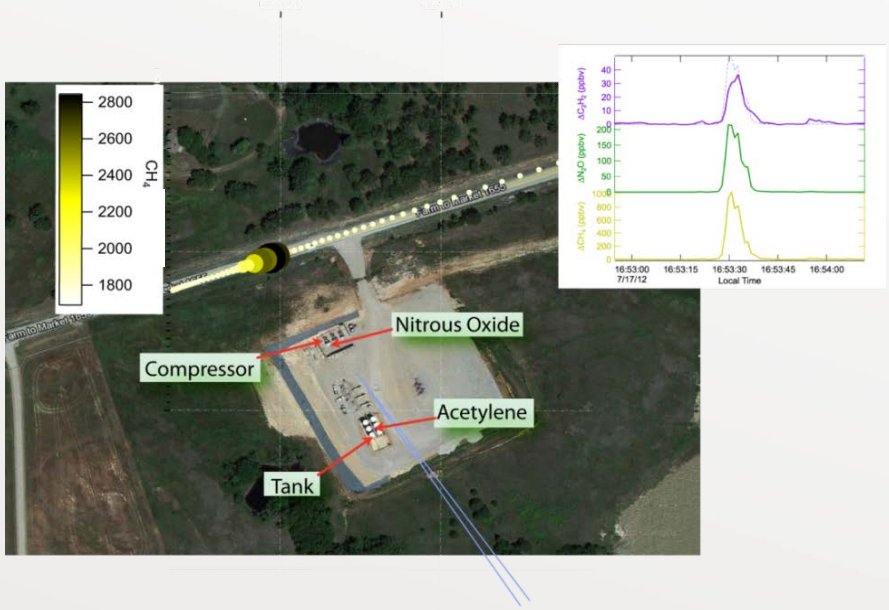
Many of the measurement systems were controlled 10-20 m from the sampling point



Were all the potential sources sampled?

Both direct source and downwind sampling performed for 13-20% of sites

- Emissions were estimated based on downwind measurements using dual tracer method at over 20% of the well completion sites and 13% of the production sites
- Method required steady winds, suitable topography and downwind access (not all sites satisfied these conditions); tracers released on site; downwind sampling done with mobile van
- Use ratios of tracer and methane concentrations downwind to estimate emission rates
- Downwind measurements consistent with direct source measurements and estimates, indicating that direct source measurements and estimates captured major sources



Findings

- Completion flowbacks: well completion emissions are lower than previously estimated
- Wells in routine operation: emissions from pneumatic controllers and equipment leaks are higher than EPA national emission projections
- Liquid unloadings: more sampling is needed; planning for additional sampling underway
- Implications for national emission estimates: estimates of total emissions are similar to the most recent EPA national inventory of methane emissions from natural gas production

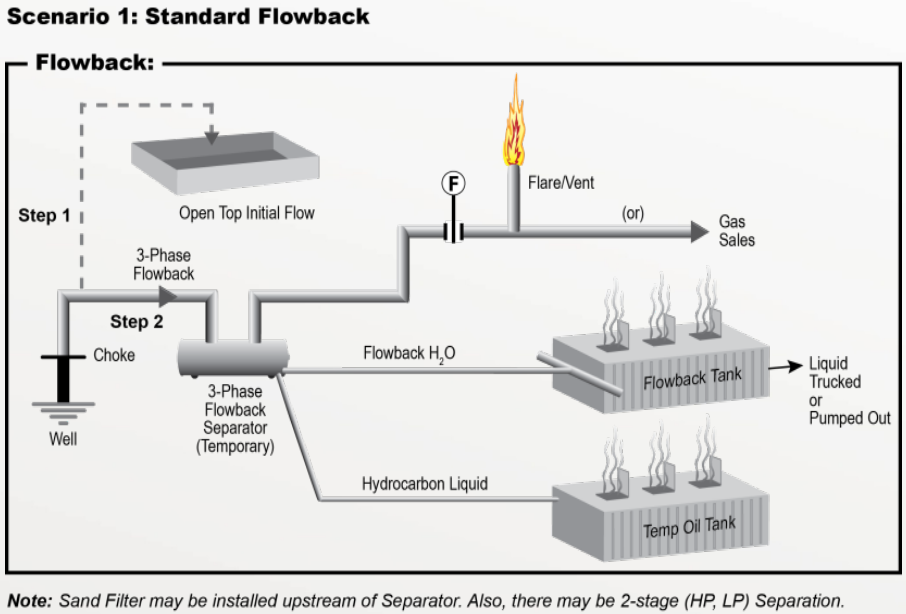
Completion flowbacks

(see animation available on YouTube)

If the link above doesn't work, please copy this URL into a new browser window:
http://youtu.be/BmP0EcDOcdM

Findings: Completion Flowbacks

- Completion flowbacks clear fractured wells of liquid to allow production
- 18 of the 27 completion flowbacks (67%) that were sampled captured or combusted potential methane emissions
- When emissions from completion flowbacks were captured or controlled, measured emissions were 99% less than potential emissions
- For the 33% of completion flowbacks without controls or capture, the vented emissions were low (comparable or lower than many of the completions with capture or control); the potential emissions were less than 1% of the average potential emissions of wells with capture or control
- Summed over all 27 completions, measured emissions were 1.4% of potential emissions (98.6% reduction)



Note: Sand Filter may be installed upstream of Separator. Also, there may be 2-stage (HP, LP) Separation.

Potential methane emissions includes all methane leaving well (measured emissions + methane captured or controlled)

Findings: Sites in routine production

- 150 well sites, 489 hydraulically fractured wells sampled
- Pneumatic controllers, pneumatic pumps and equipment leaks quantified
- Emissions per pump were within 10% of emissions estimated using EPA emission factors
- Emissions were higher for intermittent controllers (29% higher) and low bleed pneumatic controllers (270% higher) than estimated using EPA emission factors
- No controllers identified as high bleed were observed during this study
- Emissions of methane per well from equipment leaks were comparable to EPA estimates made using EPA emission factors
- Some regional variability observed

Liquid Unloading

(see animation available on YouTube)

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Liquid unloadings

- Unloadings clear operating wells of liquid to increase gas production
- 9 unloadings sampled (first measurements reported)
- Four of the 9 measured unloadings accounted for 95% of the emissions; wells sampled unloaded between 1 and 12 times per year; some unloading events were one time events for the life of the well
- Emission estimates from national surveys of wells with unloadings (API/ANGA) indicate half of the wells account for 90% of the estimated emissions; some wells unload daily; this study did not sample unloadings that occur daily
- More sampling is needed; planning for additional sampling underway; sampling strategies will carefully account for varied well characteristics

Liquid unloadings: lessons learned from initial sampling

- Wells with emissions from liquid unloading are varied in their characteristics
- Due to well characteristics, there are more unloadings in some production regions than others
- For the 9 wells sampled, current emission estimation methods make assumptions that tend to overestimate emissions
- For the brief periods when unloadings occur, emissions can be the equivalent of a few wells to thousands of wells in routine production; accounting for unloadings is important in reconciling ambient measurement snapshots with emission estimates

National implications of measurements made in this work

$$\text{Emissions in a region} = EF_i * AF_i$$

EF_i = Emission Factor for region I (e.g., emissions per well)

Emission factors based on measurements made in this work

AF_i = Activity Factor for region I (e.g. number of wells)

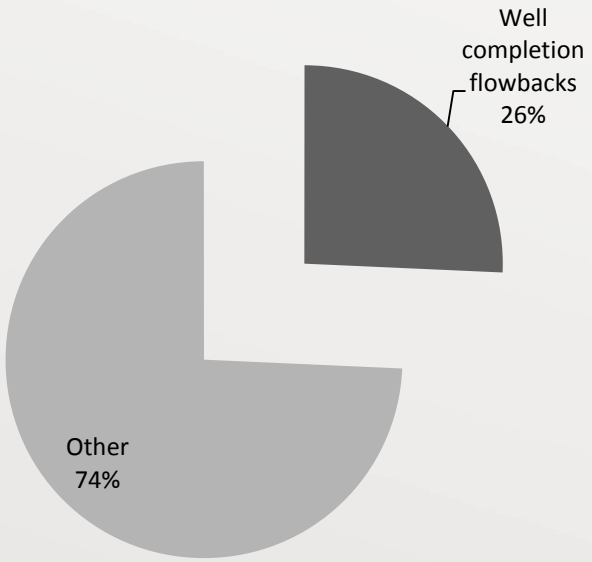
Activity factors based on 2011 EPA national greenhouse gas inventory

Assumptions made in estimating national implications

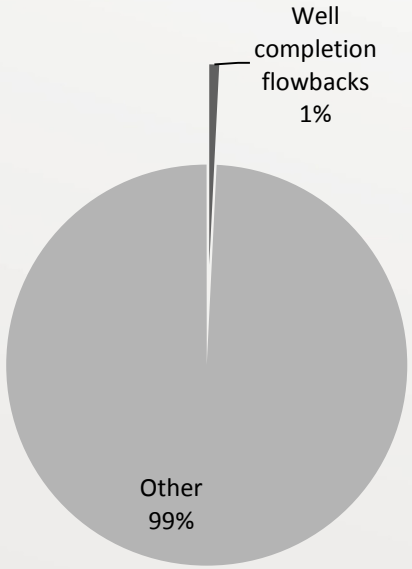
- Measurements were assumed to be representative of national populations
  - For all of the sources sampled, the measured data are a small percentage of total sources (27 of ~8000 completions; 489 of ~500,000 wells; 305 of ~450,000 pneumatic controllers)
  - Sites from nine companies, who voluntarily participated, were sampled; these companies represent 12% of US well count, 16% of gas production and about half of new well completions
  - Not all production regions were sampled
- Activity counts were assumed to be known and equal to the counts in the most recent EPA national inventory
- When national emissions estimates from this work are compared to the EPA national inventory, comparisons will be made to “net” emissions
  - Net emissions = potential emissions - regulatory reductions - voluntary reductions

Completion flowbacks: Comparison of EPA national methane emission inventory for natural gas production to estimates based on this work

Emissions reported in 2011 greenhouse gas inventory (654 Gg annual emissions, inventory released in 2013)



Emissions estimated based on measured data from this work, 18 Gg/yr

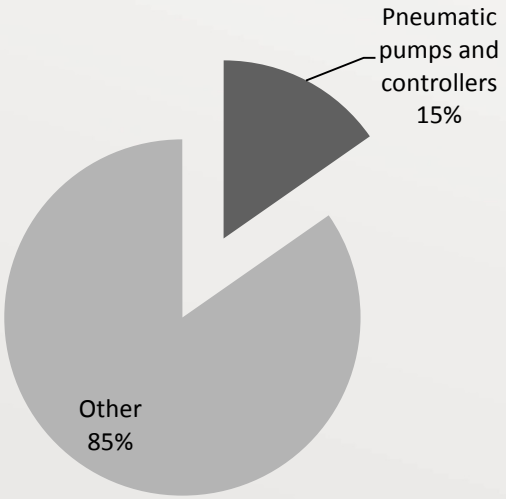


67% of the completion flowbacks that were sampled captured or combusted 99% of potential methane emissions

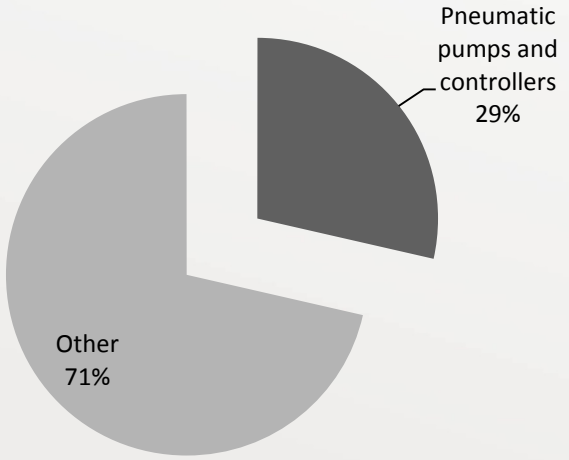
For the 33% of completion flowbacks without controls or capture, the vented emissions were low (comparable or lower than many of the completions with capture or control)

Pneumatics: Comparison of EPA national methane emission inventory for natural gas production to estimates based on this work

Emissions reported in 2011 greenhouse gas inventory (389 Gg annual emissions, inventory released in 2013)



Emissions estimated based on measured data from this work, 648 Gg



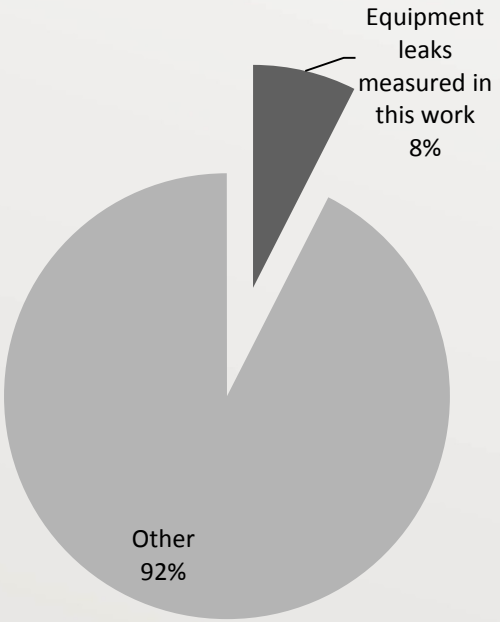
Emissions per pump were within 10% of potential emissions estimated using EPA methods

Emissions were higher for intermittent controllers (29% higher) and low bleed pneumatic controllers (270% higher) than estimated using EPA emission factors

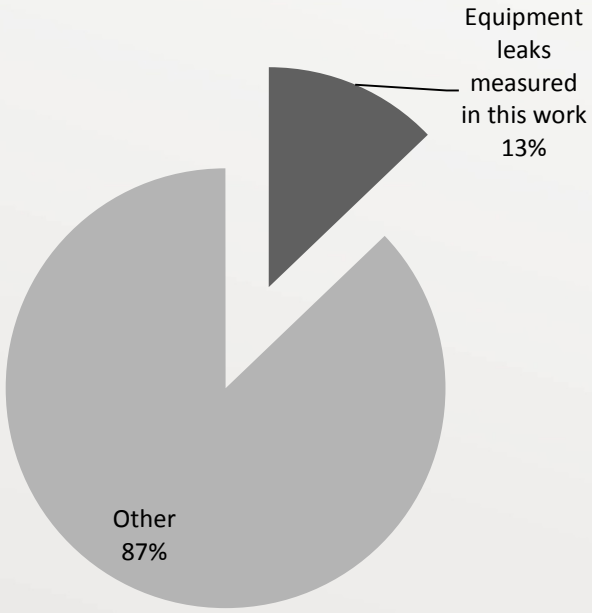
National emission estimates are sensitive to the assumed populations of low-bleed, high bleed and intermittent devices

Equipment leaks: Comparison of EPA national methane emission inventory for natural gas production to estimates based on this work

Emissions reported in 2011 greenhouse gas inventory (191 Gg annual emissions, inventory released in 2013)



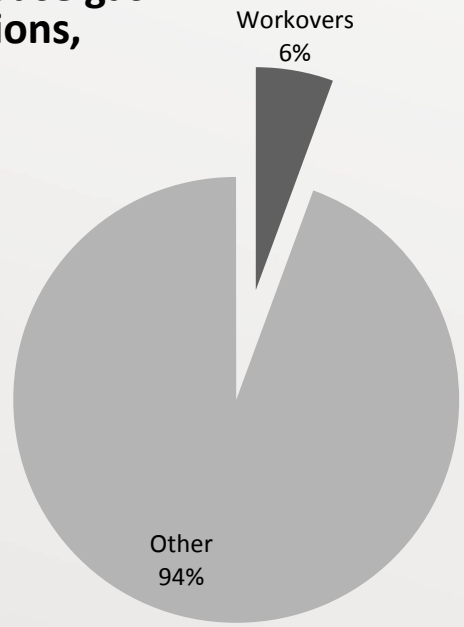
Emissions estimated based on measured data from this work, 291 Gg



Emissions of methane per well from equipment leaks were ~50% higher than net EPA estimates

Workovers: EPA national methane emission inventory for natural gas production: potential implications of measurements made in this work

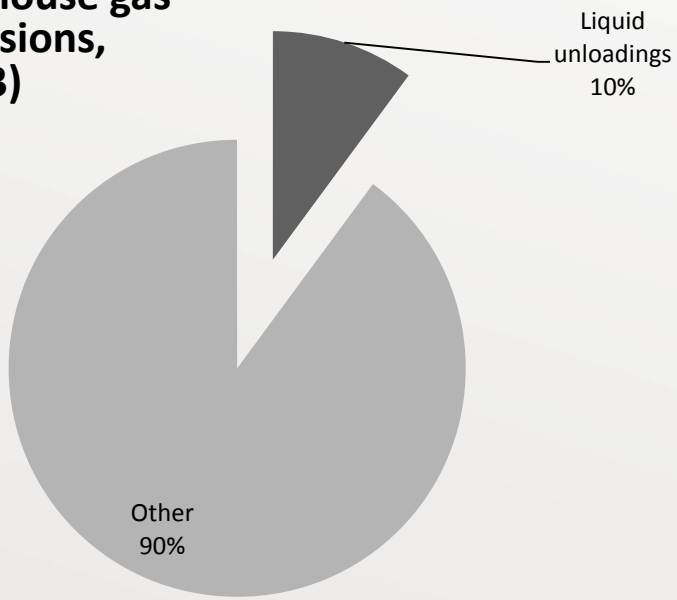
Emissions reported in 2011 greenhouse gas inventory (143 Gg annual emissions, inventory released in 2013)



Workovers with hydraulic fracturing have characteristics similar to well completion flowbacks; the results from this work on completion flowbacks are suggestive of a lower estimate for these emissions

Liquid Unloadings: EPA national methane emission inventory for natural gas production: potential implications of measurements made in this work

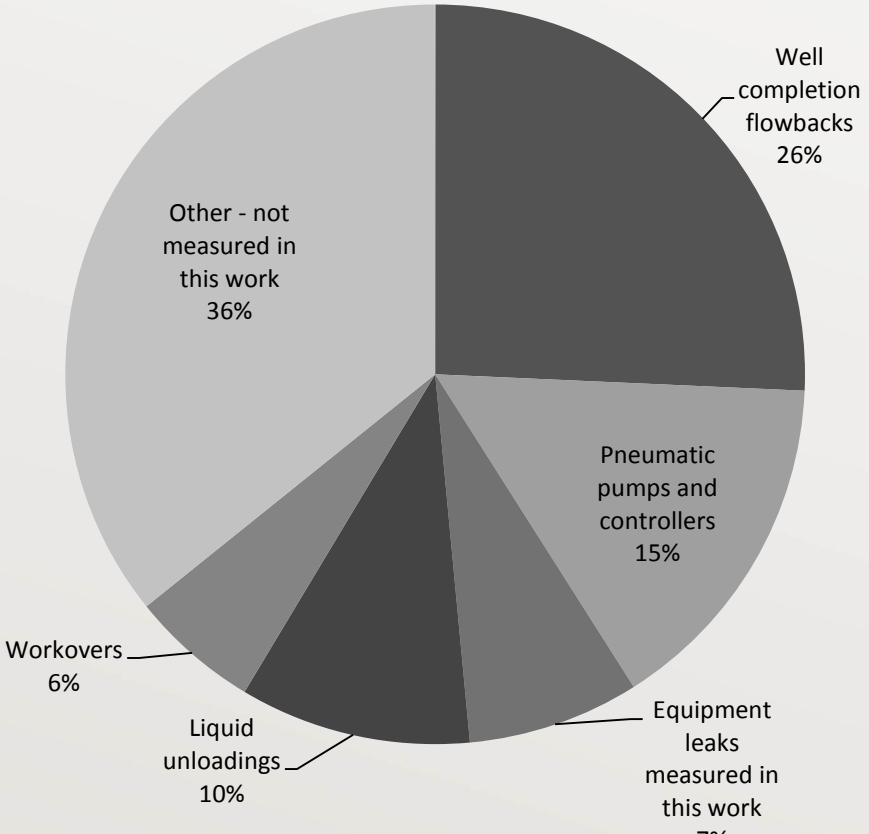
Emissions reported in 2011 greenhouse gas inventory (257 Gg annual emissions, inventory released in 2013)



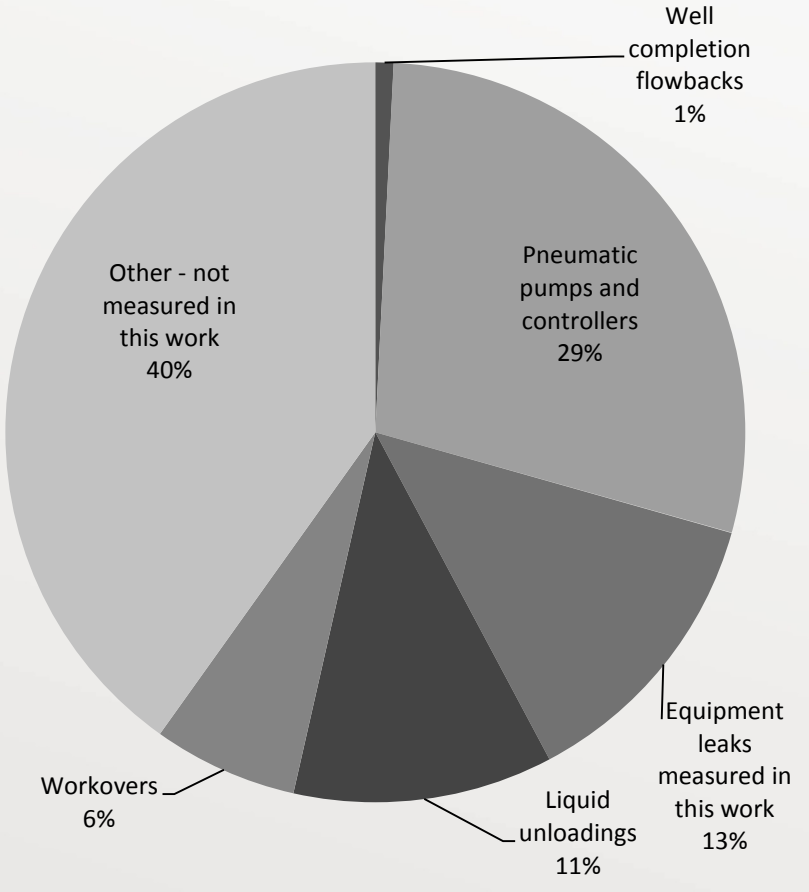
Unloading emissions have a high degree of uncertainty due to the varied nature of unloading events; additional sampling later this year

Natural Gas Production: Comparison of EPA national methane emission inventory to estimates based on this work (Gg/yr)

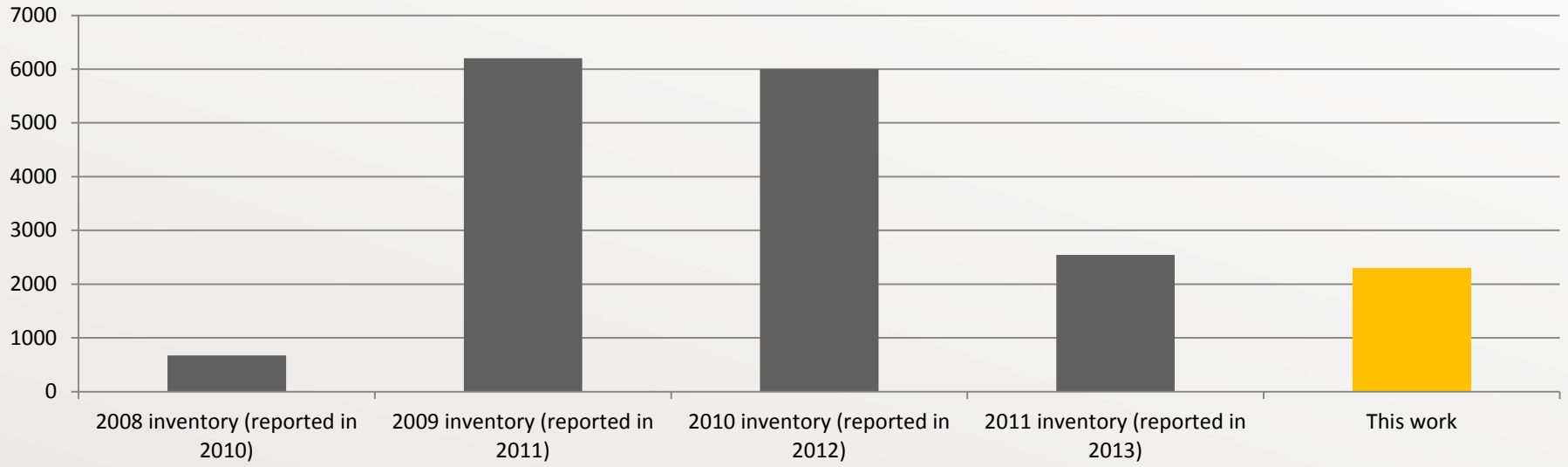
Production emissions reported in 2011 greenhouse gas inventory (annual emissions in Gg, inventory released in 2013), 2545 Gg



Production emissions estimated based on measured data from this work, 2300 Gg/yr



Natural Gas Production: Comparison of EPA national methane emission inventory to estimates based on this work (Gg/yr)



Summary

- Direct, on-site measurements of methane emissions from gas production operations were made; for some sources (well completions and unloadings) these are the first measurements reported
- 67% of the hydraulically fractured well completions sampled during the study had equipment in place that reduces methane emissions by 99%. Because of this equipment, methane emissions from well completions are 97% lower than calendar year 2011 national emission estimates, released by EPA in April 2013.
- Emissions from pneumatic devices are 70% higher than current EPA net emissions estimates, and equipment leaks are 50% higher than current EPA net emission estimates; collectively these emissions account for more than 40% of methane net emissions from natural gas production.
- Methane emissions from gas production, from all sources measured in the study, were comparable (957 Gg ± 200 Gg)to the most recent EPA estimates (~1200 Gg)
- The 957 Gg in emissions for completion flowbacks, pneumatics and equipment leaks, coupled with EPA national inventory estimates for other categories, leads to an estimated 2300 Gg of methane emissions from natural gas production (0.42% of gross gas production).