

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

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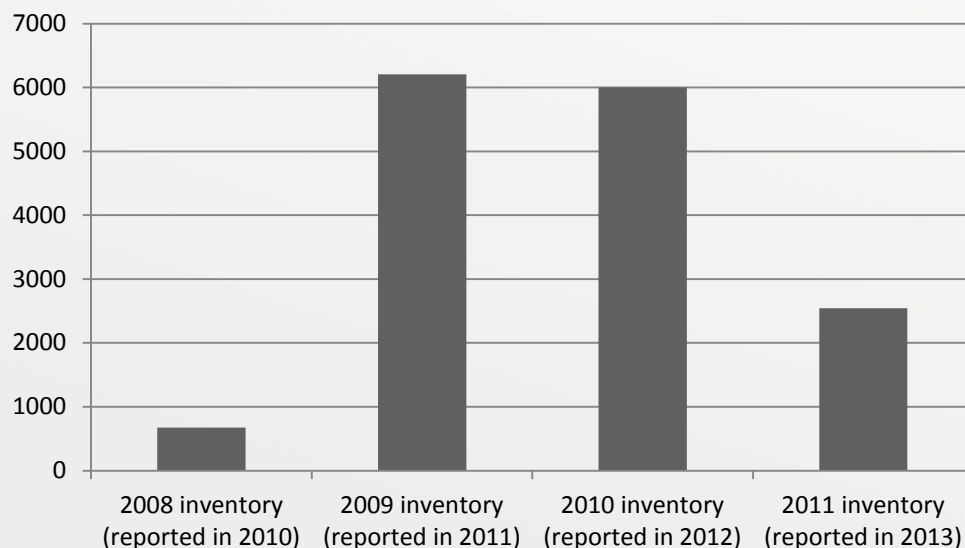


# Need for Study

- 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)

Gg/yr\*

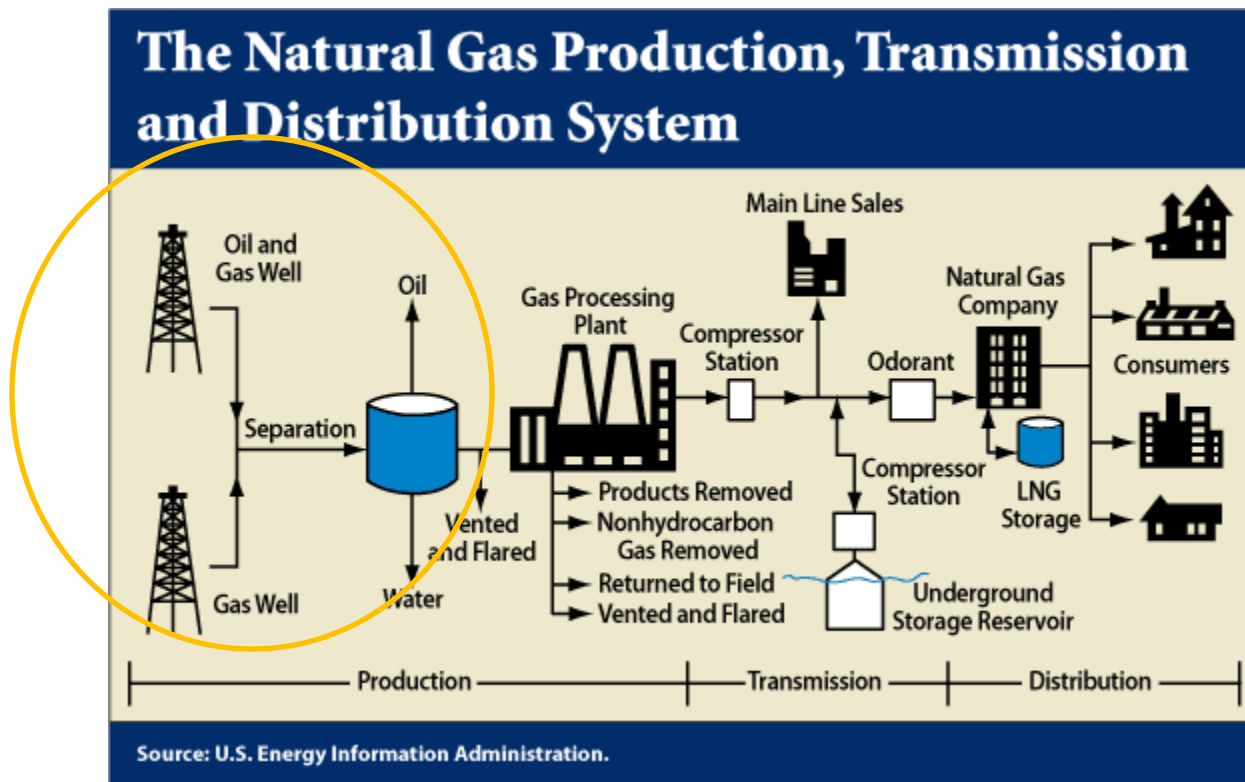


\*6000 Gg/yr is 2% of the national greenhouse gas inventory (in carbon dioxide equivalents, GWP=21; 6% if GWP for methane is 72)

# A Unique Partnership

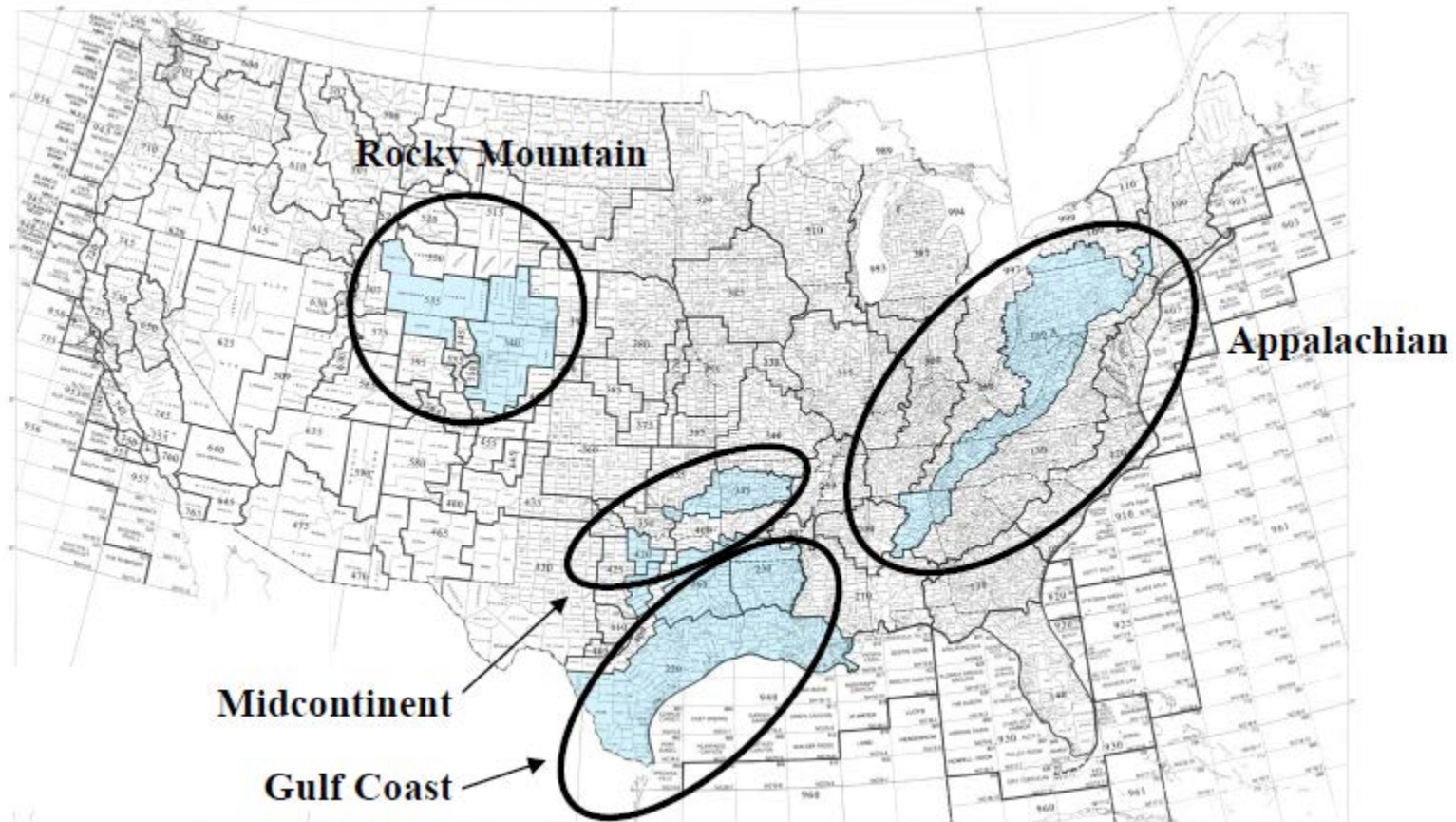
- Sponsors were an environmental group and nine natural gas producers
  - Environmental Defense Fund (EDF), Anadarko Petroleum Corporation, BG Group plc, Chevron, Encana Oil & Gas (USA) Inc., Pioneer Natural Resources Company, SWEPI LP (Shell), Southwestern Energy, Talisman Energy USA, and XTO Energy, 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

# 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

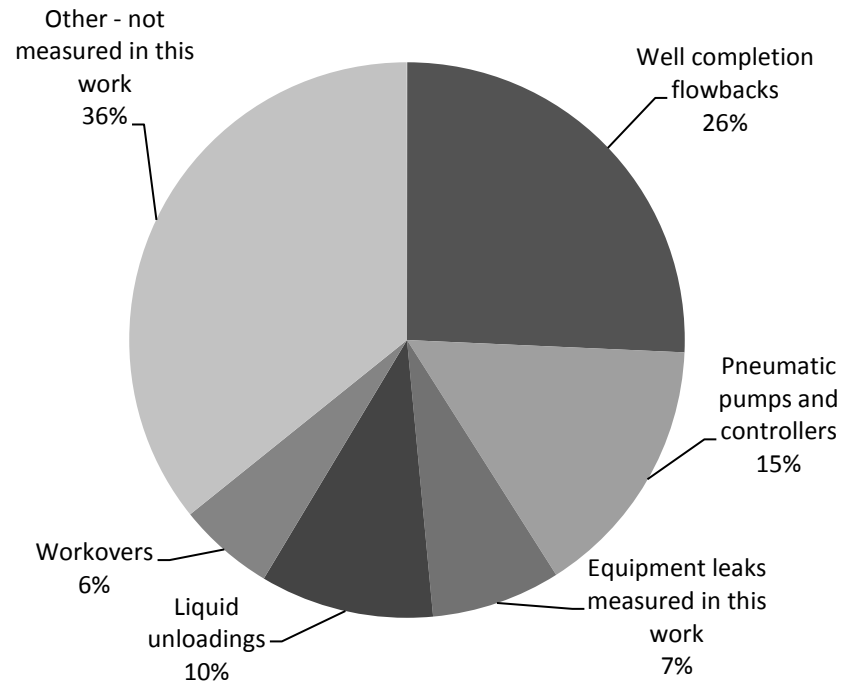


# Measurements focused on methane:

## 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)



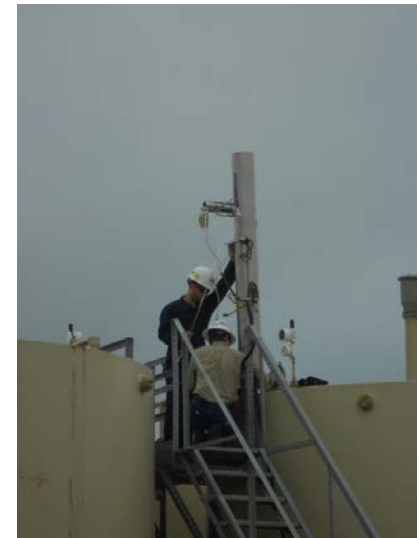


# Direct source measurements

(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



# 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



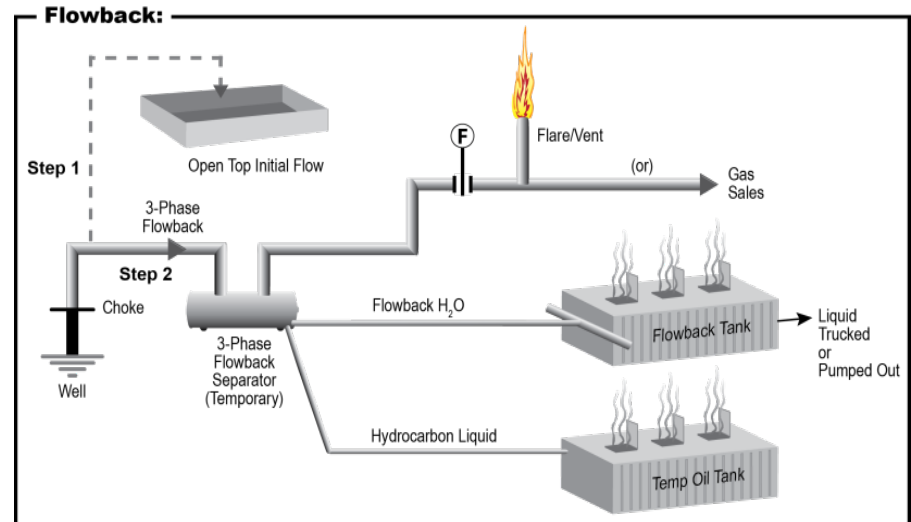
# Completion flowbacks

Well completion flowback

# 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)

**Scenario 1: Standard Flowback**

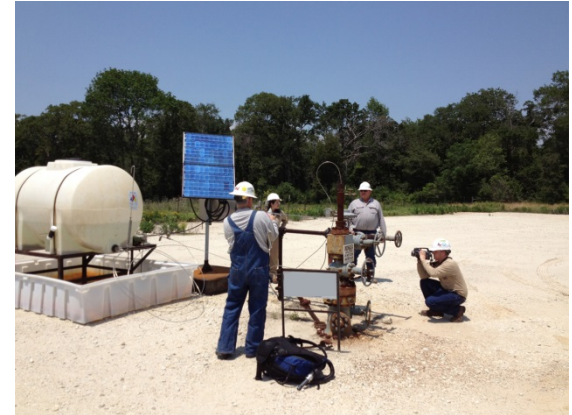


*Note: Sand Filter may be installed upstream of Separator. Also, there may be 2-stage (HP, LP) Separation.*

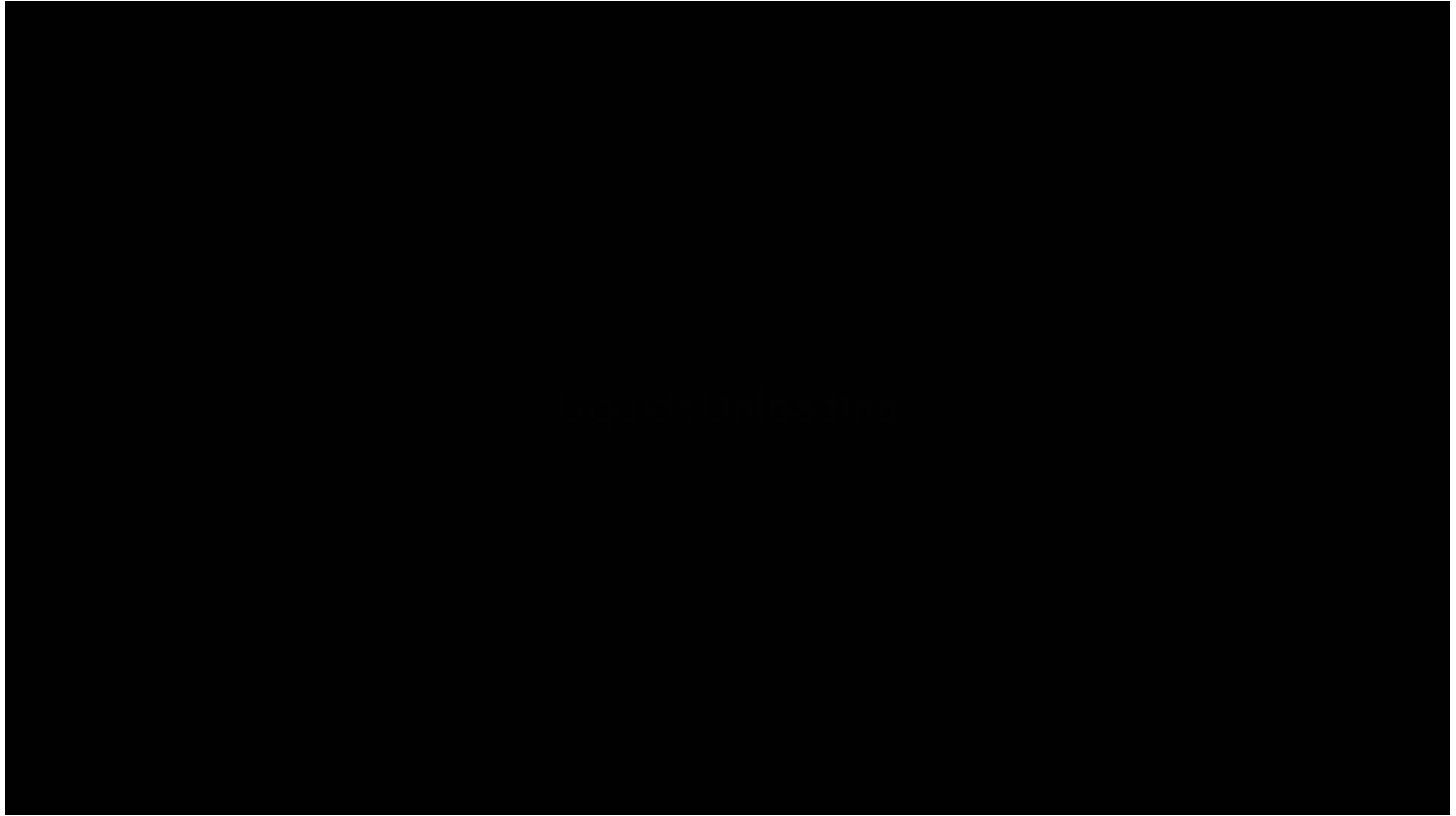
Potential methane emissions includes all methane leaving well (measured emissions + methane captured or controlled)

# 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



# 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

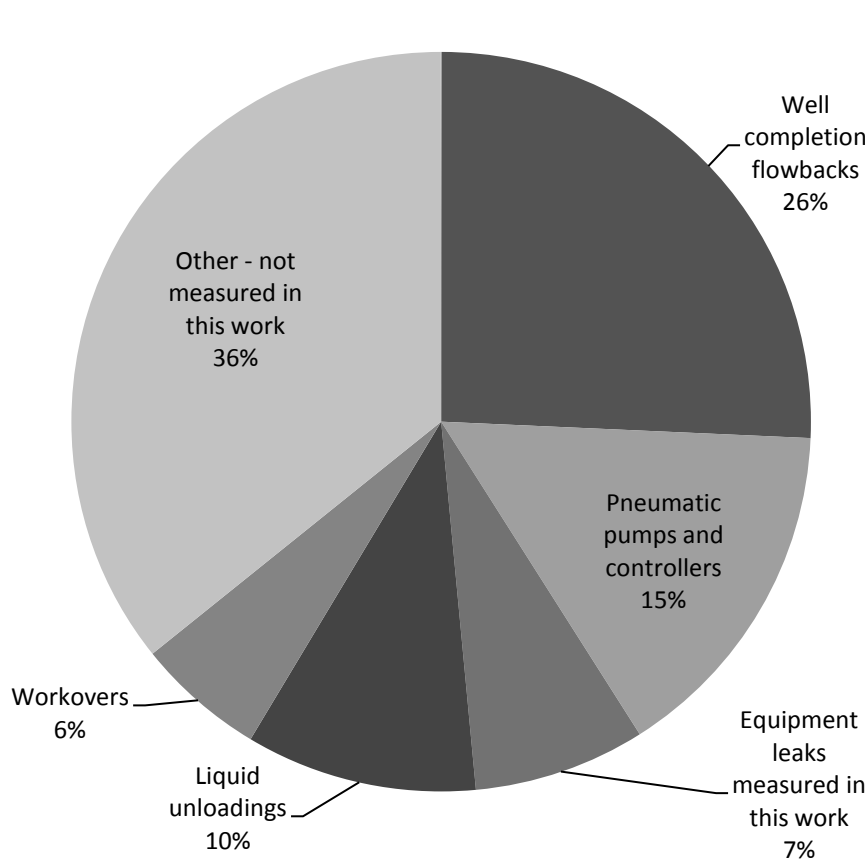


# Assumptions made in estimating national implications

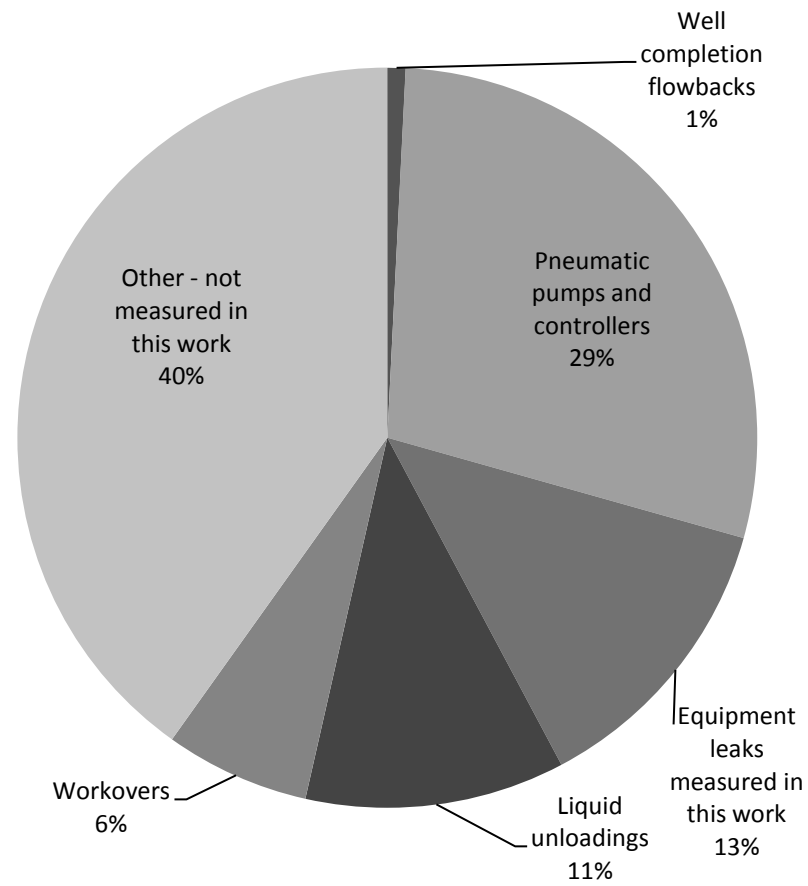
- Measurements were assumed to be representative of national populations
  - For all of the sources sampled, the measured data are a small percentage of total sources (27 of ~8000 completions; 489 of ~500,000 wells; 305 of ~450,000 pneumatic controllers)
  - Sites from nine companies, who voluntarily 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

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

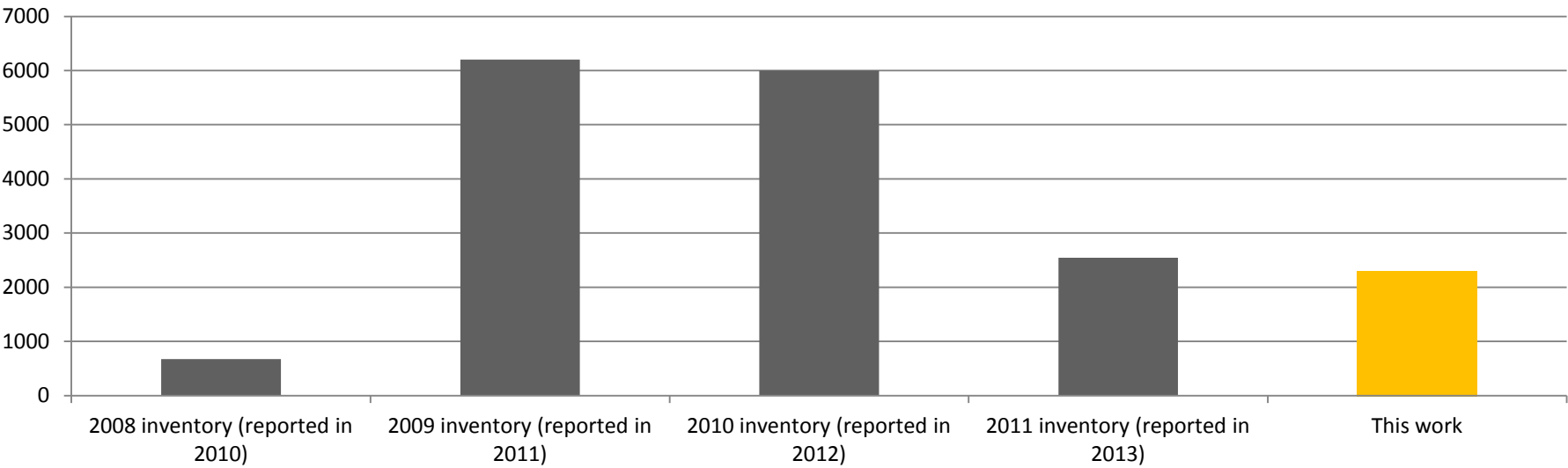
**Production emissions reported in 2011  
greenhouse gas inventory (annual  
emissions in Gg, inventory released in  
2013), 2545 Gg**



**Production emissions estimated based on  
measured data from this work, 2300 Gg/yr  
(0.42 vol % methane/total national natural  
gas production)**



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



# Allocation of methane emissions

- Gas wells produce both gases and liquids
- How should we allocate the 2300 Gg of emissions among the products?
- Allocations based on mass, energy and value of natural gas, natural gas liquid and hydrocarbon liquid products
  - Methane emissions assigned to natural gas 0.0020-0.0021 scf methane/scf natural gas vs. 0.0042 scf methane/scf natural gas for unallocated emissions
- Both allocated and unallocated emissions significantly below values based on 2009 EPA inventories, released in 2011

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Switching to compressed natural gas (CNG) vehicles from gasoline powered cars results in net climate benefits in 100 years at methane leak rates less than 3-4.5%, depending on whether the emissions are a long term conversion or a one time event; climate benefits increase over time

Switching to natural gas combined cycle electricity generation from coal powered electricity generation results in immediate net climate benefits if methane leak rate is less than 2.9%; climate benefits increase over time

Switching to CNG vehicles from gasoline powered cars results in immediate net climate benefits at methane leak rates less than 1.4%; climate benefits increase over time

Switching to CNG vehicles from diesel powered heavy duty vehicles results in immediate net climate benefits at methane leak rates less than 0.9%, climate benefits increase over time

(adapted from Alvarez, et al., PNAS, 109, 6435-6440, 2012)

# Methane emissions as a percentage of total natural gas produced

