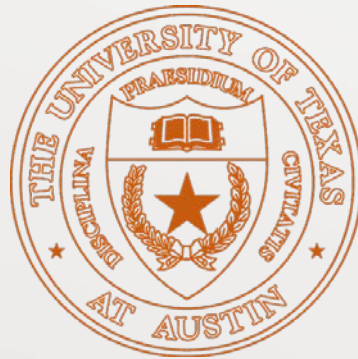


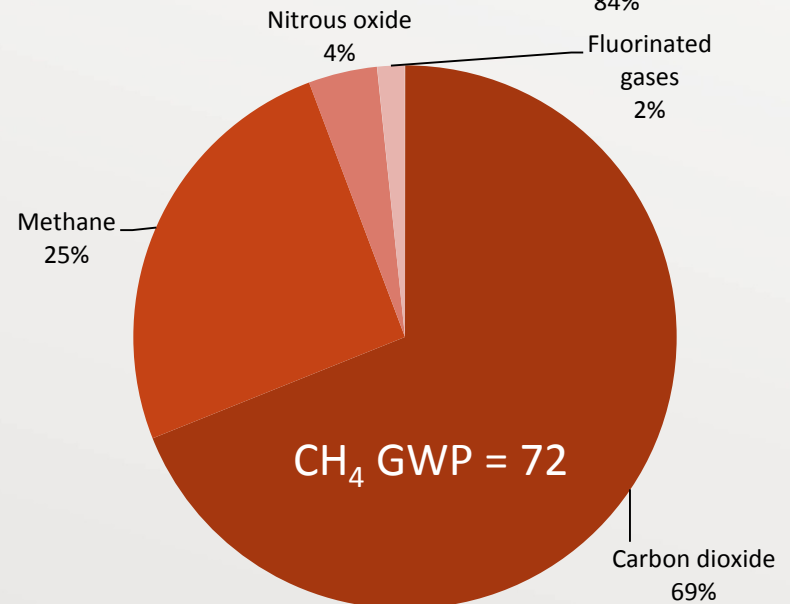
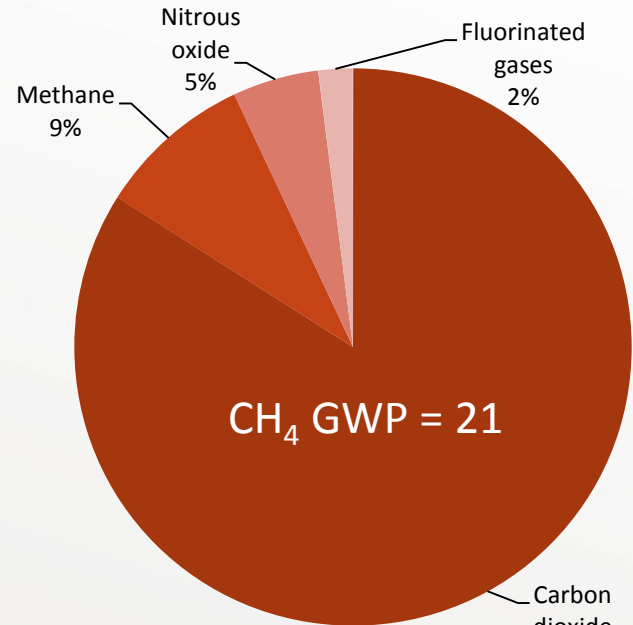
Measurements of Methane Emissions at Natural Gas Production Sites in the United States



Why is methane important?

The role of methane in the national greenhouse gas inventory

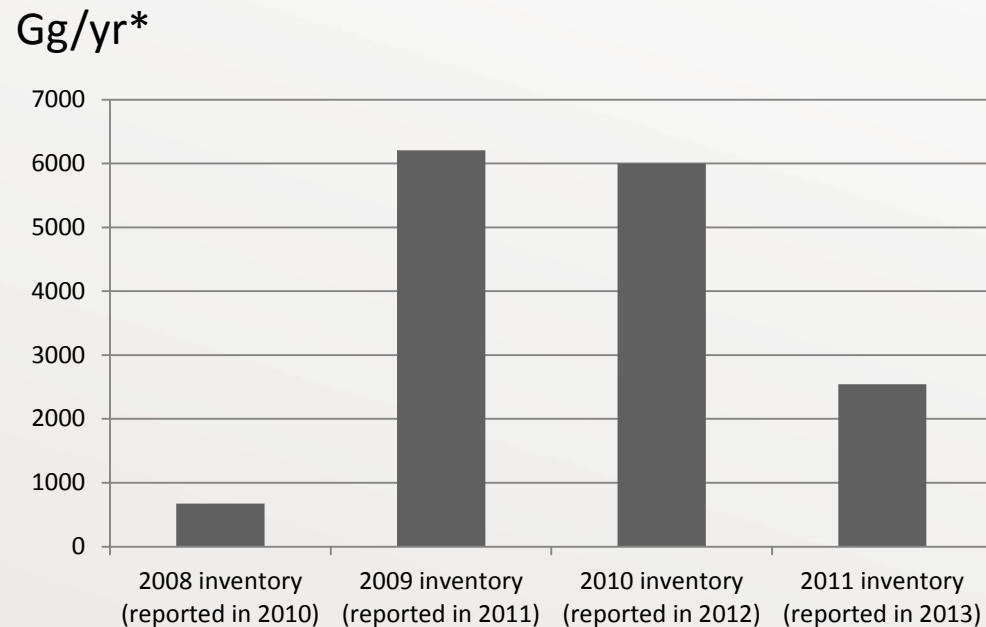
- Most recent national greenhouse gas inventory from EPA assumes a GWP for methane of 21, using a 100 year time horizon; methane accounts for 9% of the carbon dioxide equivalent emissions in the inventory
- The potency of methane is sensitive to our time frame of interest since methane is converted to CO₂, 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)

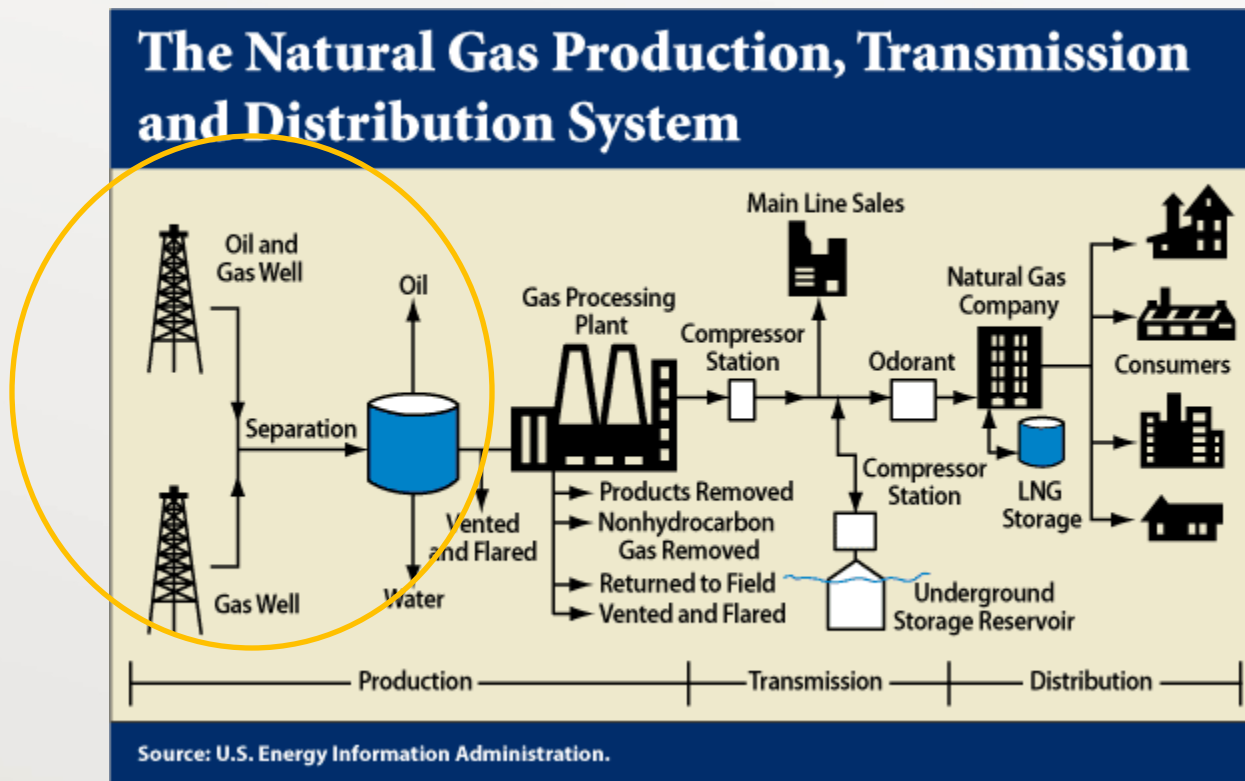
A Unique Partnership

- 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

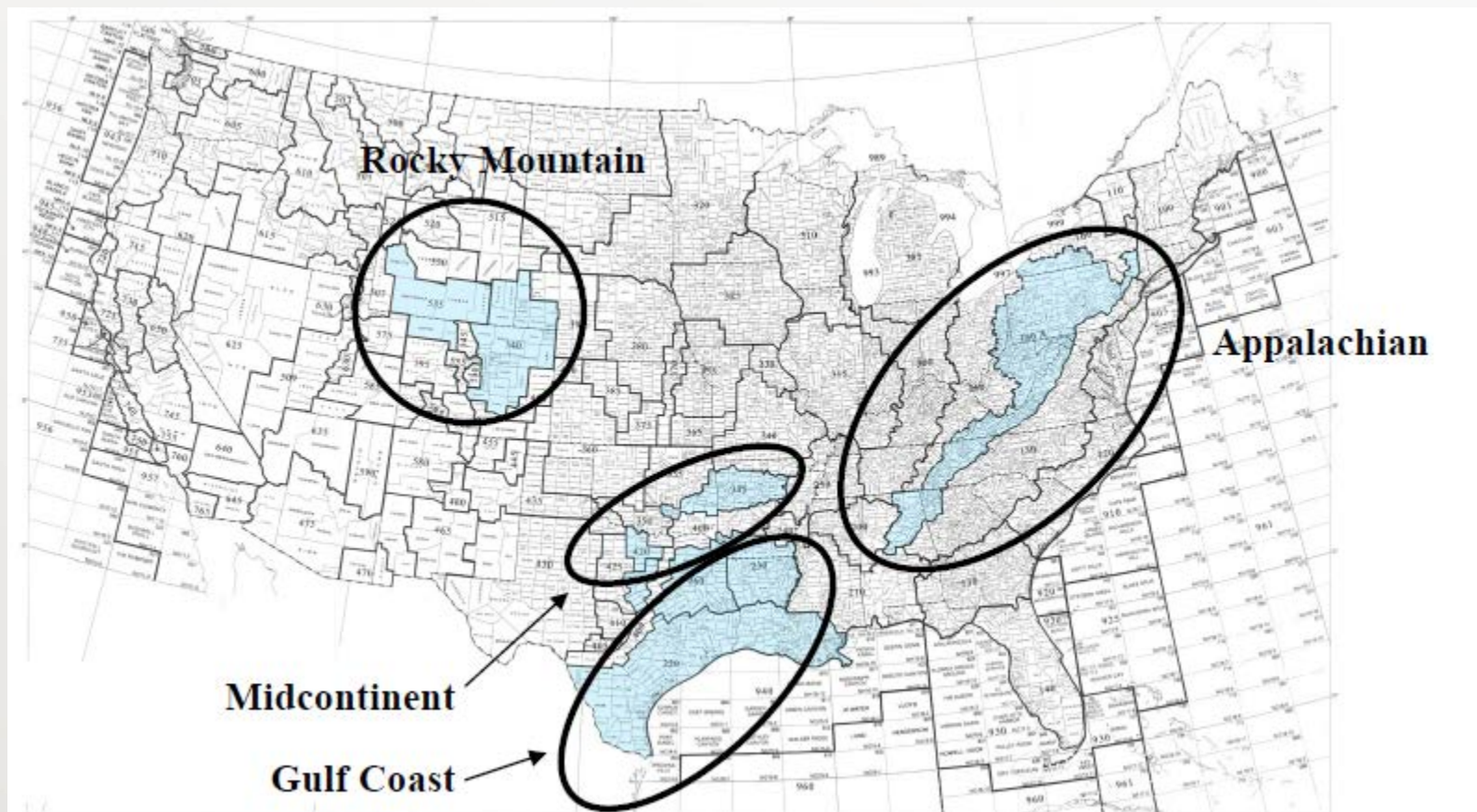
- **A unique partnership:** Study design, data, and findings were all reviewed by the study team, Environmental Defense Fund, participating companies, and an independent Scientific Advisory Panel
- **Direct access:** Participating companies provided access to production sites and equipment, and assisted 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

Scope of Study



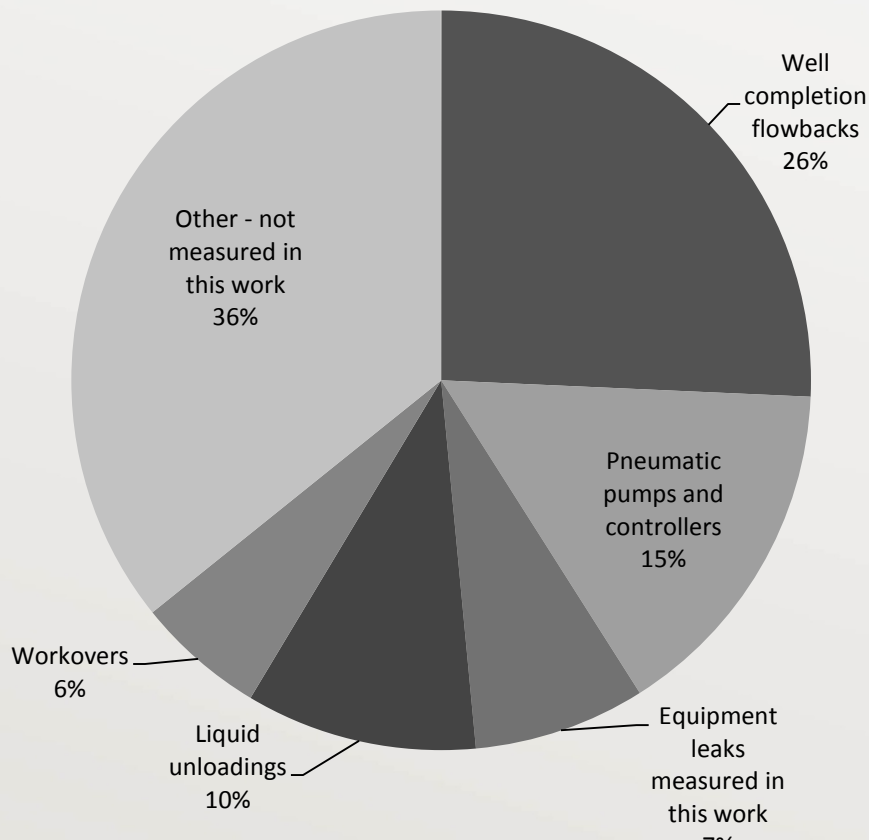
Environmental Defense Fund, with different groups of companies and study teams, are engaged in projects addressing the rest of the supply chain for natural gas

Multiple production regions were sampled

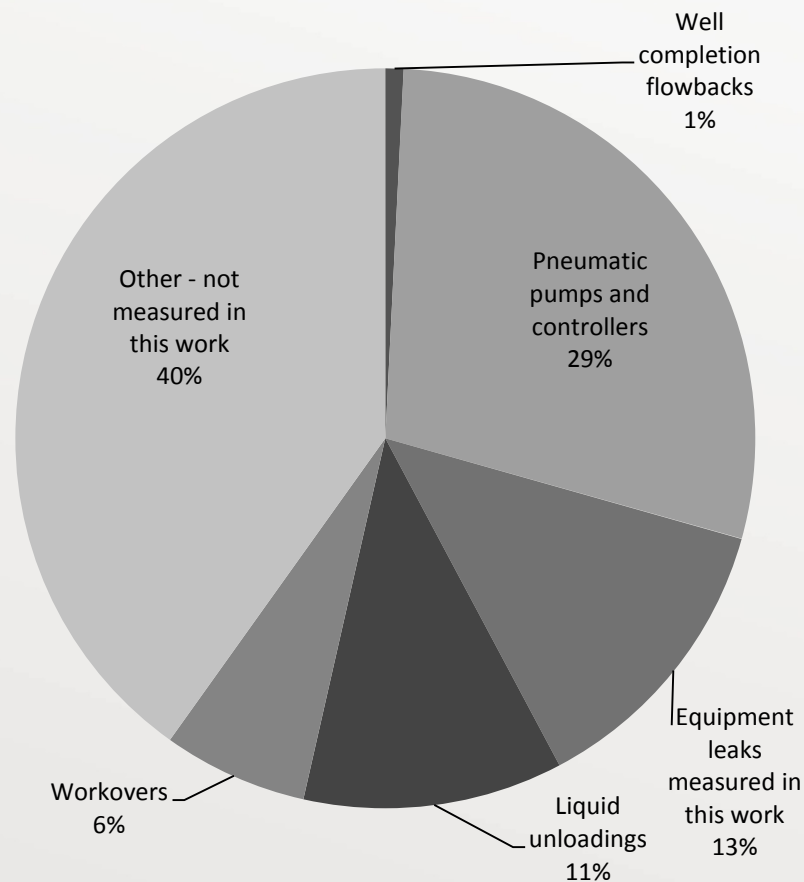


Natural Gas Production: Comparison of EPA national methane emission inventory to estimates based on this work (Gg/yr)

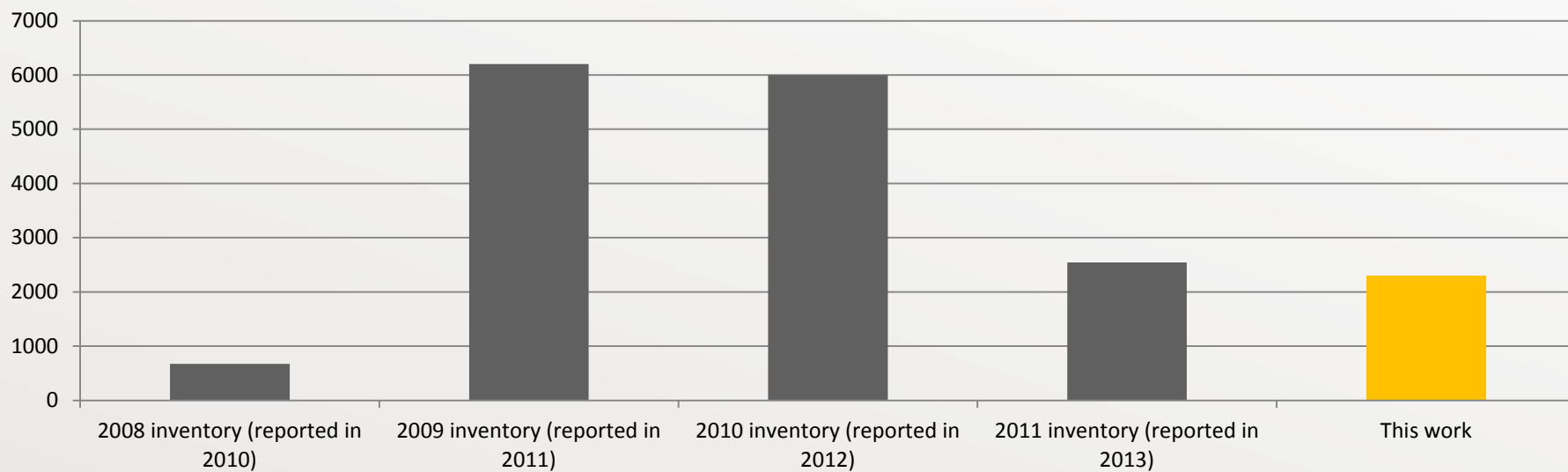
Production emissions reported in 2011 greenhouse gas inventory (annual emissions in Gg, inventory released in 2013), 2545 Gg



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).