Methane Emissions from Process Equipment at Natural Gas Production Sites in the United States: Liquid Unloadings

FREQUENTLY ASKED QUESTIONS

Frequently asked questions are organized into sections addressing (i) methods and results, (ii) comparing this work to other studies, and (iii) interpreting the results.

Methods and Results

What is a liquid unloading?
Gas well liquid unloading is a procedure, implemented periodically, where liquids that have accumulated in a gas well are removed to surface equipment. The liquids accumulation can include oil, condensate, and water, and may be due to a variety of causes, including decreases in gas velocity in the well, decreases in reservoir pressure, or changing gas to liquid ratios. As liquids accumulate, well production can decline and an operator may choose to unload the liquids from the well to restore gas production.

Liquids can be removed from well bores in a variety of ways. For example, the well tubing can be modified to increase gas velocity or a pump may be installed to remove downhole liquids. Neither of these methods result in venting of emissions. Other unloading methods, such as temporarily diverting the flow from the well to an atmospheric vent, do lead to emissions. This work focuses on unloadings that result in emissions.

Do all natural gas wells have liquid unloadings that result in emissions?
In the most recent national inventory of greenhouse gas emissions (for calendar year 2012, released in 2014, referred to as the EPA 2012 GHG NEI), the EPA estimates that 60,810 natural gas wells, out of an estimated 470,913 natural gas wells in the United States (not including oil wells with associated gas production), had liquid unloadings that result in methane emissions.

The temporal patterns of emissions can vary among wells. Some wells release unloading emissions several times per day while others may release unloading emissions only once per year or once during the well's decades long production life cycle. Wells may only release unloading emissions for a portion of their production lifetime, leading to some dependence of unloading emissions on well age.

Why was the study done and what is unique about the methods used and data reported in this study?
These are the first extensive measurements of methane emissions from liquid unloadings reported in the peer-reviewed scientific literature. The features of this study are:

- A unique partnership: Study design, data, and findings were all reviewed by the study team, Environmental Defense Fund, participating oil and gas companies, and an independent Scientific Advisory Panel.
- Direct access: Participating companies provided access to wells with liquid unloadings that vent emissions, and assisted in the design of safe sampling protocols, making possible measurements of emissions directly at the source.
- First extensive measurements: For liquid unloadings, only very limited measurements

of emissions (9 wells) have been reported in the scientific literature, and those measurements were exclusively for hydraulically fractured wells and for wells without plunger lifts. These measurements significantly expand the scope and number of measurements.

What types of emission sources were measured and what is the difference between wells with and without plunger lifts?

Unloading emissions were sampled for a variety of natural gas well types, including tight gas, shale gas, vertical wells, horizontal wells, and directional wells. In addition, wells both with plunger lifts and without plunger lifts were sampled.

In an unloading of a well without a plunger lift, an operator manually diverts the well's flow from a production separator, which typically operates at pressures of multiple atmospheres, to an atmospheric pressure tank. This allows the well to temporarily flow to a lower pressure destination (the atmospheric pressure tank or vent, rather than the pressurized separator). The resulting higher pressure gradient allows more gas to flow, increasing velocity in the production tubing and entraining and lifting liquids out of the well. Gas is discharged through the tank vent to the atmosphere until liquids are cleared. Manually triggered unloadings of wells without plunger lifts occur, on average, less than 10 times per year. In a small number of wells (~0.1% of wells reported by companies participating in this work), this process is automated and unloadings are more frequent (>100 events per year), resulting in two sub-categories of unloadings for wells without plunger lifts, manual and automatic. All of the measurements reported in this work for wells without plunger lifts are for wells that had unloadings that were manually triggered; no wells without plunger lifts were observed in the sampling that had automated unloadings.

Liquids can also be unloaded from a well using a plunger lift system. This liquid removal operation holds a plunger at the top of the well, and either manually or by automation occasionally closes (shuts-in) the well and releases the plunger, allowing it to fall down the well bore below the accumulated liquids. The well is then reopened, allowing the gas to push the plunger and the liquid back up the well bore as a slug of liquid. If the plunger returns to the top and the liquid and gas flow to the separator, there is no venting and all gas from the separator is routed to sales. In some cases, if the plunger does not return to the surface as expected, the plunger controller may bypass the separator and direct the flow to an atmospheric pressure vent, such as a vented tank. Directing flow to the lower pressure vent causes the plunger to return to the surface but also allows gas to vent. Plunger cycles may be initiated manually, on a timed interval, or based on certain well parameters, such as reduced gas flow. In this work, measurements were made on both wells in which the unloading was automated through use of a controller (automatically triggered), and wells in which the plunger lift cycle was manually initiated by an operator (manually triggered). Unloadings of wells with plunger lifts occur, on average, more than 200 times per year. Although the events are more frequent than for wells without plunger lifts (<10 events/yr), the emissions per event are lower for wells with plunger lifts.

How were sites selected for sampling? What steps were taken to eliminate bias in the sites sampled?

Sampling of emissions from gas well liquid unloadings was conducted in four major regions (Appalachian (AP), Gulf Coast (GC), Mid-continent (MC), Rocky Mountain (RM)). It was anticipated that in each of the four regions, gas wells with and without plunger lifts would be sampled, and that within each of these categories, there would be a range of unloading frequencies, durations and liquid production rates. To adequately sample regions, well types (plunger and without plunger) and unloading event characteristics, it was anticipated that measurements of unloading emissions from approximately 100 different wells would be required.

With a goal of 100 well unloading measurements, the project team conducted approximately 20 one-week visits to natural gas production regions with unloading emissions. It was anticipated that 5 wells could be sampled in a typical week. Each week of sampling was conducted with a single company in a single basin location.

Basins in which sampling was conducted were selected based on emissions reported through the EPA's Greenhouse Gas Reporting Program (GHGRP, Reporting Year 2012). The ten companies participating in this work reported 60% of the total unloading emissions for GHGRP reporting year 2012, and account for 26% of the wells that reported emissions. The Study Team, consisting of URS and University of Texas personnel, was solely responsible for the selection of regions and Basins in which to sample. The selection of company sites required a balance among a number of goals. One goal was to sample at least 3 companies in each major region (AP, GC, MC, RM). A second goal was to sample the basins with the largest reported emissions in the GHGRP. A third goal was to be able to sample each of the participant companies at least once. All participant companies that reported wells with unloading emissions were sampled in this program.

Once a basin was targeted for sampling, selection of the particular company to visit started with the participant company with the largest reported emissions in the basin, unless that company had already been sampled elsewhere, or unless one of the other participant companies only reported emissions in that single basin. Once a Basin and company to be sampled were selected, local contacts for participant companies provided descriptions of the types of unloadings and typical frequencies expected. No companies refused a site visit. Once at a site, the Study Team measured emissions from as many wells as could be visited and measured in the week. In some cases this involved sampling every unloading that occurred during the week for the company being visited. When more unloadings were available than could be sampled during a week, the Study Team selected which wells to visit.

Are the raw data publicly available? Are any data not being released?

The full dataset is available and more information can be found at the web site of the Cockrell School of Engineering at the University of Texas at Austin: http://dept.ceer.utexas.edu/methane2/study

All of the measurement data collected during the study are available in the publicly available study reports and dataset.

Why focus only on methane?
Much uncertainty exists about the amount of methane emissions resulting from natural gas production activities, such as unloadings, and the focus in this work was on resolving that uncertainty, using direct measurements of emissions at the source of the emissions. Natural gas exploration and production operations can produce a variety of emissions. Expanding the chemicals targeted for measurements would have significantly expanded the scope and complexity of the study.

Why make measurements in different regions and why would emissions vary from geologic basin to basin?
The study team made measurements in the Appalachian, Gulf Coast, Mid-continent, and Rocky Mountain regions. Differences in the geological formations that are the source of natural gas and the condensates that are produced with natural gas can lead to differences in operating procedures, such as unloadings, and emissions. Differences in the total magnitude of unloading emissions among regions are largely due to the number of wells that have high frequencies of unloading emission events in a region, rather than the emissions per event.

Comparing this work to other studies

How do these results compare to emissions reported by the U.S Environmental Protection Agency? In the 2012 EPA Greenhouse Gas National Emission Inventory, liquid unloadings from 60,810 wells are estimated to emit 273.6 Gg of methane per year (14.2 billion standard cubic feet, bcf), or approximately 14% of the estimated 1,992 Gg of methane emissions from the natural gas production portion of the natural gas supply chain. The estimates of methane emissions from liquid unloadings in the EPA 2012 GHG NEI are generally consistent with more recent information collected through the EPA's Greenhouse Gas Reporting Program (for calendar year 2012, released in 2013, referred to here as the EPA 2012 GHGRP). The GHGRP reports approximately 276 Gg of methane emissions from liquid unloadings at facilities that meet threshold reporting requirements. Information for 58,663 wells that have unloading emissions was reported in 2012.

The overall emission estimate for liquid unloadings (plunger and non-plunger wells), based on the measurements made in this work, is 270 Gg (14 bcf/y), which is within a few percent of the national emissions estimated in either the 2012 GHG NEI (273 Gg/yr) or the 2012 GHGRP (276 Gg/yr). The 95% confidence range for this estimate is 190 – 400 Gg/yr, based on the reported confidence ranges in the per event emission factors, but not accounting for uncertainties in event counts. Sensitivity analyses suggest that uncertainties in event count estimates may be large, up to a factor of two or more, which could have a significant impact on national emission estimates.

How do these results compare to emissions reported by Allen et al. (2013; PNAS, 110, 17768-17773)?
Allen et al. (2013) reported a limited data set of measurements, for 9 unloading events. All were manual unloadings of relatively recent horizontal wells, without plunger lifts, in newly developed shale formations. This work collected data on many different well types, including some of the same well types reported in Allen et al. (2013). The data collected in this work for

horizontal wells, without plunger lifts, (the same well types reported by Allen, et al. (2013)) can be compared to the previously published results. Allen, et al. (2013) reported average emissions of 57,000 scf methane per event; emissions from horizontal wells without plunger lifts measured in this work averaged 52,000 scf/event. Both this work and Allen, et al. (2013) report broad ranges in per event emissions and durations of the events.

Interpreting the Results

How did the study team use its measurements to estimate national emissions?
The primary objective of the study was to collect measurements of emissions from liquids unloadings of natural gas wells. Similar to the other national level emission studies, the resulting dataset is necessarily a relatively small sample of a national population. For example, out of an estimated 60,000 natural gas wells in the United States that had liquid unloadings that resulted in methane emissions in 2012, this study sampled 107.

In this work, measurements were used to develop national emission averages (emissions per unloading event). National emissions were estimated by multiplying the average of emissions per event by the number of unloading events. Numbers of unloading events, by region, were estimated based on a survey of the companies participating in this work.

Do these new findings change the overall emission rate, expressed as a percentage of natural gas production, reported by Allen et al. (2013; PNAS, 110, 17768-17773)?
Allen, et al. (2013) reported an emission rate of 0.42% for the portion of the natural gas supply chain associated with natural gas production. This percentage was based on the estimated national emissions for 2012, divided by the total natural gas withdrawals in 2012. If the national emissions estimated in this work for 2013, including the new estimate for liquid unloadings, are divided by the total natural gas withdrawals in 2013, the percentage is 0.38%. The small differences in percentages between this work and Allen, et al. (2013) are due to both increased natural gas withdrawals in 2013, relative to 2012 and some small changes in emission estimates.