April 2022

Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2020: Updates for Anomalous Events including Well Blowout and Well Release Emissions

This memorandum discusses updates for emissions from anomalous leak events with event-specific quantified emissions occurring in petroleum and natural gas systems, including specifically for petroleum and natural gas onshore production well blowouts for the *2022 U.S. Inventory of U.S. Greenhouse Gas Emissions and Sinks* (GHGI). Additional considerations for anomalous leak events and an update for other well blowouts and releases (considered but not implemented) were discussed in a memorandum released in October 2021.[1]

1 Background and Previous (2021) GHGI Methodology

The 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories [2] included guidance on calculating emissions from "anomalous leak events" for national GHG Inventories. The 2019 IPCC Refinement provides examples of anomalous events, including emergency pressure relieving equipment and well blowouts, and specifies that these events should be evaluated and estimated on a case-by-case basis using the best available data. The GHGI currently incorporates an estimate for one anomalous leak event, the Aliso Canyon storage well event in 2015/2016.[3] The EPA updated the GHGI to include additional anomalous leak event emissions from three recent well blowouts, as discussed in this memorandum.

Oil and gas well blowouts are uncontrolled high-pressure releases of oil, gas, and/or salt water from offshore or onshore oil and gas production wells which occur when well control techniques (i.e., well blowout preventer) fail. There are three main types of blowouts: surface blowouts, underground blowouts, and subsea blowouts. Well blowouts most often occur during the drilling or completion phase of a new well, prior to production or use. An oil and gas well release is different than an oil and gas well blowout, and is characterized as a short period of uncontrolled release[4] followed by a period of controlled release in which control techniques are successfully implemented.

Well blowouts and releases present challenges for quantification including evasion of initial detection if the well is located in a remote area, limited emissions data available in many cases (e.g., limited satellite overpasses, limited aircraft overflights), significant variation in the event duration and emissions rate, and the creation of hazardous conditions at the event site as a consequence of the blowout or release.

The GHGI currently includes well blowouts emission estimates from newly drilled onshore oil wells. The data used in the GHGI is sourced from an "Industry Review Panel." The GHGI estimates the number of blowouts on a frequency of 1 blowout per 300 oil wells drilled. The GHGI estimates emissions as 2.5

[1] Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2020: Updates Under Consideration for Anomalous Events including Well Blowout and Well Release Emissions. Available online at <https://www.epa.gov/ghgemissions/stakeholder-webinar-sept-2021-natural-gas-petroleum-systems-ghg-inventory>

[2] 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2, Energy. Available online at: <https://www.ipcc-nggip.iges.or.jp/public/2019rf/vol2.html>

[3] Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2015: Incorporating an Estimate for the Aliso Canyon Leak. Available online at: <https://www.epa.gov/ghgemissions/natural-gas-and-petroleum-systems-ghg-inventory-additional-information-1990-2015-ghg>.

[4] Not including the controlled pre-separation stage of well flowback in a hydraulically fractured completion

MMScf CH_4/blowout and the corresponding CO_2 emissions quantity is estimated using the methane factor and the average ratio of CO_2 to CH_4 in associated gas (from API 4697). Well releases from onshore oil wells and well blowouts and releases from onshore gas wells are currently not included in the GHGI.

2 Summary and Discussion of Available Data

A literature review was conducted for emissions data and activity data for onshore oil and gas anomalous leak events. Three recent studies provide event-specific emissions quantification, and quantified well blowouts using a combination of satellite, aircraft, and ground-based measurements. The studies evaluated gas well blowouts in Belmont County, Ohio in 2018 ("Satellite observations reveal extreme methane leakage from a natural gas well blowout" by Pandey et al.)[5]; in the Eagle Ford Shale near Victoria, Texas in 2019 ("Multisatellite Imaging of a Gas Well Blowout Enables Quantification of Total Methane Emissions" by Cusworth et al.)[6]; and in Louisiana south of Shreveport in 2019 ("Reconstructing and quantifying methane emissions from the full duration of a 38-day natural gas well blowout using space-based observations" by Maasakkers et al.).[7]

In Pandey et al., satellite measurements of total column CH_4 (XCH_4) from the spaceborne Tropospheric Monitoring Instrument (TROPOMI) were used to quantify emissions from a 20-day gas well blowout episode in early 2018 in Belmont County, Ohio. Data from cloud-free and low aerosol conditions covering at least a quarter of the blowout region were selected. Only two days of data from the episode met this selection criteria. Only one of these days had measurements downwind of the blowout, so this day was selected for emission quantification. The Weather Research and Forecasting (WRF) model was used to simulate a blowout plume to match the TROPOMI-observed XCH_4 measurements and estimated an emission rate at 120 ± 32 metric tons/hr. Assuming this emission rate, which was calculated for the 13th day in the blowout period, is the representative average emission rate during the blowout period, the total CH_4 emissions of the episode were estimated to be 60,000 ± 15,000 metric tons. The authors note that this amount is equivalent to a quarter of the annual oil and gas CH_4 emissions reported to EPA's Greenhouse Gas Reporting Program (GHGRP) in the state of Ohio.

As documented in Cusworth et al., in November 2019 a gas well blowout occurred in the Eagle Ford Shale at a surface site consisting of four co-located horizontally drilled gas wells. On the 14th day of the event, the wellhead was capped, and gas was diverted to an open pit where it was flared. On the 20th day, the well was deeply injected with fluid resulting in an effective shut in. The Cusworth et al. study used a combination of monitoring data from space and from the ground to estimate emissions from the gas well blowout event. Ground level data included in situ volatile organic compound measurements within 5 km of the blowout at several sites. Additionally, the study used other downwind measurements

[5] Pandey, S., Gautam, R., Houweling, S., van der Gon, H. D., Sadavarte, P., Borsdorff, T., et al. (2019). Satellite observations reveal extreme methane leakage from a natural gas well blowout. *Proceedings of the National Academy of Sciences*, 116, 26376– 26381. https://doi.org/10.1073/pnas.1908712116
[6] Cusworth, D.H., Duren, R.M., Thorpe, A.K., Pandey S., Maasakkers, J.D., Aben, I., et al. (2021). Multisatellite imaging of a gas well blowout enables quantification of total methane emissions. *Geophysical Research Letters*, 48, e2020GL090864. https://doi.org/10.1029/2020GL090864
[7] Maasakkers, Joannes D., Mark Omara, Ritesh Gautam, Alba Lorente, Sudhanshu Pandey, Paul Tol, Tobias Borsdorff, Sander Houweling, Ilse Aben (2022). Reconstructing and quantifying methane emissions from the full duration of a 38-day natural gas well blowout using space-based observations. *Remote Sensing of Environment.* https://doi.org/10.1016/j.rse.2021.112755

at state-operated air quality monitoring stations for emissions estimates. These measurements were used with chemical transport modeling and well compositional data to infer CH_4 concentrations to estimate emissions from the event. Data from space included a combination of measurements from TROPOMI, the GHG-Sat-D satellite, the Visible Infrared Imaging Radiometer Suite (VIIRS) instrument (CH_4 concentrations inferred from the radiant heat of flaring), and the PRecursore IperSpettrale della Missione Applicativa (PRIMSA) satellite imaging spectrometer. In situ sampling and satellite measurements were combined to fully capture the event and overcome certain equipment limitations including spatial coverage, spatial resolution, revisit frequency, weather specific issues and the presence of flaring. The observation dates in Cusworth et al. (2019) are listed below:

TROPOMI: November 2, 3, 15, and 18.
GHGSat-D: November 10.
in situ VOC measurements (i.e., pentanes and butanes): November 2, and 5-8.
PRISMA: November 15.
SkySat: November 15.
VIIRS: November 15-20.

The total estimated integrated emissions rate for the Eagle Ford event from Cusworth et al. was 4,830 ± 980 metric tons of CH_4.

Maasakkers et al. assessed emissions from a 38-day well blowout event in Louisiana. The event began in August of 2019. Emissions were quantified using observation data from TROPOMI and VIIRS. The event impacted two wells and involved burning at the wellhead, venting at the wellhead, and burning at a flare pit. For more than half of the duration of the blowout, gas was burned at the flare pit; however, it is estimated that over 80 percent of emissions came from the venting phase. The study observed venting methane using TROPOMI (7 days of observations), and calculated methane from flaring using nighttime VIIRS radiant heat. The total emission estimate for the Louisiana event was 49,000 (21,000-63,000) metric tons of CH_4.

Appendix A provides an overview of the study design of each paper.

3 Analysis of Available Data

EPA incorporated anomalous leak events for the 2022 GHGI using event-specific published emissions.

A previous version of this memo contained an analysis of state datasets that have information on the frequency of well blowouts and well releases in the U.S.[8]

[8] Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2020: Updates Under Consideration for Anomalous Events including Well Blowout and Well Release Emissions. Available online at <https://www.epa.gov/ghgemissions/stakeholder-webinar-sept-2021-natural-gas-petroleum-systems-ghg-inventory>

4 Time Series Considerations

Well blowouts and well releases are unpredictable and episodic. EPA incorporated available emissions data for three large events into the GHGI. EPA will continue to review information available on large anomalous leak events for potential incorporation into the GHGI.

5 National Emissions Estimates for Well Blowouts in the 2022 GHGI

EPA incorporated emissions from three well blowout events into the 2022 GHGI. These events are detailed in Section 2 and include emissions for years 2018 and 2019.

Table 1 shows the emissions estimates from large blowout events incorporated into the 2022 GHGI.

Table 1: Well Blowout National CH_4 Emissions in the 2022 GHGI (Metric Tons CH_4)

Source	2018	2019	2020
Gas Well Blowouts	60,000	53,800	NO

NO (Not Occurring)

6 Requests for Stakeholder Feedback

EPA sought stakeholder feedback on the approaches under consideration through two 2021 webinars, in the October 2021 memo, and in the public review draft of the GHGI. EPA received stakeholder comments on the October 2021 version of the memo. Stakeholder feedback is summarized here.

A stakeholder commented that the satellite studies utilized methods that involved a number of assumptions and estimations and in some cases very few data points. The stakeholder noted that emissions from well blowouts and well releases are not steady state, and suggested that EPA consider other simulation tools to quantify emissions. The stakeholder also suggested that EPA should consider quantifying the emissions values based on a time scale rather than per event.

The requests for stakeholder feedback below were not updated for this memorandum and are copied from the October 2021 memorandum:

1. EPA seeks stakeholder feedback on the incorporation of data on well blowouts with event-specific emissions quantification.
    a. EPA seeks stakeholder feedback on the data currently available, including on measurement methods and quantification approaches used in the two highlighted studies.
    b. EPA seeks stakeholder feedback on the number of observations used to develop an estimate for an anomalous leak event. The 2018 blowout event study had one day of emissions data (from a TROPOMI concentration observation) the 2019 event had data for around 13 days from a variety of instruments and approaches.
    c. EPA seeks stakeholder feedback on assumptions applied to calculate emissions rate when data are unavailable. Pandey et al. assumed that the emission rate quantified for the observed day was applicable for the duration of the event. Other events such as the blowout quantified in Cusworth et al. and the Aliso Canyon event as incorporated into the GHGI had data over several days of the event which were used to quantify a changing emission rate over time.

    d. EPA seeks information on well blowouts with event-specific emission quantification in addition to the two identified in this memorandum.
2. EPA seeks stakeholder feedback on incorporation of additional types of anomalous events, including on the types of events that could be considered and data availability.
3. EPA seeks stakeholder feedback on approaches for estimating emissions from anomalous events where measurement data are unavailable but other records exist.
4. EPA seeks stakeholder feedback on updating the current estimate for well blowouts without event-specific quantification and the incorporation of an estimate for well releases.
    a. EPA requests stakeholder feedback on the use of the same emissions value (i.e., 2.5 MMScf CH_4/event) for well blowouts and well releases and whether there are additional/updated data that should be considered for adjusting these emissions values.
5. If there are not additional sources of emissions data, EPA is considering including a single source of emissions by well type (e.g., onshore gas well blowouts and releases; onshore oil well blowouts and releases) as opposed to separate emissions sources for well blowouts and well releases for each well type as presented in Tables 6 and 7.
6. EPA seeks stakeholder feedback on the use of the Texas RRC data (rather than a combination of identified sources in the literature) for establishing a national average frequency of well release and well blowout events.
    a. EPA seeks stakeholder feedback on the general methodology to assign events to the categories of well release and well blowouts used with the Texas RRC data.
7. EPA seeks stakeholder feedback on the time-series approach in section 4 of this memorandum.

Appendix A – Study Design Information

Study	Measurement Type	Description/Number of Sources	Location and Representativeness	Emissions / Activity Data Calculation Method
Pandey et al.	Satellite observations from TROPOMI and simulation modeling using the WRF model	Gas well blowout in Belmont, OH occurring over a 20-day period in 2018.	Each event is unique and is being considered as a line-item reporting rather than reflected in an average emissions value, so location/representativeness were not considered.	The combination of satellite observations and simulation modeling yielded a 120-130 metric tons per hour emissions rate which was applied to the entire duration of the event yielding an estimated event total emissions of 60,000 metric tons CH_4 released.
Cusworth et al.	Satellite observations from TROPOMI, GHG-Sat-D, VIIRS, and PRIMSA; Simulation techniques including WRF and the integrated methane enhancement algorithm.	Gas well blowout in Victoria, TX at a surface site consisting of four horizontally drilled wells occurring over a 20-day period in 2019.		The combination of satellite observations and simulation modeling yielded an event estimate of 4,800 metric tons CH_4 released.
Maasakkers et al.	Satellite observations from TROPOMI and VIIRS and simulation modeling using WRF-Chem.	Gas well blowout in Louisiana occurring over a 38-day period in 2019.		The combination of satellite observations and simulation modeling yielded an event estimate of 49,000 metric tons CH_4 released.