

Author response to open comments

Open comment by Daniel Cusworth

Williams et al. presents a very extensive summary of U.S. oil&gas emissions using a combination of bottom-up modeling and atmospheric observations. The breadth of the survey should be commended for bringing additional information to this important emission sector. I do have one comment to help clarify the study, especially as it relates to the study's title. The use of the wording "disproportionate" is not supported by the results of the study. In fact, the authors' conclusion in this manuscript is that the majority of emissions result from small emitters, and that small emitters represent the majority of infrastructure in oil&gas basins. Therefore, the aggregate emissions from small sources are essentially proportionate to their numbers. It would be clearer and more correct to strike the word "disproportionate" from the title. This seems particularly important given that one of the author's main points is that methane mitigation policy needs to address emissions from large numbers of smaller emitters in addition to a small number of super-emitters.

We thank Dr. Daniel Cusworth for taking the time to read through our pre-print and offer his insights on this paper.

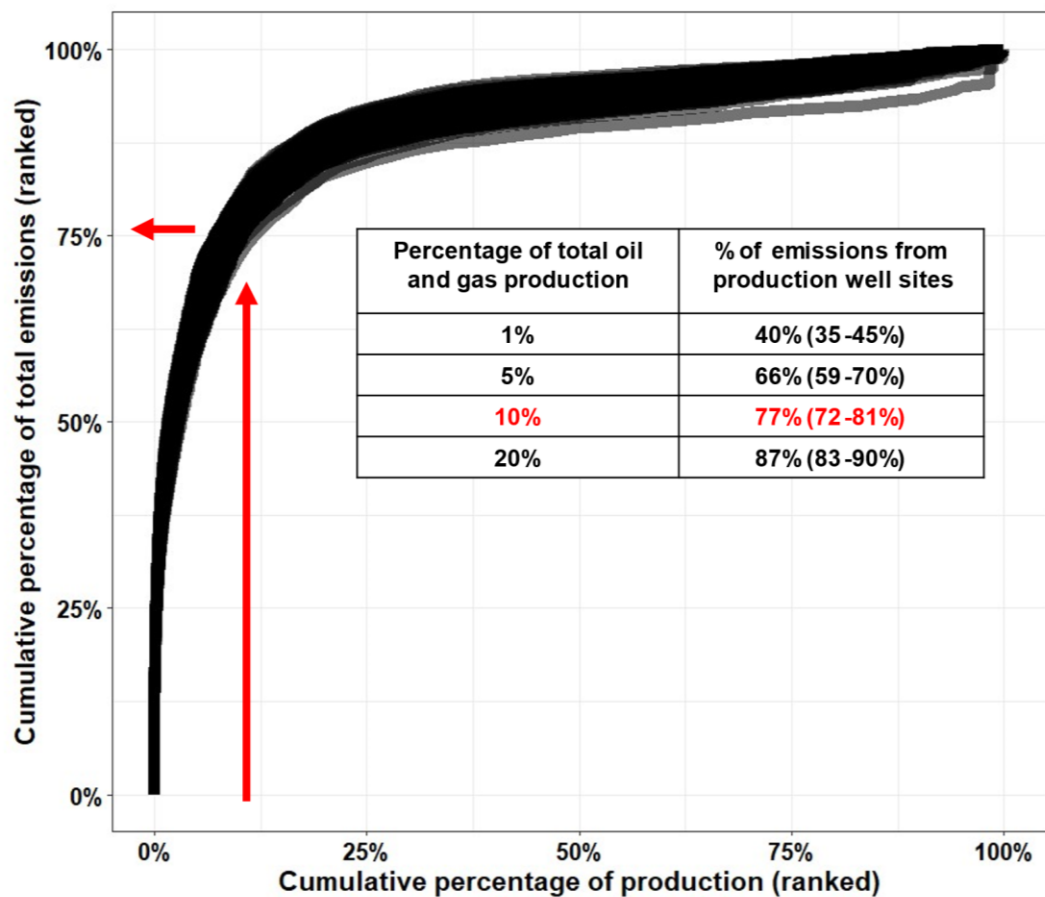
We do agree that the word “disproportionately” as used in the current title may be misconstrued to indicate a disproportionate relationship between facility counts and total emissions. In the case of our work, when we use the term “disproportionate” we are referencing the large majority of cumulative emissions contributed from facilities emitting at relatively low emission rates (i.e., <100 kg/hr/facility). In addition, our work also finds a large majority of cumulative emissions from well sites (i.e., the facility category contributing 68% of total emissions from our estimates) that contribute a small percentage of overall production. To clarify these points, we have made some changes to the text in the main paper, including a slightly revised title and new figures in the SI. We hope that the following changes address the comments expressed by Dr. Cusworth.

- Revised title of the manuscript:
 - [title] *“Small emission sources in aggregate disproportionately account for a large majority of total methane emissions from the US oil and gas sector”*
- New text in the Abstract/Results/Conclusions that highlights the disproportionately high emissions from well sites contributing a minority of overall production:
 - [page 1] *“We estimate that production well sites were responsible for 70% of regional oil/gas methane emissions, from which we find the well that accounted for only 10% of national oil and gas production in 2021, disproportionately accounted for 77% (72-81%) of the total well site emissions.”*
 - [page 20] *“Production well sites constitute the bulk of total methane emissions among the facility categories we considered, with most of these emissions contributed from low production well sites. Overall, we find that 77% (72-81%) of well site emissions originated from only 10%*

of national oil and gas production in 2021 (Fig. S7), highlighting a disproportionately large fraction of emissions relative to production. In terms of individual well site level production values, the same 77% (72-81%) of total cumulative methane emissions were contributed from well sites producing 0.43 kt/yr (0.43-0.45 kt/yr) or lower. For well sites producing 15 boe/day (i.e., 0.13 kt/yr) or lower, which is the production threshold used to define a well site as being marginally producing in previous work (Deighton et al., 2020; Omara et al., 2022), we find that these low producing well sites accounted for 65% (58-69%) of total well site emissions, or 6.4 Tg/yr (4.7-6.8 Tg/yr).”

- [page 31] “3. Production well sites were found to be responsible for 70% of regional oil/gas methane emissions, from which the sites that accounted for only 10% of national oil and gas production in 2021, disproportionately accounted for 77% (72-81%) of the total well site emissions.”

- A new figure in the SI that illustrates the relationship between well site production and cumulative emissions from well sites



- “Figure S7: Results from 500 model simulations showing the cumulative methane emissions distribution curves for total well site oil/gas methane emission rates versus the percentage of cumulative combined oil and gas production. Results are ranked first by individual well-site

emission rates, and then by well-site combined oil and gas production. The inset table shows the specific percentages of total emissions contributed from production well sites for cumulative well site production values of 1%, 5%, 10%, and 20%. The red arrows correspond to the percentage of total well site emissions contributed from well sites cumulatively producing 10% of total CONUS oil and gas production in 2021.”