***Petrochemicals to Waste: Examining the Lifecycle Environmental and Climate Effects of Plastic***

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Before the

**Senate Environment and Public Works Committee**

Subcommittee on Chemical Safety, Waste Management, Environmental Justice, and Regulatory Oversight

March 30th, 2023

Chairman Merkley, Ranking Member Mullin, and Members of the Committee,

Thank you for the opportunity to testify on the topic of greenhouse gas emissions of plastics manufacturing.

I am Arvind Ravikumar, co-Director of the Energy Emissions Modeling and Data Lab [1] or EEMDL and a faculty in the Petroleum and Geosystems Engineering Department at the University of Texas at Austin. I have published over 40 articles in peer-reviewed journals, primarily in the areas of greenhouse gas emissions measurements, life-cycle emissions assessments, and energy systems analysis. Over the past decade, I have led several large-scale, field campaigns in the US to measure greenhouse gas emissions from the oil and gas supply chain. In addition, my research group has evaluated many innovate technologies such as drones, satellites, and aircraft-based systems for detecting emissions from the oil and gas infrastructure. Throughout my research, I have worked in close collaboration with the industry, state and federal agencies, and non-governmental organizations.

I want to make three key points in my testimony.

First, up to 50% of the lifecycle greenhouse gas emissions impact of plastics is associated with the upstream oil and gas supply chain that serves as feedstock to chemical manufacturing that become plastics.

[1] The University of Texas at Austin, Energy Emissions Modeling and Data Lab (EEMDL) https://www.eemdl.utexas.edu

Second, geographic variation in the production of oil, natural gas, and natural gas liquids that serve as feedstock to the chemicals industry results in significant differences in lifecycle emissions of plastics, depending on where they are manufacturing.

Third, uncertainty in greenhouse gas emissions accounting and emissions allocation methods to different upstream products is a key driver of uncertainty in lifecycle greenhouse gas emission impacts.

The most significant sources of emissions in the lifecycle of plastics production are upstream emissions associated with oil and gas feedstocks, process and combustion emissions associated with the plastic manufacturing process, and emissions associated with electricity used in manufacturing. These do not include emissions associated with end-of-life management such as pyrolysis-based chemical recycling methods, which can be a significant source of greenhouse gas emissions. Upstream feedstocks come in the form of petrochemicals and hydrocarbon liquids that are byproducts of crude refining and natural gas processing, respectively. In the context of plastics, upstream greenhouse gas emissions associated with feedstocks – primarily methane – can account for up to 50% of total lifecycle emissions [2]. As the electricity grid rapidly decarbonizes and manufacturing facilities take advantage of cheap renewable energy, the contribution of upstream methane emissions and process emissions during manufacturing to total lifecycle emissions will only increase. Therefore, addressing methane emissions associated with the oil and gas supply chain is a key approach to reducing lifecycle greenhouse gas impacts of plastics.

In the US, the production of natural gas liquids has increased threefold over the past decade to 6 million barrels per day in 2021, tracing the growth in shale resource development. These liquids are co-produced with oil and gas in different shale basins. In particular, liquids rich basins such as the southwest Marcellus in OH and WV, Permian basin in Texas, and Haynesville shale in LA have seen significant increases in liquids production. More than 90% of this production comes from natural gas processing plants. Methane emissions across these shale basins vary significantly, resulting in marked differences in lifecycle emissions associated with plastics production. For example, recent field campaigns have shown methane leakage as low as 1% in the Marcellus shale basin in Pennsylvania to as high as 9% in the Permian basin [3]. Furthermore, official estimates such as the US greenhouse gas inventory have been shown to underestimate US methane emissions from the oil and gas sector by 60% [4,5]. This impacts the life-cycle

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[2] Q. Chen et al. (2022). Mapping Greenhouse Gas Emissions of the U.S. Chemical Manufacturing Industry: The Effect of Feedstock Sourcing and Upstream Emissions Allocation. *ACS Sustainable Chem. Eng.* 10 5932. https://pubs.acs.org/doi/10.1021/acssuschemeng.2c00295

[3] D.H. Cusworth et al. (2022). Strong methane point sources contribute a disproportionate fraction of total emissions across multiple basins in the United States. *Proc. Natl. Acad. Sci.* 119 (38). DOI: https://www.pnas.org/doi/abs/10.1073/pnas.2202338119

[4] R.A. Alvarez et al. (2018). Assessment of methane emissions from the US oil and gas supply chain. *Science*. 361 186. DOI: https://www.science.org/doi/full/10.1126/science.aar7204

[5] J.S. Rutherford (2021). Closing the methane gap in US oil and natural gas production emissions inventories. *Nat. Communications* 12 4715. https://www.nature.com/articles/s41467-021-25017-4

greenhouse gas emissions of plastic in two critical ways. One, current estimates of emissions intensity of plastic production is highly location specific. Two, underestimation of methane emissions from oil and gas supply chains risks minimizing the lifecycle greenhouse gas impacts of plastic production. A key driver of this emissions underestimate is the disproportionate role of intermittent methane super-emitters in contributing to total supply chain emissions [6]. These methane super-emitters are often unpredictable, intermittent, and vary by location [7]. Thus, plastics produced from feedstock sourced from the Permian basin will likely have a significantly higher lifecycle greenhouse gas emissions compared to feedstock sourced from the Marcellus shale basin. Effective and frequent monitoring and mitigation of methane emissions will be critical in reducing supply chain emissions of plastic production. In this context, the US Environmental Protection Agency's proposed methane regulations will be a key driver in reducing emissions from high methane leakage basins.

I want to conclude by highlight two key issues in effective carbon accounting across plastic supply chains. First, allocation methods – the process of assigning upstream greenhouse gas emissions to different co-products such as crude oil, natural gas, and natural gas liquids – can change lifecycle emissions by a factor of 2. For example, ethylene production via steam cracking can have emissions intensity ranging from 2.5 to 4.2 kg $CO_2e$/kg production, depending on how upstream emissions are assigned to natural gas and natural gas liquids feedstocks. There are several approaches to emissions allocation that are all valid under different contexts. One approach is to allocate emissions based on the energy content of products – thus, co-products with high energy density will be assigned higher emissions. Energy allocation is commonly used in a regulatory context such as the California low carbon fuel standards program. Another approach is to allocate all emissions to natural gas, making natural gas liquids and crude oil 'emissions free' [8]. A third approach is to allocate by market value of co-products, with the justification being that emissions allocation to a high economic value product will encourage adoption of emissions mitigation measurements. Ensuring a uniform allocation method for upstream emissions associated with plastic feedstock is essential for meaningful comparisons across plastic supply chains. This also highlights another challenge in addressing emissions associated with plastics – natural gas liquids used as feedstock for chemicals is often co-produced in a delicate balance with natural gas or crude oil based on resource characteristics. Rapid changes to feedstock demand will also simultaneously affect the production volumes of co-products, namely crude oil and natural gas, depending on the basin. Thus, policies to increase efficiency of feedstock use should be carefully designed to minimize disruption to other product streams.

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[6] J. Wang et al. (2022). Multiscale methane measurements at oil and gas facilities reveal necessary frameworks for improved emissions accounting. *Environ. Sci. Technol.* 56 1473. https://pubs.acs.org/doi/abs/10.1021/acs.est.2c06211

[7] R.M. Duren et al. (2019). California's methane super-emitters. *Nature* 575 180. https://www.nature.com/articles/s41586-019-1720-3

[8] Y. Chen et al. (2022). Quantifying Regional Methane Emissions in the New Mexico Permian Basin with a Comprehensive Aerial Survey. *Environ. Sci. Technol.* 56 4317. https://pubs.acs.org/doi/full/10.1021/acs.est.1c06458

Second, transparent carbon accounting is essential to build accurate estimates of the emissions intensities of different plastic supply chains. Differences in feedstocks, upstream methane emissions, and downstream processes can enable differentiation in the markets that allow for a target-based approach to reducing lifecycle emissions. However, this differentiation requires a level of accuracy and trust in supply chain carbon accounting frameworks that is currently not present. Emissions measurements conducted across the supply chain must be interpreted in a way that is transparent, scientifically robust, reliable, and timely [9]. Carbon accounting that is not transparent with measurement data or analytical systems will make it challenging to build trust on the global stage. The Department of Energy has a key role to play in supporting public-private partnerships to collect, interpret, and make public plastic supply chain emissions information. Other carbon intensive products reduced emissions through voluntary approaches such as labeling schemes and third-party certification. Effective carbon accounting can enable the plastics industry to flexibly reduce emissions through a technology-agnostic carbon intensity standard.

In summary, up to 50% of the lifecycle greenhouse gas emissions impact of plastics is associated with the upstream oil and gas supply chain that serves as feedstock to plastic manufacturing. Because upstream emissions are dominated by methane emissions, lifecycle emissions of plastics vary significantly based on the location of the manufacturing plant and the source of feedstocks. Improved monitoring and estimation of supply chain greenhouse gas emissions is essential to develop target-based approaches to reduce the emissions intensity of plastics manufacturing.

Thank you for your time.

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[9] W. Daniels et al. (2023). Towards multi-scale measurement-informed methane inventories: reconciling bottom-up inventories with top-down measurements using continuous monitoring systems. *Preprint*. https://chemrxiv.org/engage/chemrxiv/article-details/63e526b9fcfb27a31f7c0a6c