Status of Hydrogen and Pipeline Research and Development Activities in the US

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Chairman Lucas and Members of the Committee,

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 and energy systems analysis. Over the past decade, I have led several large-scale, field campaigns in the US to measure methane 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 natural gas infrastructure. Throughout my research, I have worked in close collaboration with the industry, state and federal agencies, and non-governmental organizations.

The United States, by far, leads the world on both technology innovation and direct measurements of greenhouse gas emissions from the oil and gas natural gas infrastructure. Voluntary industry efforts, federal research campaigns such as those funded through the Department of Energy, NOAA, and NASA, as well as field campaigns by non-governmental entities such as Environmental Defense Fund have all contributed to a significant body of work on improving our understanding of emissions across the oil and gas supply chain [2]. This matters for three reasons. First, we know the gaps in research that need to be filled – this includes both the natural gas supply chain and emerging areas such as hydrogen that could substantially use existing infrastructure. Second, as the largest exporter of liquefied natural gas or LNG, transparent information on supply chain carbon accounting gives US gas a significant advantage over other suppliers [3]. Third, our continued and long-term investments in research related to oil

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

[2] Wang et al. (2022). Multiscale Methane Measurements at Oil and Gas Facilities Reveal Necessary Frameworks for Improved Emissions Accounting. *Environ. Sci. Tech.* 56 14743. https://pubs.acs.org/doi/full/10.1021/acs.est.2c06211

[3] S. Roman White et al. (2021). LNG Supply Chains: A Supplier-Specific Life-Cycle Assessment for Improved Emission Accounting. *ACS Sustainable Chem. Eng.* 9 10857. https://pubs.acs.org/doi/full/10.1021/acssuschemeng.1c03307

and gas emissions measurements have supported dozens of new start-up companies and small businesses that have created high-paying jobs across the US [4].

While we have made tremendous progress on understanding methane emissions from oil and gas infrastructure broadly, direct measurements from pipelines is still lacking. A recent peer-reviewed meta-analysis of field campaigns demonstrated that measurement-based emissions estimates were about 60% larger than the US EPA greenhouse gas inventory [5]. However, this still only included measurement-informed estimates from upstream production facilities and midstream compressor stations. Measuring emissions from pipelines is a challenging task compared to other types of facilities – the US has over 300,000 miles of interstate transmission pipelines, over 400,000 miles of gathering pipelines, and over 3 million miles of distribution pipelines. Technologies to measure emissions across this vast network cost-effectively need to be fast, be able to detect emissions remotely, and provide actionable information to the operator [6]. This has led to a significant gap in emissions measurements from the natural gas pipeline network, particularly in gathering pipelines and the transmission network. Recent evidence from the Permian basin suggests that emissions from gathering lines are a significant source of emissions and can be fixed cost-effectively [7]. To do that requires dedicated research that focus on developing emissions estimates across US gathering and transmission pipelines. Furthermore, research on upstream facilities have shown that emissions vary significant across different oil and gas basins – thus measurements done in the Permian basin is unlikely to be representative of emissions in the Marcellus basin in Pennsylvania [8]. Regional, basin-specific studies on pipelines, much like what the Department of Energy is currently funding for upstream facilities, would close the gap in our supply chain emissions measurement portfolio. Furthermore, several urban regions are embarking on multi-year pipeline replacement programs to improve safety of our aging distribution pipeline infrastructure. A multi-year measurement campaign across major distribution systems, coordinated by the Department of Energy, will be critical to assess the success of these programs. Periodic, large-scale measurements of the distribution system will be critical to ensure that our distribution infrastructure is safe for current and future use cases such as hydrogen blending.

The Department of Energy has been historically successful in supporting technology innovation in leak detection. Many of the early-stage technologies supported through the ARPA-E program over a decade ago are now some of the fastest growing companies in the emissions detection space. The availability of test facilities such as the Methane Emissions Technology Evaluation

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[4] Clean Air Task Force (2022). Good rules, good jobs: Employment opportunities from emissions standards for oil and gas. https://www.catf.us/resource/good-rules-good-jobs-employment-opportunities-from-emissions-standards-for-oil-and-gas/

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

[6] Highwood Emissions Management (2022). Leak detection methods for natural gas gathering, transmission, and distribution pipelines. https://highwoodemissions.com/wp-content/uploads/2022/04/Highwood_Pipeline_Leak_Detection_2022.pdf

[7] J. Yu et al. (2022). Methane emissions from natural gas gathering pipelines in the Permian Basin. *Environ. Sci. Tech. Lett.* 9 969. https://pubs.acs.org/doi/full/10.1021/acs.estlett.2c00380

[8] D. 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 https://www.pnas.org/doi/abs/10.1073/pnas.2202338119

Center or METEC at Colorado State University has provided significant dividends in terms of our ability to test, evaluate, and deploy new technologies [9]. We now see several major oil and gas companies voluntarily deploy these technologies at their facilities to find and fix methane emissions. Some of these technologies have been used in detecting distribution system leaks while have used aircraft-based sensors to detect methane emissions from gathering pipelines.

We are now in a new phase of technology development. This new phase of technology development will focus on networked continuous monitoring sensor systems along a pipeline, autonomous drone surveys, and in-line measurements that will increasingly make use of advances in machine learning and data analytics [10]. It will usher in new capabilities that will enable companies to remotely monitor their pipeline systems for leaks, develop predictive models, and integrate operational data with sensor information. These innovations will significantly reduce the cost and efforts associated with reducing emissions and improving safety of our pipeline network. The Department of Energy, in collaboration with NIST and PHMSA should fund research on these next generation sensor technologies, and develop comprehensive, multi-scale modeling and data analytic capabilities. Like in prior research, close collaboration with the industry will be essential to rapidly translate research into technology trials and large-scale deployment. In addition, the US also needs expanded test facilities to evaluate new sensor systems that will operator across a wide variety of facilities, geographies, and weather conditions. A network of standardized test facilities across the US would ensure that we continue to lead the world in technology development, evaluation, and deployment. Furthermore, these test facilities could be designed to simultaneously evaluate infrastructure for the growing hydrogen economy. That brings me to the next topic of the hearing.

Hydrogen is a key element of the US' future energy system, helping provide flexibility and improve resiliency of our infrastructure. A growing hydrogen economy can expand US manufacturing, create high-paying jobs, and help reduce emissions from hard-to-abate industrial sector [11]. Because of the unique properties of the hydrogen molecule, we need a broad-based research program to understand material impacts, leakage, and system integration associated with the production, conversion, transportation, and use of hydrogen in our energy systems. Activities in this space should encourage both basic research in technologies, materials, and computational capabilities as well as applied research in developing pilot demonstration facilities and integrating of hydrogen technologies into existing energy systems.

A key area of research is understanding how can we use existing natural gas pipelines for transporting hydrogen. There are significant advantages in repurposing existing infrastructure as

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[9] A.P. Ravikumar et al. (2019). Single-blind inter-comparison of methane detection technologies – results from the Stanford/EDF Mobile Monitoring Challenge. *Elem. Sci. Anthro.* 7 37. [Journal link]

[10] C. Schissel et al. (2023). Comparing the emission reduction effectiveness of continuous monitoring to periodic Optical Gas Imaging surveys for methane emissions at oil and gas production sites. *Preprint*. https://chemrxiv.org/engage/chemrxiv/article-details/63e53c7ffcfb27a31f7dd8d4

[11] C. Bauer et al. (2022). On the climate impacts of blue hydrogen production. *Sustain. Energy Fuels.* 6 66. https://pubs.rsc.org/en/content/articlehtml/2022/se/d1se01508g

it reduces costs, lead time, and enables rapid deployment for hydrogen end uses. However, several open questions remain. Hydrogen leaks pose a safety as well as an environmental risk. Understanding how hydrogen leaks occur in natural gas pipelines, how different blend ratios of hydrogen and natural gas affect transport properties, and how the presence of hydrogen impacts materials used in pipelines are all critical areas of research that needs to be studied before large-scale adoption. As with methane emissions from natural gas pipelines, research should focus on funding new technology and sensor development, dedicated test facilities to evaluate hydrogen leak detection systems, new materials that can withstand the corrosive effects of hydrogen, and innovation centers that identify and solve challenges associated with integration of hydrogen with conventional energy systems.

A key aspect of hydrogen production and end use is that significant difference in cost, emissions, and storage and transportation infrastructure across US. For example, blue hydrogen production – hydrogen that is produced from natural gas with carbon capture and sequestration – has a significantly lower emissions profile if produced in the Marcellus basin in OH and PA than in the Permian basin in TX. Furthermore, pipeline capacity limits in the Permian basin favor production of methanol as a hydrogen carrier instead of hydrogen gas that would require pipelines. Permian production of hydrogen could also benefit from abundant solar and wind resources in the region. Thus, the form of hydrogen production, transportation, and end use will vary across the US and must be tailored to unique regional strengths. The Department of Energy should support research on detailed geospatial and region-specific studies to identify regionally-optimized approaches for hydrogen production, transportation, and end use that maximize benefits to the region's economy. One size does not fit all.

Finally, the success of these efforts on the international stage will rest on our ability to develop effective and trusted carbon accounting systems across energy supply chains. This includes both the existing natural gas supply chains and future hydrogen supply chains. As the largest exporter of liquefied natural gas or LNG and potentially of hydrogen, the US has a vested interest in demonstrating the environmental and economic benefits of US energy supply chains over other suppliers [12]. This requires that we have a transparent, scientifically-robust, and trusted approach to estimating supply chain carbon emissions. 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 supply chain emissions information across US oil and gas infrastructure.

In summary, the US has invested in cutting-edge research and technology development on addressing methane emissions from the oil and gas infrastructure. We must continue to invest in these and other new areas such as hydrogen to lead the world in critical areas of future energy

[12] 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

systems. The Department of Energy, in coordination with NIST and PHMSA, should fund research in next generation technologies and sensors for pipeline leak detection and inspection, conduct direct measurements of greenhouse gases from gathering and transmission pipeline network, set up a network of test facilities to evaluate new systems, and invest in developing new machine learning and other data-intensive approaches to improve safety and reliability of the pipeline infrastructure. The Department of Energy has been successful in supporting technology innovation in the natural gas space for the past decade. Similar efforts on hydrogen focused on new technology and sensor development, test facilities to evaluate hydrogen leak detection systems, new materials research, and innovation centers that study integration of hydrogen with conventional energy systems would be valuable. These research investments in our pipeline infrastructure and hydrogen technology will ensure that the US continues to lead in energy research and development with broad-based benefits to the oil and gas industry, consumers, communities, and the environment.

Thank you for your time,

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