NATURAL GAS *brief*

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Stanford | Natural Gas Initiative
School of Earth, Energy & Environmental Sciences and Precourt Institute for Energy

The Stanford Natural Gas Initiative held a three-day Methane Emissions Symposium of nearly 200 global thought leaders from industry, universities, NGOs, and government, to highlight the latest technological advances in methane management and discuss possibilities for rapid deployment to dramatically reduce emissions.

NGI holds Methane Emissions Symposium of world-class methane experts

By Evan D. Sherwin, Jeffrey S. Rutherford, Yuanlei Chen, and Adam R. Brandt

As worldwide demand grows for low-carbon fuels, methane emissions from the oil and gas system are coming sharply into focus. Natural gas is a dispatchable complement to wind and solar electricity and a valuable high-grade heating fuel, with combustion emissions far lower than coal. However, emissions from the natural gas system can release substantial amounts of methane into the atmosphere, potentially undermining the climate benefits of natural gas. For this reason, current climate policy in North America and Europe has a strong focus on reducing methane emissions from the oil and gas value chain.

ABOUT THE AUTHORS

Evan Sherwin
Dr. Evan Sherwin is a data-informed energy policy analyst focusing on leveraging emerging technologies and datasets to find and fix methane emissions across the oil and gas value chain. Evan is a Postdoctoral Research Fellow at Stanford University's department of Energy Resources Engineering and the founder and chair of the Methane Emissions Technology Alliance international seminar series.

Jeff Rutherford
Jeff Rutherford is a PhD student working at the intersection of energy, economy, and environment, using life cycle assessment tools to better understand the impacts and trade-offs of energy technologies. His current work focuses on incorporating methane emissions into assessment of oil and gas carbon intensity, uncovering the sources of historic underestimation of methane emissions and producing tools to improve our estimates moving forward.

Yuanlei Chen
Yuanlei Chen is a PhD student in Adam Brandt's lab at Stanford studying greenhouse gas emissions from oil and gas operations. Her current research focuses on testing and synthesizing broader insights from airborne methane detection and quantification technologies, for both onshore and offshore applications, using a combination of engineering knowledge, data collection in the field, applied statistics, computer vision, and remote sensing.

Adam Brandt
Prof. Adam Brandt's research focuses on reducing the greenhouse gas impacts of energy production and consumption, emphasizing fossil energy systems. Research interests include life cycle assessment of petroleum production and natural gas extraction. He also researches computational optimization of emissions mitigation technologies, such as carbon dioxide capture systems. Adam is an Associate Professor in Energy Resources Engineering at Stanford University.

> *"Solving the methane emissions challenge is a key part of reducing impacts from our energy use. Gas will continue to be a vital part of the energy system as we transition toward renewables, so it is crucial that we get the methane problem solved."*
> *—Professor Adam Brandt*

Thankfully, methane leakage is a fixable problem. Numerous technologies have emerged in the last decade to help industry operators find, fix, and prevent unintentional and routine emissions. We now have a much better understanding of where in the oil and gas system methane emissions come from and how they are distributed, which helps us know where to look for emissions. Of course, we have always known how to fix leaks once we find them and replace equipment with high routine emissions.

2021 SYMPOSIUM

The Stanford Natural Gas Initiative held a Methane Emissions Symposium from February 23-25 to synthesize the latest advances in our understanding of the sources of methane emissions, the technologies we can use to find this invisible gas, and innovative ways we can bring emerging solutions to market. With seven panel discussions and two standalone speakers, the virtual symposium was attended by nearly 200 thought leaders from the oil and gas industry, technology providers, academia, government, and the nonprofit sector.

DAY ONE | THE BIG PICTURE

Setting the stage, speakers and panelists on the first day outlined the current state of understanding of where methane emissions come from and how they are distributed through space and time across the oil and gas system and beyond. These contributions, beginning with opening remarks by Prof. Adam Brandt, incoming Faculty Director of the Natural Gas Initiative, highlighted several key facts about methane emissions from oil and gas. First, across essentially all stages of the oil and gas system, from production to transmission to distribution, a small percentage of super-emitter sources account for the majority of emissions. Finding these large emissions is complicated by the fact that emissions are spread out across space and time in the far-flung oil and gas system and are intermittent over time. The better we can understand the real-world operation of these engineered systems, the more effectively we can identify design changes and other interventions to stop emissions before they start. Large uncertainties remain even in relatively well-studied countries in North America and Europe. Dr. David Lyon of the Environmental Defense Fund, and Dr. Chris Konek, formerly of the United Nations Environment Programme, discussed ongoing foundational empirical measurement campaigns to improve our understanding of methane emissions from oil and gas systems across the world. Allyson Book of Baker Hughes profiled several hardware and artificial intelligence-based methane mitigation technologies, highlighting the safety benefits that often come from methane mitigation. Lastly, Stanford's Prof. Rob Jackson also provided an overview of methane emissions from sources other than fossil fuels, highlighting several ▶

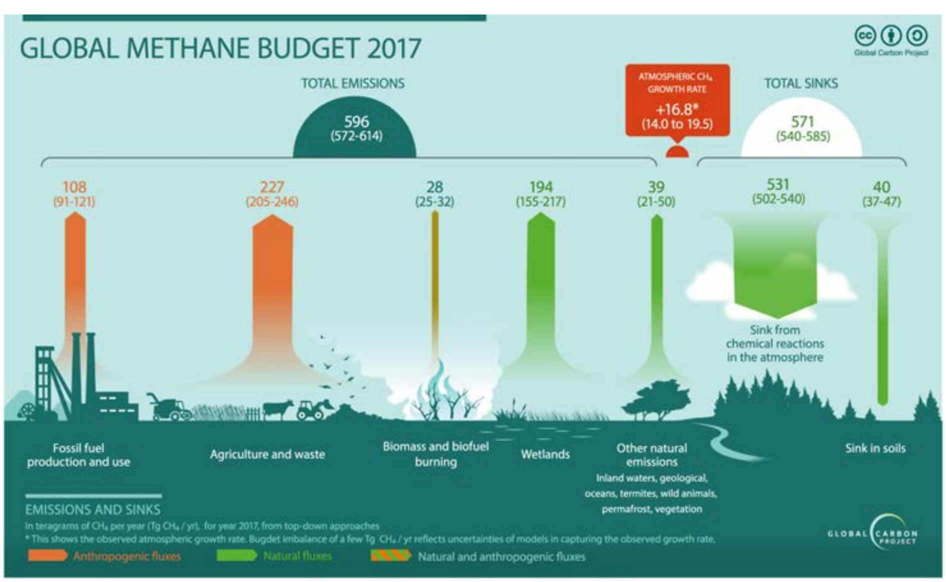
promising solutions to agricultural methane emissions, particularly from rice cultivation and cattle digestion.

The panel on natural gas distribution systems, which deliver gas to homes and businesses, focused on vehicle-based methane sensing technologies. Prof. Zach Weller of Colorado State University discussed the capabilities of vehicle surveys, and presented his findings that emissions from natural gas distribution mains may be as much as five times higher than previous estimates (Weller et al. 2020). Dr. Meghan Thurlow presented Aclima's continuously generated vehicle-based maps of methane, ethane, and criteria pollutants across numerous cities worldwide. This can help distribution utilities find their largest leaks and understand which regions have anomalously high odds of natural gas emissions, potentially indicating priority areas for repairs and retrofits. On the operator side, François Rongere and Davide Scrocchi highlighted some of the latest advances in preventing and mitigating methane emissions at California-based Pacific Gas & Electric and Italy-based SNAM, respectively.

Historically, methane leak detection and repair (LDAR) practices in production, midstream, and distribution have focused on labor-intensive, highly sensitive leak surveys, with ground crews visiting an individual asset at most every few months and in some cases every few years. The outsized importance of a small number of high-consequence super-emitters across geographically distributed infrastructure motivates a different approach: Rapid screening technologies to find and fix the largest emissions first.

DAY TWO | EMERGING TECHNOLOGIES

In that spirit, the second day focused on emerging technologies and their deployment, beginning with spirited discussion on the merits of methane emissions detection and quantification technologies at a variety of spatial and temporal scales. Stephane Germaine introduced satellites, such as those operated by his company GHGSat, that have the potential to rapidly find larger emissions of ~100 kg of methane per hour or higher. However, given the intermittent nature of methane emissions and the large number of emissions well below satellite detection limits, continuous monitoring systems, such as those introduced by Dr. Anna Scott of Project Canary will likely play a role in methane monitoring. Technologies such as airplane, drone, or vehicle-based sensors have the potential to trade off between detector sensitivity and spatial and temporal coverage. Dr. Erin Tullos of the Gas Technology Institute presented results from field deployments ▶



Global sources and sinks of methane emissions, presented by Prof. Rob Jackson, Chair of the Global Carbon Project. Source: Jackson et al. 2020 of airborne methane sensing technologies across a range of oil and gas assets. Dr. Clay Bell of the Methane Emissions Technology Evaluation Center (METEC) made the case for independent single-blind testing to improve our confidence in the capabilities of these technologies.

When deployed in the field, emerging remote sensing technologies provide valuable insights. Dr. Daniel Cusworth of Jet Propulsion Laboratory as well as Yulia Chen and Dr. Evan Sherwin of Stanford presented results of airborne surveys of oil and gas basins, with the former using the AVIRIS-NG and Global Airborne Observatory, and the latter using Kairos Aerospace instruments, respectively. In both cases, researchers found a significant number of emissions larger than any ever detected in ground-based methane surveys. Such population-scale surveys thus capture the largest 0.1% and 0.01% of emission sources, which can account for a substantial fraction of total emissions but are generally missed by smaller ground surveys. Such a population-scale approach improves our ability to characterize methane emissions from oil and gas production, processing, and transmission.

Illustration of a tiered approach to methane measurement, combining satellites, airplanes, and ground-based sensors. Figure courtesy Riley Duren, NASA/JPL-Caltech

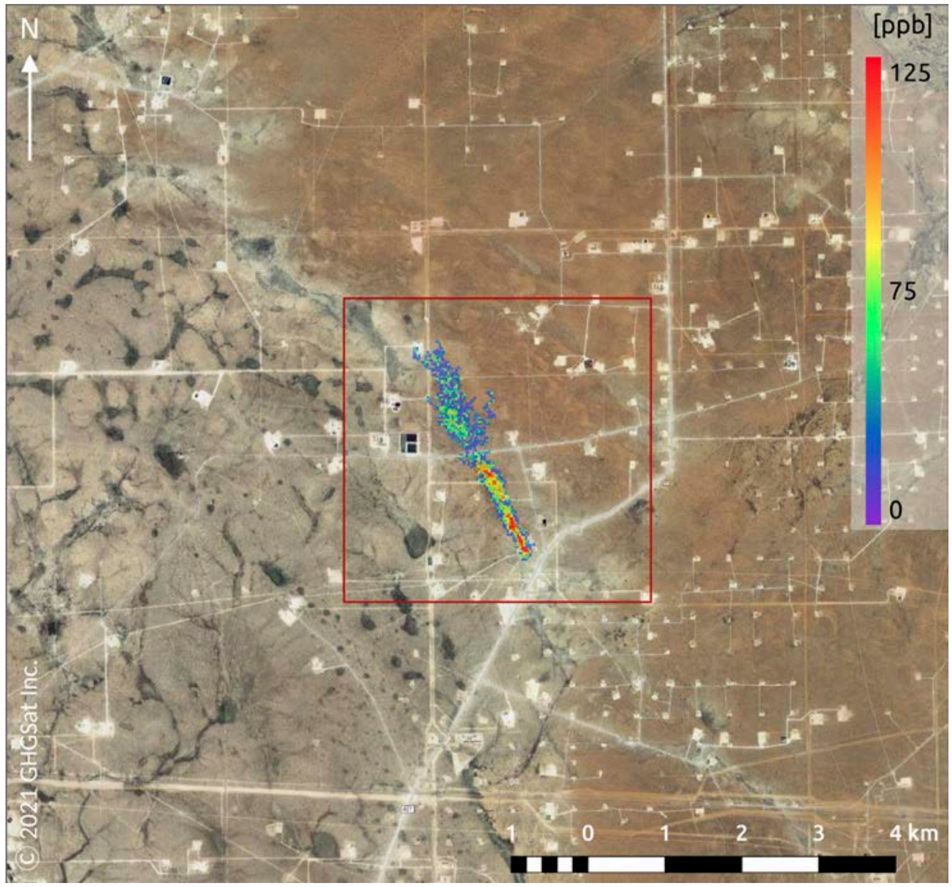
Dr. Faye Gerard of bpx energy discussed their tiered approach to methane sensing, deploying multiple technologies to capture emissions at different spatial and temporal scales.

The emergence of new technologies raises questions about the future of methane management across the oil and gas system. In the past, regulations have required the use of highly sensitive but costly and labor-intensive ground surveys. Prof. Arvind Ravikumar of Harrisburg University made the case for the use of rapid screening or continuous monitoring technologies to quickly find and fix the largest emissions. Along these lines, Lindsay Campbell of the Alberta Energy Regulator in Canada described their Alternative Fugitive Emissions Management Program, providing an example that other regulators can learn from and potentially emulate.

DAY THREE | METHANE INNOVATION

In a changing policy environment, how will the many emerging methane management technologies reach mass commercial deployment? The first panel of our third day focused on business models and investment cases in this space, highlighting several primary drivers of technology deployment. ▸

Alastair Handley of Radicle explained how explicit policy design, such as Alberta's allocation of carbon credits for verifiable reductions of methane emissions that go beyond business as usual and regulatory requirements, can provide a clear incentive to invest in emissions reductions in the oil and gas sector. George Wayne (Kinder Morgan) described how gas transport companies are working to develop transparent, verifiable mechanisms to satisfy rising customer demand for responsibly sourced natural gas. Dr. Brian Jones of Kairos Aerospace pointed out a hopeful trend: In many cases, companies are investing in novel methane detection and management technologies in the absence of any clear policy requirement simply due to increased investor demand for improved environmental, social, and governance (ESG) performance.



A methane plume identified by GHGSat from oil and gas production in the Permian Basin in the United States. Reproduced with permission from GHGSat.

The final talks in the symposium focused on natural gas flaring, which is intimately related to both questions of methane emissions and the life-cycle carbon intensity of oil and gas. Flares remain a low-cost way of safely disposing of uneconomic associated gas and are quite efficient at converting methane to less potent carbon dioxide, as long as they are operating properly. In the field, variation in gas flow, gas composition, and wind speed can cause flares to go out, and indeed aerial and satellite field campaigns are increasingly identifying unlit flares as a major source of greenhouse gas emissions.

In this context, much of the final panel focused on emerging technologies for converting associated gas into a useful product. Gas-to-liquids technology has been around for some time, with large facilities in operation in several countries, but it had proven difficult to scale the technology down to levels useful for flare-gas applications. Liz Myers of Greyrock presented their small-scale gas-to-liquids system, which converts associated gas into longer-chain liquid hydrocarbons such as gasoline blends and diesel. Prof. Matteo Cargnello of Stanford made the case for the small-scale thermo-, photo- and electrochemical methane conversion systems he and his colleagues are developing. Sahar El Abbadi of Stanford ▶

proposed an alternative use for stranded methane: feeding it to microbes to produce protein-rich animal feed (El Abbadi et al. 2021).

SUMMARY | CHARTING A COURSE

These three action-packed days pointed to numerous opportunities for near-term methane mitigation while highlighting areas in need of future research. Given substantial variation in methane emissions across space and time, how can industry stakeholders deploy existing technologies to reliably certify that a customer is receiving low-emission gas? What are the prospects for anonymized industrial data sharing to improve the general state of understanding of the engineering root causes of many sources of methane emissions? What is the potential role of satellites and other emerging technologies in improving our understanding of methane emissions from less-measured countries? How can methane policy balance between facilitating substantial reductions in emissions, promoting the cost-effective deployment of new technologies, and ensuring the resilience of any new policies to future changes in the political tides?

This symposium highlights the role played by the Stanford Natural Gas Initiative in bringing stakeholders and researchers together to dive deep into the most important questions related to improving the environmental performance of oil and gas.

The technologies presented at this symposium illustrate that the potential exists for massive reductions in global methane emissions at low cost. By working together, we hope to make this possibility a reality. ■

FOR MORE INFORMATION

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Natural Gas Briefs:
ngi.stanford.edu/briefs

NOTE

This event was held under the Chatham House Rule to ensure open discussion. In select cases above, we directly attribute statements and slides to individual participants with their approval.

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THE NATURAL GAS INITIATIVE AT STANFORD

Major advances in natural gas production and growth of natural gas resources and infrastructure globally have fundamentally changed the energy outlook in the United States and much of the world. These changes have impacted U.S. and global energy markets, and influenced decisions about energy systems and the use of natural gas, coal, and other fuels. This natural gas revolution has led to beneficial outcomes, like falling U.S. carbon dioxide emissions as a result of coal to gas fuel switching in electrical generation, opportunities for lower-cost energy, rejuvenated manufacturing, and environmental benefits worldwide, but has also raised concerns about global energy, the world economy, and the environment.

The Natural Gas Initiative (NGI) at Stanford brings together the university's scientists, engineers, and social scientists to advance research, discussion, and understanding of natural gas. The initiative spans from the development of natural gas resources to the ultimate uses of natural gas, and includes focus on the environmental, climate, and social impacts of natural gas use and development, as well as work on energy markets, commercial structures, and policies that influence choices about natural gas.

The objective of the Stanford Natural Gas Initiative is to ensure that natural gas is developed and used in ways that are economically, environmentally, and socially optimal. In the context of Stanford's innovative and entrepreneurial culture, the initiative supports, improves, and extends the university's ongoing efforts related to energy and the environment.

Join NGI

The Stanford Natural Gas Initiative develops relationships with other organizations to ensure that the work of the university's researchers is focused on important problems and has immediate impact. Organizations that are interested in supporting the initiative and cooperating with Stanford University in this area are invited to join the corporate affiliates program of the Natural Gas Initiative or contact us to discuss other ways to become involved. More information about NGI is available at ngi.stanford.edu or by contacting the managing director of the initiative, Naomi Boness, Ph.D. at naomi.boness@stanford.edu.