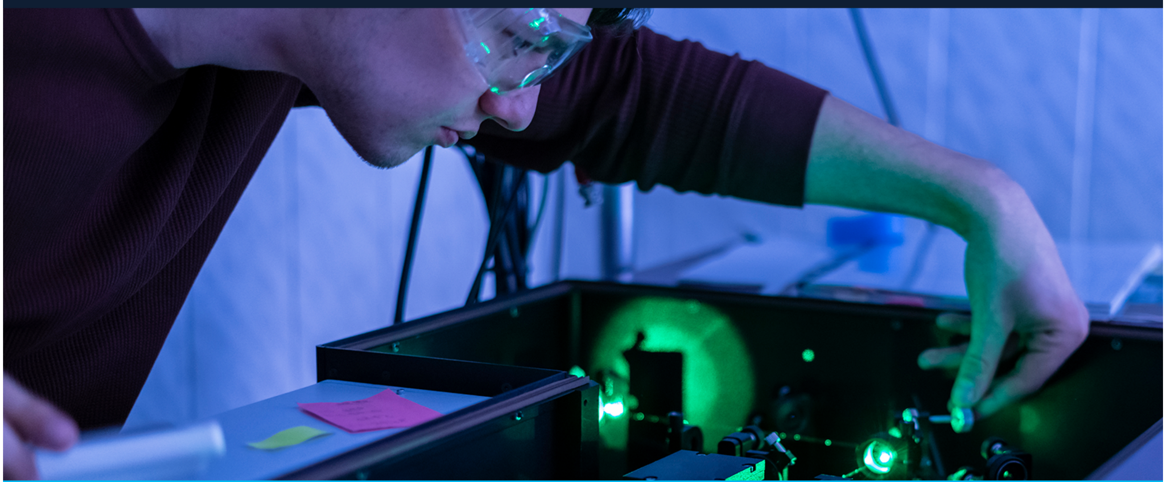
AIP
PHYSICS TODAY

The race to cut methane emissions ramps up worldwide

Governments, private companies, and nongovernmental organizations are teaming up to eliminate methane leaks and flaring from the oil and gas industry.

Alex Lopatka

Physics Today **75** (10), 26–28 (2022);
https://doi.org/10.1063/PT.3.5098



The race to cut methane emissions ramps up worldwide

Governments, private companies, and nongovernmental organizations are teaming up to eliminate methane leaks and flaring from the oil and gas industry.

FRIENDS OF THE EARTH US

GAS FLARES, like this one in Nigeria, burn methane to safely depressurize oil wells, but they also release toxic gases and particulates and contribute to global warming.

Although carbon dioxide is the primary culprit for global warming, methane also packs quite the punch. It's the second-most emitted greenhouse gas, and ton for ton, CH_4 has a warming potential some 30 times that of CO_2 on century time scales.

At the 26th Conference of the Parties meeting on climate change in Glasgow, UK, in November 2021, the US, European Union, and 11 other countries announced a Global Methane Pledge. The 121 participants have agreed to collectively reduce CH_4 emissions by 30% from 2020 levels by 2030. Those reductions would come from all CH_4 sources and would reduce the global temperature rise by 0.2 °C by 2050. But some of the largest fossil-fuel emitters, including China, India, and Russia, haven't joined the pledge.

Methane is emitted from oil and gas wells, agricultural activity, natural biological processes, and other sources. Emissions from the oil and gas industry are easier to detect and control than those from other sources because they come from well-defined locations. Some one-third of anthropogenic CH_4 emissions come from the production and transport of fossil fuels.

A May 2022 report from the American Physical Society (APS) and Optica explored how best to reduce CH_4 emissions in the oil and gas industry. Researchers have started to develop and demonstrate the CH_4 detection and pipe-repair technologies necessary to hit the emissions-reductions targets specified by the United Nations (UN).

Finding leaks

Methane remains in the air for about a decade, unlike the hundreds or thousands of years that CO_2 lingers. The short lifetime of atmospheric CH_4 paired with its high warming potential means that any emissions reductions of CH_4 will have an outsize effect on air temperatures. In recent years, however, global CH_4 emissions have been rising by 0.5% per year, according to the UN's Intergovernmental Panel on Climate Change. "We need to prioritize methane. . . . If you manage to decrease emissions, you'll see the effect in a decade," says William Collins, a senior scientist at Lawrence Berkeley National Laboratory, who was a lead author for the intergovernmental panel's last three reports and cochair of the committee that wrote the APS–Optica report.

Globally, 30% of CH_4 emissions come from the oil and gas sector. The APS–Optica report (https://doi.org/10.1364/OE.464421) concludes that more than half of those emissions come from leaks or deliberate releases, predominantly from up to a tenth of the oil and gas wells in operation. Targeted policies that focus on that handful of locations could substantially reduce emissions. A 2015 study by Steven Hamburg of the Environmental Defense Fund and colleagues, for example, found that at any given time, 2% of the oil facilities in the Barnett Shale oil and gas field in Texas were responsible for half of the CH_4 emissions in that region. Similar CH_4 super emitters exist in Algeria, Iran, Kazakhstan, and Russia, according to a 2022 paper coauthored by Thomas Lauvaux of France's Laboratory for Sciences of Climate and Environment.

The search for CH_4 emissions and leaks occurs on three spatial scales. At the ground level, technicians may inspect individual pipes or specific locations at an oil well to pinpoint small leaks or deliberate releases. But that's unrealistic for monitoring thousands of wells and millions of kilometers of pipeline.

Remote methods use spectrometers to monitor the IR wavelengths that CH_4 absorbs. The characteristic spectral lines can be used to identify and quantify CH_4 leaks. The active-sensing approaches on low-flying airplanes use onboard light sources to improve the signal-to-noise ratio of CH_4 measurements. Those aircraft can detect small CH_4 leaks, with a discharge rate as low as 1 kg/h.

The largest leaks—those that spew more than 30 kg/h—contribute 60–80% of the CH_4 emissions from oil and gas production and are detectable with satellites. Satellite detection relies on passive radiation from the Sun to record the spectrum of atmospheric CH_4. Although satellite and airplane methods can scan far larger areas than ground-based approaches, they may miss intermittent leaks.

The APS–Optica report calls for a cohesive, multiscale system for monitoring CH_4 from the oil and gas industry: Measurements would be collected continuously, and the data would ideally be freely available so that outside parties could ensure that companies are complying with regulations. In support of that vision, the US Department of Energy's Office of Fossil Energy and Carbon Management announced in August that it will award $32 million toward developing such a monitoring system.

Methane's complexity

Methane may have only five atoms, but the four carbon–hydrogen bonds add many degrees of freedom in which the molecule can vibrate. The many molecular motions translate to various rotation–vibration states, which can be excited when a molecule absorbs IR light.

To obtain a meaningful CH_4 observation in the field, researchers typically compare spectral measurements with known absorption features of the molecule for which temperature, pressure, and other properties are carefully controlled in a lab setting. One of the APS–Optica report's coauthors, Michelle Bailey, works as a research chemist in the optical measurements group at NIST. She and her colleagues measure the spectral features of well-characterized CH_4 and other gas samples with ultrasensitive techniques offering high spectral resolution.

The intrinsic physical parameters that Bailey and her collaborators—and other groups worldwide—collect are used to benchmark theoretical models. The data and models are disseminated in an open-access database called HITRAN; scientists can then use the data to simulate the behavior of atmospheric CH_4.

But clouds, aerosols, atmospheric mixing, and other environmental conditions complicate field measurements and their comparisons with theoretical CH_4 spectra. "As you increase your path length from near surface to the upper atmosphere, the instrument is subjected to a number of potential interferences," explains Bailey.

Nearby non-point-source emissions, particularly agricultural ones, are another challenge to collecting meaningful measurements of CH_4 emissions from oil and gas point sources. Isotope fingerprinting may help. Methane produced from an agricultural source, for example, contains a different mixture of carbon isotopes than CH_4 from an oil and gas source. The difference in molecular mass affects the frequencies of absorbed light, so IR optical-sensing methods can distinguish CH_4 sources.

Patching pipes

In addition to detection improvements, researchers have also been developing technologies to quickly and autonomously repair leaks from oil and gas operations. DOE launched its Methane Mitigation Technologies program in 2016 with the goal of eliminating emissions from the oil and gas supply chain by 2030. The program's priority is to develop technologies that could later be commercialized.

For example, the DOE collaborated with the Southwest Research Institute to repurpose a fixed-laser sensor to scan for CH_4 leaks at wells. The upgraded sensor is mounted on a drone to autonomously estimate emissions. A research manager of the program interviewed for this story said that a lot of R&D has focused on repair technologies for the over 3 million kilometers of pipeline that crisscross the US.

In collaboration with Oceanit Laboratories, headquartered in Honolulu, Hawaii, the DOE program has supported the development of DragX—a friction-reducing, corrosion-resistant, and nontoxic coating that could be applied to existing pipelines. The 100-micron-thick film can reduce surface roughness by some 50% and improve the pipeline's durability. Many of the coating's technical details are confidential, although preliminary analysis indicates it can last for years.

The DOE program is also supporting the development of robotic repair devices with ULC Technologies in New York. They're designed to travel the length of a pipeline and measure localized pressure changes, which are used as a proxy for material defects. If such a defect is found, the robot magnetically applies a temporary patch, which technicians later replace with a permanent one during a routine evacuation of the pipeline section.

Although many prototype technologies have been evaluated in laboratory settings and have seen success in limited field testing, they may not ultimately be deployed by oil and gas companies. "We do systems analysis to consistently evaluate technical feasibility and cost effectiveness but we don't pick winners," says the DOE program manager for methane-mitigation technologies. "You can't force commercialization on industry, and most all technologies will commercialize as a function of market forces."

The flaring problem

Besides emissions from undetected or unrepaired leaks, oil and gas companies routinely emit CH_4 intentionally. Oil extracted from below the surface often contains CH_4, sometimes referred to as associated natural gas. Even though CH_4 has several uses—either as fuel or as a chemical feedstock in various industrial processes—a pipeline may not be available to transport the gas to a refinery or chemical-processing facility.

Instead, in a process known as flaring, companies burn CH_4 and other unwanted by-products associated with oil extraction. The practice is responsible for up to 20% of the total CH_4 emissions from oil and gas operations, according to the APS–Optica report. To limit flaring, governments, companies, and other stakeholders are exploring economically viable alternatives.

Some flares are large enough to be observed from space by satellites. Oil producers can also self-report them. But the two data sources are often inconsistent. Discrepancies, the APS–Optica report concludes, arise from incomplete monitoring. Many states do not require producers to report flaring activity to regulators, and independent satellite-measured flaring is episodic. Only a few observations can be made per month at a given location because of satellites' orbits.

FORMER WORLD BANK PRESIDENT Jim Yong Kim (center left) and former secretary general of the United Nations Ban Ki-moon (center right) participated in the 2015 Spring Meetings of the World Bank and International Monetary Fund in Washington, DC. The event marked the beginning of a global effort to curb methane emissions: the Zero Routine Flaring by 2030 initiative. (Photo by Dominic Chavez/World Bank; courtesy of World Bank Photo Collection/CC BY-NC-ND 2.0/Flickr.)

To limit and eventually stop the practice of routine flaring globally, the World Bank has set up the Global Gas Flaring Reduction Partnership, made up of governments, oil and gas companies, and nongovernmental organizations. The partnership launched the Zero Routine Flaring by 2030 initiative in 2015. Signatories make a nonbinding pledge to not flare in any newly developed oil fields and to commit to ending routine flaring in legacy locations by 2030.

During the oil-extraction process, the pressure in a well can vary dramatically, and a sudden pressurization can cause an explosion. Gas flaring in those nonroutine situations and in response to immediate safety concerns is excluded by the initiative.

Some 34 governments—including Iraq, Nigeria, Russia, and the US, which are among the top flaring countries—and more than 50 oil companies, including BP, Chevron, ExxonMobil, Saudi-Aramco, Shell, and TotalEnergies, have signed on to the initiative. A 2018 study by the World Bank estimated that the total cost to end routine flaring by 2030 would be at least \$100 billion. A May 2022 press release from the World Bank said that "2021 showed disappointing progress" toward meeting the 2030 target.

Among the contributions to the sticker price are the costs of separating CH_4 from other hydrocarbons and transporting it to energy markets, where it can displace coal and other more-polluting fuels. Zubin Bamji, the program manager of the World Bank partnership, says financing comes from various sources, including project developers, equipment suppliers, strategic investment funds, commercial banks, and private capital funds.

Investing in pricey infrastructure has its own business risks, especially given the strain on energy supplies because of the war in Ukraine. Still, says Bamji, "governments and companies remain committed to zero routine flaring by 2030, and some have even more ambitious targets. We can't lose sight of the need to decarbonize global energy supplies." Bamji also cites an encouraging statistic: Although the past 26 years have seen a 20% increase in oil production, associated gas flaring has fallen by 13% in that time.

Alex Lopatka PT