Estimating emissions potential of decommissioned gas wells from shale samples

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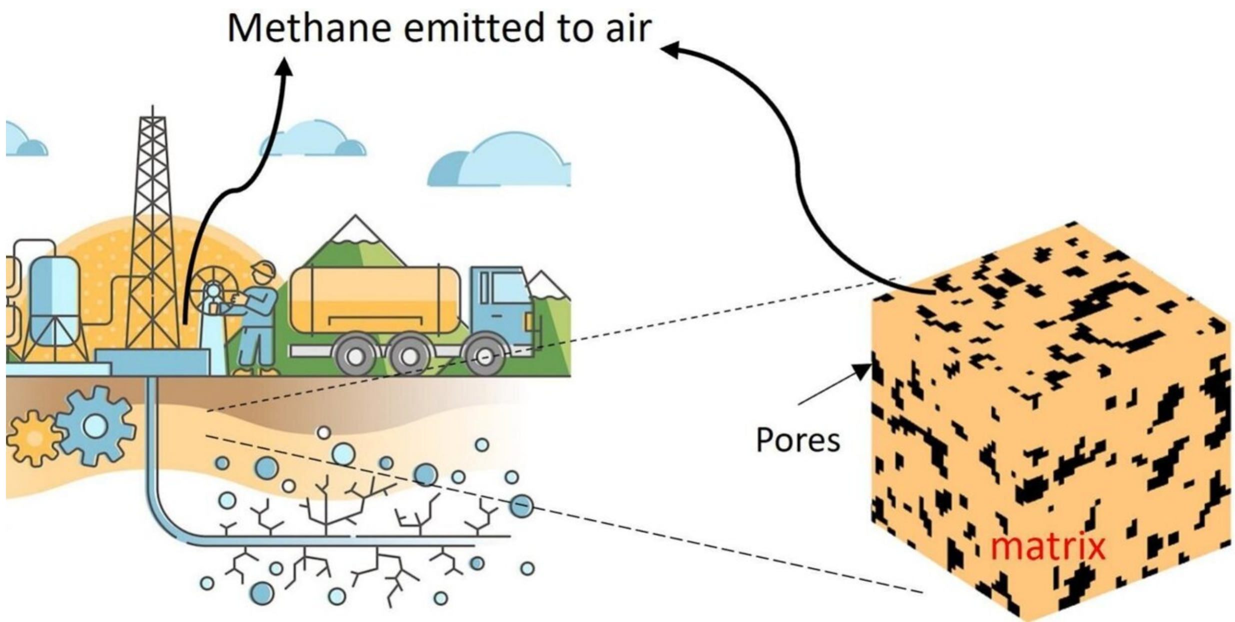

Graphical abstract. Credit: *Science of The Total Environment* (2023). DOI: 10.1016/j.scitotenv.2023.169750

Extracting natural gas from shale formations can provide an abundant, lower-carbon footprint fossil fuel, but also creates concerns over increased methane emissions. A team led by Penn State researchers has developed a new tool that can estimate the emission potential of shale wells after they are no longer active.

The findings, published in the journal *Science of the Total Environment*, revealed that methane begins diffusing from the shale formation after a well is decommissioned and that this represents a notable source of methane emissions—comparable to the most significant emissions during drilling and operation of the well.

"Natural gas is an important energy resource that has helped the U.S. lower its carbon dioxide emissions, but we also understand methane can be a potential hazard," said Shimin Liu, professor of energy and mineral engineering at Penn State and a co-author of the study. "What this work does is give us a proactive way to understand what's going on in the subsurface."

Shale formations have low permeability, meaning gas does not move through the rock easily. Operators drill down thousands of feet—more than a mile—to reach shale and then drill thousands of feet more horizontally through the formation. They pump a mixture of liquid and sand at high pressure into the shale to open tiny fractures and allow gas to escape from the rock.

But this may only recover a fraction—about 20% or less—of the total natural gas resource. The rest remains trapped within small pores, and the lack of interconnected pore system means that the gas does not flow easily through the shale.

By analyzing shale samples, the scientists were able to create a mathematical model to predict the flux—or movement—of methane that remains in the formation based on the pore structure. Called a unified gas transport model, the tool integrates how all the gases in the shale move and the structure of the shale to predict methane's flux behavior. The team validated their model against experiments with Marcellus shale conducted on specialized equipment in Liu's laboratory at Penn State.

"What industry can take away is they have drilling cutting or samples of the shale available, they can calculate the methane emissions flux based on their sample information," said Yun Yang, lead author of the study who conducted the research while completing her doctoral degree at Penn State and as a postdoctoral fellow at the University of Calgary, who is now a postdoctoral fellow at Los Alamos National Laboratory. "They can use it as guidance to see how much potential there is for methane leakage after a well is abandoned."

Methane emissions have a stronger global warming potential than carbon dioxide, and mitigating emission is a priority for the United States its international partners through efforts like the Global Methane Initiative, the scientists said.

This could be especially important in areas like Pennsylvania, where more than 20,000 shale gas wells have been drilled since the start of the Marcellus shale gas boom in 2005.

"One major problem is that methane leakage has higher global warming potential compared to carbon dioxide," said Haoming Ma, a postdoctoral fellow at the University of Texas at Austin and co-author. Ma conducted the work while a research associate at the University of Calgary. "The U.S. and other countries have committed to reducing global methane emissions by about 30% by 2030, highlighting the urgency of mitigation."

Because methane diffuses slowly from the shale, the scientists said regulatory requirements should be implemented to provide long-term monitoring of methane emissions from abandoned shale gas wells.

The researchers found that when a well ceases production and the pressure within the reservoir drops, the diffusion of methane across the complex microporous system of shale matrices increases. Diffusion is a slower process and contributes to a long-lasting flow of methane from the formation towards the abandoned wellbore, the scientists said.

Methane emissions from diffusion are comparable to emissions from flowback fluid, the liquid and sand injected into the ground during fracking that returns to the surface, according to the researchers.

Previous studies have focused on evaluating emissions released by fracking, completion and operation of wells, but understanding emissions potential after they are no longer active is an important missing piece, the scientists said.

"In this work, we found that after a well is decommissioned, if you don't implement proper plugging techniques—if you leave the well open to the surface—methane emissions will accumulate over time," Yang said. "And if you wait for sufficient time, the emission flux will be the same as emission observed from flowback operations."

Because diffusion increased as reservoir pressure decreased in the study, maintaining that pressure even after a well stops producing could be an effective strategy to reduce methane emission potential from abandoned shale gas wells, the scientists said.

More information: Yun Yang et al, Impact of unrecovered shale gas reserve on methane emissions from abandoned shale gas wells, *Science of The Total Environment* (2023). DOI: 10.1016/j.scitotenv.2023.169750

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