

COMMENT

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A natural-gas well site in New Mexico where energy company Halliburton is conducting hydraulic fracturing.

Should fracking stop?

Some say a moratorium is needed to deal with the health and environmental effects of extracting gas and oil by hydraulic fracturing; others say a pause would be devastating.

POINT

Halt for assessment

Natural gas extracted from shale comes at too high a cost to the environment, say Robert W. Howarth and Anthony Ingraffea.

Natural gas from shale is widely promoted as clean compared with oil and coal, a 'win-win' fuel that can lessen emissions while still supplying abundant fossil energy over coming decades until a switch to renewable energy sources is made. But shale gas isn't clean, and shouldn't be used as a bridge fuel.

Shale rock formations can contain vast amounts of natural gas (which is mostly methane). Until quite recently most **PAGE 272 ►**

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POINT: HALT TO ASSESS ▶ of this gas was not economically obtainable, because shale is far less permeable than the rock formations exploited for conventional gas. Over the past decade or so, two new technologies have combined to allow extraction of shale gas: 'high-volume, slick-water hydraulic fracturing' (also known as 'fracking'), in which high-pressure water with additives is used to increase fissures in the rock; and precision drilling of wells that can follow the contour of a shale layer closely for 3 kilometres or more at depths of more than 2 kilometres (see 'Getting the gas'). Industry first experimented with these two technologies in Texas, starting about 15 years ago. Significant shale gas production in other states, including Arkansas, Pennsylvania and Louisiana, began only in 2007–09. Outside North America, only a handful of shale-gas wells have been drilled.

Industry sources claim that they have used fracking to produce more than 1 million oil and natural gas wells since the late 1940s. However, less than 2% of the well fractures since the 1940s have used the high-volume technology necessary to get gas from shale, almost all of these in the past ten years. This approach is far bigger and riskier than the conventional fracking of earlier years. An average of 20 million litres of water are forced under pressure into each well, combined with large volumes of sand or other materials to help keep the fissures open, and 200,000 litres of acids, biocides, scale inhibitors, friction reducers and surfactants. The fracking of a conventional well uses at

most 1% to 2% of the volume of water used to extract shale gas¹.

Many of the fracking additives are toxic, carcinogenic or mutagenic. Many are kept secret. In the United States, such secrecy has been abetted by the 2005 'Halliburton loophole' (named after an energy company headquartered in Houston, Texas), which exempts fracking from many of the nation's major federal environmental protection laws, including the Safe Drinking Water Act. In a 2-hectare site, up to 16 wells can be drilled, cumulatively servicing an area of up to 1.5 square kilometres, and using 300 million litres or more of water and additives. Around one-fifth of the fracking fluid flows back up the well to the surface in the first two weeks, with more continuing to flow out over the lifetime of the well. Fracking also extracts natural salts, heavy metals, hydrocarbons and radioactive materials from the shale, posing risks to ecosystems and public health when these return to the surface. This flowback is collected in open pits or large tanks until treated, recycled or disposed of.

Because shale-gas development is so new, scientific information on the environmental costs is scarce. Only this year have studies begun to appear in peer-reviewed journals, and these give reason for pause. We call for a moratorium on shale-gas development to allow for better study of the cumulative risks to water quality, air quality and global climate. Only with such comprehensive knowledge can appropriate regulatory frameworks be developed.

We have analysed the well-to-consumer lifecycle greenhouse-gas

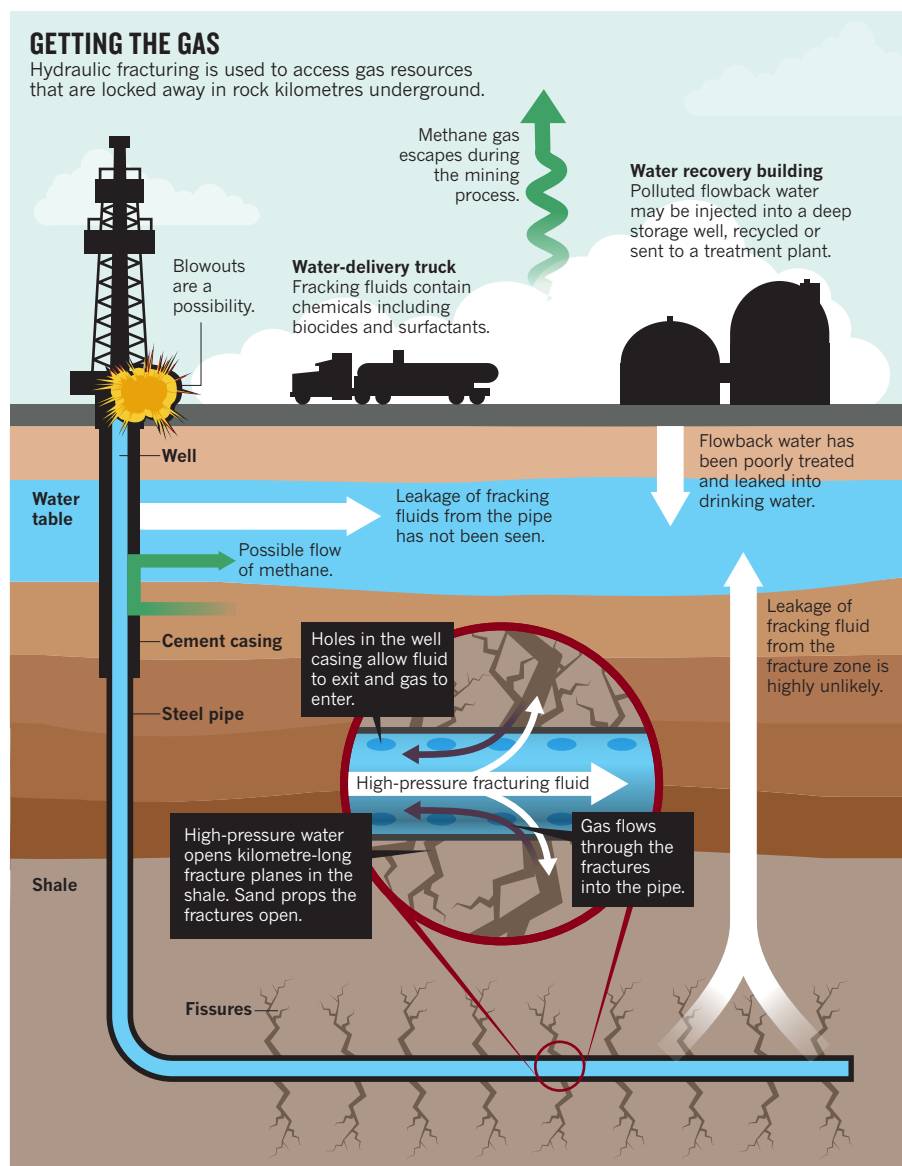
footprint of shale gas when used for heat generation (its main use), compared with conventional gas and other fossil fuels — the first estimate in the peer-reviewed literature². Methane is a major component of this footprint, and we estimate that 3.6–7.9% of the lifetime production of a shale gas well (compared with 1.7–6% for conventional gas wells) is vented or leaked to the atmosphere from the well head, pipelines and storage facilities. In addition, carbon dioxide is released both directly through the burning of the gas for heat, and to a lesser extent indirectly through the process of developing the resource.

Methane is a potent greenhouse gas, so even small emissions matter. Over a 20-year time period, the greenhouse-gas footprint of shale gas is worse than that for coal or oil (see 'A daunting climate footprint'). The influence of methane is lessened over longer time scales, because methane does not stay in the atmosphere as long as carbon dioxide. Still, over 100 years, the footprint of shale gas remains comparable to that of oil or coal.

When used to produce electricity rather than heat, the greater efficiency of gas plants compared to coal plants slightly lessens the footprint of shale gas³. Even then, the total greenhouse-gas footprint from shale gas exceed those of coal at time scales of less than about 50 years.

Methane venting and leakage can be decreased by upgrading old pipelines and storage systems, and by applying better technology for capturing gas in the 2-week flowback period after fracking. But current economic incentives are not sufficient to drive such improvements; stringent regulation will be required. In July 2011, the US Environmental Protection Agency released a draft rule that would push industry to reduce at least some methane emissions, in part focusing on post-fracking flowback. Nonetheless, our analysis² indicates that the greenhouse-gas footprint of shale gas is likely to remain large.

Another recent peer-reviewed study looked



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at private water wells near fracking sites⁴. It found that about 75% of wells sampled within 1 kilometre of gas drilling in the Marcellus shale in Pennsylvania were contaminated with methane from the deep shale formations. Isotopic fingerprinting of the methane indicated that deep shale was the source, rather than biologically derived methane, which was present at much lower concentrations in water wells at greater distances from gas wells. The study found no fracking fluids in any of the drinking water wells examined. This is good news, because these fluids contain a variety of hazardous materials and methane itself is not toxic. However, methane poses a high risk of explosion at the levels found, and it suggests a potential for other gaseous substances in the shale to migrate with the methane and contaminate water wells over time.

Have fracking-return fluids contaminated drinking water? Yes, although the evidence is not as strong as for methane contamination, and none of the data have yet appeared in the peer-reviewed literature (although a series of articles in *The New York Times* documents the problem, for example go.nature.com/58hxot and go.nature.com/58koj3). Contamination can happen through blowouts, surface spills from storage facilities, or improper disposal of fracking fluids. In Texas, flowback fluids are disposed of through deep injection into abandoned gas or oil wells. But such wells are not available everywhere. In New York and Pennsylvania, some of the waste is 'treated' in municipal sewage plants that weren't designed to handle these toxic and radioactive wastes. Subsequently, there has been contamination of tributaries of the Ohio River with barium, strontium and bromides from municipal wastewater treatment plants receiving fracking wastes⁵. This contamination apparently led to formation of dangerous brominated hydrocarbons in municipal drinking water supplies that relied on these surface waters, due to interaction of the contaminants with organic matter during the chlorination process.

Shale-gas development — which involves huge diesel pumps to inject the water — also creates local air pollution, often at dangerous levels. Volatile hydrocarbons such as benzene (which occurs naturally in shales, and is also a commonly used fracking additive) are one major concern. The state of Texas reports benzene concentrations in air in the Barnett shale area that sometimes exceed acute toxicity standards⁶, and although the concentrations observed in the Marcellus shale area in Pennsylvania are lower⁷ (so far, with only 2,349 wells drilled at the time these air contaminants were reported, out of a total of 100,000 expected), they are high enough to pose risk of cancer from chronic exposure⁸. Emissions from drills, compressors, trucks and other machinery can lead to very high levels of ground-level ozone, as documented in parts of Colorado that had not experienced severe air pollution before shale-gas development⁹.

UNPROFITABLE PROGRESS

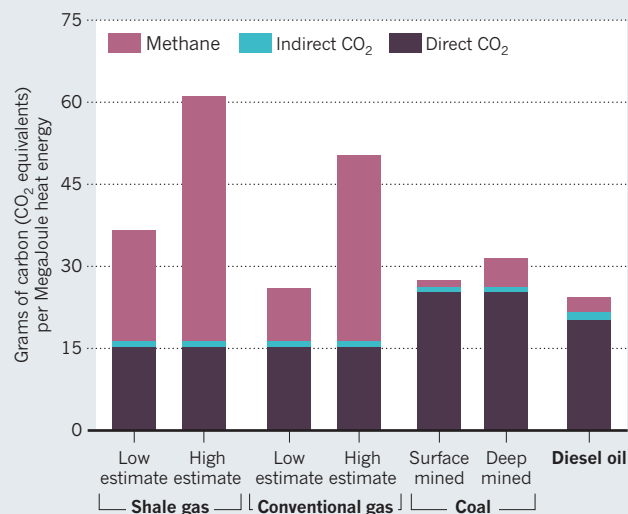
The argument for continuing shale-gas exploitation often hinges on the presumed gigantic size of the resource. But this may be exaggerated. The Energy Information Administration of the US Department of Energy estimates that 45% of US gas supply will come from shale gas by 2035 (with the vast majority of this replacing conventional gas, which has a lower greenhouse gas footprint). Other gas industry observers are even more bullish. However, David Hughes, a geoscientist with more than 30 years experience with the Canadian Geological Survey, concludes in his report for the Post Carbon Institute, a non-profit group headquartered in Santa Rosa, California, that forecasts are likely to be overstated, perhaps greatly so³. As this article went to press, the US Geological Survey had released a new estimate of the amount of gas in the Marcellus shale formation (the largest shale gas formation in the United States), concluding that the Department of Energy has overestimated the resource by some five-fold¹⁰.

Shale gas may not be profitable at current prices, in part because production rates for shale-gas wells decline far more quickly than for conventional wells. Although very large resources undoubtedly exist

“Have fracking-return fluids contaminated drinking water? Yes.”

A DAUNTING CLIMATE FOOTPRINT

Over its lifetime, shale gas is likely to have a greater greenhouse effect than conventional gas or other fossil fuels.



in shale reservoirs, an unprecedented rate of well drilling and fracking would be required to meet the Department of Energy's projections, which might not be economic³. If so, the recent enthusiasm over shale gas could soon collapse, like the dot-com bubble.

Meanwhile, shale gas competes for investment with green energy technologies, slowing their development and distracting politicians and the public from developing a long-term sustainable energy policy.

With time, perhaps engineers can develop more appropriate ways to handle fracking-fluid return wastes, and perhaps the technology can be made more sustainable and less polluting in other ways. Meanwhile, the gas should remain safely in the shale, while society uses energy more efficiently and develops renewable energy sources more aggressively. ■

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