As discussed on page 139, a study led by scientists from the US National Oceanic and Atmospheric Administration (NOAA), headquartered in Washington DC, and the University of Colorado in Boulder looked at methane and other emissions from a natural-gas field north of Denver, where fracking methods are used to open up sand formations.

They estimated cumulative emissions from the field using not industry reports or conceptual models, but concentrations of pollutants in air samples. This is important because the atmosphere does not misrepresent data or make mistakes; nor does it bend to ideology or political will.

The data suggest that methane emissions from natural-gas operations could be substantially higher — and so be worse for global warming — than was thought. At works in the Denver-Julesburg Basin, methane emissions were roughly double the official estimate.

This will by no means settle the debate. The NOAA scientists had to make assumptions to convert atmospheric data to cumulative emissions from a vast energy complex. They readily acknowledge substantial uncertainty in their calculations, and estimate that between 2% and 8% of the methane produced from wells in the Denver-Julesburg Basin is lost to the atmosphere, with a best guess of 4%.

These numbers, which are higher than estimates from Cornell and the US Environmental Protection Agency (EPA), should serve as a red flag to the gas industry, policy-makers and the academic community. Researchers will need to confirm the findings, reduce the uncertainties and determine emissions from other locations. But the issue clearly warrants attention. The study should also be a reminder that although it is necessary for the industry to collect data on its practices and run calculations, independent monitoring and verification are needed.

More generally, the study further complicates understanding of what is considered the world's cleanest fossil fuel. Many in industry and science have talked about using gas as a bridge fuel for the transition from coal to cleaner sources of electricity, but the picture is unclear.

In many places, including the United States, gas-fired electricity is likely to be significantly cleaner than coal in terms of carbon emissions even with the extra methane leakage — if only because newer gas-fired plants are much more efficient than the behemoths that provide most coal-fired electric generation. By contrast, a modelling study by Tom Wigley, a climate scientist at the US National Center for Atmospheric Research in Boulder, last year found that switching from coal to natural gas would actually increase global temperatures for decades, by reducing emissions of pollutants that reflect solar radiation back into space (T. M. L. Wigley *Climatic Change* **108,** 601–608; 2011). In the end, natural gas might be preferable to coal just because it reduces harmful air pollution. But the climatic benefits are murky at best.

"Emissions from natural-gas operations could be substantially higher than was thought."

The good news is that the natural-gas industry has the capacity to reduce methane leakage by cleaning up its operations. Technologies are already available to capture methane during fracking rather than venting it into the atmosphere when bringing a gas well online. As it happens, the EPA is currently considering mandatory regulations that encourage such activities by limiting various pollutants from natural-gas operations. These regulations would indirectly reduce methane emissions, and the EPA must press forward. ■

Hypocritical oaths

History judges some research as unethical, despite approval at the time.

Ethical boundaries for experiments on humans can be stated very simply. "The limits of justifiable experimentation upon our fellow creatures are well and clearly defined," Canadian physician William Osler, one of the grand old men of US medicine, wrote more than a century ago. "For man absolute safety and full consent are the conditions which make such tests allowable."

Although US standards have evolved, the concepts of informed consent and safety still underpin research on humans. How, then, could leading health officials in the United States approve a set of barbarous experiments in the 1940s, in which government physicians intentionally infected hundreds of people in Guatemala with venereal diseases?

The people were labelled volunteers, but evidence suggests that they did not provide consent. And as the News Feature on page 148 shows, records indicate that some of the people exposed to syphilis, gonorrhea and chancroid subsequently went untreated.

Such recklessness seems abhorrent now, but this is far from an isolated case. In 1941, US physician William Black infected children, including a 12-month-old baby, with the herpes virus. When Black submitted his paper to the *Journal of Experimental Medicine*, it was rejected. Francis Peyton Rous, the journal's editor, told Black that his work was "an abuse of power". Nonetheless, the paper was published soon after by the *Journal of Pediatrics*.

And Rous was less concerned about a study in which residents of a psychiatric hospital in Michigan were infected with influenza, even though it seems that at least some of the patients could not give their consent. It might be tempting to explain away such research abuses as the work of rogue scientists, but the Michigan study was conducted by a leading researcher of the time, Thomas Francis Jr, and his young colleague, Jonas Salk, who went on to develop the polio vaccine.

And two decades later, in 1963, a team run by Chester Southam injected tumour cells into extremely infirm patients at the Jewish Hospital for Chronic Disease in New York without informing them that the shots contained cancer. Southam was later put on probation by the New York State medical licensing board, but many researchers defended the work and he was later elected president of the American Association for Cancer Research.

What kind of work deemed as accepted today will be denounced by future generations? The question is one that all researchers should bear in mind, because history may judge them more harshly than their peers do. One example could be denial of treatment to sick people through the use of placebos in clinical trials and the ways in which some of these trials are carried out in developing nations, amid accusations of abuse of poor, uneducated participants. Broadening to other types of research, attitudes to work on embryonic stem cells may harden. And future generations may extend the protection currently in place for humans to cover other species, such as chimpanzees.

In the case of chimpanzees, Gabon and the United States are the only nations known to still use them for research, and a committee of the US National Research Council last year recommended that the United States should sharply limit their use, but stopped short of calling for a complete ban. Meanwhile, some researchers have been able to avoid bans in their own countries by travelling to the United States. Since 2005, foreign scientists have conducted at least 27 experiments at US chimpanzee centres (see *Nature* **474,** 268–271; 2011).

There is, of course, clear water between the Guatemalan experiments and chimpanzee research. The Guatemala research was illegal, even in the 1940s, and most of the data did not prove useful and went unpublished. Still, as with research on embryonic stem cells, there is considerable debate about the ethics of using chimpanzees as experimental subjects. In these and other cases, nations would do well to heed some of the lessons that emerged from the investigation of the experiments in Guatemala. Governments and other funders of research must exert full oversight, provide as much transparency as possible and ensure that regulations are clear, strong and evolve with the times. ■

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