EDITORIALS

CLIMATE Careful conditions should allow geoengineering work **p.8**

WORLD VIEW The dangers of partisanship in science policy **p.9**

DECLINE Fussy bees could hunger after long-gone flowers **p.10**

The uncertain dash for gas

The United States and other countries have made huge investments in fracking, but forecasts of production may be vastly overestimated.

A decade ago, fracking was a misprint. Now, hydraulic fracturing is heralded as the future of energy supplies. Leading the way is the United States, which is tapping its rich shale deposits to produce more natural gas than at any other time in its history. The International Energy Agency projected in November that global production of shale gas would more than triple between 2012 and 2040, as countries such as China ramp up fracking of their own shale formations.

How much gas and oil is down there? Predictions about future shortages and abundances of various fuels are tricky, because although the geological presence of resources can be surveyed to some degree, how much would be profitable to extract is a moving target. Academic journals are filled with earnest projections about future energy dynamics, which usually turn out to be wildly inaccurate. Even worse, governments and companies wager billions of dollars on dubious bets. This matters because investment begets further investment. As the pipework and pumps go in, momentum builds. This is what economists call technology lock-in.

This week, *Nature* presents previously unpublished data suggesting that the lock-in of technology into shale-gas production may be a riskier bet than previously realized, at least in the United States. *Nature* has obtained detailed US Energy Information Administration (EIA) forecasts of production from the nation's biggest shale-gas production sites. These forecasts matter because they feed into decisions on US energy policy made at the highest levels. Crucially, they are much higher than the best independent academic estimates.

The full story is contained in a News Feature on page 28. The conclusion is that the US government and much of the energy industry may be vastly overestimating how much natural gas the United States will produce in the coming decades.

The EIA projects that production will rise by more than 50% over the next quarter of a century, and perhaps beyond, with shale formations supplying much of that increase. But such optimism contrasts with forecasts developed by a team of specialists at the University of Texas, which is analysing the geological conditions using data at much higher resolution than the EIA's. The Texas team projects that gas production from four of the most productive formations will peak in the coming years and then quickly decline. If that pattern holds for other formations that the team has not yet analysed, it could mean much less natural gas in the United States' future.

Like all energy forecasts, the lower projections from the Texas team could turn out to be inaccurate. Technological advances in the next few decades could open up more resources at lower costs, driving US production even higher than the EIA has predicted. But it is also possible that the Texas forecasts are too high, and that gas production will fall off even faster than the team suggests.

The one certainty here is that the United States and other nations have invested relatively little in tracking and assessing their natural resources. The EIA has a total budget of US$117 million, less than the value of one day's gas production from the country's shale formations. The agency's budget has increased in recent years, but US natural-gas production has grown much more rapidly. There are now tens of thousands of wells tapping shale formations, and thousands more are started each year.

US federal and state governments have also failed to keep up with environmental concerns associated with fracking of shale formations for gas. For each well, drillers use tens of millions of litres of water, as well as untold amounts of chemical additives — and most states do not require them to report which compounds they use. Environmental groups have charged that fracking fluids can contaminate drinking water near wells, and emissions associated with drilling and production have caused air pollution. There have been few government or academic studies so far, but some research has found evidence of contamination associated with shale-gas production. Similar environmental problems plague fracking of shale deposits for oil, which has led to a sharp rise in US petroleum production in the past five years. And then there is the bigger picture: the extra greenhouse-gas emissions that come from new sources of fossil fuels.

> ***"Nations have invested relatively little in tracking and assessing their natural resources."***

Fracking has momentum. It will probably continue to grow to become an important part of the energy mix in many parts of the world. But for strategic, economic and environmental reasons, all involved should take a hard look at the numbers. ■

Harsh reality

Two reports highlight the plight of postdocs on both sides of the pond aiming for academia.

When hundreds of UK scientists were asked in a recent exercise to describe high-quality scientific research, the most popular word that they suggested was "rigorous". Most were probably referring to its dictionary definition as "extremely thorough and careful". But more than a few must have been aware that the word has some other, equally valid, synonyms: rigidly severe, harsh, tough.

Good science is tough. But is it also harsh and severe? And if so, does it need to be? At what point do the legitimate demands of competitive academic research tip into a demoralizing lack of job security and intolerable pressure? It has been said before, not least in these pages, but two reports published this week on either side of the Atlantic highlight perhaps the most common pinch point: the postdoctoral years.

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Although the lament of the postdoc may be a familiar cry, all who care about the current state of science and where it is heading would do well to look at the separate reports, which present a visceral and honest snapshot of opinions from life in the squeezed middle of academia.

The UK report is the work of the Nuffield Council on Bioethics. Earlier this year, it surveyed 970 people involved in research at UK universities and institutions, and held detailed discussions with another 740. Postdocs made up the largest single group, but significant numbers of respondents held more senior posts, right up to heads of department.

The US effort is a write-up of an October seminar held by postdoc researchers in and around Boston, Massachusetts (G. S. McDowell *et al. F1000 Res.* http://doi.org/xg9; 2014). It is published ahead of a related symposium at the annual meeting of the American Society for Cell Biology in Philadelphia, Pennsylvania, which starts this weekend.

Given a platform to complain, most people will. Both reports grumble about perennial problems that are perceived to run through research. Government funding is insufficient, external focus on journal impact factors stifles creativity, and bureaucracy and distractions mean that everyone has less time to spend on what they really want to do.

These are common legitimate concerns, but how about this: a whopping 58% of scientists in the UK report said that they were aware of colleagues feeling tempted or under pressure to compromise on research integrity or standards. Asked whether they felt this way themselves, just 21% of scientists aged 35 or over said yes; strikingly, that figure shot up to one-third of those aged under 35. In the United States, postdocs consistently called themselves "the lost people" and "the invisible people". The US report states that "junior scientists are primarily treated as cheap labor rather than as participants in a well-rounded training program".

It is no longer acceptable for senior scientists to ignore such complaints. Research in 2014 is a brutal business, at least for those who want to pursue academic science as a career. Perhaps the most telling line comes from the UK report: of 100 science PhD graduates, about 30 will go on to postdoc research, but just four will secure permanent academic posts with a significant research component. There are too many scientists chasing too few academic careers.

"Research in 2014 is a brutal business."

That has been the reality for some time, but the message is yet to penetrate. The US report says that lab heads train scientists "in their own image, that is, for a career in academia, though only a small minority will obtain tenure-track faculty positions". Postdocs say that an academic career is still presented to them as the default outcome. There is a "complete lack of information on number of postdocs", notes the US report.

There is a gap between reality and expectations. Ironically for a career that demands dispassionate judgements based on data and evidence, the postdoc experience is too often a leap of faith that leaves bright and talented people disillusioned and directionless.

The solutions are many, but will require time because they demand a change in culture. Postdoc contracts need to be more than an entry-level position for a career that few will follow. Institutions that offer them must be transparent about future prospects and help postdocs to develop transferable skills to ease their transition into the broader job market.

The philosophy can be boiled down to this: it is a good thing, for both the individuals and society at large, that these young people spend some of their most productive years tackling research. And it is a good thing that most take that independence into other occupations. ■

Look ahead

Research into climate engineering must proceed — even if it turns out to be unnecessary.

The irony in discussions about climate engineering is that, while society considers its merits, the process itself is already in full swing. With vast amounts of heat-trapping molecules released each day into the atmosphere, humans are deliberately altering the planet's climate in unpredictable ways. The magnitude of the resulting climate change is worryingly uncertain. Even more uncertain are the physical, social and economic side effects of global warming. There is every reason to believe that, by and large, they will be harmful.

Why, then, is the idea that future generations could use a little science and engineering to deliberately cool the world so controversial? The answer, of course, is that the cure could be worse than the disease.

Adding sulphate into the high atmosphere, for example, is one of a broad range of geoengineering techniques proposed in response to the warming driven by greenhouse gases. If the technique helps to destroy the ozone layer or increases drought risk in vulnerable regions, then there is a strong argument not to do it.

Scientists are not solely responsible for the problem of global warming. And many argue forcefully that they should be wary of simply replacing one evil with another. Even scientists who are directly involved in geoengineering studies often admit that they do not like the prospect of their research becoming a real-world necessity.

There are some aspects of geoengineering on which all can agree. It should not distract from efforts to curb emissions. An effective political agreement to radically reduce greenhouse-gas emissions, such as that being discussed this week at the United Nations climate-change conference in Lima, must take priority over speculative notions to instead tinker with the atmosphere to meet climate goals.

In fact, geoengineering practices that do pose significant further risk to the environment must be prohibited, if necessary by international law. After all, no single nation — let alone any faction of science — can assume the right to deliberately modify the physical set-up of the planet.

Large-scale and possibly irreversible atmospheric interventions are clearly beyond what is scientifically and ethically justified. But apart from behemoth plans (which nobody is seriously promoting), there are many more limited climate-engineering options that do deserve serious consideration and study. To that end, leading scientific societies are this week discussing a set of guiding principles for responsible field experiments (see page 20). It would greatly enhance the credibility of the field if it could adopt such a scientific code of conduct.

The geoengineering option that seems simplest — scraping carbon dioxide from the air and permanently locking it somewhere secure — is already being intensely investigated. Carbon capture and storage technology is now widely considered to be safe, but technical and financial challenges limit its wide-scale adoption. Because the world's appetite for fossil fuels has not yet peaked, it is as important to encourage and fund research on the carbon capture side of the technology as on the carbon storage aspect. But whether this technology will really help to fight climate change depends on political governance, such as whether it becomes standard in the international energy sector to fit new coal-burning plants with carbon capture equipment.

In its last report, the Intergovernmental Panel on Climate Change (IPCC) left little doubt that some form of geoengineering (or 'negative emissions', in IPCC language) will probably be needed to meet the goal of limiting global warming to 2 °C. Having delivered its fifth full climate assessment report since 1990, the IPCC is considering adopting a new role in the future. If the group were to switch to more-focused, trimmed-down reports, delivered on demand, a special report on climate engineering might be the perfect place to start. Meanwhile, researchers should work fast to clear the way for more responsible research, even if responsible action means that its results will never be needed. ■

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