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and let them participate in knowledge," says Frank Lehner, the DESY physicist who is coordinating Solar Energy for Science. "How can we create new schemes between institutions and also promote and foster deployment of renewable energies in the region? We see scientific cooperation as a key instrument for capacity building—so that people in MENA are able to get into R&D in solar energy and innovation to build their own plants. This is the idea of Solar Energy for Science."

In the longer term, Lehner says, "we can imagine that research infrastructures in Europe could trade a physical transfer of energy from the desert and in return offer participation in our facilities. Why not push European infrastructures as the first customers for solar energy?" **Toni Feder**

Shale-gas extraction faces growing public and regulatory challenges

Two federal agencies are scrutinizing the shale-gas industry and its use of "fracking," but gas producers insist that state regulators provide sufficient environmental oversight.

Over the past decade, advances in drilling technology for natural-gas wells have opened up a vast new domestic source of energy that had been considered too expensive to exploit. But environmental concerns with the process used to recover shale gas are slowing its development in the Northeast. The US possesses 827 trillion cubic feet (1 tcf = 28×10^{12} L) of potential gas resources in shale deposits, according to the Energy Information Administration, part of the Department of Energy; that amount is double the EIA estimate of just one year ago. The agency now estimates the US has enough gas from all sources to meet domestic demand for 110 years at 2009 consumption levels. Production of shale gas is booming; US output grew at an average annual rate of 48% from 2006 to 2010. By 2035, the EIA projects, shale gas will account for 35% of total domestic gas production, compared with 14% in 2009.

Although it's long been known that shale formations contain abundant natural gas, it took development of a new type of unconventional recovery technique known as hydraulic fracturing, or fracking, to make extracting the gas economically viable. In the fracking process, a well is drilled horizontally through shale formations, which generally lie 1000 meters or more beneath the surface. Next, explosives are used to blow holes through the well casing. Then a fluid consisting mainly of water and sand is injected down the well at very high pressures, causing the shale to fracture. Once pressure is released, the fracking fluid flows back to the surface, and gas from the shale flows into the well.

Shale-gas fracking was developed in the early 2000s in the Barnett shale formation beneath northern Texas and Oklahoma. More recently, the technology is being used in exploiting gas in the Marcellus shale formation, which extends from southern New York across Pennsylvania and into western Maryland, West Virginia, and eastern Ohio. Two-thirds of Pennsylvania lies atop the Marcellus formation, and more than 3000 shale-gas wells have been drilled there.

Injection wells and recycling

Although the fracking process is essentially the same in the Barnett and Marcellus shales, the disposal of wastewater generated in fracking differs greatly between the two. In Texas, shale-gas drillers can inject their waste into some of the thousands of oil and gas waste-injection wells located in and near the Barnett formation. Nationwide, there are more than 144 000 waste-injection wells, also known as Class 2 wells, according to the Environmental Protection Agency. More than 2 billion gallons of waste, mostly brine, from oil and gas drilling and production are injected into those wells each day. Pennsylvania has only a handful of Class 2 wells, says Anthony Ingraffea, a Cornell University engineer and fracking expert.

New York State has no disposal wells. In sharp contrast to its neighbor to the south, New York has yet to permit a single shale-gas well that uses the fracking technique. Drilling won't begin there until an environmental impact assessment is finalized. The assessment process began in 2009, and Governor Andrew Cuomo (D) recently ordered the state's environment department to finish it by 1 July, when a moratorium he issued on shale drilling is due to expire. Although the state's Democrat-controlled assembly voted to extend the ban by nearly another year, the Republican-controlled senate is unlikely to concur.

The lack of injection wells has forced Marcellus shale frackers to find other means for disposing of up to 7 million gallons of wastewater generated at each well. Although fracking fluids are more than 99% water and sand, they also contain a number of chemicals, including some that are toxic at the parts-per-billion level, such as benzene, antimicrobial agents, and corrosion inhibitors.

Shale-gas drillers consider the composition of their fracking fluids to be proprietary. But with increasing pressure for disclosure from the public and environmental groups, big Marcellus players such as Chesapeake Energy and Devon Energy have recently begun to make the ingredients public. The state legislature in Texas passed a bill in May to mandate disclosure of the fluid ingredients. Democrats on the federal House Energy and Commerce Committee released a report in April that identified 29 chemicals that are either known or possible carcinogens and are subject to EPA regulation under the Clean Water Act. Oil and gas fracking, however, was exempted from the act in 2005 by a provision tucked into the Energy Policy Act.

Spills and emissions

Environmental groups clamoring for federal regulation point to uneven enforcement by state agencies and to spills and other environmental incidents at drilling sites and in transport of waste and chemicals. Public records show that 1200 violations of environmental regulations occurred at gas wells in Pennsylvania last year, according to the advocacy group Clean Water Action. In April, that state's governor Tom Corbett (R) asked well operators to voluntarily refrain from disposing of their fracking wastewater at municipal water treatment plants, which cannot remove bromides and other dissolved solids from the fluid. Speaking to a meeting of the Geological Society of America in March, Pennsylvania State University researcher David Yoxtheimer estimated that two-thirds of wastewater generated from fracking operations in Pennsylvania (44 million of 65 million gallons) had been recycled during a two-year period ending in May 2010.

Chesapeake Energy in May agreed to pay a record $1.1 million after state regulators concluded that the company's improperly drilled gas wells had allowed gas from shallow,

nonMarcellus formations to contaminate 16 residential water wells. Many other residents living above the Marcellus and Barnett shales have blamed shale-gas fracking operations for polluting their water. Some residents can be seen on YouTube videos igniting the gas flowing from their kitchen taps.

The gas industry asserts there has never been a documented case in the US of groundwater contamination caused by fracking. William Whitsitt, an executive vice president at Devon Energy, said multiple barriers stand between groundwater and fracking. Each wellbore is surrounded by at least two casings with a layer of cement between them and around the outside diameter. Further preventing contamination is the "layer upon layer of impenetrable rock" that separates the shale from groundwater, Whitsitt told the House Committee on Oversight and Government Reform.

Ingraffea says thousands of cases of groundwater contamination due to oil and gas drilling have been documented. Indeed, it's been shown that a certain percentage of oil and gas wells will fail right away or over time. The drilling of a shale-gas well is more likely to cause groundwater contamination than the fracking process, he adds.

Groundwater isn't the only concern. In April, a shale-gas well in northern Pennsylvania owned by Chesapeake Energy blew out during fracking, spilling thousands of gallons of fracking fluid on surrounding land. A similar event occurred in June 2010 at a well in that state operated by EOG Resources, and for 16 hours thousands of gallons of fracking fluid spilled over the surrounding fields. The company and its drilling contractor were fined $400 000 for the accident, which was blamed on untrained personnel and faulty drilling procedures. Sharon Wilson, an activist against fracking in the Barnett shale, says drilling-pad operations adjacent to her suburban neighborhood drove her to sell her home at a loss. Now working for the environmental group Earthworks, Wilson says she is most concerned about fugitive emissions that occur at multiple points during fracking and production. In addition to methane, those emissions include the neurotoxin carbon disulfide, she says.

Federal regulation ahead?

In response to a directive from Congress last year, the EPA initiated a study to examine the relationship between fracking and drinking water. "We are doing [the study] with input from the public, industry, and our Science Advisory Board," EPA administrator Lisa Jackson told the Oversight Committee. "In the meantime," she said, "EPA will use its authorities to protect local residents if a driller endangers water supplies and state and local authorities have not acted."

SHARON WILSON, EARTHWORKS

An aerial view of a hydraulically fractured shale-gas well in the Barnett shale formation in northern Texas.

An initial report generated by the EPA study is expected to be issued by the end of 2012. But Paul Anastas, EPA assistant administrator for R&D, told the House Committee on Science, Space, and Technology on 11 May that parts of the study won't be completed until 2014. University of Houston engineering professor Michael Economides complained during the same hearing that both the EPA's choice of scientists for the study's review panel and the agency's selection of sites for case studies display a bias toward a conclusion that fracking ought to be federally regulated. Economides was especially critical that the EPA had chosen only four fracking wells for detailed case studies. "There is simply no way four retrospective case studies can be considered a representative or fair sampling of any process, regardless of how carefully those cases are selected," he said. "Our risk as a nation is that one bad well will condemn an entire fracturing process with this study approach."

Earthquakes in Arkansas

The Department of Energy entered the fracking fray in early May, when President Obama instructed it to convene an advisory committee to recommend measures that could immediately improve fracking safety and environmental performance. The panel, organized as a subcommittee of the Secretary of Energy Advisory Board, was given just 90 days to issue its findings. The president also called for the panel to produce within six months advice to agencies on shale-gas extraction processes that will ensure the protection of public health and the environment. The panel is chaired by former Central Intelligence Agency director John Deutch of MIT.

During their first meeting, the advisers were told by US Geological Survey director Marcia McNutt about hundreds of earthquakes that have occurred over several months in an area of Arkansas where fracking wastewater was being injected to depths of 2–4 kilometers. The largest, a 4.7-magnitude temblor, caused some damage in nearby towns. Since state regulators halted further waste injections at two wells in April, McNutt told the panel, the number and magnitude of earthquakes have fallen dramatically.

On 1 June executives from the shale-gas companies told the committee that state regulators should be left in charge. Deutch was receptive. "The sympathy of the committee is to keep regulation at the state level," he said. The industry representatives promised to quickly implement additional best practices and develop standards for safety and environmental protection. The industry is moving rapidly to develop fluids with "more friendly chemistries," said Steven Mueller of Southwestern Energy; he added that biocides, among the

more "aggressive" fluid constituents, might be replaced with UV treatment.

Jack Williams, of ExxonMobil subsidiary XTO Energy, said the company tests all drinking-water wells within 762 meters of a new shale-gas well, and finds detectable levels of methane in one-quarter of those water wells. Ingraffea says the issue is whether methane levels increase after drilling and fracking. A study by Duke University researchers published in the online edition of the *Proceedings of the National Academy of Sciences* on 9 May found a strong correlation between elevated methane levels in water wells and shale-gas drilling in the Marcellus.

David Kramer

Europe to invest billions in multinational science initiatives

Coordinating fragmented efforts in selected research areas is expected to provide a strong basis for future technological innovation, economic growth, and other benefits for society.

With ambitious goals and large investments, the European Commission's future and emerging technologies (FET) flagship projects in information technologies have been compared to the US Apollo program, which made the first lunar landing in 1969. "But we want to do something that is more useful than going to the Moon," says Paolo Dario, director of the BioRobotics Institute in Pisa, Italy, and coordinator of Robot Companions for Citizens, one of the FET pilot projects.

A total of 6 pilots—culled from a field of 21—were announced on 4 May at a conference in Budapest. In addition to the robot companions project, the pilots focus on graphene, simulation of the human brain, socially interactive IT for sustainability, customizable autonomous energy-scavenging personal assistants, and IT for personal medicine. Each is to get €1.5 million ($2.1 million) for one year, and late next year two of the projects will be selected as flagships, to be funded at about €1 billion each over a decade.

The idea behind the FET flagships is to bring together scattered multidisciplinary research efforts to achieve breakthroughs that lead to applications with social impact and to make Europe the world leader in certain areas. The flagships "aim to improve today's insufficient transfer of research efforts to technological solutions and industrial applications," Neelie Kroes, the European Commissioner for Digital Agenda, said in Budapest. "This conference," she said, "is about what ICT [information and communications technologies] could do—if we want it to. It is about how science can go beyond fiction when it gets the right support."

Small packages, big potential

The Robot Companions for Citizens project aims to build "sentient" machines that help people, particularly the elderly. A companion robot "is like your pet, able to understand your emotions, live in the house without breaking furniture, and have emotional interactions with you," says Dario. "But it will also do tasks for you." The robots would be useful to people with disabilities or neurological diseases. Other potential applications, he says, could be in rescue situations such as cleaning oil spills, retrieving a cockpit black box, or aiding recovery in the aftermath of the Fukushima partial nuclear meltdown. His team is aiming for an affordable price for the robots "so that every household can have one." They will be based on "new materials, new actuators, new mechanisms, new energy sources, new nervous systems," Dario says. "They will be inspired by the biological world."

The robot companions project has about 250 collaborators in eight countries. But Dario expects the number of collaborators to grow to more than 1200. If selected as a flagship, he says, the development of sentient machines that perhaps "could be expected in 20 or 30 years could be accelerated and done in 10, providing a solution to a deep social problem."

With Guardian Angels, the FET pilot with energy-scavenging personal assistants, researchers envision miniature sensors that power themselves with any available source of energy, such as light or movement. "We want to develop smart, autonomous personal assistants. It will be a network of body sensors, monitoring a diversity of things: blood sugar levels, heart rates, activity levels—with accelerometers and gyroscopes," says project coordinator Adrian Ionescu, a nanoscientist at the École Polytechnique Fédérale de Lausanne (EPFL) in Switzerland. A watch or mobile phone could serve as a central interface. At a more advanced stage,