But "the devil is in the details," says John Gibbons, assistant to the president for science and technology. The details for assessing and weighing risks, Gibbons believes, "may result in less protection for more sensitive or exposed segments of the public," such as children, pregnant women, the elderly, the chronically ill, and certain workers.

The bill would require agencies to use risk assessment and cost-benefit analyses to rank hazards and to decide how much to spend on reducing or removing them. For any proposed action that is expected to cost industry more than $25 million, agencies would need to do the following: assess all relevant scientific data; spell out uncertainties, particularly when extrapolating from animal data; compare the magnitude of the threat to other potential risks; and weigh estimated savings—such as increased productivity from a reduction of injuries in the workplace—against the costs to industry of compliance. Agencies already use some of these analyses in preparing rules estimated to cost more than $100 million, and they apply scaled-down versions of these analyses for lesser rules.

Many industry scientists are eager to see these analyses applied more systematically. The bill would "require agencies to lay out the assumptions they're making," says Colin Park, who handles risk assessment issues for Dow Chemical. But scientists familiar with the bill are also bothered by provisions that would require agencies to "provide the best estimate or estimates" of a risk to people or natural resources. The problem is that there is no way to define a best estimate of risk when different scientific models give widely varying estimates. "That's the alchemy in the bill," says Finkel.

"There's been a lot of controversy about what a 'best estimate' means," says Elaine Faustman, a University of Washington reproductive toxicologist who teaches a course on risk assessment. "Is it a best estimate for the 'average' person? Or should it reflect the variability in the human population?"

Lead regulations are an example of EPA's view of risk as seen through the eyes of the most susceptible populations. Several studies have linked a subtle learning deficit in children to blood lead levels. These findings, although controversial, have caused the Centers for Disease Control and Prevention to lower its "level of concern" for concentrations of lead in the blood to 10 micrograms per deciliter (μg/dl). A relatively successful campaign has reduced blood lead levels to the point where that concentration is exceeded in only 9% of all 10-year-old U.S. children, compared with 88% in 1980. Now, EPA wants to tighten regulations even further to reduce exposures in populations where blood levels are still high, including black children in low-income, urban families, where 20% exceed the 10 μg/dl threshold.

"It would be very difficult to do this" if the current bill were enacted, says Joseph Carra, acting director of EPA's office of pollution prevention and toxics. Such a law, he says, might even preclude the issuance of a regulation if the agency's best estimate was the risk posed to the entire U.S. population. And EPA could be sued if it tried to enforce stricter standards. "It could well be that we would end up constraining our scientists to using certain population estimates to make sure we're not creating a huge cost for the agency in litigation," says Lynn Goldman, EPA's top risk assessment official.

Next month the Senate will hold hearings on a similar bill, sponsored by Majority Leader Robert Dole (R–KS), and opponents hope it will be more deliberative than the House. "Risk assessment is a young science, with a lot of uncertainty," says Faustman. "It makes me nervous that concepts such as 'best estimate' may get codified at this point."

–Richard Stone

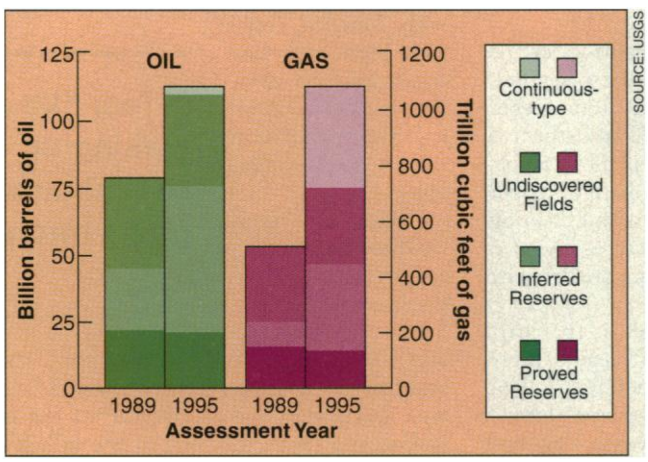
RESOURCES

U.S. Oil and Gas Fields Double in Size

Like a prudent pensioner gauging what remains to support her in her later years, the United States periodically takes stock of how much oil and gas it has in the "bank." The government can't simply consult a ledger, however. It has to rely on innumerable geologic clues to guess at how much oil and gas is left to be found and extracted. But this guesswork, unlike a pensioner's bank account, can produce some happy surprises.

That was the case at last week's annual McKelvey Forum, a conference on energy and the environment in Washington, D.C., sponsored by the U.S. Geological Survey (USGS). The last assessment, in 1989, had been discouraging, but this time around the USGS announced that known oil and gas fields now look far larger than had been thought.* U.S. oil fields were already credited with 20 billion barrels in "proved" reserves, but if intense, sophisticated drilling probes the fields' geologic nooks and crannies, the USGS estimates that they could yield another 60 billion barrels. That's triple the amount of so-called inferred reserves estimated by the USGS in 1989, and equal to an additional 24 years' production at present rates. Inferred reserves of gas enjoyed a similar boost in the new assessment, to 322 trillion cubic feet.

The abundance remaining in known fields isn't exactly like money in the bank; it's more like a long-term bond. At today's prices, much of it would be prohibitively expensive to extract, but it could be extremely valuable early in the 21st century when, USGS researcher Charles Masters told the meeting, "there will be some serious problems" with world oil and gas supply. And the new estimates of inferred reserves are especially welcome because another part of the picture hasn't brightened since the last assessment: the amount of oil and gas in fields yet to be discovered. Those estimates, based on an inventory of likely-looking geologic structures, had declined drastically in the 1980s, and they remain little changed in the new assessment at 30 billion barrels of oil and 259 trillion cubic feet of gas (excluding federal offshore areas).



Big "finds." Estimates of oil and gas resources still to be found in existing fields (inferred reserves) show a sharp jump. The continuous-type category includes widely dispersed, dilute resources.

A combination of geologic peculiarity and oil-industry economics accounts for the dramatic growth of the inferred reserves, explains Donald Gautier of the USGS in Denver, the assessment's project chief. In large, complex oil fields like those in West Texas, he says, the more you drill, the more the known field grows. Previously untapped pools may turn up above or below a known pool, the field may expand laterally as wells are drilled farther away, and a well sunk between two existing wells may tap into oil

*_1995 National Assessment of United States Oil and Gas Resources_, U.S. Geological Survey Circular 1118, free on application to U.S. Geological Survey, Information Services, Box 25286, Federal Center, Denver, CO 80225.

cut off from the more distant wells by impermeable barriers in the rock. Sophisticated extraction techniques—heating and thinning the viscous oil by pumping steam into the rock or floating the oil upward with injections of water—can also wring unexpected amounts of oil from the rock. Given such extra effort, many fields "just seem to grow and grow," says Gautier, some with no end in sight.

In the 1980s, there was plenty of extra effort because of the "feeding frenzy" among drillers when oil prices skyrocketed in the late 1970s and early '80s. During the boom, the intensive, at times scattershot drilling enlarged some fields more than expected. And fields continued to grow faster than expected even after the boom collapsed, says Gautier, as drillers were forced to become more efficient at finding oil and gas. New technology like 3D subterranean seismic imaging and horizontal drilling helped them capitalize on clues that had come to light during the drilling boom, adds William Fisher of the University of Texas, Austin.

The USGS had based its gloomy 1989 assessment on data collected by industry groups between 1969 and 1979, before the field-expanding boom and bust. This time the assessment team was able to use more recent proprietary data on 46,000 fields, collected from companies by the Department of Energy from 1977 to 1991. By extrapolating from the pace of new oil and gas discoveries in known fields over that period, the team estimated the total oil and gas remaining in the fields.

Gautier and his colleagues caution that their huge new "finds" will only materialize if the drillers can sustain the success rate they achieved in the 1980s. Gas fields, in particular, may not respond so well to greater drilling effort, warns Joseph Riva of the Congressional Research Service; because gas is so much more mobile than oil, a smaller number of wells may be enough to fully exploit a field. And the new estimates ignore how much it would cost to steam, flood, or otherwise coax out the additional oil and gas. Certainly no one would bother with much of these inferred reserves at today's low oil and gas prices, but prices can change.

That was Masters's message to the forum. "In the next couple of decades, there will probably be lots of oil and gas" worldwide from a range of suppliers both large and small, he said. But "in the middle part of the next century," he warned, "the gap is pretty big between what we think we know about [world] supply and what demand may be." The Middle East will come to dominate the oil supply and Russia the gas supply, he said, and the threat of "economic terrorism" will loom. Even pricey inferred reserves could look good then.

–Richard A. Kerr

PLANT GENETICS

Shedding Light on the Ticking Of Internal Timekeepers

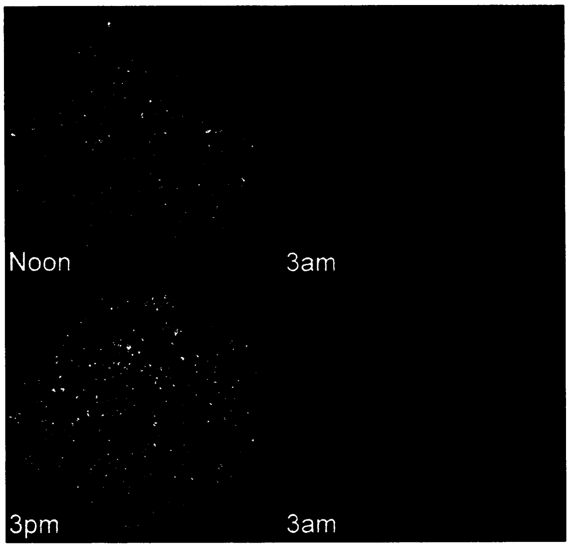
As any jet-lagged traveler knows, our internal clock is a powerful timepiece that can keep a globetrotter wide awake at night and yawning through the day. Experiments over the years have shown that such clocks govern a host of daily physiological events, such as body temperature changes in animals and leaf position in plants, and can be set—and reset—by exposure to light.

But the inner workings of these clocks, as well as the means by which they are set, have remained a mystery, and nowhere was that mystery murkier than in plants. Now, in two papers on pages 1161 and 1163 of this issue, a research team headed by Steve Kay of the University of Virginia has begun to crack the plant clock puzzle. In one paper, they identify genetic mutations that alter the internal clocks of the tiny laboratory plant *Arabidopsis*. And in the other, they show that both red and blue light can influence the clock's rhythms, and do so via two different biochemical pathways.

"This is the first time anybody has been able to get a handle on the molecular basis of the clock in higher plants," says Dartmouth Medical School geneticist Jay Dunlap, who studies these daily clock-driven cycles, known as circadian rhythms, in the bread mold, *Neurospora*. Eventually, understanding plant clocks should enable biologists to compare clocks from widely different species, says Brandeis University biologist Michael Rosbash, who studies the circadian clocks of fruit flies, and thus address a central question: "Will these turn out to be universal mechanisms and universal genes, or is the clock really quite different in different organisms?"

In recent years, researchers have begun to gain some understanding of how clocks work in two model organisms, *Neurospora* and fruit flies (see box on p. 1092), and several groups have recently cloned clock-related genes from mice, hamsters, and cyanobacteria, although little is yet known about how those genes work. But amid this progress in other systems, plant researchers have remained unable to identify any clock genes in plants.

The problem is in the difficulty of pinpointing mutant plants whose clocks are out of synch. To find such mutants in other organisms, biologists have typically used "brute-force" screens, searching through thousands of organisms to find those with abnormal rhythms—for example, mice that run in their exercise wheels while all the other mice are sleeping, or *Neurospora* colonies that put up fruiting bodies at the wrong time of day. But such screens have daunted plant biologists because plant rhythms are so subtle, says Dartmouth's Dunlap. "It would be really tough to do a brute-force screen on thousands of plants, looking for the leaves to be up when they are supposed to be down."



MILLAR ET AL.

Out of synch. Circadian rhythms should make all these *Arabidopsis* seedlings turn a glowing pigment on and off at the same time. But some, clock mutants, glow out of step.

Kay solved this problem in *Arabidopsis* with a bit of genetic engineering. He and graduate student Andrew Millar began with the DNA regulatory sequences from a clock-regulated *Arabidopsis* gene called CAB (chlorophyll-*a*/*b*-binding protein). CAB is normally switched on during the day and off at night, and maintains that rhythm—directed by the plant's internal clock—even when the plants are kept in constant light.

The researchers hooked those regulatory sequences up to the *luciferase* gene from fireflies, which produces an enzyme that causes a chemical called luciferin to glow. The experiment worked "like a dream," recalls Kay. When sprayed with luciferin, the plants carrying the engineered *luciferase* gene glowed during daytime hours and didn't glow at night. That made the search for clock mutants simple: Just look for seedlings that glow at the wrong times.

Millar did just that. At various points in a 24-hour period, he took petri dishes filled