lead to plasma found only in exotic places in astrophysics," says Todd Ditmire, who heads a 1-PW laser facility at the University of Texas at Austin and is considering collaborating with the Romanian branch of ELI. "We are not going to let the grass grow under our feet just because the Europeans are going ahead with ELI." He notes UT's involvement in a US university-industry-national lab team that is talking about an exawatt (10^{18} W) laser.

Paul Drake of the University of Michigan, whose article on high-energy-density physics appears on page 28 of this issue, says, "The ELI project is trying to push up by a significant amount in intensity and an awful lot in rep rate. I would note that Gérard Mourou is one of the greatest developers in technology around. If it can be done, that team ought to be able to do it."

Competing technologies

Two different technologies for chirped-pulse amplification (CPA; first demonstrated 25 years ago by Mourou) will be used for ELI's 10-PW lasers, and tests getting under way in the UK and France will narrow the choice for the 100-PW-class laser, which will be the sum of 10 beams of 10–20 PW each.

The pros of optical parametric CPA, says Mourou, "are that the material is transparent, so no energy is deposited. The amplifier does not heat up. And it has high gain." One con is that it uses a very short pulse pump, on the order of 1 ns.

The other candidate is titanium:sapphire CPA. It uses a longer pulse pump (roughly 30 ns), but growing large enough titanium:sapphire crystals is slow and tricky. "The devil is in the details," says Mourou. "Only when you understand the technologies fully can you make the decision."

"It's a binary decision between two competing technologies," says Sandner. "We are confident both would work, and we have the luxury to develop both to 10 PW in the context of the first three pillars. We don't lose time—we gain security to have the best available technology without having to make a premature decision." The specifications and the site for ELI's highest-power laser will be set in 2012.

More sites, more impact

Originally planned for a single site, ELI was spread by politics over at least three countries. The former Soviet bloc countries are eager to take part in the pan-European project, but will contribute significantly only if they can host it. Each site will cost an estimated €280 million ($350 million) to construct and €30 million a year to run. So making the more than €1 billion ELI a multisite project eases the fundraising process. Money for the first three pillars is close to certain, but must still be found for the 100-PW site.

Most of the money will come from EU structural funds to new members. "This money is foreseen for social cohesion, and it's basically devoted to less-developed regions," says Szabó. So far, he adds, such monies have been used mostly for roads, sewage systems, and the like. "But now the idea is that social cohesion could be supported by investing in science." That money is the good news, although some bureaucratic hoops still have to be jumped through before it is finalized. The bad news, says Szabó, "is that these funds have to be used very quickly. The money is not available beyond 2015. If we cannot make ELI quickly enough, we may face problems at the end of the story." In Hungary, soil mechanics studies are under way, and construction is slated to start next year.

Because of additional buildings, lasers, and other redundancies, splitting the project boosts ELI's tab by about €300 million, says Mourou. It will also be more complex to run. But each country is committing €250 million to €300 million. Mourou, who initially opposed splitting the project, says that in giving talks he "started to feel the impact. You could see the excitement of people in these countries. I started to see that we are broadening the community. You have to weigh things. The pros are much bigger than the cons." Among the pros, Mourou lists the solid commitment from three countries, a larger workforce and more lasers total, and more opportunities for students. All told, he says, "the impact will be much bigger."

ELI "will be an example of a distributed facility," says Rus. "We have one mission, coordinated goals, one governing body, and one user community."

The project is also a good marketing tool, Szabó says. "We have to work hard to produce the necessary human resources. The whole European laser community is not enough to build and run ELI. We need to get new young talent into the business." One effort is a master's program being launched jointly by three Hungarian universities to train students in laser physics. Educational programs that link the three pillars are also in the works. Says Szabó, "We are also trying to attract people from other countries. It is generally perceived that we need people available in the next five to seven years. This is not unrealistic. We hope they will want to come here. These places will be the top places in laser physics."

Toni Feder

DOE begins rationing helium-3

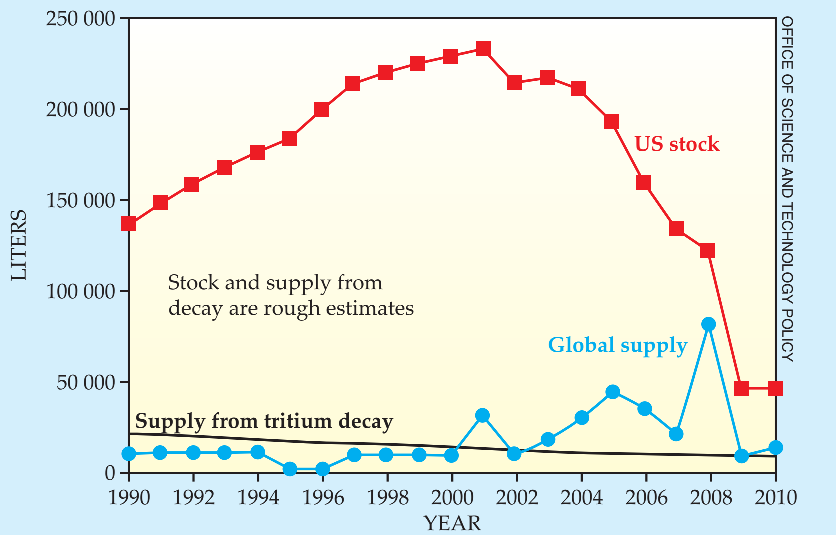
As the extent of the shortage becomes clear, an interagency task force is giving scientific users priority, but some say the material is not available at any price.

Casting about for new sources of helium-3 to alleviate what one Department of Energy (DOE) official has called "a critical shortage in the global supply," a federal interagency task force is seeking to strike deals with Canada and is exploring other avenues to obtain additional supplies. In the meantime, some scientific users of ^{3}He have reported having to pay more than $2100 per liter of the gas for an isotope that cost them less than $100 a couple of years ago.

On the heels of a broad ^{3}He crisis (see PHYSICS TODAY, October 2009, page 21) and with DOE's inventory of the gas now well below a single year's demand, the task force instituted a rationing system this year that gives first priority to applications that have no known substitute. Topping the list are cryogenics needed for physics below 1 K, ring lasers used for missile guidance and space navigational systems, and magnetic resonance imaging of the lungs. The interagency group suspended all distributions in 2009 and curtailed releases this year to less than 12 000 liters of world demand, estimated at 70 000 to 76 000 liters, while it seeks ways to address the shortage of ^{3}He for use in radiation monitors at ports, airports, and border crossings—which had been the largest ^{3}He consumer by far. A warning by DOE officials that scientists at neutron scattering facilities abroad need to look elsewhere for their requirements has set off a scramble to find alternative neutron-detection technologies.

In addition, the International Atomic Energy Agency has been informed by the US, long the IAEA's major supplier of ^{3}He for nuclear safeguards inspections, that future shipments are unlikely. The US provided just 1800 of the 2800 liters that the IAEA had requested for this year.

Demand for ^{3}He accelerated after 9/11, drawing down US stocks



Surging demand from radiation portal monitors and plunging nuclear weapons requirements combined to deplete US stocks of helium-3 by more than three-quarters from their peak in 2001. DOE suspended all releases of ^{3}He last year. The agency has allocated just 12 000 liters for 2010, which compares to an estimated annual demand upward of 70 000 liters.

Demand up, supply down

Drained by years of high demand for Department of Homeland Security (DHS) and DOE radiation-detection applications, the US inventory of ^{3}He has plunged from a peak of well over 200 000 liters in 2001 to somewhere between 43 000 and 48 000 liters (see chart). Worse, DOE anticipates that it will have fewer than 8000 liters per year of ^{3}He to sell for years to come.

Agency documents provided to the investigations and oversight subcommittee of the House Committee on Science and Technology contain inconsistent data on DOE's total releases of ^{3}He. According to a recent DOE memorandum, 313 000 liters were distributed from 1991 through January of this year. But William Brinkman, director of DOE's Office of Science, testified that 200 000 liters have been distributed since 2003, and another 58 000 liters have been dispensed since 2001 for the Spallation Neutron Source (SNS) at Oak Ridge National Laboratory.

In the US, ^{3}He is generated as a byproduct of tritium, which is used in nuclear weapons. With a 12.3-year half-life, tritium in warheads must be replenished every five years or so. The ^{3}He that is generated when tritium decays is extracted during replenishment. As thousands of warheads were dismantled over the past two decades, enough tritium was freed up for recycling into remaining warheads and no new tritium was needed. Production at DOE's Savannah River Site was halted in 1988. It resumed in 2007, at a far lower level, in a commercial reactor operated by the Tennessee Valley Authority.

Although more tritium could be produced in commercial reactors to help meet ^{3}He demand, the cost would be prohibitive—more than $20 000 per liter, by one estimate—and the process could take 20 years or more to yield significant quantities of ^{3}He. A more immediate source could be the processing of tritium from heavy-water reactors, and the isotope could also be separated from natural-gas fields that have a high concentration of helium. There, ^{3}He occurs at a ratio of 0.2 parts per million of ^{4}He and, according to David O'Connor, a nuclear engineer at General Electric (GE) Co, can easily be separated from ^{4}He by gaseous diffusion. O'Connor estimates that a "fair-sized" extraction plant would provide 5000–10 000 liters per year. Industry cost estimates provided to DOE last year for such a plant were in the "tens of millions," he says.

Canadian tritium sought

For more than a year, US and Canadian officials have been discussing the use of ^{3}He stored at an Ontario nuclear power plant. Ontario Power Generation (OPG) has been filtering tritium from heavy-water reactors at a complex near Toronto since 1990 and now filters it from 16 CANDU (Canada deuterium uranium) reactors in Ontario. Steve

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Fetter, assistant director of the White House Office of Science and Technology Policy, estimated that 20 000 liters of ^{3}He could be separated annually from OPG's tritium storage beds for three years, and 10 000 liters per year could be extracted for the following seven years. At a 22 April US House subcommittee hearing, Brinkman said feasibility and cost studies will be completed in the fall.

Canada offers the greatest near-term potential for more ^{3}He, since it has 22 heavy-water reactors, half the global total. But OPG operates the world's only heavy-water tritium separation plant. The recovery of ^{3}He alone is unlikely to justify the expense of tritium removal, Fetter says, although other nations, including South Korea, Argentina, and China, may well decide, as OPG did, to remove tritium for environmental reasons.

In recent years, scientific users of ^{3}He were increasingly elbowed out by the burgeoning needs of DHS and DOE for neutron detectors. The two departments have equipped US and foreign ports, border crossings, and airports with hundreds of radiation portal monitors to detect surreptitious shipments of weapons-usable nuclear materials in cargo and baggage. The resulting spike in demand occurred as the US stockpile of tritium shrank in response to the steep decline in the numbers of nuclear weapons. At one 2009 interagency meeting, a DOE official noted that two-thirds of the ^{3}He that had accumulated over 40 years was dispensed in only six years.

Russian material disappears

The price of ^{3}He skyrocketed as the full extent of the shortage became apparent. As recently as a year ago, a liter cost less than \$100. But Giorgio Frossati, president of the Dutch dilution refrigerator manufacturer Leiden Cryogenics, says he recently paid \$2150 per liter for 50 liters. The material's origin wasn't disclosed to him, he said, but it "could very well be from Russia." US customers fortunate enough to have DOE accept their application can still get the material at \$450 per liter, he says, a situation that is "unfair towards the non-US scientists." But some US customers have been unable to get the gas they need, and others have been told to wait until next year. "You can imagine that a young scientist with starting money who must show results on a short term will be in a very difficult situation," Frossati laments.

Brinkman told lawmakers that customers are currently paying \$350–\$400 per liter. He admitted there were reports of higher prices, but none, he said, came close to \$1000 per liter. Brinkman blamed the sudden shortage on Russia's abrupt withdrawal from the ^{3}He market, which he said had occurred late in 2008. Russia, the only supplier other than the US, had sold an average of 25 000 liters annually in the US from 2004 to 2008, but it has provided none since. No one seems to know why, though there have been suggestions that Russia may be using the gas in portal monitors to equip its ports and nuclear facilities.

Representative Brad Miller (D-NC), chair of the House subcommittee, upbraided DOE and DHS for failing to see the shortage coming. He said the two agencies should have recognized years ago that "it would be a disaster to base radiation-detecting equipment on helium-3 technology."

DOE labs are hit too

Even research related to national security has been caught up in the crunch. In a 16 April letter to Miller, Lawrence Livermore National Laboratory scientist Darin Kinion said he's been waiting for seven months for a response to his request for 23 liters of ^{3}He required to operate the dilution refrigerator needed for his quantum computing project. Sponsored by the Intelligence Advanced Research Projects Activity, the project involves experiments at a temperature of just a few millikelvin. "Working on an intelligence-backed activity at a National Laboratory, I am a bit surprised at the trouble I am facing from the Department of Energy," Kinion wrote. Janis Research Co, which built his dilution refrigerator, has loaned him some ^{3}He as a stopgap. But he said Janis doesn't have enough to loan it to every customer.

Northwestern University physics professor William Halperin told the House hearing that his continued inability to get 20 liters for his dilution refrigerator imperils his NSF grant. "Should Janis and other companies stop providing refrigerators, low-temperature science will end," Halperin warned. Brinkman, however, said the interagency task force had approved the full 1000 liters that cryogenics users had requested in fiscal year 2010. He added that it may be several months before the supply and demand situation stabilizes.

A total of 60 000 liters of ^{3}He has been used to date for neutron tubes that equip about 1300 portal monitors for detecting radioactive materials at US ports, border crossings, and airports, according to Richard Kouzes, a fellow at Pacific Northwest National Laboratory. Another 1000 portal monitors are in use elsewhere around the world, many of them installed through DOE's "second line of defense" program to find illicit nuclear materials prior to shipment to the US. In addition, multiple agencies have been stocking up on handheld and backpack radiation detectors for battlefield and civilian use. All are equipped with ^{3}He-filled tubes. Overall, security-related neutron detection has accounted for about one-third of demand in recent years.

Radiation portal monitors are the biggest user of ^{3}He, since a single one contains anywhere from 8 to 100 liters, says Thomas Anderson, a product line manager with GE Energy. GE manufactures both the tubes containing ^{3}He and portal monitors and other radiation-detection devices.

Saved by the delay?

Thousands more neutron detectors were proposed to be deployed in a second-generation portal monitor known as the advanced spectroscopic portal (ASP) system. Aimed at curtailing the high rate of nuisance alarms that occur when everyday slightly radioactive materials like ceramics and cat litter pass through today's portals, the ASP system would require an estimated 200 000 liters of ^{3}He, Miller stated. At that level, portal monitors alone would have constituted 80% of future demand, according to Brinkman. Miller voiced his astonishment that the Domestic Nuclear Detection Office (DNDO) hadn't verified the availability of adequate ^{3}He supplies.

Procurement of ASP monitors has been pushed back by several years due to performance problems unrelated to ^{3}He, and William Hagan, acting director of the DNDO, assured lawmakers that the agency has enough ^{3}He to meet its needs through at least September 2011. Officials from DOE's nonproliferation program also have informed the interagency task force that the program can make do with its existing supply until then.

Demand for neutron detectors in scientific applications also has taken off, nowhere more so than in neutron scattering. As many as 1000 neutron detectors are required for some of the neutron scattering experiments planned for the \$1.4 billion SNS, said GE's Anderson. Although DOE has already set aside 58 000 liters of ^{3}He for the SNS, the facility wants another 26 000 liters by 2015. The interagency task force has said that the numerous other large neutron scattering sources that are under construction or in development will need to fend for themselves: "The US can no longer be the major supplier satisfying these needs," Brinkman said.

Substitutes are needed

Ronald Cooper, detector team leader at the SNS, said his own survey of large neutron scattering facilities around the world yielded a projected demand totaling 125 000 liters of ^{3}He through 2015. Some of the biggest wish-list items were 21 000 liters for the China SNS, 16 000 liters for the neutron source at the Japan Proton Accelerator Research Complex, and 14 556 liters for the Los Alamos Neutron Science Center. But Cooper said the neutron science community is well aware that such volumes won't be available. Alternatives to ^{3}He for large detector arrays are being "actively pursued" by 10 research groups around the globe, he said, with boron-10-lined detection tubes and scintillator arrays being the "two main thrusts."

The two approaches offer the greatest opportunity for alternatives in security applications as well. GE expects to begin selling portal monitors that use ^{10}B neutron-detection tubes later this year, says Anderson. Gaseous boron trifluoride is both corrosive and caustic, so GE opted to coat the insides of the tubes with boron metal and fill them with an inert gas. Although ^{10}B has a lower sensitivity to neutrons than ^{3}He does, GE will still be able to fit the new tubes within the relatively large housings of its current line of portal monitors. But Anderson says alternatives will be far more difficult for such applications as pager-sized or handheld neutron detectors, which use as little as 0.1 liter of ^{3}He. For those uses, he says, "We're going to have to do a lot more work and redesign [with] boron-10 in order to achieve [^{3}He] kind of sensitivity."

Less-developed alternative technologies are lithium-6-loaded glass fibers and ^{6}Li-coated plastic fibers. Since a neutron lacks charge, GE's O'Connor notes, detecting one requires a reaction that produces a charged particle. And only a handful of isotopes will do that: ^{3}He, ^{6}Li, ^{10}B, gadolinium-157, uranium-233, uranium-235, and plutonium-239. DOE has also been urging users to recycle the ^{3}He that may be sitting around in outmoded instruments.

David Kramer

Physicist stands up for laughs

I want you all to relax tonight, okay? No one's expected to get all these jokes. Just do the best you can in the time remaining. And remember, if you come to a joke and you are unsure of the joke, skip over the joke and go to the joke. . . . Yeah, I taught the f-word. Physics.

Norm Goldblatt was on the faculty at the Rochester Institute of Technology for a decade. In 1979 he left academia for industry, and for the past 30 years his day job has been doing laser research and product development. He currently works on ophthalmic applications of lasers at Optimedica in Santa Clara, California. On the side, he does standup comedy.

Goldblatt does a gig or so a week, at corporate functions, schools, and professional society meetings, among other locales. He performs around the country, although mostly in the San Francisco Bay Area. He has written for Jay Leno. And, officially a professional, he is barred from amateur competitions. He bantered with PHYSICS TODAY earlier this spring.

PT: How did you get into standup comedy?

Goldblatt: I've been writing humor from an early age. The fact that I take science and math so seriously is part of the humor in it all. My wife and I moved to California in the late 1970s. This was a time when comedy was king in San Francisco. Simultaneously, the Silicon Valley was burgeoning and the social ineptitude of our ilk really amused me before it was chic to be geek. Having taught physics for 10 years, I was used

Norm Goldblatt holds a "laser loaf" like the one he made for laser co-inventor Arthur Schawlow to use as comic relief at an awards dinner in 1986.