About a year ago, the University of Tokyo's president said he had raised half the money needed to sustain the Kavli IPMU. "I can breathe," says director Hitoshi Murayama. Research highlights at the IPMU include insights into six-dimensional Calabi–Yau manifolds, dark matter, and the dynamics of new types of supernovae.

Ripple effects

One of the WPI's missions is to reform Japan's academic system. That means shifting from a traditional hierarchy to a more flexible system that encourages creativity, initiative, and mobility. "We want to take the better aspects of US departments," says Yanagisawa. For example, Japanese university labs tend to have a rigid hierarchy from full professor down to graduate student. At Tsukuba's WPI-IIIS, he says, "we have a nonhierarchical personnel structure."

Center directors have discretion over hiring; in a break from tradition, salaries do not follow a set formula based on age and seniority, and directors can negotiate nimbly to make competitive offers. "We recruited someone who we are paying way beyond what the university president makes," says Murayama. "It's a great appointment. It shows the way forward."

On average, 40% of WPI researchers are non-Japanese. The international makeup is roughly one-third each from Asia, Europe, and the US, with a sprinkling of researchers from Latin America and the Middle East. The character of each center is strongly influenced by its leadership—the IPMU's five-year extension is contingent on Murayama staying on. (See the interview with Murayama in the 2013 story "Juggling dual-country careers" on PHYSICS TODAY's website.)

As for whether the WPI is having ripple effects, Murayama, Kotani, and others point to more foreigners on the faculties of their universities, more joint appointments with overseas institutions, and new programs that make it easier for overseas graduate students and more-senior researchers to adjust to Japan's academic system. At the University of Tokyo, says Murayama, "salaries can now be adjusted by market."

WPI Academy

In recent years Japan's strapped economy has led to growing concerns about the host institutions taking over responsibility for the WPI centers when their 10-year MEXT grants wrap up. "The continual tightening of funding to universities in Japan and the weaker economic performance render it extremely difficult for universities to sustain WPI centers on their own," says Akira Ukawa, deputy program director for the WPI and a scientist at the RIKEN Advanced Institute for Computational Science. Over the past decade, government support for university salaries has decreased by about 10%. And whereas competitive grants have become increasingly narrow and applications oriented, the WPI is looking to do basic research on longer time scales. Following the four 2015 extension denials, says Ukawa, "the big issue became how the four centers would continue."

MEXT's answer is the WPI Academy, an umbrella for graduated and current WPI centers. The academy has three aims, says MEXT's Takuya Saito: uphold the elite WPI brand for the centers; serve as a forum for centers to share their experiences in science, globalization, and system reform; and act as a hub for global circulation of scientists.

MEXT has requested around $6 million to establish the WPI Academy next year, Saito says. If it comes through, it could provide some support to academy members. It would be a lot less than before, notes Murayama, "but it's probably very important symbolically" and could help attract additional funds.

Based on what MEXT has learned from the WPI experience so far, the ministry is changing its requirements for new centers. First, proposals will have to take "a clear stance on human resource development," says Saito. In the past, he explains, the emphasis has been on research, but future centers will need to include an education component. Second, the host institutions will have to spell out more clearly how they will build and sustain their centers after MEXT money runs out.

The MEXT move to establish the WPI Academy and the formation of new centers underscore the success of the WPI program, says Ukawa. "There is a strong feeling that cutting off support won't do. The centers are a valuable long-term asset for science in Japan." **Toni Feder**

Erratic helium prices create research havoc

Researchers report forgoing salaries and taking on fewer graduate students to cope with volatile prices for liquid helium.

In the past six years, Sophia Hayes has seen the price for liquid helium increase by 250% before falling back somewhat this year. A chemist at Washington University in St. Louis, she needs 1900–2500 liters of liquid helium per year to cool the superconducting magnets of the three nuclear magnetic resonance spectrometers in her lab. She currently pays $13 per liter, but as recently as January 2016, she paid $17.35. At that level, her annual helium cost was more than a graduate student stipend.

Before purchasing an instrument with a recirculating helium system, which only occasionally needs to be topped off with helium, Hayes used a continuous-flow cryostat for chilling samples for NMR analysis, and it consumed an average of 40 liters a day during experiments. Even at the $5 per liter prevailing price in 2010, the liquid helium bill was about $30 000 a year. At current prices, the continuous-flow method would be "simply not sustainable," Hayes says.

PRICES FOR LIQUID HELIUM have soared in recent years, and some scientists are reporting difficulty in obtaining the essential commodity for low-temperature research.

Hayes isn't alone. A recent report prepared by the American Physical Society, American Chemical Society, and Materials Research Society says about 400 US researchers experiment at liquid-helium temperatures, and several thousand scientists use NMR spectrometers, superconducting quantum interference devices, and other instruments requiring liquid helium. Most of the low-temperature experiments and instruments housing superconducting magnets must be continuously replenished with helium, which boils off at a rate of a few liters per day. A typical low-temperature researcher has gone from spending 10% of a typical NSF grant on helium five years ago to more than 25% today, according to the report.

Prices are also volatile. "If I'm doing low-temperature research and purchasing liquid helium and I'm trying to forecast whether I can hire that next PhD student as part of this grant, I have no clue what the helium price is going to do next month," says Simon Bare of SLAC, who cochaired the committee that wrote the report.

Scientists fear that the impending 2021 shutdown of the US federal helium reserve, mandated by a 2013 law, will cause further price increases and imperil access to the irreplaceable element. In recent years, the reserve has supplied 15–30% of the world's demand. Helium is a byproduct of natural gas extraction from fields where the helium concentration is high enough—generally 0.3% or greater—to make its separation economical. Most domestic output is from gas fields in Colorado, Kansas, Oklahoma, Texas, Utah, and Wyoming.

Small fish

A major problem for academic researchers is their lack of purchasing clout, says the report. When supplies are tight, small users aren't prioritized for deliveries and might not get helium at all. That can spell disaster for an NMR system, which must be cooled constantly to protect its magnet from damage caused by transitioning to a nonsuperconducting state. About 90% of NMR users don't have the requisite equipment to safely shut down the magnets and must hire a vendor to do so, at a cost of $5000–$10 000, says Hayes. And cooling the magnet back down to a superconducting state can require as much as 1000 liters of helium.

Big helium consumers include MRI (20%), weather and other balloons (14%), and electronics and semiconductors (11%). Today's high price is not the first time the helium market has caused havoc. A worldwide shortage in 2006–07 forced some researchers to reallocate grant funds or petition funding agencies for additional monies to cover their helium costs (see PHYSICS TODAY, April 2013, page 28).

Mark Elsesser of the APS public affairs office says most of the more than 70 researchers surveyed for the report consume fewer than 5000 liters each year, and many use less than 1000 liters. Prices paid by individual researchers ranged from $5 to $28 per liter, with no correlation to location or consumption level. Nearly half of the researchers reported paying between $10 and $14 per liter, but 22 paid $15 or more. In 2010 prices were $7–$10 per liter, according to a National Research Council report, *Selling the Nation's Helium Reserve*.

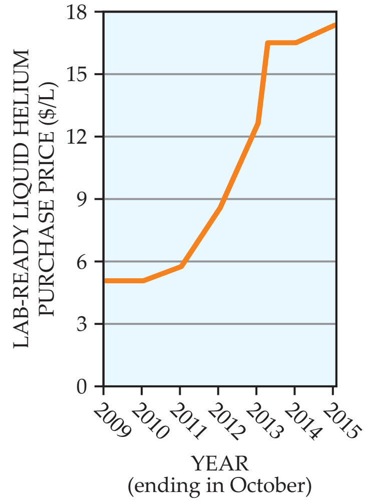
Like others who were interviewed, Bare is at a loss to explain the disparity in pricing. "We couldn't figure out why the price varies so much among the users. There's no logic." It could be that "as soon as this one little thing happens somewhere, everything is so interlinked that there is a chain reaction. A plant goes down for maintenance, there's some interruption, or some huge new demand," he says. "The damping factor has been the helium reserve, and it will be closing in a few years."

But Sam Burton, acting field manager for the Bureau of Land Management's (BLM's) Amarillo Field Office, which operates the federal helium reserve, says many factors could account for the wide disparity in prices. A purchase made on short notice or in emergencies might cost four to five times what a long-lead-time buyer would pay, he says.

"I've heard of stories where a grad student on Friday forgets to turn [an instrument] off, and all weekend it's using helium for nothing," says John Hamak, helium resources evaluation manager at the Amarillo office. "Come Monday, they're out of helium and they put in an emergency order."

Since 2009, the open-market price for crude helium (containing 50–70% He) from the reserve has risen more than 60%. Rising prices caused Qatar to expand its helium output, which in turn led to a supply glut that began in 2015 but is not expected to last. The shutdown of a single processing facility for maintenance could cut off a major portion of the world supply, Burton notes.

Future supplies are uncertain. A huge find estimated at 1.5 billion cubic meters was reported this year in the Rift Valley in Tanzania. But Elsesser notes that prices would have to be considerably higher than today's for industry to invest in the infrastructure needed in that eastern African nation to extract,



THE PURCHASE PRICE for liquid helium for chemist Sophia Hayes of Washington University in St. Louis rose nearly 250% during the five years ending October 2015. (Adapted from the APS/ACS/MRS report *Responding to the U.S. Research Community's Liquid Helium Crisis*.)

refine, liquefy, and ship the helium.

The report warns that scientists are abandoning areas of research that require helium and institutions are shying away from hiring new faculty in cryogenic fields. Alexander Barnes, an assistant professor of chemistry at Washington University in St. Louis, uses copious amounts of liquid helium for his experiments in the nascent field of dynamic nuclear polarization. His solid-state NMR system allows him to obtain images of the structures of drugs within cells—something he says isn't possible with any other imaging technique; operating at 10 K, versus the 100 K achievable with liquid nitrogen, makes the experiments 10 000 times faster.

But Barnes burns through $2000 worth of helium during each six- to eight-hour experiment. At that rate, his grant from the National Institutes of Health is sufficient to pay for only "a couple months" worth of helium. Because innovative junior faculty have less equipment funding available than more established investigators, he worries that aspiring newcomers to the field may be put off by the helium cost. "At $10–$14, we can at least limp along," Barnes says. But if the price doubles, "this technology development will stop."

Recovery and relief

A few large universities operate centralized helium recovery and liquefaction plants. William Halperin runs one such facility at Northwestern University. His own lab recycles 95% of its liquid helium. Other campus users—roughly one-third physicists, one-third chemists, and one-third materials scientists, biologists, electrical engineers, and others—recycle most of their helium, but the university still buys about 10 000 liters a year, for which it pays $6.50 per liter under a five-year contract. Halperin says the low price is due to the contract duration and to having a single, high-volume delivery point. He notes that nearby Argonne National Laboratory has no central recycling plant and pays about $3 more per liter for deliveries to multiple points. Central recycling facilities are far more common in Europe and Asia, where helium prices have historically been higher than in North America, he says.

The societies' report says that a central facility such as Northwestern's could be economical for institutions consuming 30 000 or more liters per year. A "bare bones" system capable of producing 25–50 liters per hour will cost $1 million to $4 million and require a full-time operator. Cornell and Princeton Universities, the University of Florida, and a few others have such plants. Many top-tier research universities would probably meet the usage threshold, Elsesser says, and Texas A&M University is planning to build one.

Single investigators, or a few that share instruments, can purchase a liquefier capable of recycling 1 liter per hour for $100 000–$200 000, the societies' report says. The capital investment can be recouped in three years or less. In one case, Carnegie Mellon University chemist Michael Hendrich has saved $175 000 annually on liquid helium from an upfront investment of $150 000 in a liquefier, the report notes.

Washington University's Hayes says the upfront cost of liquefiers for her four NMR setups is "almost impossible." Having multiple low-temperature researchers on campus, the university buys in volume, and investigators must coordinate buys and avoid wastage. Hayes's cost to fill a 100-liter dewar is about $13 a liter, whereas using a 60-liter container would cost $19 a liter. But buying a larger container won't produce savings if the helium sits around and boils off, and topping off instruments isn't always a good idea, she notes.

APS and ACS have partnered with the Defense Logistics Agency (DLA), part of the Department of Defense, to create a liquid helium purchasing program. As a broker, DLA increases the purchasing power of the program's dozen university members. Since the program began in June, participants have received an average savings of 15% on their helium purchases, Elsesser says, with some reporting a 25% reduction.

Efforts to recruit additional universities to the DLA program continue, Elsesser says, but institutions' existing contractual arrangements and other factors have kept more from signing on.

The BLM's Hamak says the DLA "is starting to get universities and researchers to understand that the farther out you can put your order in, the cheaper you will get it."

Adding a recirculating system to an instrument is an upfront expense that few investigators can afford. Beginning in 2014, NSF's division of materials research has allocated $2 million a year to help with recirculator purchases by grantees who spend $20 000–$30 000 annually on liquid helium. But that's only enough to help 4–5 investigators per year, out of 60–70. The societies' report recommends that a portion of the proceeds from helium sales from the federal reserve be set aside to help universities finance new helium recovery facilities and equipment requiring minimal helium recharges.

More buyers of new equipment are demanding "dry" or "cryogen-free" closed systems that require little or no liquid helium replenishment, says Zuyu Zhao, executive vice president of Janis Research. But he notes that due to their mechanical refrigeration systems, those instruments can produce vibrations that make them unsuitable for some experiments.

The societies' report recommends that BLM eliminate a "major helium requirement" of 7500 liters per year that they say prevents small scientific users from getting a discount on crude helium from the reserve. But that's a misunderstanding, says Hamak: There is no minimum volume required to obtain the 20% discount; researchers simply have to find a helium supplier that will sell them refined reserve helium. That supplier is then required to purchase a comparable amount of crude helium from the reserve. In practice, however, a small buyer of liquid helium won't save much after the cost of purifying and liquefying the crude gas is considered. "If your helium requirement is two 500-liter dewars per year, you probably won't get much of a break," notes Hamak.

The report also calls for BLM to establish a royalty in-kind program that will provide a source of helium to federal users, including grantees, from BLM-leased natural gas formations, once the reserve is closed. The BLM officials say they will begin that process this spring.

David Kramer

With Trump in charge, uncharted waters lie ahead for science

Now that Congress and the White House are firmly in Republican control, President-elect Trump has a clear path to enact his science policy, when it emerges.

Although the incoming administration remains a virtual blank slate on most areas of science policy, Donald Trump's campaign rhetoric and his selection of Oklahoma attorney general Scott Pruitt to head the Environmental Protection Agency point to keeping his campaign promises to roll back President Obama's policies on climate change. Less certain, perhaps, is whether Trump will follow through on his pledge to tear up the landmark 2015 agreement that severely curtailed Iran's nuclear ambitions in exchange for the lifting of international economic sanctions.

Compared with Obama, who for most of his two terms faced a hostile Congress, Trump enters office with both chambers firmly in the control of his own party. Thus, the president-elect should be able to implement his policies through legislation, which will put them on much firmer ground than the administrative actions Obama was forced to use to implement his climate change agenda. Trump will be able to undo many of Obama's climate regulations without having to consult Congress.

Although Trump famously called climate change a hoax, in a 22 November interview with the *New York Times* he had seemed to backpedal on his campaign promise to tear up the 195-nation climate change agreement that was reached in Paris last year. "There is some connectivity," he said, between human activity and climate change, and he added that he had "an open mind" on the issue. In another possible sign he could be tempering his views, Trump and his daughter Ivanka Trump met former vice president and noted climate activist Al Gore on 5 December.

But Pruitt, who has sued the EPA to block implementation of Obama's Clean Power Plan (CPP) to impose limits on carbon emissions from power plants, has questioned the link between human activities and climate change. Pruitt's