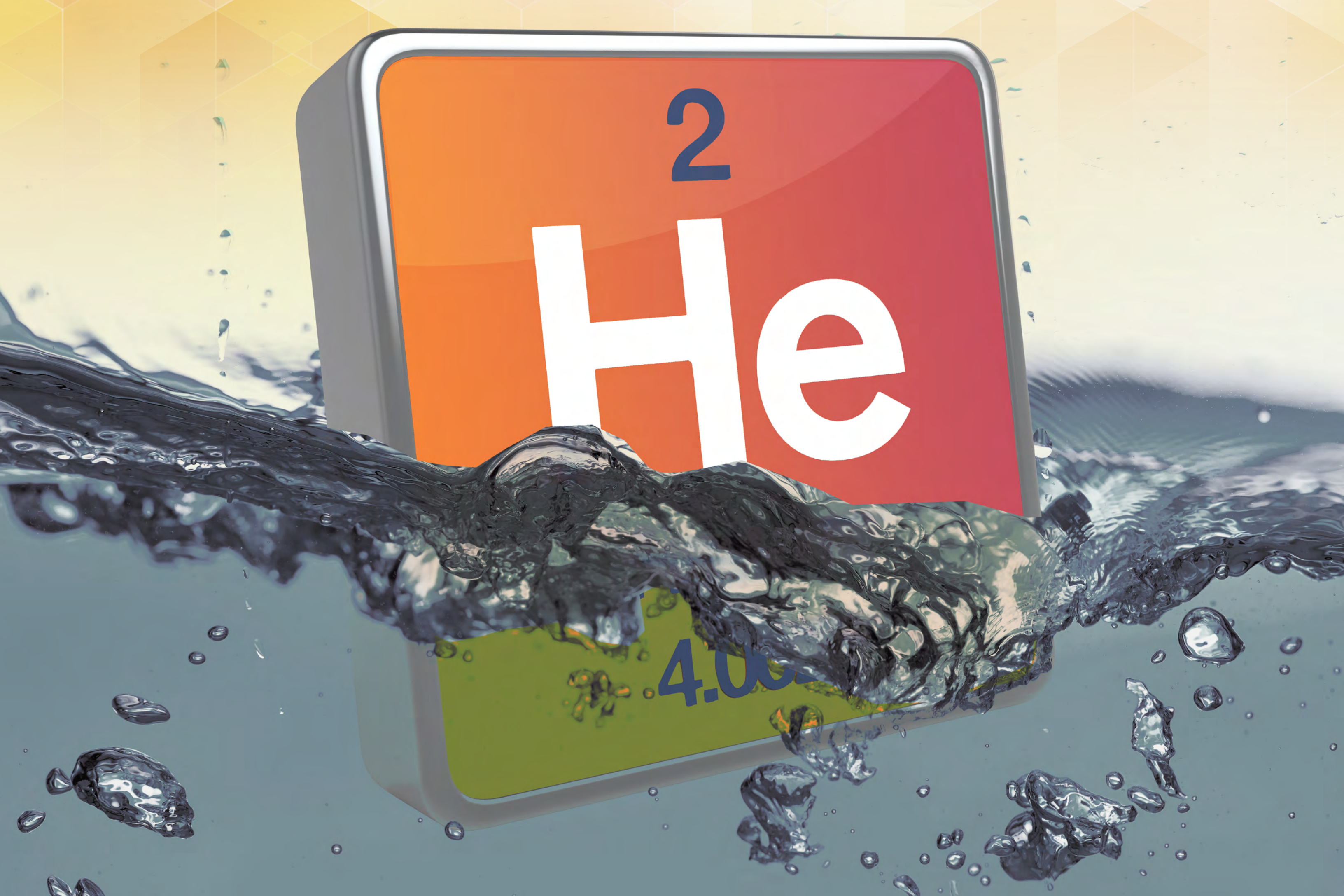
RESPONDING TO

The U.S. Research Community's Liquid Helium Crisis



An Action Plan to Preserve U.S. Innovation

A SCIENCE POLICY REPORT ISSUED BY: American Physical Society, Materials Research Society, American Chemical Society
Representing more than 200,000 scientists, engineers, and innovators worldwide

ABOUT APS & POPA

Founded in 1899 to advance and diffuse the knowledge of physics, the American Physical Society (APS) is now the nation's leading organization of physicists with approximately 53,000 members in academia, national laboratories and industry. APS has long played an active role in the federal government; its members serve in Congress and have held positions such as Science Advisor to the President of the United States, Director of the CIA, Director of the National Science Foundation and Secretary of Energy.

This report was overseen by the APS Panel on Public Affairs (POPA). POPA routinely produces reports on timely topics being debated in government so as to inform the debate with the perspectives of physicists working in the relevant issue areas.

ABOUT MRS

The Materials Research Society (MRS) is an international organization of nearly 16,000 materials researchers from academia, industry, and government, and a recognized leader in promoting the advancement of interdisciplinary materials research to improve the quality of life. MRS members are engaged and enthusiastic professionals hailing from physics, chemistry, biology, materials science, mathematics and engineering – the full spectrum of materials research.

Headquartered in Warrendale, Pennsylvania, MRS membership now spans over 80 countries, with more than 48% of its members residing outside of the United States. MRS organizes high-quality scientific meetings, attracting over 13,000 attendees annually and facilitating interactions among a wide range of experts from the cutting edge of the global materials community. MRS is also a recognized leader in education, outreach and advocacy for scientific research.

This policy report was supported by the MRS Government Affairs Committee.

ABOUT ACS

With more than 157,000 members, the American Chemical Society (ACS) is the world's largest scientific society and one of the world's leading sources of authoritative scientific information. A nonprofit organization, chartered by Congress, ACS is at the forefront of the evolving worldwide chemistry enterprise and the premier professional home for chemists, chemical engineers and related professions around the globe. The Society publishes numerous scientific journals and databases, convenes major research conferences and provides educational, science policy and career programs in chemistry. The ACS plays a leadership role in educating and communicating with public policy makers and the general public about the importance of chemistry in our lives. This includes identifying new solutions, improving public health, protecting the environment and contributing to the economy. This policy report was approved by the ACS Board Committee on Public Affairs and Public Relations.

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PUBLICATION DATE: OCTOBER 2016

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Executive Summary

Liquid helium is the professional lifeblood of tens of thousands of scientists and engineers across America's discovery and innovation landscape, including universities, industries, and national laboratories. It has enabled the development of billion-dollar industries, fueled essential life-saving medical diagnostic tools, led to thousands of patents, generated numerous Nobel prizes – and it remains essential to future innovation.

There is no replacement for liquid helium. Helium is unique among all elements for its ability to reach ultra-cold temperatures. Its essential role in the U.S. scientific enterprise has been documented in multiple reports and statements by many esteemed scientific organizations, including the American Physical Society, Materials Research Society, American Chemical Society, and the National Academy of Sciences.

The quantity of liquid helium used in scientific research is only a small fraction of the total helium market. As a result of this relative small market usage, the scientific community has little, if any, purchasing power in the helium market, and researchers suffer from unpredictability and instability in both supply and price. During the last five years, some researchers have seen prices increase by more than 250%, and the supply has been severely limited and uncertain.

If nothing is done to address these price and supply issues, then there will be a lasting negative effect on the scientific enterprise in the U.S. In fact, as helium has become less available and much more expensive, we have already begun to see damaging signs:

- scientists are abandoning areas of research that require liquid helium;
- professors are having to cut the hiring of graduate students; and
- institutions are moving away from hiring new faculty in areas of research that require the use of liquid helium, which jeopardizes the future health of vibrant areas of scientific research.

This report lays out the issues facing researchers who use liquid helium and the negative impact on U.S. innovation. The report then proposes five key steps that will have a transformative effect on the ability to maintain the ready availability of helium and ensure the vibrancy of the U.S. low-temperature research capability. These recommendations focus on: conservation of helium use; a mechanism to pay for the capital investment required for helium recycling; a mechanism to ensure an appropriate price is paid by researchers for helium; and a methodology which allows researchers to best explore the options available to them.

The comprehensive and achievable recommendations covering the Executive Branch, Congress, and scientific societies are as follows:

1. The White House Office of Science and Technology Policy (OSTP) and the Office of Management and Budget together should develop guidance to federal agencies, which use or support the use of helium, on establishing plans to conserve helium without compromising their mission or the vitality of their research and development programs. The National Science Foundation's Division of Materials Research program to fund small-scale liquefiers for researchers it supports serves as an example, and agencies are encouraged to explore other avenues to conserve and recycle helium. Given the urgency of the situation, federal agencies should submit their plans to OSTP within six months of the issue date of any directive.

2. Congress should mandate that a portion of the monies raised through the sales of crude helium from the Federal Helium Reserve be used to help finance the capital investment in equipment that reduces academic researchers' helium consumption.

3. The Bureau of Land Management (BLM) should clarify and then widely publicize its regulations regarding the in-kind helium program to explain that federal grantees are eligible for the program. The “major helium requirement” volume threshold should be removed for federal grantees.

4. BLM should establish a royalty in-kind program for helium. A portion of the helium extracted from federal lands should be marked as in-kind and sold to vendors based on the current and established pricing methodology. Vendors would be required to refine and resell the helium to federal end-users.

5. The professional scientific societies should develop a methodology to help academic researchers determine if – given helium costs, scientific requirements and existing infrastructure – it is financially beneficial to make a capital investment in equipment to reduce their helium usage. The societies should facilitate contact between interested researchers worldwide and manufacturers of helium liquefiers and recyclers.

Introduction: The Vital Role of Liquid Helium in U.S. Innovation

1

At room temperature, helium is a colorless, odorless gas that is lighter than air. These unpresuming properties at room temperature mask the high scientific value of liquid helium, which allows unprecedented research in the diverse fields of physics, chemistry, and biology.

Helium is unique among all elements for its ability to enable research at ultra-cold temperatures – no other material can enable scientists to reach temperatures that approach absolute zero.[1] Consequently, the vast majority of laboratory equipment that reaches ultra-cold temperatures relies on liquid helium, and reliable access to liquid helium at a manageable cost is essential for many groups conducting basic research at low temperatures.[2]

Liquid helium is the *professional lifeblood* of tens of thousands of scientists and engineers across America's discovery and innovation landscape, including industries, universities, hospitals, and national laboratories. Its crucial role in the U.S. scientific enterprise has been documented in multiple reports and statements by leading scientific organizations, including the National Academy of Sciences (NAS), the American Physical Society (APS), the Materials Research Society (MRS), and the American Chemical Society (ACS).[3]

Liquid helium has *enabled breakthrough discoveries* in medicine, national security, computer technology, and fundamental science. These breakthroughs have spawned billion-dollar industries. Examples include magnetic resonance imaging, semiconductor devices, fiber-optic telecommunications, and space propulsion.

Helium is a scarce and *non-renewable* natural resource. Its availability on Earth is low, and, because it is not gravitationally bound to our planet, any time helium is vented and not recovered at the source – whether during natural gas extraction or while performing scientific

Absolute Zero and The Kelvin Scale

Absolute zero is defined as the temperature at which all motion ceases. On the Fahrenheit temperature scale, absolute zero is reached at -459.67°F. The Kelvin scale is defined as the temperature scale at which absolute zero is equal to 0 K.

Helium's Unique Properties

- Helium liquefies at 4.2 K, colder than any other element.
- It is the only material that does not solidify under normal atmospheric conditions.
- There are two forms of helium – helium-3 and helium-4 – that when combined can be used to reach temperatures less than .01 K.
- Liquid helium is a "superfluid" – a state of matter that behaves like a fluid but with zero viscosity – and the rate at which heat passes through this material is greater than any other known substance.

1 Helium liquefies at 4.2 K, colder than any other gas, and is the only material that does not solidify under normal atmospheric conditions. In addition to the predominant isotope of ^{4}He, there is a lighter and more rare isotope, ^{3}He, which liquefies at even lower temperature. A combination of ^{3}He and ^{4}He can be used in cryogenic systems to reach base temperatures of less than 10 mK.

2 In addition to cryogenic applications, the inert nature of helium makes it an excellent carrier gas for chromatography, purging applications, and nuclear engineering.

3 Examples include: the APS's Conservation of Helium statement: https://www.aps.org/policy/statements/95_3.cfm; NAS's 2010 study titled "Selling the Nation's Helium Reserve": http://www.nap.edu/catalog/12844/selling-the-nations-helium-reserve; APS-MRS joint report titled "Energy Critical Elements: Securing Materials for Emerging Technologies": https://www.aps.org/policy/reports/popa-reports/upload/elementsreport.pdf

research – it is lost forever. And there exists no alternative for this important resource when the worldwide supply is exhausted. There is no substitute.

WHERE DOES HELIUM COMES FROM?

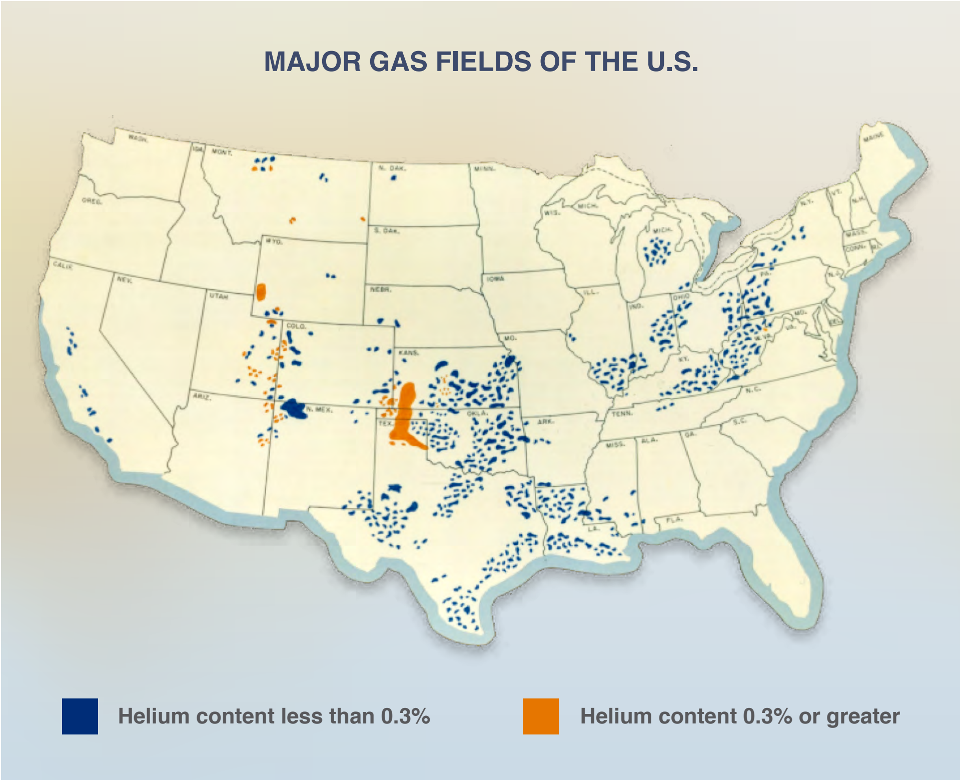
Helium is a product of the radioactive decay of heavy elements located in the Earth's crust, a process that takes hundreds of millions of years to occur; there are no alternative processes to produce helium on a useful timescale. Most helium atoms produced via radioactive decay diffuse to the Earth's surface and escape to the atmosphere where, given current and anticipated future technologies, they cannot be recaptured economically.

A small fraction of the helium naturally produced in the Earth's crust is trapped by underground, impermeable rock formations and – depending on its concentration – may be recovered as a byproduct during natural gas extraction. Given current technology, separating helium during natural gas extraction is only commercially viable for a limited number of natural gas wells.[4] Figure 1A shows the gas fields located in the U.S. that contain a concentration of helium appropriate for recovery.[5]

FIGURE 1A

Helium content of major gas fields in the U.S. Only a small number of gas fields contain the minimum concentration (>0.3%) of helium necessary to make recovery commercially viable.

Image provided by the Bureau of Land Management.



4 Typically, for helium extraction to be economically viable, a natural gas well would contain at least 0.3% percent helium.

5 Figure 1A displays U.S. gas fields where helium was detected by the mid 1970s. According to BLM officials, it generally represents the current understanding of helium distribution in the U.S.

THE HELIUM SUPPLY CHAIN

Getting helium from natural gas fields to the end-user is an intricate, multi-step process. The first step is extracting helium from the mix of gases in natural gas fields that contain a minimum of 0.3 percent helium. The result is “crude” helium, which contains approximately 50-70 percent pure helium with the remainder a collection of various impurities. The crude helium is then refined in a multi-stage process – the details of which depend on the purity of the crude helium supply stream and the intended use – that results in laboratory-ready liquefied helium with purity greater than 99.99 percent.

The distribution of the refined liquid helium is accomplished by large tankers, which transport it from the refining facilities to large liquid helium customers, to redistribution depots, and to U.S. ports for export to international customers. Most end-users in the U.S. receive their helium through secondary distribution channels. Liquid helium, for example, is most often delivered by truck in 50- to 500-liter containers.

A key cog in the current helium supply chain is the Federal Helium Reserve (Reserve), which the U.S. Government, via the Department of Interior and Bureau of Mines, established in 1960 through amendments to the Helium Act of 1925.[6] Initially, the Reserve, which is located outside of Amarillo, TX, was to serve as a strategic repository of helium. Using taxpayer dollars the federal government provided incentive to private oil and natural gas producers to build up the Reserve’s helium supply until 1973, when it became clear that the amount of helium being supplied to the Reserve was far outpacing the federal demand. After passage of the Helium Privatization Act of 1996, the Bureau of Land Management (BLM) was given responsibility for operating the Reserve and charged with recouping the taxpayers’ investment by selling its crude helium to private vendors, a practice which continues today. However, as a means to transition to a full private market for helium, recent congressional action requires BLM to sell off the vast majority of the Reserve during the next several years and cease its operations by Fall 2021.[7]

ENABLER OF INNOVATION & BILLION DOLLAR INDUSTRIES

An initial discovery enabled by liquid helium was that some materials, when cooled to low temperature, suddenly lose all electrical resistance. These materials, known as superconductors, have and will continue to alter the innovation landscape – from their magnetic-levitation (Maglev) abilities used to “float” high-speed passenger trains to the potential for superconducting wires to transform portions of our aging electric power infrastructure through lossless electric power transmission. They are also part of an indispensable medical diagnostic tool: magnetic resonance imaging (MRI). More than 11,000 MRI machines are in hospitals, universities, and medical facilities providing essential – and often life-saving – diagnostic information to patients that cannot be collected in any other way.[8] Without liquid helium, all MRI machines would become inoperable. There is currently no equivalent diagnostic technology to replace it.

Superconductors

Superconductors are materials that display zero electrical resistance when cooled below a characteristic “critical temperature”. Most metallic superconductors have critical temperatures below 30 K and, therefore, require cooling with liquid helium to remain in their superconducting state.

6 For a full history and purpose of the Reserve see: http://www.blm.gov/nm/st/en/prog/energy/helium_program/about_helium.html

7 See the Helium Stewardship Act of 2013: https://www.congress.gov/113/plaws/publ40/PLAW-113publ40.pdf

8 https://data.oecd.org/healtheqt/magnetic-resonance-imaging-mri-units.htm

Superconducting Magnets

A superconducting magnet is created by passing electric current through coils of superconducting wire. The superconducting coils, when cooled below their critical temperature, can conduct significantly larger currents than their ordinary wire counterparts generating magnetic fields that are both high in intensity and more stable. Superconducting magnets, cooled by liquid helium, are widespread in hospital MRI machines, in research labs, and particle accelerators.

Liquid helium is also essential to conducting experimental high-energy physics, often referred to as particle physics, where it is used to cool the superconducting magnets employed at large-scale particle accelerators around the world. The Large Hadron Collider at CERN (near Geneva, Switzerland) – where the Higgs boson was discovered – and the Relativistic Heavy Ion Collider at Brookhaven National Laboratory (Upton, NY) are examples of facilities that rely on liquid helium to operate.

In addition to the dramatic discovery of superconductivity, liquid helium has enabled numerous other fundamental scientific discoveries. Multiple Nobel Prizes have been awarded to discoveries that relied on liquid helium including, but not limited to, the Josephson effect (1973), superfluidity (1978, 1996), the quantum Hall effect (1985) and quantum computing (2012).

Many of the discoveries enabled by the cooling power of liquid helium have found their way into commercial application. In fact, since 1975, more than 5,200 patents relying on liquid helium have been awarded in the U.S.

One particular application that uses liquid helium – nuclear magnetic resonance (NMR) – has become an innovation workhorse. It is ubiquitous in the fields of medicine, chemistry, pharmacology, and physics. NMR instruments are in virtually every research university in the country and even in smaller undergraduate institutions. These instruments are also essential equipment for the pharmaceutical and chemical industries. NMR has revolutionized the synthesis of organic chemicals that have led to new drugs, plastics, and numerous other commercially successful and essential products.

FIGURE 1B

Liquid helium-enabled research has generated breakthrough discoveries, enabled billion dollar industries, spawned innovation and is essential for MRI operation.

Nuclear Magnetic Resonance (NMR) Spectroscopy

NMR Spectroscopy is a common research tool used throughout the physical and biological sciences to investigate the structure and dynamics of atoms and molecules and the materials they comprise. Generally, a sample is placed in a high magnetic field, pulsed with radio waves, and then probed for a response. Modern NMR spectrometers employ superconducting magnets that require liquid helium to maintain the low temperature necessary for the magnet to remain in its superconducting state.

In addition to being essential to billion-dollar industries, cooling essential medical diagnostic tools, and playing a role in historic discoveries, liquid helium will remain essential to future innovation. For example, liquid helium is enabling recent developments in nanoscience that allow the synthesis of tailored materials where electrical, magnetic, mechanical and other properties can be controlled almost atom-by-atom. Helium is also enabling discoveries related to entirely new materials, such as graphene and topological insulators.

Liquid helium has been the lifeblood of tens of thousands of America's researchers and scientists. But we now face a liquid helium supply crisis that – if we do not take appropriate steps – would put American innovation at risk.

The Low Temperature Frontier

Ultra-cold temperatures provide a science frontier, where cutting-edge research can lead to transformative discoveries. Although absolute zero cannot be reached, each step closer to 0 K has provided us new insights about the nature of materials.

2

The Liquid Helium Crisis

During the last few years, liquid helium has become less available and much more expensive. This trend is leading to a crisis for a significant portion of the scientific community who operate with constrained budgets from the federal science agencies. Researchers who are supported by federal grants cannot afford the rising helium costs without sacrificing other aspects of their research programs. This crisis is leading to a reduction in our research and innovation capacity, thereby harming the U.S. economy.

LIQUID HELIUM USERS

Researchers across the physical sciences and engineering disciplines in the U.S. rely on liquid helium to perform a diverse array of experiments and maintain critical instruments. In academia, for example, it is estimated that 400 research groups rely on liquid helium for low temperature experiments, primarily in the physical sciences, and several thousand research groups utilize liquid helium-enabled instruments, such as nuclear magnetic resonance (NMR) spectrometers and superconducting quantum interference devices (SQUIDs), for their research.

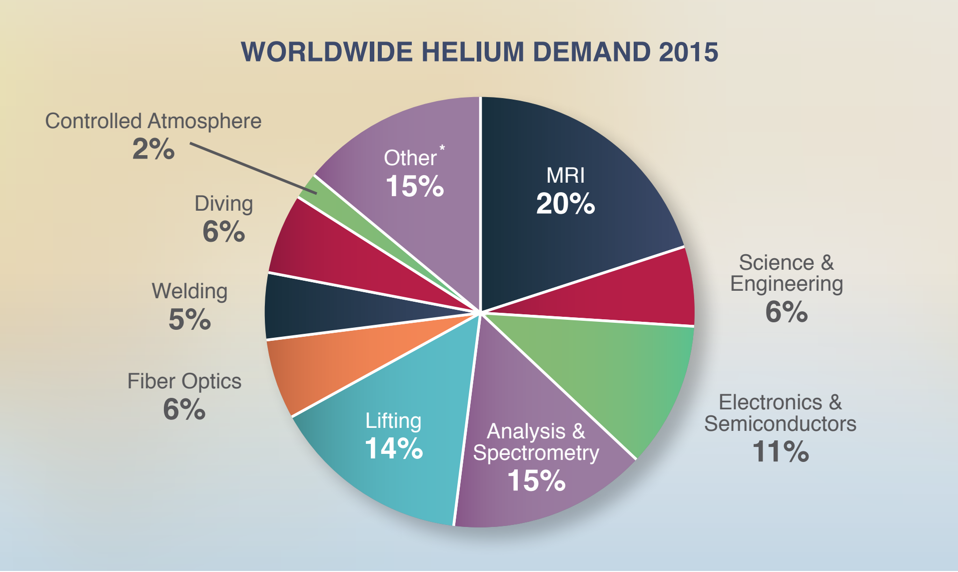


FIGURE 2A

The wide range of uses for helium. In 2015, worldwide demand was estimated at 6.0 billion cubic feet. Data provided by Intelligas Consulting.

* Includes leak detection, pressurization, purging, and other minor uses.

While the number of scientific researchers relying on liquid helium is large, scientific research only accounts for a small fraction of the global helium usage, as displayed in Figure 2A. MRIs, lifting, and semiconductor processing are responsible for nearly half of all helium use worldwide. As a result of its relatively small fraction of the market size, the scientific community has little to no purchasing power in the helium market, and researchers suffer from increasing prices and unpredictability in supply. In recent years, the only certainty for researchers with respect to helium is that the price rises, a trend that is having a crippling impact on the research community.

PRICING

As discussed in Section 1, BLM is currently responsible for operating the Federal Helium Reserve.[1] Figure 2B displays BLM's open-market/conservation price[2] for crude helium. Since October 2009, the open-market price for crude helium has increased by more than 60 percent. While the price for crude helium has increased substantially during the last several years, liquid helium end-users at research institutions across the U.S. have experienced even more dramatic price increases. A chemistry professor at a Midwestern tier-one research university, for example, is currently paying nearly 250 percent more for liquid helium today than the individual paid in 2009 (also displayed in Figure 2B).

"I'm a small-quantity user. Since 2009, my colleagues and I have had our helium price increase by nearly 250 percent."

Because funding agencies do not plan or account for such a dramatic increase in supply costs, many research groups do not have the funds to operate at capacity and have had to make cuts to their research programs – in some cases forgoing their own summer salaries – in order to cover liquid helium costs.

The persistent price increases for helium have imposed hardships on researchers who work with essentially fixed budgets and have had a crippling effect on American innovation. During the mid-2000s, individual investigator awards from the National Science Foundation (NSF)'s Division of Materials Research (DMR) were approximately $130,000 per year and a typical low-temperature researcher would spend up to $15,000 (approximately 10 percent) of their grant annually on liquid helium. In 2015, while the typical DMR grant for an individual investigator has only barely increased to approximately $140,000 per year, awardees are now spending upwards of $40,000 – ***more than one-quarter of their grant and more than the stipend for a graduate student researcher*** – annually on liquid helium.[3] This model is clearly not sustainable, and is having a direct effect on the type, impact, and productivity of the research that is performed. It is certainly not a model to attract the best researchers to begin their research careers in low temperature science.

"I have no buffer. I've skipped my summer salary so I can pay for helium."

1 In addition to selling crude helium to vendors for refinement and resale to industry end-users, BLM sells crude helium from the Reserve under a so-called "in-kind" purchasing program to vendors that is marked for federal end-users, which includes scientists who receive federal grants. In 2014, BLM altered its pricing methodology for in-kind helium, switching from a cost-plus basis (BLM's cost of crude helium plus costs for infrastructure improvements, inflation and maintenance) to simply charging 80 percent of the conservation price. Since 2009, the price of in-kind crude helium, which is offered at a reduced rate, has increased by more than 30 percent.

2 For more information concerning BLM's helium pricing and pricing methodology visit:
http://www.blm.gov/style/medialib/blm/nm/programs/0/helium_docs.Par.50876.File.dat/FY2011PostedPricefinal.pdf
http://www.blm.gov/style/medialib/blm/nm/programs/0/helium_docs.Par.95874.File.dat/FY 2015 Method calc posted price Helium a.pdf

3 As presented by NSF to the Report Committee: http://www.aps.org/policy/issues/energy/helium/upload/helium-meeting-11-19-2015.pdf

FIGURE 2B

Graph displaying helium prices over time. BLM's open market/conservation price for crude helium has increased by more than 60 percent since October 2009. During the same time period the purchase price for liquid helium for a professor at a Midwestern tier-one research university has gone up by nearly 250 percent.

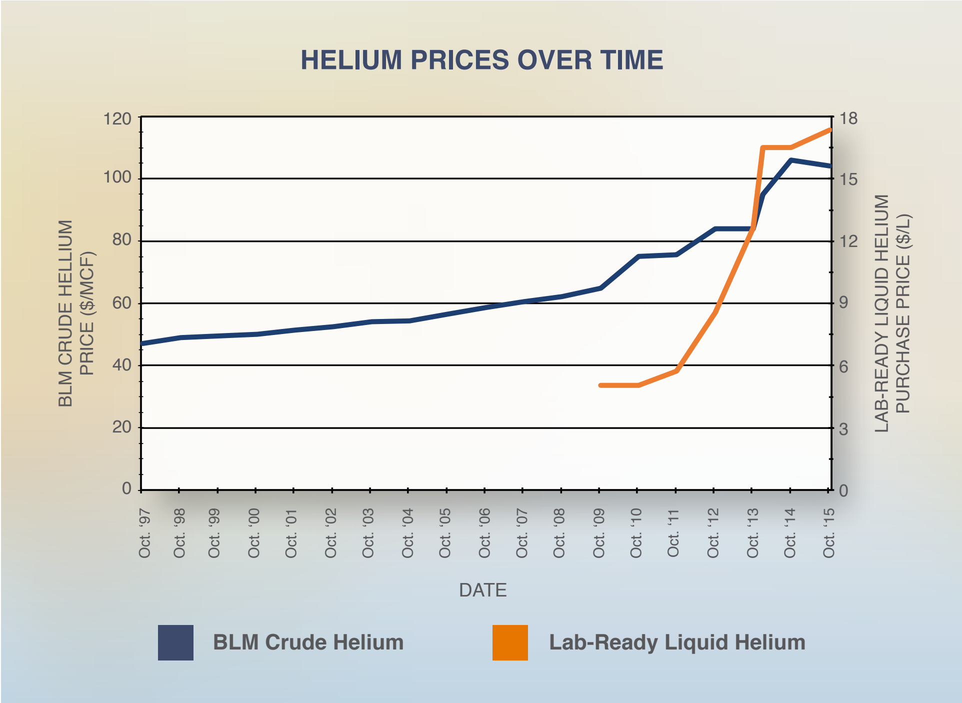
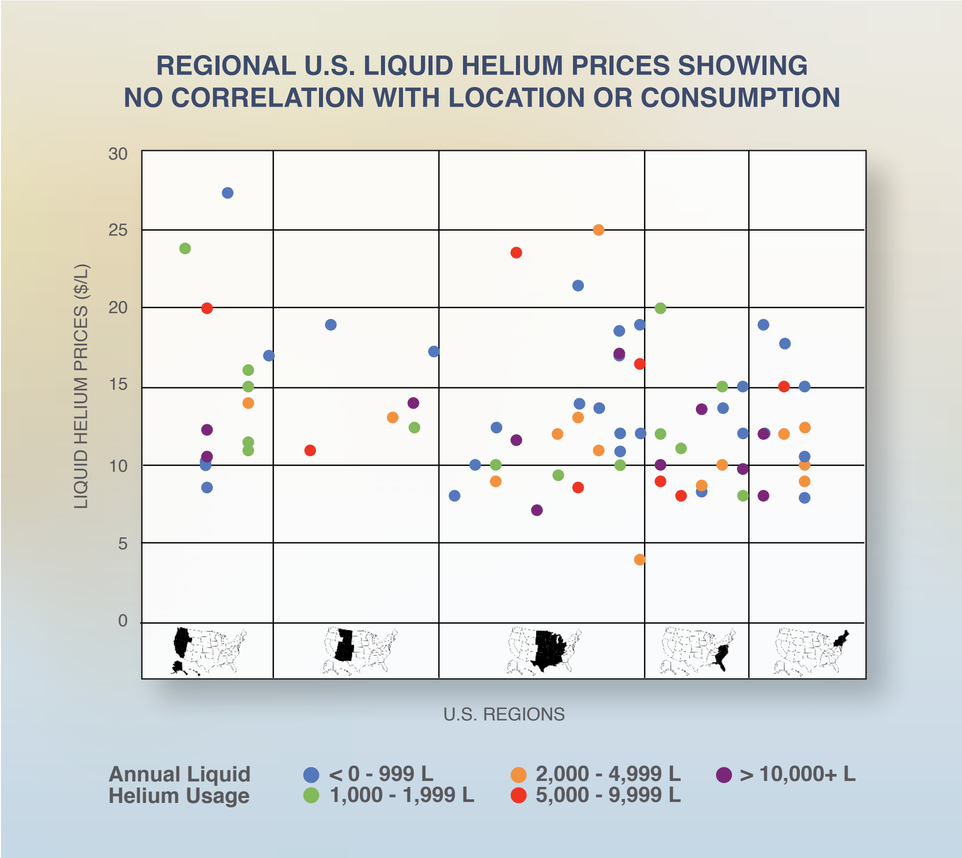


FIGURE 2C

Liquid helium prices for 2014-15 from more than 70 U.S. institutions grouped into five regions. Each marker represents pricing and consumption data from user(s) at a single institution.



Unfortunately, the federal science funding agencies do not collect formal data concerning the price grantees pay for helium; however, broad anecdotal evidence gathered from the academic community over the last several years indicates end-users have experienced substantial – and more importantly, unsustainable – increases in price coupled with unreliability in delivery. As shown in Figure 2C, prices vary greatly, from approximately $5 per liter to $30 per liter, depending on location and usage. But nearly all researchers have experienced dramatic price increases during the last several years.

As previously noted, because scientific researchers account for only a small percentage of the world's annual helium usage, they have no purchasing power in the helium market. The scientific community is – and will continue to be – at the mercy of market pricing determined by negotiations between the large industry end-users and major helium vendors unless other mechanisms are established.

SUPPLY AND DELIVERY

High and volatile prices are only part of the negative impacts that academic researchers face. Unreliable supply and delivery have also plagued researchers in recent years and continue to threaten research groups going forward.

In general, as noted previously, helium supply issues are complex, with supply and demand not always coupled due to a number of factors, including: helium is a by-product of the natural gas industry; it is only supplied by a small number of producers; and the Federal Helium Reserve sales lead to fluctuations in both pricing and supply.

Demand for helium is also difficult to predict, with rapid demand growth during the 1990s due to the development of the electronics and MRI industries followed by slowing demand growth during the times of tight helium supply. Overall, growth in the demand for helium is expected to be tied to the health of the economy. The electronics industry, one of the major helium demand drivers, has rebounded well from the economic downturn and is expected to be a growth driver for helium going forward. Estimated future helium demand will increase 2-3 percent annually, barring introduction of any new helium requiring technologies.[4]

A worldwide helium shortage in 2006-7 interrupted the supply, and therefore the research efforts, of many scientists. In the best-case situations, researchers experienced helium price spikes; they either reallocated funds or petitioned funding agencies for supplemental monies to cover their increased helium costs. Without the resources to cover their helium needs, principal investigators were forced to adjust their research plans. In some cases, grant monies originally slotted to hire and train new graduate students were reallocated to cover the costs of helium.

Less fortunate researchers saw their helium supply cut off completely. There is a severe consequence, should researchers see a gap in the delivery of helium. Many experiments and equipment must be ***continuously*** supplied with liquid helium to remain cold for extended periods of time. Equipment can become useless or permanently damaged if the liquid helium supply is suddenly cut off, and it warms above a threshold temperature. So, an uninterruptable supply of liquid helium is necessary for a vast number of university researchers,

> *"MRIs are in nearly every hospital in the country. And if they don't get their helium – if they warm – they die."*

4 See: Garvey, M. D., CryoGas International, June 2014, 32-36, and Glowacki, B.A., Nuttall, W. J., Clarke, R.H., IEEE Transactions on Applied Superconductivity, 23(3), June 2013.

"We're losing research, we're losing trained students – and there's a long-term cost to that. Never before has the U.S. lost an entire area of research."

hospitals, pharmaceutical companies, and high-tech industries.

And although recent production from Qatar has greatly expanded the helium supply – even creating a surplus in 2015 – current excess in the market is only predicted to last for another 3-4 years, and any changes in natural gas production could quickly change helium availability.[5] New domestic and international helium sources are being developed, but it is not clear that they will be able to meet the projected increases in demand. Moreover, the Federal Helium Reserve's stocks, which accounted for approximately 15 percent of the world's supply in 2015[6] – and more than 30 percent as recently as 2013[7] – are being drawn down, and the recently enacted Helium Stewardship Act of 2013 mandates the Reserve close and dispose of its assets no later than September 30, 2021.

Going forward, there continues to be a risk of demand outpacing supply, and shortages will likely result in retail providers being unable to fulfill their orders. And if the current mode of operation for researchers using helium remains the status quo, researchers will face difficult decisions that jeopardize innovation. With scientists at institutions outside the U.S. facing similar issues with helium pricing and availability, the crisis will only intensify over time.[8]

CONSEQUENCES

Helium's price volatility and instability of supply are severely impacting individual researchers, universities, and national laboratories. As helium has become less available and much more expensive:[9]

- scientists are abandoning areas of research that require helium;
- professors are having to decrease the hiring of graduate students and change spending allocations to pay for liquid helium; and
- institutions are moving away from hiring new faculty in areas of research that require the use of liquid helium, which jeopardizes the future health of vibrant areas of scientific research.

The U.S. now risks losing vital segments of its scientific workforce and entire areas of research crucial to the nation's innovation landscape. The following chapters of this report identify steps that can be taken to address the crisis and ensure the future availability of liquid helium for scientific research.

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5 See, for example: http://www.chemweek.com/sections/basic_chemicals_plastics/74824.html; and Kornbluth, P., CryoGas International, Sept. 2015, 34-36.

6 The Federal Helium Reserve accounted for 938 million cubic feet of the worldwide supply of 5.8 billion cubic feet.

7 The Federal Helium Reserve accounted for 1,442 million cubic feet of the worldwide supply of 4.7 billion cubic feet.

8 Researchers at Universities across Asia and Europe have seen their helium prices increase and have encountered disruptions in their helium supply. For example, in Korea, prices doubled for many researchers from 2011 to 2013; in China, prices increased and delivery was sporadic; Japan recently had its supply cut in half; and prices have steadily increased in Europe.

9 In addition to numerous testimonials from faculty at institutions across the U.S., see for example:
http://www.wired.com/2015/07/feds-created-helium-problem-thats-screwing-science/;
http://www.reuters.com/article/us-helium-shortage-analysis-idUSBRE98I0AN20130919;
http://www.dailyillini.com/article/2015/03/department-of-physics-invests-600000-in-helium-recycling-program;
http://www.phys.ufl.edu/~cryogenics/pdf/physics today helium shortage hampers research and industry.pdf

Paths to Alleviating the Crisis

3

The scientific community recognizes that the challenges associated with helium supply and procurement are not going away. The scientific community and its advocates have developed and are continuing to explore strategies, both short- and long-term, both supply-side and demand-side, to help scientific researchers who rely on helium for their work.

NEAR-TERM ALLEVIATION: THE BROKERAGE

As previously discussed, the helium crisis is impacting scientific researchers at institutions across the U.S. Most research groups have limited options for supply. And scientific researchers at small institutions, located in remote regions of the country, are often the most vulnerable. They typically have small helium requirements, irregular delivery schedules and lack purchasing power in the helium marketplace.

Individual users bring little leverage to the bargaining table, and in areas where there is a single helium vendor, they have no means to negotiate price. Additionally, when small users encounter delivery problems, such as receiving under-filled tanks,[1] they have no path for recourse. When shortages occur, they are not prioritized and may not receive helium at all. Simply put, individual users and small research groups are not a priority for helium vendors.

In an effort to improve liquid helium procurement for federally funded researchers, APS and ACS partnered with the Defense Logistics Agency (DLA) to create the Liquid Helium Purchasing Program, or LHeP^2, which provides more affordable and reliable liquid helium to program members. DLA is not limited to representing end-users affiliated with the Department of Defense; they are permitted to purchase liquid helium and other chemicals on behalf of any federal grantee.

For LHeP^2 enrollees, DLA serves as a broker. By combining its customers' needs, DLA substantially increases its purchasing power when negotiating contracts and price. Additionally, DLA offers program members a more reliable liquid helium procurement route – DLA has established relationships with multiple liquid helium suppliers, and its customers are not necessarily tied to a single vendor. Moreover, as a federal agency, DLA has better ability to enforce breach of contract penalties. The program enrollees achieved more reliable deliv-

1 Liquid helium boils off at a rate of a few liters per day, and small users are often the last stop on a delivery route.

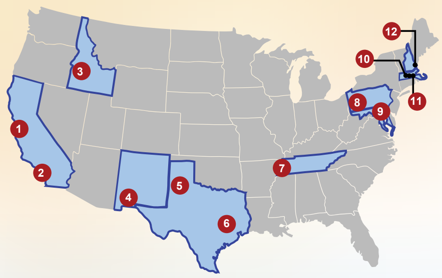
ery and an average savings of 15 percent; one enrollee experienced savings of more than 25 percent.

FIGURE 3A

Map of Institutes participating in LHeP2 beginning June 1, 2016

Liquid He Purchasing Program

PARTICIPATING INSTITUTIONS



The colleges/universities enrolled	Location
1. Stanford University	Palo Alto, CA
2. Occidental College	Los Angeles, CA
3. Boise State University	Boise, ID
4. New Mexico State University	Las Cruces, NM
5. West Texas A&M University	Canyon, TX
6. Texas A&M University	College Station, TX
7. University of Memphis	Memphis, TN
8. IUP Research Institute	Indiana, PA
9. Johns Hopkins University	Baltimore, MD
10. Amherst College	Amherst, MA
11. Worcester Polytechnic University	Worcester, MA
12. University of New Hampshire	Durham, NH

Source: Data from Liquid Helium Purchasing Program APS graphic

LONG-TERM SUPPLY-SIDE ALLEVIATION: R&D TO CAPTURE MORE HELIUM

> *"For the near-term, the program has ensured that we can get the helium when we need it at a stable cost."*

If helium is not captured at the wellhead during natural gas extraction, the helium is vented into the atmosphere, where it will eventually break free from Earth's gravity and escape into space. Thus, there is no economically viable means to recover helium from our atmosphere, and those helium atoms are lost forever. Because the vast majority of natural gas fields within the U.S. (see Figure 1A) contain helium at concentrations less than 0.3 percent – which represents the minimum concentration necessary to make helium recovery economically feasible with current technology – significant amounts of helium are vented into the atmosphere daily during natural gas production.

For natural gas manufacturers to recover helium from sources containing less than 0.3 percent it must be profitable. To improve the economics of recovering helium during natural gas production, one solution is to improve the efficiency of capturing helium at the wellhead during natural gas extraction. By making advances in the membrane technology used in the production process, helium could be recovered at a higher rate and potentially lower cost. Next generation membranes could make it economically favorable for natural gas manufacturers to capture helium from a much larger number of natural gas fields.

This strategy was part of the 2013 Helium Stewardship Act and is currently being implemented by the Department of Energy (DOE) through its Advanced Manufacturing Office (AMO) within DOE's Office of Energy Efficiency and Renewable Energy (EERE) and the Office of Isotopes within the Office of Nuclear Physics in DOE's Office of Science.[2]

2 Section 17(b)(2) of the Act charges DOE with the following: "The Secretary of Energy shall support a research program to develop technologies for separating, gathering, and processing helium in low concentrations that occur naturally in geological reservoirs or formations…" Further, it authorizes up to $3 million to be used for programs under Section 17.

Currently, there are on-going AMO programs that address advanced manufacturing helium gas separation technologies. Included in AMO's budgets for both FY15 and FY16 are line items that are supportive of development of enhanced gas extraction technology programs. In FY 2015, these activities were undertaken through Small Business Innovation Research (SBIR) awards totaling more than $1 million. These projects involve the development of highly selective membranes envisioned to facilitate gas extraction of helium from feedstocks with concentrations below what is currently techno-economically feasible. Implementation of developed innovations in membrane technology would bolster the overall helium supply chain and would improve helium availability for scientific researchers.

LONG-TERM DEMAND-SIDE: TRANSITION TO RECYCLING

Joining a consortium to reduce helium costs can help researchers stretch their funding dollars and mitigate issues in the near-term. But Earth's irreplaceable helium resources continue to be depleted, and reducing our long-term use of helium is vital. To mitigate the helium crisis, academic researchers must reduce their helium consumption to ensure we do not lose our capacity to conduct experiments requiring ultra-low temperatures.

If researchers have no recycling capability, then as they conduct their ultra-low temperature experiments, the liquid helium boils off and vents into the atmosphere where it cannot be recovered. Implementing a helium recycling system, which allows the vast majority of helium to be reused, provides the researcher several benefits, including dramatically reducing their liquid helium costs and conserving a finite resource. In addition, scientists who recycle helium are better protected from the occasional – but severe – helium supply shortages.

There are a number of technology options available for researchers capable of reducing helium usage. Closed-cycle cryostats – or "dry" systems – require either a rare charge of liquid helium or no liquid helium at all to operate,[3] depending on the model and researcher's need. Helium can also be recycled. A recycling system usually involves capturing some or all of the helium gas and reliquefying on-site. Liquefiers can be large turboexpanders with the ability to liquefy approximately 50 to 200 liters/hour, intermediate size Gifford-McMahon cycle systems, or smaller compressor-driven cryocoolers that liquefy approximately 0.5 to 5 liters/hour. For the larger systems, gas can be recaptured and purified. Smaller systems can be mounted directly on the cryostat without an involved gas collection system. Gas capture without reliquefaction can also be accomplished, but it requires much of the infrastructure needed for reliquefaction and agreements with the supplier on helium gas buy-back.

Academic researchers have clearly demonstrated that investing in equipment/instrumentation with helium recovery capabilities, or that are helium-free, can reduce annual helium consumption by more than 95 percent. Moreover, a capital investment in new instrumentation can pay for itself - through reductions in helium purchases - in less than three years for some users.

The recent experience of Chemistry Professor Michael Hendrich at Carnegie Mellon University illustrates this economic strategy for transitioning researchers to new technologies. Prior to 2012, Dr. Hendrich was using instruments that vented helium during operation. That year, with the cost of liquid helium rising significantly and helium supply unpredictable,

> *"I transitioned to a system that recycles helium instead of venting it. At the current price of helium, the new system paid for itself in three years."*

3 "Dry" systems that do not use liquid helium cannot reach as low a temperature as "dry" systems that do use liquid helium.

Professor Hendrich made a decision based on what made the most economic sense. He invested in a new system that had the capability to recover – and not vent – the helium. The capital investment for the liquefier was approximately $150,000, but Professor Hendrich's reduction in liquid helium expenses, because of recovery capabilities, has resulted in $175,000 in savings annually.

The circumstances that made it economically and scientifically favorable for Professor Hendrich to invest in new equipment with helium recovery capabilities are not unique to his laboratory. This was recognized by the NSF's Division of Materials Research (DMR), which, in 2014, began allocating approximately $2 million annually to finance the purchase of small-scale liquefiers for a few grantees who were selected during the grant renewal process. To qualify for the funding, researchers needed to have an established record of receiving DMR grants and to typically spend $20,000-$30,000 annually on helium. According to DMR representatives, there are approximately 60 to 70 more grantees that currently meet these criteria. Unfortunately, DMR's current allocation for the program only affords it the ability to provide four or five researchers the funding to purchase small-scale liquefiers for their laboratories. If no new researchers were added to the pool of candidates, it would still take DMR approximately 15 years to provide the current list of qualified grantees funding to transition to systems with helium recovery capabilities. Moreover, researchers funded by DMR represent only a small fraction of the researchers who rely on liquid helium. There are potentially hundreds of research groups that would find it economically and scientifically favorable to participate in a DMR-equivalent program.

Because most academic researchers do not have sufficient funds to make the lump sum, capital investment necessary to purchase equipment that would dramatically reduce their helium consumption, they are forced to resort to a "pay-as-you-go" system to purchase liquid helium. This results in academic researchers spending millions of taxpayer dollars annually on liquid helium to carry out their research programs. For many, this is clearly not the most efficient use of their funding, and it is literally money evaporating into thin air. Making an investment in equipment that affords a researcher the ability to recover and reuse helium may be the better choice. The next section briefly discusses the current helium recycling technologies available to researchers and offers criteria, which academic researchers should consider when evaluating whether transitioning to systems with recycling capabilities is economically and scientifically viable.

A Decision-Making Methodology for Scientists

4

Effectively addressing the helium crisis requires scientists to evaluate the appropriate action to manage their use of helium. For example, while a transition to a new system that recycles helium may be an excellent decision for some researchers, it may be economically or scientifically prohibitive for others. This section lays out the leading options available to researchers and an appropriate decision-making methodology.

Following the worldwide shortage in 2006-7, continuing fluctuations in availability and escalating prices have encouraged many users to explore other options as a means to minimize helium market exposure. The various approaches are outlined in Figure 4A. Adoption of new methods to manage risk will also affect the demand in growth of helium usage going forward. The adoption of certain technologies has already permanently replaced demand for helium by some applications.

> *"For many researchers, if no recycling method is adopted, they will be highly vulnerable to the risks of escalating prices and supply uncertainty."*

Helium prices have risen rapidly in the past and further price escalations are likely. In addition, many researchers are small-helium consumers and do not have the ability to negotiate favorable long-term pricing agreements as a means to minimize effects of market fluctuations. As such, understanding the current recycling options for helium-using equipment is imperative for determining when current helium use methods are no longer sustainable.

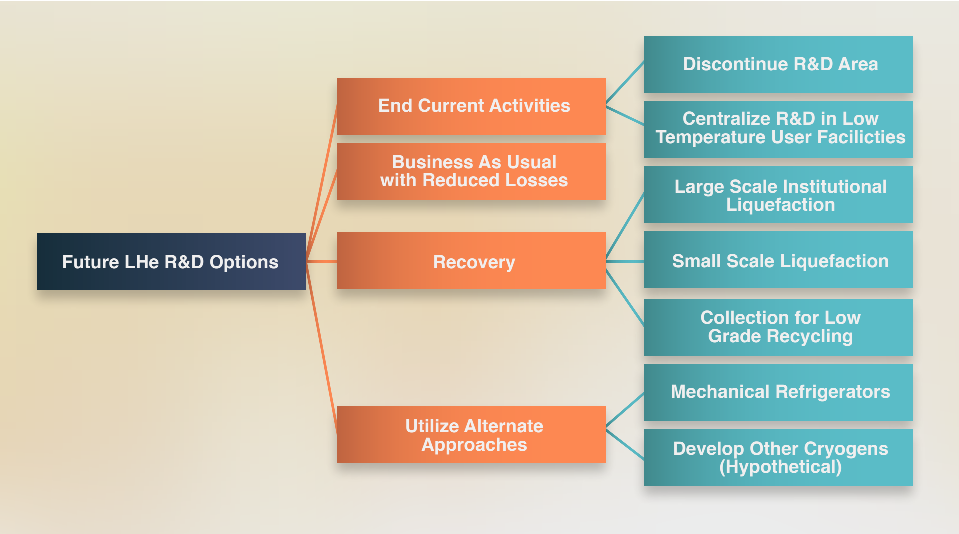


FIGURE 4A

Decision tree outlining possible approaches to reduce exposure to liquid helium supply and pricing variability.

These options are briefly described and evaluated below.

OPTION 1: SHOULD I RECAPTURE HELIUM AND RELIQUEFY AT A LARGE INSTITUTIONAL SCALE?

For academic institutions that serve a number of departments, with annual liquid helium usage greater than approximately 30,000 L/year, it could be economically favorable to invest in small-scale liquefiers, which are typically capable of producing 25 to 50 liters of liquid helium per hour. As a starting point, institutions should develop and evaluate an implementation plan for installing a facility-wide liquefaction system with suitable storage to permit regular bulk delivery. Also, gas recovery from remote laboratories should be included, as feasible. Once fully operational, the system's helium recycling efficiency should exceed 95%. A bare-bones liquefaction system with adequate storage for 3,000 L of liquid, and a corresponding amount for high-pressure gas storage, is an investment of approximately $1.5 to 4 million. Generally, a full-time operator is employed.[1]

Option 1: Recapture and Reliquefy at Large Institutional Scale	
Decision Criteria	What supply of liquid He is needed over what time frame? These systems tend to be delivery-on-demand (i.e. they require only 1 day notice as opposed to 1-2 weeks, as for an order from a vendor), almost regardless of amount. Typical production rates are in the range 25 to 50 liters/hour.
Infrastructure Needs	A facility-wide liquefaction system will require one full-time staff with a part-time back-up staff member depending on scale (i.e., more than ~30,000 liters/year) and all instruments must be plumbed into the system. Dewars are used to transport liquid to users and also are part of the cost.
Cost	Capital cost of liquefaction system estimated at $1.5M-$4M, staff (1-1.5 FTE). In addition, there will be long-term maintenance costs on the large liquefier, large physical footprint, energy costs and cooling costs. Replenishing the helium supply is needed because of unavoidable losses, and costs depend on percent of supply recovered.
Cost Recovery	Installation will result in reduced expenses for liquid He.
Pros	1. Large-scale equipment systems have more long-term use and hence, user experience, and are offered by multiple vendors. 2. In a supply shortage, the on-site inventory can weather a short-term supply issue as long as the losses from the system are not large.
Cons	1. Maintenance for such equipment can be expensive. 2. The constant need for monitoring and maintenance leads to higher labor costs.

1 This has been done at numerous institutions, including Cornell University, Northwestern University, Princeton University, University of Florida, University of Illinois Urbana-Champaign, University of Kentucky and University of Wisconsin-Madison.

OPTION 2: SHOULD I RECAPTURE HELIUM AND RELIQUEFY AT A SMALL SCALE?

The advent of small-scale helium liquefiers introduced by Cryomech in 2007, which are commercially available through many companies, is a significant departure from the previous options available for recycling helium. Single investigators can utilize a small-scale liquefier, which can provide a researcher with requirements of 1 L/hour at an initial system cost of approximately $100-200K. For individual laboratories, helium losses can be reduced to less than 5 percent. Small groups of laboratories can share one or multiple small-scale liquefiers connected to the same recovery system if higher yields are required. Systems should have adequate gas storage (25 L) per unit and liquid storage of 150 L per unit.[2]

Option 2: Recapture and Reliquefy at a Small Scale	
Decision Criteria	**What supply of liquid He is needed over what time frame?** These systems produce a limited throughput of liquid helium (typically 1 liter/hour for one cooling unit). Are these sufficient for the needs of one or more researchers?
Infrastructure Needs	A small-scale liquefier is required (with different siting requirements) and most systems require a gas bag/bladder and gas storage tanks. Utility requirements include high power and cooling (chilled water or an electric chiller). Requires helium gas recovery plumbing from all instruments.
Cost	Capital cost of liquefaction system estimated to be $100k - $200k. Helium losses are small but depend on technology (typically 5%, but for some equipment there can be additional losses depending upon recovery pressure). Periodic maintenance on equipment is needed and can be costly – for example, maintenance is likely to be required every 3 years at an estimated cost of $8,000.
Cost Recovery	Installation will result in reduced expenses for liquid helium.
Pros	1. Dedicated staff is not needed; these are small-footprint systems. 2. Users can be protected from short-term supply shortages.
Cons	1. There have been reports of vibrations in direct systems (closed-cycle or dry) interfering with measurements. 2. Due to the relatively recent market introduction, there is uncertainty about vendor longevity and continued support. 3. Requires coordination if more than one user; helium is not available "instantly" and may require time to collect with slower throughput.

2 This has been done by principal investigators at numerous institutions, including Brown University, Carnegie Mellon University, Dartmouth College, Massachusetts Institute of Technology, Rutgers University, University of California Los Angeles, and University of Maryland.

OPTION 3: SHOULD I RECAPTURE GASEOUS HELIUM?

Researchers interested in helium conservation – but with liquid helium requirements that do not meet the threshold necessary to invest in a reliquefier – may choose to recapture gaseous helium, which results from liquid helium boil off. Because the gaseous helium is not purified and reliquefied, it is generally resold to vendors at “balloon-grade” prices. While the total installation cost for a helium gas recovery system is less than the total cost for a system with reliquefaction capabilities, the resale value of “balloon-grade” helium will most likely not be high enough to result in a good return on investment.

Option 3: Recapture Gaseous Helium	
Decision Criteria	**Will price for resale of recaptured helium and/or public relations/ goodwill be enough to justify effort?** Because helium is not purified and reliquefied, most gas vendors will purchase it at “balloon-grade” pricing.
Infrastructure Needs	System requires piping from all instruments, collection is into a gas bag, and high-pressure compression is needed to fill gas bottles. (The physical size of sufficient low-pressure gas storage is prohibitive because of the 700 to 1, gas to liquid expansion ratio.) Personnel needed to monitor gas filling and coordinating gas bottle pickup/delivery periodically.
Cost	Installation of plumbing/piping between all helium-using instruments, space and plumbing for a tank farm, compressor, and gas bag/bladder.
Cost Recovery	Installation will result in a small amount of cost recovery for resale as “balloon-grade” helium. Typically this will not be enough to give a good return on investment.
Pros	The system is easy to set up and leads to reuse of a nonrenewable resource.
Cons	The system expense will likely not be recovered.[3]

3 The infrastructure capital costs will likely not be recouped during the tenure of a single principal investigator.

Policy Recommendations

5

Helium is a non-renewable, irreplaceable natural resource. Researchers across biology, chemistry, materials science, physics, medicine, and engineering rely on its unique physical properties – its versatility as a cooling liquid, for example – to perform their experiments. Helium-enabled research has yielded critical discoveries in a number of fields, including medicine, energy, national security, and computer technology, and resulted in numerous Nobel prizes. Put simply, as described in Section 1 of this report, helium is central to our nation's innovation ecosystem and global competitiveness.

Without a ready supply of liquid helium, the nation's innovation ecosystem is put at risk, as described in Section 2 of this report. For example, as the helium price continues to rise, the nation's innovators are being forced to allocate a larger portion of their research budget to purchase helium. In some cases, academic researchers are now spending more than one-third of a federal grant on helium. If this trend continues, academic researchers could be priced out of pursuing projects requiring helium. Without changes to U.S. government policies and practices concerning helium, entire fields of research are at risk of elimination.

Outlined below are actionable recommendations for the Administration, Congress, federal agencies and professional scientific societies, which will help ensure a stable, long-term supply of helium for end-users while reducing the research community's consumption over time.

EXECUTIVE BRANCH: OFFICE OF SCIENCE AND TECHNOLOGY POLICY

Helium is essential to the U.S. scientific enterprise, the supply is limited, and it cannot be produced on a realizable timescale. Yet, the United States currently does not have a federal helium conservation policy in place.

The U.S. government, via its funding agencies, is the principal supporter of research that relies on helium. The National Science Foundation (NSF), for example, funds hundreds of research proposals annually that require liquid helium. Additionally, a significant portion of the research conducted at our national laboratories, managed by the Department of Energy (DOE), relies on helium. The Department of Defense (DOD) and National Aeronautics and Space Administration (NASA) also utilize helium to carry out their missions.

However, it appears that, to date, only the NSF's Division of Materials Research (DMR) has taken steps to develop and implement a strategy to help reduce our helium consumption. For a subset of the research groups (i.e., groups that typically spend $20,000-$30,000 annually on liquid helium) DMR funded – to a limited extent – the purchase of small-scale liquefiers during the grant renewal process in 2014. DMR currently allocates approximately $2 million per year to this effort, a level of support that allows a handful of research groups to transition to liquefiers each year. To date, DMR funding has enabled only nine research groups – a small fraction of the community and far short of the current need – to purchase small-scale liquefiers to reduce their helium consumption.

The DMR program is too modest to address helium conservation alone and the United States government currently offers no guidance, recommendations, or best practices to agencies on how to engage in helium conservation.

RECOMMENDATION:

The White House Office of Science and Technology Policy (OSTP) and the Office of Management and Budget together should develop guidance to federal agencies, which use or support the use of helium, on establishing plans to conserve helium without compromising their mission or the vitality of their research and development programs. The National Science Foundation's Division of Materials Research program funding small-scale liquefiers for researchers it supports serves as an example, and agencies are encouraged to explore other avenues to conserve and recycle helium. Given the urgency of the situation, federal agencies should submit their plans to OSTP within six months of the issue date of any directive.

CONGRESS

During the last decade the price of helium has increased by as much as 250%, and today many academic researchers are spending more than one-third of their grants on liquid helium. As the cost rises, researchers are forced to allocate more of their grant funds to purchasing helium and are thereby cost-restricted from exploring new research areas, updating equipment, and hiring graduate students and postdoctoral researchers.

One solution is clear: where possible, scientific researchers must transition to helium recycling to reduce their helium consumption. Congress can enable this pathway.

There is a capital investment associated with transitioning researchers to helium recycling. With the exception of the modest program within NSF's DMR, federal agencies have not budgeted to support wide-range adoption of recycling technology. Unless new funding streams are created to help address the issue, the U.S. risks losing the research capacity responsible for many significant breakthroughs in areas such as medicine, national security, and fundamental science.

The helium being purchased today by many researchers comes from the Federal Helium Reserve, which was established by the federal government and paid for with taxpayer dollars. The Helium Privatization Act of 1996 required that the initial investment plus interest be returned to the American taxpayers through the sale of crude helium to private vendors, and that requirement was fulfilled in 2013.

The Helium Stewardship Act of 2013 requires that a portion of the helium stored in the

Federal Helium Reserve be sold under terms that "maximize the total financial return to the taxpayer." That is not happening. Instead, the taxpayer is being charged twice for the same helium. That unfortunate circumstance comes about because taxpayer dollars were used to put the helium into the Reserve, and now taxpayer dollars – through the researchers' federal grants – are being used to buy the helium back from the Reserve. Charging federally funded end-users for helium from the federally funded Helium Reserve – at a price higher than the cost of operation – means that the taxpayer is being charged twice.

So, this process that charges federal users near-market or market rates for helium from the Reserve does not maximize the total financial return to the taxpayer. In fact, it minimizes the financial return to the taxpayer. *A far better return on investment for the taxpayer would be to use the profits from the federal helium sales[1] – approximately $430,000 per day currently – to finance the purchase of equipment and/or instrumentation that reduces helium consumption for scientific researchers.*

Providing researchers with equipment that dramatically reduces their helium usage would significantly decrease the helium expenditures on their federally funded grant. This will enable researchers to use their federal research dollars to support and train the next generation of scientists, increase their research portfolios to include high-risk, high-reward experiments, and ensure the U.S. retains its critical research capabilities in areas of physics, chemistry, biology, and engineering.

RECOMMENDATION:

Congress should mandate that a portion of the monies raised through the sales of crude helium from the Federal Helium Reserve be used to help finance the capital investment in equipment that reduces academic researchers' helium consumption.

EXECUTIVE BRANCH: BUREAU OF LAND MANAGEMENT

The Helium Privatization Act of 1996 initiated the in-kind program, which allowed federal agencies to indirectly purchase helium from BLM by purchasing refined helium from an authorized federal helium supplier; the supplier was then under contract to purchase an equivalent quantity of crude helium from BLM. The in-kind program requires federal helium suppliers to give federal agencies and their contractors priority over nongovernment users. Additionally, the price of in-kind helium can be less than the open-market price; BLM's current pricing methodology, for example, sets the in-kind crude helium price to be 80 percent of the open-market price.

But not all federal helium users have been able to benefit from the in-kind program. The National Academies 2010 report, Selling the Nation's Helium Reserve, recognized that small-scale researchers – often located at colleges and universities – were disproportionately impacted by the helium price spikes and shortages. Prior to the report, BLM distinguished between helium users under contract with a federal agency and helium users supported

1 Currently, the sale is generating roughly $430,000 per day: http://www.blm.gov/nm/st/en/prog/energy/helium_program/about_helium.html

by federal grants. Those under contract were eligible for the in-kind program while federal grantees did not qualify. Additionally, nearly all small-scale researchers did not meet the "major helium requirement" criteria, approximately 7,500 liters of liquid helium per year, to qualify for the in-kind program.

The National Academies report noted its committee and BLM representatives discussed the in-kind program on several occasions. Ultimately, BLM indicated it believed that researchers supported by federal grants were eligible to participate in the in-kind program. However, the regulations concerning federal grantees' eligibility for the in-kind helium program remain unclear and most academic researchers are unaware of their eligibility. Moreover, federal agencies and suppliers continue to operate with the understanding an end-user must meet the "major helium requirement" volume threshold to qualify for in-kind helium.

RECOMMENDATION:

The Bureau of Land Management should clarify and then widely publicize its regulations regarding the in-kind helium program to explain that federal grantees are eligible for the program. The "major helium requirement" volume threshold should be removed for federal grantees.

The in-kind program relies on the Federal Helium Reserve to function. Purchasing from the Reserve provides researchers a necessary cushion against market volatility. These researchers are on multi-year grants with fixed helium budgets, and therefore they need the additional predictability of price that's provided by the Reserve. Without a federal supply of crude helium, researchers face the price spikes and the price increases that can derail their multi-year federal grant and require suddenly dedicating more of their federal research dollars to purchasing helium.

Ideally, the Federal Helium Reserve would remain open indefinitely and continue to serve the U.S. government's helium supply needs by providing in-kind helium to vendors that is marked for federal end-users, including scientific researchers supported by federal grants. But under current law, the Federal Helium Reserve will stop operations during Fall 2021. Without the Federal Helium Reserve, the current in-kind program cannot operate, and federally supported scientists and researchers would have to face an unpredictable and more costly helium open market. Given the helium market's recent history of price spikes and shortages, there is little certainty in the price academic researchers will have to pay going forward for helium. To ensure the scientific community can continue to have access to a predictable and steady supply of helium, a new in-kind program should be created.

RECOMMENDATION:

The Bureau of Land Management should establish a royalty in-kind program for helium. A portion of the helium extracted from federal lands should be marked as in-kind and sold to vendors based on the current and established pricing methodology. Vendors would be required to refine and resell the helium to federal end-users.

SCIENTIFIC SOCIETIES

The academic research community spends millions of dollars annually to purchase helium. For researchers utilizing helium in open systems – where helium is simply vented to the atmosphere, and not recycled, during the course of an experiment – helium costs can make up more than one-third of their annual research budget. Additionally, researchers using open systems are extremely vulnerable to price spikes; if the cost of helium unexpectedly doubles, as it did for many in 2012-13, they may not have the funds to cover their supply costs.

For the scientific community to maintain its research capacity in fields reliant on helium, where possible, it must reduce its helium consumption. For many helium users, investing in new equipment with recycling capabilities would dramatically reduce their helium consumption and save significant research dollars. While the capital investment in new equipment can be high, it has been demonstrated that the investment in a small-scale liquefier can pay for itself in less than three years, depending on annual helium costs, scientific requirements, and existing infrastructure.

NSF's DMR arrived at the same conclusion: for a subset of academic researchers the best use of federal grant dollars is to purchase new equipment/instrumentation that provides researchers the ability to reduce their helium usage. For 2014-15, DMR dedicated approximately $2 million annually to funding small-scale reliquefiers for a small number of academic researchers, four to five per year, which met the program's criteria. DMR representatives communicated to the committee that there are currently more than 60 academic researchers that meet the program's criteria to receive funding; they are simply limited by the funds available.

Investing in systems to reduce helium usage has proven to be financially viable for a subgroup of researchers. Additionally, manufacturers of such systems (small-scale liquefiers, recyclers, etc.) now offer creative financing options, such as payment plans and lease-to-own choices. However, most academic researchers are unaware of the new financing options and lack a general method to determine if investing in a new system to reduce helium consumption makes financial sense for them. A strong effort should be made to pair academic researchers with manufacturers.

RECOMMENDATION:

The professional scientific societies should develop a methodology to help academic researchers determine if – given helium costs, scientific requirements and existing infrastructure – it is financially beneficial to make a capital investment in equipment to reduce their helium usage. The societies should facilitate contact between interested researchers worldwide and manufacturers of helium liquefiers and recyclers.