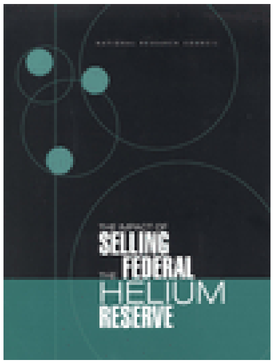
The Impact of Selling the Federal Helium Reserve



Committee on the Impact of Selling the Federal Helium Reserve, Commission on Physical Sciences, Mathematics, and Applications, Commission on Engineering and Technical Systems, National Research Council

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Board on Physics and Astronomy
Commission on Physical Sciences, Mathematics, and Applications
National Materials Advisory Board
Commission on Engineering and Technical Systems
National Research Council

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Preface

In 1996 the U.S. Congress passed the Helium Privatization Act (P.L. 104-273), which ordered the Department of the Interior to begin liquidating the U.S. Federal Helium Reserve by 2005 in a manner consistent with "minimum market disruption" and at a price given by a formula specified in the act. Helium is a rare and nonrenewable resource, however, with many properties critical to a number of important technologies in the commercial, military, and fundamental scientific research sectors. Unlike ordinary goods and services that can be produced virtually forever, every unit of helium that is produced and consumed today will eventually escape Earth's atmosphere and become one less unit available for use tomorrow. The prospect of liquidating the U.S. Federal Helium Reserve is thus a matter of great concern in the commercial, academic, and government sectors. In response to this concern, the Helium Privatization Act also mandated, in Section 8, that the Department of the Interior "enter into appropriate arrangements with the National Academy of Sciences to study and report on whether such disposal of helium reserves will have a substantial adverse effect on U.S. scientific, technical, biomedical, or national security interests."

This report is the product of that mandate and was conducted by a committee, the Committee on the Impact of Selling the Federal Helium Reserve, convened under the auspices of the Board on Physics and Astronomy and the National Materials Advisory Board of the National Research Council (NRC), which is the operating arm of the National Academy of Sciences and the National Academy of Engineering. Nine committee members (none of whom are in the helium supply business) were carefully selected by the NRC to provide a suitable range of expertise and an appropriate balance of experience in helium usage, helium-based research and development, and resource economics. To provide a meaningful context for this effort, the committee examined the helium market and the helium industry as a whole, in order to determine how the users of helium would be affected under various scenarios for selling off the reserve within the constraints set forth in the pertinent legislation. The committee did not assess the pricing strategy spelled out in the legislation because that issue lies outside of its charge. Specifically, the committee's task incorporated the following elements:

- Identify the major current applications of helium in the scientific, technical, biomedical, and national security communities. Determine how much helium each consumes and of what purity.
- Assess whether these applications are likely to grow or shrink over the next 10 to 20 years. Identify any important new uses of helium that can be foreseen over the same period in the user communities being considered.
- Identify any alternatives to the current use of helium in each application above, including conservation, recycling, the use of different purity grades of helium, and the substitution of other materials or other technologies.
- Examine how the above users currently pay for the helium. Assess the flexibility of the funding sources and the price sensitivity of the demand for the various uses.
- Assess the current and projected U.S. market for refined helium, including worldwide helium demand by industrial and other users as well as the users identified above. Examine the availability and reliability of worldwide supply, technical opportunities to increase that supply (e.g., improved recovery), and the relationships among supply, demand, and market price.
- Assess the economic implications of the sales method prescribed in the legislation.
- Develop several scenarios for how the federal helium reserve might be sold, including both full and partial privatization and considering various approaches to the sale, such as futures, incentives, and market timing.
- Under each scenario, determine the likely impact on the cost and availability of helium for the scientific, technical, biomedical, and national security uses examined above.
- Under each scenario for price and availability, assess how access to helium would be affected for users in these communities.
- Synthesize the results of all the above to assess the impact of the sale of the reserve on helium users in the scientific, technical, biomedical, and national security communities. Present several options for accomplishing the sale, with an analysis of each option's advantages and disadvantages for the user communities being considered.
- Suggest ways in which the federal government or others could mitigate any adverse impacts that are identified for each option, by financial mechanisms, by advancing the technology for helium production, recovery, conservation, and recycling, or by other means.

To accomplish its task, the committee collected information from four main sources:

- A site visit by several committee members to the Federal Helium Reserve in Amarillo, Texas, including an extensive briefing session from the technical staff, an inspection of the reserve facilities, and a town forum, in which members of the local community could make statements and ask questions of the committee members;
- Meetings by several committee members with helium industry personnel, including a site visit to the ExxonMobil facilities in southern Wyoming;

- A supplier workshop, in which members of the Helium Advisory Committee of the Compressed Gas Institute briefed the committee on the nature of the helium gas fields, the private helium extraction and purification industries, and the private helium distribution industry; and
- A user workshop, in which representatives of the major users of helium briefed the committee on such areas as fuel-tank purging, leak detection, welding, production of fiber-optic cable, nuclear power generation, magnetic resonance imaging, and fundamental scientific research. The fundamental scientific research session was organized by the American Physical Society.

In each of the cases, the committee permitted the main communities to organize their own briefing sessions. The agendas of the four meetings of the committee, the third of which included the user's workshop, are presented in Appendix A.

The committee's deliberations are organized in six chapters. Chapter 1 provides an overview of the properties that make helium unique and a history of helium's discovery and usage. Chapter 2 details the contents of the federal legislation and the capabilities of the U.S. Federal Helium Reserve in Amarillo, Texas. Chapters 3 and 4 provide overviews of helium demand and supply respectively. The economics of the helium market are reviewed in Chapter 5, and the committee's findings and recommendations concerning the potential long-term consequences of the sale of the Federal Helium Reserve are discussed in Chapter 6.

Robert Ray Beebe and John D. Reppy, *Co-chairs*

Committee on the Impact of Selling the Federal Helium Reserve

Acknowledgments

The committee would like to thank the following people for their support of this project and for ensuring that the committee had prompt access to all of the information it required: Robert Doyle of the Department of the Interior's Bureau of Land Management (BLM), Timothy Spisak of BLM, Carl T. Johnson, president of the Compressed Gas Association, and Robert Park of the American Physical Society. The committee would also like to thank Arthur Francis of AWF Consulting, who provided comprehensive briefings and valuable insight into the history and development of the Federal Helium Reserve.

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The committee also thanks BPA staff members Kevin Aylesworth and Donald Shapero and National Materials Advisory Board staff members Robert Ehrenreich and Daniel Morgan.

Finally, the co-chairs of the committee thank the committee members for their dedication and patience during the course of this study. It could not have been completed without their diligence and goodwill.

Acknowledgment of Reviewers

These proceedings have been reviewed by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's (NRC's) Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the authors and the NRC in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The contents of the review comments and the draft manuscript remain confidential to protect the integrity of the deliberative process. The committee wishes to thank the following individuals for their participation in the review of this report:

P.W. Anderson, Princeton University,
Edward Dowling, Cleveland Cliffs, Inc.,
Howard Hart, General Electric (retired),
Larry Lake, University of Texas at Austin,
J. Ross Macdonald, University of North Carolina (emeritus),
William D. Nordhaus, Yale University,
Doug Osheroff, Stanford University,
Christopher Sims, Princeton University, and
John Tilton, Colorado School of Mines.

Although the individuals listed above have provided many constructive comments and suggestions, the responsibility for the final content of this report rests solely with the authoring committee and the NRC.

Contents

Executive Summary

BACKGROUND

The Helium Privatization Act of 1996 (P.L. 104-273) directs the Department of the Interior to begin liquidating the U.S. Federal Helium Reserve by 2005 in a manner consistent with "minimum market disruption" and at a price given by a formula specified in the act. It also mandates that the Department of the Interior "enter into appropriate arrangements with the National Academy of Sciences to study and report on whether such disposal of helium reserves will have a substantial adverse effect on U.S. scientific, technical, biomedical, or national security interests."

This report is the product of that mandate. To provide context, the committee has examined the helium market and the helium industry as a whole to determine how helium users would be affected under various scenarios for selling the reserve within the act's constraints.

The Federal Helium Reserve, the Bush Dome reservoir, and the Cliffside facility are mentioned throughout this report. It is important to recognize that they are distinct entities. The Federal Helium Reserve is the federally owned crude helium gas that currently resides in the Bush Dome reservoir. The Cliffside facility includes the storage facility on the Bush Dome reservoir and the associated buildings and pipeline.

IMPACT OF THE LEGISLATION

The helium community is currently enjoying an extended period of stability. Since the mid-1980s, there have been no drastic increases in the price of helium and no shortages of supply. The industry has consistently been emphasizing conservation. All the companies on the Bureau of Land Management (BLM) pipeline store their excess crude helium in the Bush Dome reservoir, and their net storage has led to the accumulation of a private stockpile of approximately 4 billion standard cubic feet (scf), equivalent to 110 million standard cubic meters (scm).

The price of helium will probably remain stable through at least 2010. The price established by the Helium Privatization Act for sales from the Federal Helium Reserve is approximately 25 percent above the current commercial price for crude helium. For this reason and because all helium refiners on the BLM pipeline have long-term take-or-pay contracts with producers of crude helium, it is highly unlikely that the refining industry will buy and use gas from the Federal Helium Reserve rather than from private stockpiles or cheaper commercial suppliers.

Once the private reserves are exhausted, however, refiners will have no realistic option other than to begin purchasing the crude available from the Federal Helium Reserve. (The only other source is more production, and production is driven by the demand for natural gas, not the demand for helium.) Nevertheless, under various plausible supply-demand scenarios, private industry will not need to purchase the entire Federal Helium Reserve to meet demand through 2020.

As the Hugoton-Panhandle gas fields are depleted and the Reserve is exploited, the price of crude helium will increase. However, because transportation and purification costs account for a large portion of the price of refined helium, an increase of 25 percent in the price of crude helium would probably increase the price of pure helium by only 8 to 10 percent.

Finding: Based on the information assembled for this report, the committee believes that the Helium Privatization Act of 1996 will not have a substantial impact on helium users.

FOLLOW-ON ACTIVITIES AND RECOMMENDATIONS

Although the committee does not believe the legislation will have a substantial impact over the next two decades, it recommends consideration of a number of research programs and follow-on studies. These will ensure that the legislation has no adverse long-term (beyond 2020) effects, and that sufficient supplies of helium will continue to be available after 2020 to satisfy the needs of known and potential users.

Reviews of the Helium Industry

First, the committee recommends that future reviews of the helium industry be commissioned by BLM either (1) in response to drastic increases or decreases in helium capacity or use or (2) regularly, every 5 or 10 years. The BLM should assist this review by improving its methods for tracking helium capacity and use. The following recommended improvements will help ensure the timely identification of important shifts in the industry:

- Develop and implement a consistent and credible taxonomy of helium uses.
- Develop and implement better methods for tracking the international helium market.
- Report helium reserves using the natural gas industry's classification scheme.

Study of the Depletion of the Reserve

Second, the committee recommends that the BLM study the adequacy of the Bush Dome reservoir as the reserves are depleted. Specific study tasks that should be considered include the following:

- Determine the optimal size of a federal stockpile of crude helium.
- Develop models of gas extraction at the Bush Dome reservoir to predict the helium content of future extracted gas.
- Determine whether the quantity of gas that remains in the Bush Dome reservoir will be adequate to meet future federal needs in the event of a temporary drop in private production.
- Reassess the pricing structure for the storage of helium at the Cliffside facility so that it more accurately reflects the value of the facility.

Research and Development

Finally, the committee recommends that the Department of the Interior conduct research and development to ensure the continued supply of helium into the future. Goals should include (1) new geological models and exploration technologies, (2) improved helium storage systems, and (3) enhanced technologies to conserve, recycle, and eventually replace helium. The following specific tasks should be considered:

- Determine the geological characteristics and processes that permit the formation of helium-rich gas fields and develop methodologies and databases to assist in the discovery of these fields.
- Identify potential sites for natural storage facilities to permit the establishment of new facilities near future major helium producers and to allow an increase in the storage and conservation capabilities of helium users.
- Develop economic models for the extraction and storage of joint-product, nonrenewable resources the production of one of which is dominated by supply and demand for the other.
- Incrementally improve the efficiency of technologies that currently depend on helium and develop alternative technologies that do not require helium

Overview

BACKGROUND: PROPERTIES, USES, AND SOURCE OF HELIUM

Helium is an element with many remarkable properties. The helium atom is smaller than that of any other element, and helium is second only to hydrogen in lightness. It has a particularly stable and symmetrical structure. The nucleus of the atom consists of two protons and either one or two neutrons, depending on the isotope. The two electrons of the helium atom form a closed spherical shell that is tightly bound to the nucleus. The ionization potential for helium is higher than that for any other element. As a result, helium is chemically inert and does not form stable compounds with other elements. The attractive forces between helium atoms are also so weak that helium has the lowest liquefaction temperature of all the "permanent" gases and, unlike all other elements, does not freeze under its own vapor pressure as the temperature is lowered toward absolute zero. At 1 atm, ^{4}He liquefies at 4.2 K, whereas hydrogen liquefies at 20.4 K and neon at 27.1 K.

The properties of helium make it critical to a wide variety of important technologies for commercial and military uses and for fundamental scientific research. For example, helium's low density and inertness make it an ideal lifting gas. Its high thermal conductivity plays a vital role in the heat treatment of optical fibers, while its high diffusivity ensures that no bubbles are trapped to destroy the fiber's properties. Helium's low liquefaction temperature makes it desirable for the purging and pressurizing of liquid-hydrogen rocket propulsion systems and for cryogenic applications such as the cooling of superconducting magnets for magnetic resonance imaging (MRI) machines and superconducting cavities for high-energy accelerators. Liquid helium is also of great scientific interest in itself. Liquid ^{4}He undergoes a phase transition to a superfluid state when the temperature is lowered below 2.2 K. The superfluid properties of liquid ^{4}He are generally believed to be a manifestation of the phenomenon known as Bose-Einstein condensation, where the whole liquid exhibits macroscopic quantum properties such as quantization of the superfluid flow field. Another important research application for liquid helium is the ^{3}He-^{4}He dilution refrigerator, which employs both isotopes and allows routine access to temperatures within a few tens of millidegrees above absolute zero.

Helium is also a rare and nonrenewable resource. Unlike ordinary goods and services that can be produced virtually forever, every unit of helium that is produced and used today will eventually escape Earth's atmosphere and become one less unit available for use tomorrow.

Although the total terrestrial inventory of helium is estimated to be 17,000 trillion standard cubic feet (scf), equivalent to 470 trillion standard cubic meters (scm), most of this supply is in Earth's atmosphere at a concentration of only 5 ppm and would be very expensive to extract. Natural gas, some of which has helium concentrations as high as 8 percent, is the source for most of the helium we use. Generally, natural gas containing more than 0.3 percent helium is considered economic for helium extraction in the United States, although the economics of helium extraction often depend on other products in a natural gas stream. Most U.S. helium-rich natural gas is located in the Hugoton-Panhandle field in Texas, Oklahoma, and Kansas, and the LaBarge field in the Riley Ridge area of Wyoming.

In 1996, the U.S. Congress passed the Helium Privatization Act of 1996 (P.L. 104-273). The act directs the secretary of the Interior to commence offering for sale the approximately 30.5 billion scf (1 billion scm) of federal crude helium at any time before January 1, 2005, and to complete offering for sale all of the crude helium in excess of a 0.6 billion scf (17 million scm) permanent reserve on a straight-line basis not later than January 1, 2015. Furthermore, the act determines a minimum acceptable price for the helium by dividing the program's total debt (about $1.4 billion) by the volume of crude helium in storage. According to the Congressional Research Service, this would establish a selling price of approximately $43 per thousand scf ($1.50 per scm), which is roughly 25 percent higher than the current commercial price for crude helium.

Since helium is a nonrenewable resource, the prospect of liquidating the U.S. Federal Helium Reserve is a matter of concern to many in the commercial and academic sectors. In response to this concern, the Helium Privatization Act also mandated that the Department of the Interior "enter into appropriate arrangements with the National Academy of Sciences to study and report on whether such disposal of helium reserves will have a substantial adverse effect on U.S. scientific, technical, biomedical, or national security interests." This report is the product of that mandate. It was conducted by a committee of experts in helium usage, helium-based research and development, and resource economics that was convened under the auspices of the Board on Physics and Astronomy and the National Materials Advisory Board of the National Research Council (NRC), which is the operating arm of the National Academy of Sciences. The committee examined the helium market and the helium industry as a whole, to determine how the users of helium would be affected under various scenarios for liquidating the reserve within the constraints set forth in the legislation.

FEDERAL AND PRIVATE HELIUM FACILITIES AND CAPACITIES

The Federal Helium Reserve is controlled by the Bureau of Land Management (BLM) of the Department of the Interior and stored in the Bush Dome reservoir in the Cliffside gas field near Amarillo, Texas. The Bush Dome reservoir has a total capacity of approximately 45 billion scf (1.2 billion scm). The facility currently contains approximately 30.5 billion scf (850 million scm) of government-owned crude helium, or about an 8-year world supply at the current rate of use, and an additional 4 billion scf of helium that belongs to private industry. There is no comparable storage facility for helium anywhere in the world.

In addition to the reservoir, the facility possesses roughly 450 mi (720 km) of pipeline and associated surface facilities. The pipeline stretches through Kansas, Oklahoma, and Texas and connects 17 private crude-helium production and refining plants to the federal reservoir. These plants are primarily extracting gas from the Hugoton-Panhandle gas field complex. The operating companies regularly deposit and extract their supplies of crude helium to and from the reserve for either storage or final purification and sale, respectively. These companies are assessed fixed charges for contract administration and connections to the government pipeline. In addition, they are assessed variable charges based on their crude helium activity. The rates for the fixed and variable charges assessed private industry for the storage of helium at the Cliffside facility are calculated to exactly offset the operating expenses of the facility.

Fourteen private companies owned a total of 20 plants in 1996. Of those plants, 13 engaged in helium extraction, 11 (with some duplications) in purification, and 8 also liquefied helium. Approximately 2.8 billion scf (78 million scm) of helium were produced from the Hugoton-Panhandle complex in 1996, 2.2 billion scf (61 million scm) of which was sold and 0.6 billion scf (17 million scm) of which was stored in the Bush Dome reservoir.

ExxonMobil's Shute Creek processing plant in the Rocky Mountain region produced approximately 1.0 billion scf (28 million scm) from the LaBarge field, with an additional 0.2 billion scf (5.5 million scm) coming from other facilities in Colorado and Utah. The Rocky Mountain gas fields do not enjoy access to the helium pipeline, so they cannot store crude gas.

The private refiners in the Hugoton-Panhandle complex that are on the federal pipeline rely on the Cliffside facility to act as a flywheel. Natural gas extraction companies generally sell crude helium to helium refiners on the basis of long-term (e.g., 20-year) take-or-pay contracts, which stipulate that the refiners must buy a negotiated quantity of helium per year from natural-gas producers for an extended period of time regardless of whether they store it, refine it, or vent it. The refiners with access to the pipeline store all of their crude helium in the Cliffside facility and remove and refine it as necessary. Any crude helium in excess of current market demand will thus remain in the Cliffside facility and become part of the company's private stockpile. The amount of helium ultimately produced from the Hugoton-Panhandle complex would certainly be less if the Cliffside facility were not available.

Helium is also produced in small quantities outside the United States. Although there is currently some helium production in Russia and Poland and small amounts in China and some African countries, the most significant helium production outside the United States is currently in Algeria. Although the helium content of the native gas produced at the Algerian facility is only 0.17 percent, economics are favorable since the gas is being liquefied to LNG for shipping, resulting in a stream more highly concentrated in helium. Algerian helium principally enters the European market.

Evaluating U.S. helium reserves and resources is the responsibility of BLM. BLM has constructed a 19,000-sample database of helium concentrations, with much of the measurement having been done at its own laboratory in Amarillo. It also uses data from a variety of sources for its analyses, including Potential Gas Committee reports (see, for example, Colorado School of Mines, 1995) and data from private producers of helium-rich natural gas.

BLM categorizes helium reserves using a U.S. Geological Survey classification system that considers both physical uncertainty and economic viability (see Box OV.1). This nonstandard terminology makes it difficult to understand how much helium is potentially available. The classification scheme used by the natural gas industry is clearer, and all new helium resources are coming from that industry.

BOX OV.1 BLM'S CLASSIFICATION SCHEME FOR HELIUM RESOURCES

BLM Helium Resource Classification Based on Physical Uncertainty

- "Identified" resources are estimated from specific geological evidence.
- "Measured" resources are based on production tests and other measurements made during actual well drilling.
- "Indicated" and "inferred" resources are based on progressively less certain geological data. "Demonstrated" resources is the combination of measured and indicated resources.
- "Undiscovered" resources are postulated to occur in unexplored areas.

BLM Helium Resource Classification Based on Economics

- "Reserves" refer to resources that can be economically extracted.
- "Marginal reserves" border on being economically producible.
- "Subeconomic reserves" are clearly not economic to produce.

The total U.S. helium resource base is estimated by BLM to have been approximately 589 billion scf (16 billion scm) as of December 31, 1996, of which 217 billion scf (6 billion scm) is classified as measured reserves. BLM's measured reserves numbers include both nondepleting reserves (i.e., known but not developed) and those in gas that is being produced but from which helium is not being extracted. BLM estimates nondepleting measured reserves of helium to be around 53 billion scf (1.5 billion scm), the bulk of which lies in deposits in the Riley Ridge area. The Riley Ridge nondepleting reserves are not likely to be produced in the foreseeable future because the gas is of poor quality. In addition, it is estimated that only 60 to 65 percent of helium-rich natural gas is being processed for helium from the Hugoton-Panhandle complex. Although this number is expected to approach 75 percent, a significant portion of these reserves will still be lost when helium-containing gas is ultimately burned as fuel. Accounting for these factors, a realistic estimate of the proved reserves of available helium is 147 billion scf (4 billion scm). At current usage of around 4 billion scf (110 million scm) per year, this reserve represents a reserve/production ratio of over 35 years.

Several factors, however, could alter the helium reserve situation. First, although the Hugoton-Panhandle field is rapidly depleting, operators are initiating programs (e.g., compression) to slow field decline. Such efforts could lead to future increases in natural gas and thus to increased helium reserves. Second, there is evidence that an increasing fraction of Hugoton-Panhandle gas is being processed for helium. Plans for helium processing plant capacity increases on the storage pipeline suggest that this trend will probably continue. Third, there is evidence that natural gas processing facilities in areas other than Hugoton-Panhandle are becoming increasingly interested in processing natural gas for helium, where feasible. All of these trends could act to increase helium reserves beyond those indicated above.

BLM also releases annual reports that track supply and demand for helium. These reports provide crucial information on the helium market and are the primary public source of data on helium use. In the 1980's BLM tracked 13 categories for helium; this was increased to 18 in the 1990s, but only 7 were usually released. These changes severely limited the ability of the committee to track helium usage over time within each category or to identify any dramatic increases or decreases in helium capacity and usage. Likewise, international consumption is not tracked very well. It needs to be tracked with the same precision as domestic consumption in order to permit the identification of any sudden changes in foreign capacity or demand. The current system primarily tracks foreign demand based on U.S. export data.

Because the data on helium demand are inadequate for predicting future trends in helium use, the committee considered a range of possible scenarios for growth in helium consumption. Although helium sales more than doubled between 1985 and 1995, the rate of increase has varied and appears to be declining. Thus, although helium consumption will probably continue to rise in the short term, it may flatten out at a level close to the current level, or even decline.

If helium demand remains constant at the 1998 level, the scenarios indicate that there will be a net storage of helium until about 2004. At that time, helium suppliers will begin to draw down their private stores, which will be exhausted in about 2015. If helium use increases at 1 percent, 3 percent, or 5 percent per year, the private reserves will be exhausted in about 2010, 2007, or 2005, respectively. If helium use decreases at 1 percent per year, the private reserves will not be exhausted until after 2020. If the amount of helium available is greater than the worst-case estimate used in these scenarios, the date at which the private reserve is exhausted will be later than indicated above.

In scenarios where the growth rate of helium consumption is less than 3 percent per year, the amount of helium private industry will need to purchase from the government to meet demand will be less than the amount the Department of the Interior is required to offer for sale. In some scenarios the difference is substantial, and it is even larger if more helium is available than the committee assumed.

ECONOMICS OF THE HELIUM MARKET

The committee's economic analysis of the helium market was based on a comprehensive framework[1] developed by Scherer (1971) and modified by Radetzki (1978) and Labys (1980) to incorporate special features of mineral commodities. These features include geological uncertainty, depletability, and multistage processing. Analysis of the helium market in particular requires recognition of four special factors.

Because helium is a nonrenewable resource, there are concerns about exhaustibility and complications when it comes to the optimal allocation of the resource. Scarcity and the variation in resource quality mean that future sources of supply will cost more to produce. Present consumption from any given source thus forgoes future profits, and the value of the resource is this forgone profit. Theoretically, in a perfectly competitive market, this value will appreciate over time at the discount rate minus the cost escalation rate. Helium prices can be expected to follow this rising path, though the rise may be offset somewhat by the discovery of new deposits or the development and implementation of new technologies (e.g., for conservation and recycling). The rise might also be accelerated somewhat by increased demand. Because helium is a by-product of natural gas, extraction costs are minimal. The appreciation rate is therefore likely to be close to the real market interest rate, currently 2 to 3 percent (4 to 5 percent nominal).

A formula in the Helium Privatization Act of 1996 specifies the future price for sales from the federal helium reserve. Mielke (1997) calculated this price to be $43 per thousand scf (in 1996 dollars). In contrast, the price in the private market is currently about $32 per thousand scf. If the federal price remains constant, the government price will eventually act as a cap on private market prices. The time at which that cap becomes relevant will depend on the rate at which

[1] The committee was unable to construct a fully articulated economic model of the helium market because historical data on the price of crude helium do not exist and the data on demand are insufficient for that task.

private market prices appreciate. If real private prices rise by only 1 percent per year, the cap will not be reached until almost 2030. If they increase at 5 percent per year, the cap will be reached in 2006. At an intermediate appreciation rate of 3 percent, the cap will be reached in 2010, the mid-point of the projected federal sales period (this rate of appreciation corresponds to a 1 percent per year increase in helium consumption according to the Hotelling model).[2] In any of these scenarios, the private price will eventually appreciate again, once the bulk of the federally owned helium has been sold.

Private purchases from the federal helium reserve may accelerate somewhat as the market price approaches the government price. If demand grows substantially and no new high-quality deposits are discovered, the reserve could be drawn down to the target level earlier than expected, or speculative private purchases could accelerate the drawing down of the reserve. The latter case would not affect actual helium consumption, but it would shift ownership from the government to the private sector and mean that carrying costs would be borne by industry.

IMPACT OF THE LEGISLATION

The helium community appears to be in the midst of an extended period of stability. Since the mid-1980s, there have been no drastic increases in the price of helium and no shortages of supply. There has also been a consistent emphasis on conservation within the industry. Every company on the BLM pipeline stores its excess crude helium, which has led to a net storage of the gas and an accumulation of a private stockpile of approximately 4 billion scf (110 million scm). As long as no major changes occur within the community (e.g., drastic increases or reductions in capacity or demand), this stability should continue.

The implementation of the Helium Privatization Act of 1996 should have only a modest impact on the producers and users of helium over the next 10 to 15 years. First, the price established for the crude helium in the Federal Helium Reserve is approximately 25 percent above its current commercial price. Since all helium refiners on the BLM pipeline have long-term take-or-pay contracts with crude-helium producers, it is highly unlikely that the refining industry will buy and use gas from the Federal Helium Reserve in preference to private stockpiles and cheaper suppliers. Second, the Helium Privatization Act dictates that the Cliffside storage facility will not be sold or surplused and will continue to be available for the storage of both privately owned crude helium and the 0.6 billion scf (17 million scm) that the federal government is mandated to permanently maintain. There will thus be no changes to the methods by which private industry conserves helium that would force it to use the crude gas that constitutes the Federal Helium Reserve. Based on these two factors, it would appear that the Federal Helium Reserve will remain largely intact over the next 10-15 years and that there will be little impact on the private producers and users of helium.

In should be noted, however, that some of the Reserve will be sold during this period for consumption by federal agencies. The Helium Privatization Act mandates that all pure helium used by federal agencies must derive from the crude helium stored in the Federal Reserve. This

[2] The idea that holders of an exhaustible resource will require a rate of return roughly equal to the real interest rate is the basic Hotelling model. This model implies that competitive private holders of helium inventory would sell all their holdings before the federal minimum sale price of $43 per thousand scf is reached. For the scenarios in which the appreciation is close to the real interest rate, the date at which the price reaches the federal minimum price is the date that the private reserve is exhausted.

quantity is modest, about 0.2 billion scf (5.5 million scm) per year. Since the price for crude helium mandated by the act is higher than commercial prices, the price paid by the federal government will be higher than the price in the commercial market.

The net storage of helium by private industries at Cliffside field will probably cease within the next 10 years, for two reasons. First, demand for helium will probably continue to rise somewhat over the next few years, so helium refining will increase to satisfy user needs. Second, the Hugoton-Panhandle gas fields are becoming depleted, meaning that less privately produced crude helium will be available for the plants on the BLM pipeline. To remain in business and satisfy demand, the refining companies on the pipeline will first exploit their private stockpiles at the Cliffside facility. Once these private stockpiles are exhausted, the companies will have no realistic option other than to begin purchasing the crude available from the Federal Helium Reserve. (The only other source is more production, and production is driven by the demand for natural gas, not the demand for helium.) The quantity of crude helium drawn will increase, and refiners will become more and more dependent on this resource. Assuming no dramatic changes in the production and use of helium, however, the Federal Helium Reserve will still last for about 20 years or more, meaning that the federal target of 0.6 billion scf will not be attained until approximately 2020 or 2025.

Some changes will occur in the helium industry during the period in which the Federal Helium Reserve is being exploited, but the overall industry will probably remain stable. Although the release of the reserve will probably keep the price of crude helium lower than if no release occurs, there may be a slight increase in the price of refined helium. As the Hugoton-Panhandle gas fields are depleted and the Federal Helium Reserve is exploited, the price of crude helium will rise to the congressionally mandated price. A large portion of the price of refined helium comes from the cost of purifying and transporting the pure gas, however, so a rise of 25 percent in the price of crude helium would probably increase the price of pure helium by only 8 to 10 percent, which is not likely to have a dramatic impact on helium users. A second possible change resulting from the rise in price might be the emergence of investor interest in purchasing helium for speculation, although it is questionable whether the price of helium will rise sufficiently to make it more attractive to speculators than other investments. Even if it does, however, because long-term storage of crude helium is currently possible only at the Cliffside facility, any such investors would eventually have to sell their resources to the refining companies on the BLM pipeline, so the material would remain available.

The only remaining question about the legislation is whether its implementation will result in the repayment of the federal debt within the stipulated time period. The committee believes that it is unlikely that the Federal Helium Reserve will be sold, and the debt repaid, by 2015, since sales of the stockpile to nonfederal users will probably not begin until about 2010 or 2015. However, the impact on helium users of a failure to repay the debt is likely to be small, because the debt no longer accrues interest and is carried by our entire society.

Finding: Based on the information assembled for this report, the committee believes that the Helium Privatization Act of 1996 will not have a substantial impact on helium users.

The Helium Privatization Act of 1996 requires that the secretary of the Interior, after receiving this report, consult with industry and others and then, if he believes the situation so warrants, make recommendations for legislation to mitigate the adverse impacts. In those consultations, a number of issues are likely to arise that are outside the main scope of the present study. These include concerns such as whether:

- Enacting legislation to reduce the price of crude helium below commercial levels or to sell it in lots at auction could seriously destabilize the helium market by increasing the probability that a single company or individual will purchase all or most of the helium in the reserve, thus creating a helium refining monopoly;
- The total supply of helium produced from wells would diminish if part of the reserve were sold before it was needed to meet the demand for helium;
- The debt repayment schedule is appropriate;
- There are alternative methods for raising revenue if the government is intent on repaying the debt faster than is possible under the current legislation; and
- The preservation of a viable, unsubsidized helium industry that helps this country to excel in many areas of science, technology, and national security outweighs the method and timing of debt repayment.

Unless new light is cast on these issues during the secretary's consultations with industry and others, the committee can find no reason to recommend seeking changes in the legislation.

FOLLOW-ON ACTIVITIES AND RECOMMENDATIONS

Although the committee believes that the implementation of the Helium Privatization Act of 1996 should not have an adverse effect on the overall production and usage of helium over the next two decades, there are a number of research programs and follow-on studies that should be considered because they would ensure that sufficient supplies of helium continue to be available to satisfy the needs of known and potential users beyond 2020.

Follow-on Studies

The committee's assessment of the impact of the Helium Privatization Act of 1996 was based on a number of assumptions about the future. The first assumption was that demand for helium would continue to rise at a steady pace, albeit much more slowly than between 1985 and 1995. The second assumption was that no drastic reductions in capacity would occur, such as a plant off the BLM pipeline ceasing production (as a result, for example, of natural disasters, plant disasters, or market decisions). The third assumption was that no new large-volume sources of helium would be discovered.

The legislation mandates that the impact of the Helium Privatization Act of 1996 should be reassessed in 2015. A mechanism should be developed, however, to ensure that a review can occur earlier, especially if anything happens that would change any of the three assumptions. The most prudent approach would be for the helium industry to be reviewed on a periodic basis, say, every 5 or 10 years.

Recommendation: The committee recommends that future reviews of the helium industry be commissioned by BLM either (1) in response to drastic increases or decreases in helium capacity or use or (2) regularly, every 5 or 10 years.

BLM should assist this continual review by improving its methods for tracking helium capacity and use. The following recommended improvements will help ensure the timely identification of important shifts in the industry:

- Develop and implement a consistent and credible taxonomy of helium uses.
- Develop and implement better methods for tracking the international helium market.
- Report helium reserves using the natural gas industry's classification scheme.

The Helium Privatization Act of 1996 stipulates that the Federal Helium Reserve should eventually stabilize at 0.6 billion scf (17 million scm), which is approximately a 2-year supply at current demand levels. The committee believes that a study is required to determine whether this is an optimal long-term supply and whether this quantity of gas can remain in the Bush Dome reservoir at sufficient concentrations to be available for future refining.

Recommendation: The committee recommends that BLM study the adequacy of the Bush Dome reservoir as the reserves are depleted. Specific study tasks that should be considered include the following:

- Determine the optimal size of a federal stockpile of crude helium.
- Develop models of gas extraction at the Bush Dome reservoir to predict the helium content of future extracted gas.
- Determine whether the quantity of gas that remains in the Bush Dome reservoir will be adequate to meet future federal needs in the event of a temporary drop in private production.
- Reassess the pricing structure for the storage of helium at the Cliffside facility so that it more accurately reflects the value of the facility.

Research Programs

To ensure the continued supply of helium into the future, research and development should be conducted in three main areas.

Recommendation: The committee recommends that the Department of Interior conduct research development to ensure the continued supply of helium into the future. Goals for this research and development should include (1) new geological models and exploration technologies, (2) improved helium storage systems, and (3) enhanced technologies to conserve, recycle, and eventually replace helium.

The following specific research and development tasks should be considered:

- Determine the geological characteristics and processes that permit the formation of helium-rich gas fields and develop methodologies and databases to assist in the discovery of these fields.
- Identify potential sites for natural storage facilities to permit the establishment of new facilities near future major helium producers and to allow an increase in the storage and conservation capabilities of helium users.
- Develop economic models for the extraction and storage of joint-product, nonrenewable resources the production of one of which is dominated by supply and demand for the other.
- Incrementally improve the efficiency of technologies that currently depend on helium and develop alternative technologies that do not require helium.

1

Properties and History

Helium is an element with many remarkable properties and a fascinating history. An accurate assessment of the possible effects of the Helium Privatization Act of 1996 is not possible without first understanding the reasons why helium is so important and the historical context of the legislation. This chapter presents and overview of the properties that make helium a unique resource and discusses the history of helium usage up to 1996, when the legislation was enacted.

UNIQUENESS OF HELIUM

The helium atom is smaller than that of any other element and second only to the hydrogen atom in lightness. It has a particularly stable and symmetrical structure. The nucleus of the atom consists of two protons and either one or two neutrons, depending on the isotope. The two electrons of the helium atom form a closed spherical shell that is tightly bound to the nucleus. The ionization potential for helium is higher than that for any other element. As a result, helium is chemically inert and does not form stable compounds with other elements. The attractive forces between helium atoms are also so weak that helium has the lowest liquefaction temperature of all the "permanent" gases and, unlike all other elements, does not freeze under its own vapor pressure as the temperature is lowered toward absolute zero. At one atmosphere pressure, ^{4}He liquefies at 4.2 K, whereas hydrogen liquefies at 20.4 K and neon at 27.1 K.

Of the two stable helium isotopes, the lightest is ^{3}He. This isotope is relatively rare and is obtained as a by-product of nuclear weapons production, following the radioactive decay of the hydrogen isotope tritium. The heavier helium isotope, ^{4}He, is the more abundant form and available from a number of sources, including Earth's atmosphere. As will be discussed in Chapter 4, however, it is most economically obtained as a by-product of natural gas production.

The first large-scale use of helium for nonscientific purposes was its substitution for hydrogen as a lifting gas in lighter-than-air applications (e.g., balloons, zeppelins, and blimps). Although hydrogen provides about 7 percent more lift than helium, it is much more dangerous to use, as was dramatically demonstrated when the zeppelin Hindenburg exploded and was then destroyed by fire at Lakehurst, New Jersey, in 1937. The inertness of helium firmly established it as the lifting gas of choice for most applications.

The properties of helium that make it desirable for application as a lifting gas (i.e., its chemical inertness and low mass) also underlie its use for many other commercial applications. There are, however, two other properties of helium that are important in some special industrial processes. First, the thermal conductivity of gaseous helium is five to six times greater than that of other gases (the exception is hydrogen, which is comparable in thermal conductivity). Second, helium atoms share with hydrogen the ability to diffuse with relative ease through many solid materials, especially at elevated temperatures. An example in which these properties play a vital role is the manufacture of optical fibers, where the high thermal conductivity is important during the heat-treatment phase of fabrication, and the rapid diffusion of helium through the glass ensures that there are no trapped bubbles that would destroy the desired properties of the fibers.

Helium's low liquefaction temperatures make it desirable for purging, pressurization, and cryogenic applications. The fact that it remains a gas at liquid hydrogen temperatures makes it especially useful in the purging and pressurization of liquid hydrogen rocket propulsion systems. Another important use for liquid helium is in the cooling of superconducting magnets, an application of increasing importance with the advent of such technologies as magnetic resonance imaging (MRI) and superconducting cavities for high-energy accelerators (see Chapter 3).

Liquid helium is also a subject of great scientific interest in itself. Liquid ^{4}He undergoes a phase transition to a superfluid state when the temperature is lowered below 2.2 K. The superfluid properties of liquid ^{4}He are generally believed to be a manifestation of the phenomenon known as the Bose-Einstein condensation, where the whole liquid exhibits macroscopic quantum properties such as quantization of the superfluid flow field. A practical aspect of superfluid helium is its extremely high thermal conductivity, which is orders of magnitude greater than that of other excellent thermal conductors (e.g., copper). Another important application for liquid helium is the ^{3}He-^{4}He dilution refrigerator, which employs both isotopes and allows routine access to temperatures within a few tens of millidegrees above absolute zero. Studies of materials at liquid helium temperatures or using liquid-helium-cooled apparatus play a central role in modern materials research. These cryogenic applications depend crucially on the unique properties of helium and can be expected to ensure a demand for helium for the foreseeable future.

HISTORY OF HELIUM USAGE

Helium was essentially unknown before the twentieth century. It was first detected in the spectra of solar prominences observed during the solar eclipse of August 18, 1868. The art of spectroscopic observations and interest in them had advanced sufficiently since the preceding total solar eclipse that at least six separate observers were able to identify a new spectroscopic line in the atmosphere of the Sun. The line was initially thought to be that of sodium, but it was concluded later that year that it was actually evidence of a new element. This element was named helium, after the Greek word for Sun.

Nearly 30 years passed before the element helium was detected from terrestrial sources. It was not until 1895 that Sir William Ramsay and Lord Rayleigh reported the spectroscopic observation of helium in gas evolved from uranium and thorium ores. Following this report, helium was soon discovered in trace quantities from a variety of sources, including the atmosphere.

BOX 1.1 NATURAL GAS

Natural gas is a naturally occurring mixture of hydrocarbons and other compounds. Like petroleum, natural gas is generated by the deterioration of organic materials under anaerobic conditions. It consists primarily of light hydrocarbons (e.g., methane and ethane) with some heavier hydrocarbons (e.g., butane and propane). Impurities (e.g., sulfur dioxide, carbon dioxide, and helium) can also occasionally be present in various concentrations.

The supply situation changed dramatically in the early 1900s, when helium was found to exist in rather large quantities in the natural gas wells of the midcontinental United States (see Box 1.1 for a description of natural gas). The best known story concerns the exploratory well drilled in 1903 at Dexter, Kansas, which produced a gas that refused to burn. Subsequent analysis of the gases from this and neighboring wells by Cady and McFarland showed that the helium was at concentrations of around 1 percent by volume. Although geologists and oil producers reported a number of natural gas fields from which helium could potentially be produced, interest in commercial recovery did not develop until the onset of World War I. For example, Kamerlingh Onnes obtained the helium for his early 1908 experiments on the liquefaction of helium by a tedious extraction from a mineral source, monazite sands.

The British government became interested in helium as a lifting gas early in War World I. Although not as buoyant as hydrogen, helium would not burn and thus could withstand enemy fire. The British initiated a research program at the University of Toronto, Ontario, in 1915, and a small experimental plant was operating near Hamilton, Ontario, by 1918. No Canadian helium was actually used in warfare, but the separation technology was demonstrated at Hamilton and later at Calgary, Alberta, in 1919 and 1920.

The task of establishing a domestic source of helium was given to the U.S. Bureau of Mines (BOM) when the United States entered World War I. BOM contracted the construction of three helium extraction plants: two at Fort Worth and one at Petrolia, Texas. The three produced about 200,000 scf (5,500 scm) of helium in experimental runs, and 140,000 scf (4,000 scm) of compressed gas was awaiting shipment to Europe at the war's end. It is not surprising that there was no thought given to long-term storage of helium at this point, except as compressed gas in cylinders ready for immediate use.

Cognizant of Germany's relative success with military zeppelins, the U.S. Navy began a program immediately after the war to develop rigid airships as naval weapons. The first full-scale U.S. helium production plant, completed near Fort Worth in April 1921, was based on the experimental wartime plant designed by Linde Air Products. The plant was operated for the Navy under contract by Linde until 1925, when it was turned over to BOM. With the Petrolia gas field nearing exhaustion, the plant was mothballed in 1929, by which time it had produced some 47 million scf (1.3 million scm) of helium. As before, no thought was given to long-term storage in a reserve.

In anticipation of the Fort Worth closure, BOM decided to build a new plant, the first unit of which went into production in April 1929, followed by a second unit in May 1930. This plant, near Amarillo, Texas, subsisted on natural gas from the Cliffside field, which was connected by a 12-mi (19-km) pipeline. The methane produced was pipelined about 7.5 mi (12 km) to Amarillo, where it was used as fuel. The plant could produce as much as 25 million scf (700,000 scm) of helium per year but never operated at full capacity.

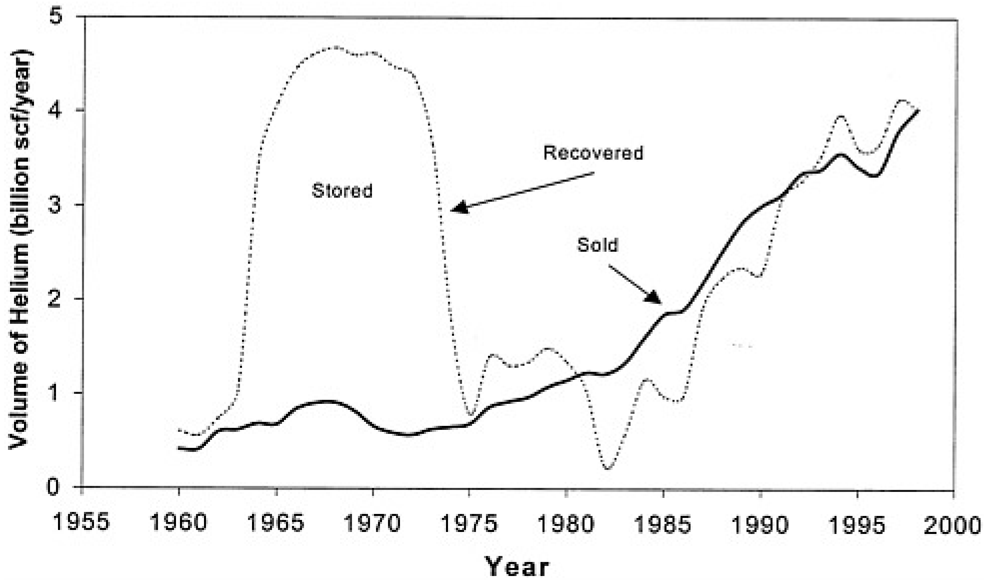

FIGURE 1.1
Annual helium recovery and sales, 1960-1997. The area between the curves is the net amount that was added to or r emoved from the reserve (courtesy of the Bureau of Land Management).

Although helium in the ground was owned by the federal government and could only be purchased—unlike oil and gas, which could be leased—the Girdler Company built two commercial helium plants in 1927-1928: one at Dexter, Kansas, and the other at Thatcher, Colorado. These plants made Girdler the only private helium producer in the world at the time. Over the next 10 years, Girdler produced some 14 million scf (380,000 scm), almost 90 percent of which went to the Navy airship program. The Girdler plants were sold to the U.S. government in 1937, returning helium to the status of a federal monopoly. Later, BOM built a fourth plant, the Exell facility in Texas, which eventually became its last operating plant.

Considerable optimism about future markets for helium developed in the 1950s, and helium began to be considered as a resource for the Cold War. As a result, Congress enacted the Helium Act Amendments (P.L. 86-777) in 1960, which in essence directed the secretary of the Interior to (1) accomplish the acquisition and conservation of helium, using the partially depleted Bush Dome reservoir in the Cliffside field for storage and (2) buy commercial crude helium, using funds borrowed from the Treasury. The act also permitted private helium production, so that BOM would become a buyer of last resort. As a direct result of the 1960 Act and on the basis of 22-year contracts with BOM, several private oil and gas producers built five new helium extraction plants. It soon became apparent, however, that the optimistic market projections were not going to be met. BOM had 35 billion scf (970 million scm) of crude helium in storage by 1973 (see Figure 1.1), plus a large and growing debt to the Treasury. Under the circumstances, the government cancelled the contracts, touching off several years of litigation, and most private helium production was suspended during that period. What had begun as an effort to assure the government of sources of helium at a time when there was no private production evolved first into a program to promote helium conservation by encouraging private companies to extract it from natural gas, then into a provision for storage to deal with the expected periodic imbalances in supply and demand, and finally into a situation that threatened the viability of the entire industry.

Private consumption of helium began to recover from this low point in the 1970s, and private production was again healthy by the mid-1980s, although BOM was still producing. By 1988, the Office of Management and Budget proposed that all helium production belonged in the private sector. This proposal was opposed by the Congress, however. In 1992, the administration suggested a compromise under which BOM's facilities would not be sold but government agencies would be free to buy helium from the private sector.

In the meantime, two major changes occurred. First, Congress eliminated BOM in 1997 and transferred responsibility for the Federal Helium Reserve to the Bureau of Land Management (BLM) of the Department of the Interior. Second, the government raised its helium prices to levels significantly above those of the private producers. As a result, just before BLM ceased helium production in 1998, more than 90 percent of domestic demand was being satisfied from private sources—up from nothing before passage of the 1960 amendments. Somewhat ironically, it was the Bush Dome reservoir and its associated pipelines that were facilitating this change and making a unique contribution to the conservation of U.S. domestic helium. In Congress, however, initial reluctance to leave the helium business had switched to eagerness to get out, provided that the complex at Cliffside field could be preserved.

2

The U.S. Federal Helium Reserve and the Helium Privatization Act

This chapter examines (1) current federal and private helium facilities and capacities and (2) the details of the Helium Privatization Act of 1996. It is critical that the distinction between the Federal Helium Reserve and the Bush Dome reservoir is understood. The Federal Helium Reserve pertains solely to the crude helium gas that currently resides in the Bush Dome reservoir and includes neither the storage facility itself nor the associated pipeline.

FEDERAL AND PRIVATE HELIUM FACILITIES AND CAPACITIES

Table 2.1 summarizes the ownership and location of all domestic helium plants as of 1998.

Federal Helium Facilities

Federal helium facilities have been involved in the entire range of helium production processes, from the extraction of the natural gas from which helium derives to the production and storage of crude helium and to the purification, liquefaction, and final transportation of pure helium. The BLM extraction operations and purification and liquefaction facilities are all located in Masterson, Texas. These facilities are relatively old, however, and were frequently criticized before Congress as inefficient. In 1996, the last full year for which statistics are available, federal operations accounted for 220 million scf (6.07 million scm) of the 2.6 billion scf (71.9 million scm) of grade A helium that was domestically sold, or approximately 8.4 percent of the total U.S. market. The plants were mothballed in 1998, as stipulated in the Helium Privatization Act of 1996. No crude or pure helium has been produced or sold by the federal government since that time.

TABLE 2.1 Ownership and Location of Helium Extraction Plants in the United States in 1998

Category and Owner or Operator	Location	Product Purity
Government-owned		
Bureau of Land Management	Masterson, Tex.	Grade A helium[a,b]
Private industry		
Air Products Helium, Inc.	Hansford County, Tex.	Grade A helium[a]
Air Products Helium, Inc.	Liberal, Kans.	Grade A helium[a]
Amoco	Ulysses, Kans.	Crude helium[c]
BOC Gases	Otis, Okla.	Grade A helium[a]
CIG Company	Keyes, Okla.	Grade A helium[a]
CIG Company	Lakin, Kans.	Crude helium
Crescendo Resources	Sunray, Tex.	Crude helium
ExxonMobil	Shute Creek, Wyo.	Grade A helium[a]
GPM	Moore County, Tex.	Crude helium
GPM	Hansford County, Tex.	Crude helium
KN Energy, Inc.	Bushton, Kans.	Crude helium
KN Energy, Inc.	Scott City, Kans.	Crude helium[d]
National Helium Corp.	Liberal, Kans	Crude helium
Nitrotec	Chillicothe, Tex.	Grade A helium[e]
Nitrotec	Cheyenne Wells, Colo.	Grade A helium
Pioneer Resources	Fain, Tex.	Crude helium
Pioneer Resources	Satanta, Kans.	Crude helium
Praxair, Inc.	Bushton, Kans.	Grade A helium[a]
Praxair, Inc.	Ulysses, Kans.	Grade A helium[a]
Trident NGL	Ulysses, Kans.	Crude helium[f]
Unocal	Moab, Utah	Grade A helium[a]
Union Pacific Resources	Cheyenne County, Colo.	Grade A helium[a,g]
Williams Field Services	Baker, Okla.	Crude helium

[a] Including liquefaction.
[b] Stopped production in April 1998.
[c] Began production in May 1998.
[d] Output is piped to Ulysses, Kansas, for purification.
[e] Began production in December 1998 (est.).
[f] Stopped production in May 1998.
[g] Began production in October 1998.

Of greater consequence for this study are the specifications of the Federal Helium Reserve. The Federal Helium Reserve is stored in the Bush Dome reservoir in the Cliffside gas field near Amarillo, Texas (Figure 2.1). The Bush Dome reservoir originally contained one of the early helium-rich natural gas deposits discussed in Chapter 1 . The formation is approximately 3,500 ft (1,100 m) deep and about 300 ft (91 m) thick and has a 10 percent porosity. The government owns approximately 50,900 acres (20,200 ha) in the Bush Dome region. The Dome has a total capacity of approximately 45 billion scf (1.2 billion scm). The facility currently contains approximately 30.5 billion scf (850 million scm) of government-owned crude helium, or about a 10-year world supply at the current rate of use. Private industry stores an additional 4 billion scf (110 million scm) of helium in the reservoir.

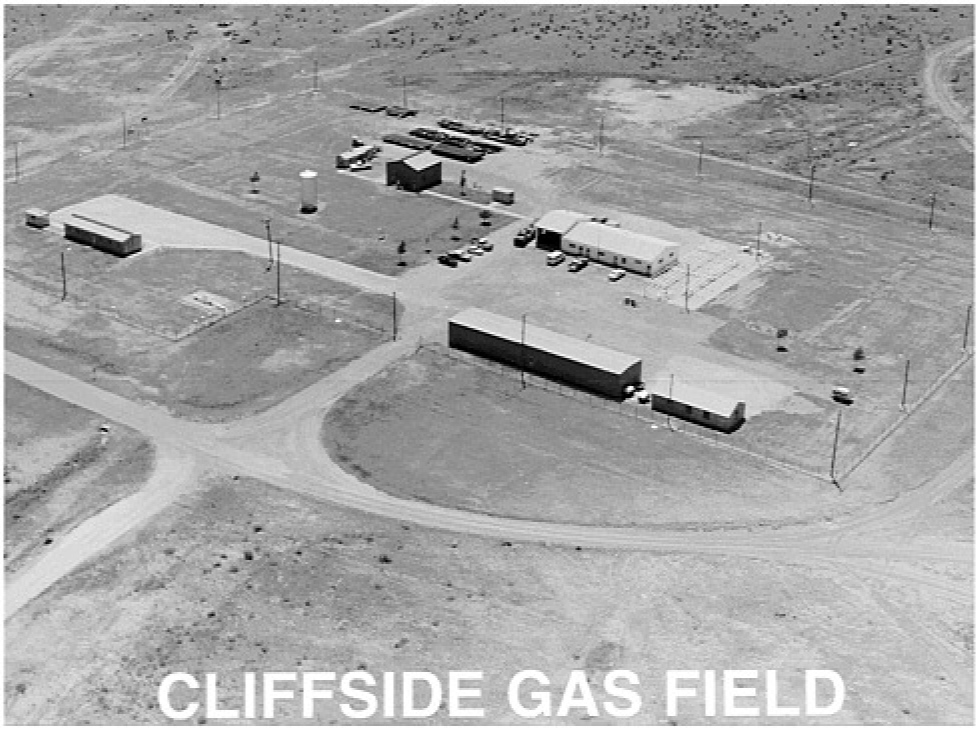

FIGURE 2.1 The storage facility at Cliffside gas field (courtesy of the Bureau of Land Management).

In addition to the reservoir, the facility possesses roughly 450 mi (720 km) of pipeline and associated hardware. The pipeline stretches through Kansas, Oklahoma, and Texas and connects 17 private crude helium production and refining plants to the federal reservoir (Figure 2.2). Many of these plants are extracting gas from the Hugoton gas field. The operating companies regularly deposit and extract their own supplies of crude helium to and from the reserve for either storage or final purification and sale, respectively. They are assessed fixed charges for contract administration and connections to the government pipeline. In addition, a company pays variable charges based on its crude helium activity.

It is important to stress three things about the Bush Dome reservoir. First, it is a unique facility. The long-term storage of crude helium would be very difficult without such a facility, and the long-term storage of both gaseous and liquefied refined helium is currently not feasible. The Bush Dome reservoir could be adapted for the storage of crude helium because of its recognized ability to contain natural gas with relatively high helium concentrations (about 1.86 percent). There is no comparable storage facility for helium anywhere else in the world. This is important, because other storage facilities will be required as the Hugoton gas field is drawn down and other fields become the primary sources of helium.

Second, as crude helium is injected into the Bush Dome reservoir, there is some mixing with the remaining native natural gas. As the crude helium inventory is reduced, the helium content can be expected to deteriorate toward the end of the life of the reserve. Thus, it may not be possible to recover all of the crude helium currently in storage without installing upgrading facilities at some time in the future. A facility for upgrading diluted crude helium as it's removed from storage could conceivably also be used to recover helium from the native gas in the reservoir.

Third, the rates for the fixed and variable charges assessed private industry for the storage of helium at the Cliffside facility are calculated to offset the operating expenses of the facility. Each company that currently stores helium in the Federal Helium Reserve has signed a helium storage contract between itself and BLM. The contract includes a cost-recovery formula that allocates the budgeted costs for the storage program to all the storers in the system. The fixed costs are $12,000 for each storage contract and $20,000 for each company connection to the crude helium pipeline. These charges reflect the approximate cost associated with these functions (i.e., contract administration and maintenance of the custody transfer point). The variable costs are based on the company's share of the activity on the storage system in the preceding year. For example, a company's total helium acceptances, redeliveries, and average helium storage are added up and compared to the total for all companies having storage contracts. This share is then applied to the remaining costs of the helium storage program (budgeted minus fixed costs). The company is billed for its fixed costs at the start of the fiscal year and its portion of the variable costs in nine monthly installments starting in January and for the remainder of the fiscal year. By the terms of the contract, all costs budgeted for a given year are collected using this formula. The moneys collected have been in the $2 million range over the last couple of years. This contractual cost-recovery system was developed by BLM personnel in 1995, with the final language having been negotiated in a series of meetings with the private storers. The cost-recovery contractual system is thus divorced from any assessment of the economic value of the storage service and could be inhibiting the amount of income generated by the facility.

Private Helium Facilities

Fourteen private companies owned a total of 20 plants in 1996. Of these plants, 13 engaged in helium extraction and 11 (with some duplications) in purification, and 8 also liquefied helium. The domestic crude helium industry can be considered to consist of three basic elements. The first element includes the private producers in the Hugoton-Panhandle complex, which are already utilizing the helium pipeline and Bush Dome reservoir. The second element includes private producers in the Rocky Mountain region, none of which are tributary to the helium pipeline network and so cannot use the Cliffside storage facility. The third element is the Federal Helium Reserve itself.

The private refiners in the Hugoton-Panhandle complex (i.e., the first element) rely on the Cliffside facility to act as a flywheel. Natural gas extraction companies generally sell crude helium to helium refiners on the basis of long-term (e.g., 20-year), take-or-pay contracts. These contracts require that refiners purchase certain quantities of helium every year, whether they take it or let it be vented. Since it is a waste of capital to let the crude helium be vented, the refiners with access to the pipeline store all of their crude helium in the Cliffside facility and remove and refine it as needed. Any crude helium in excess of current market demand will thus remain in the Cliffside facility and become part of the company's private stockpile. The amount of helium produced from the Hugoton-Panhandle complex would certainly be less if the Cliffside facility were not available.

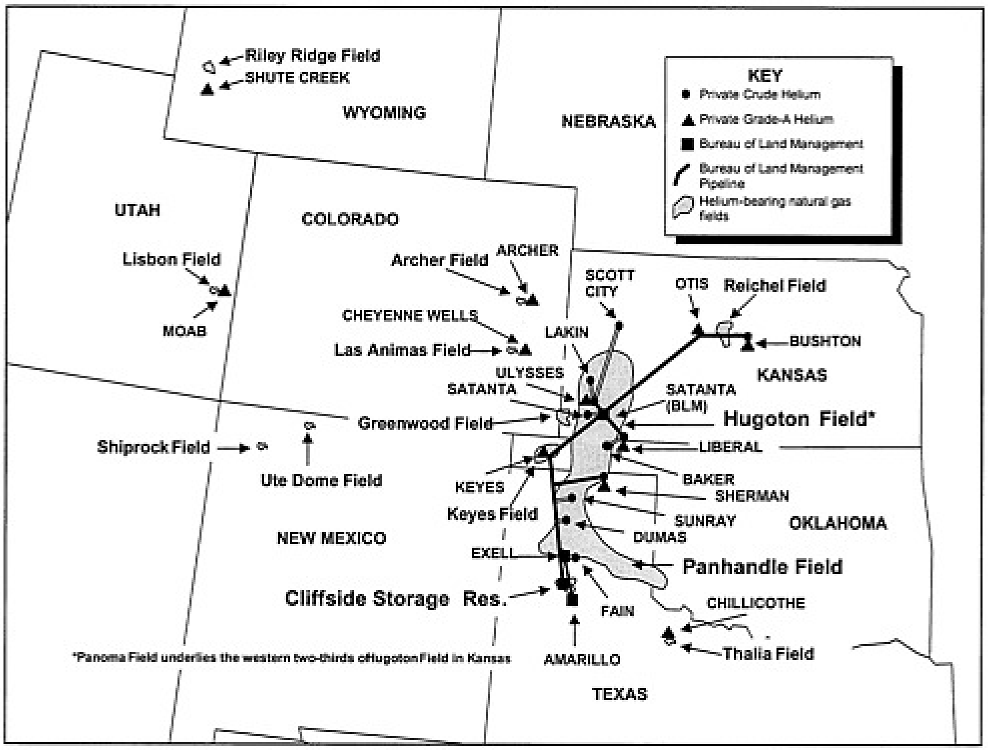

FIGURE 2.2 Major helium-bearing natural gas fields in the United States (courtesy of the Bureau of Land Management).

The existence of the Federal Helium Reserve itself (i.e., the third element) would appear to have little effect on industry as long as it is held in storage. Sale of federal crude helium assumes that the customers who buy it can purify and market the product (unless, of course, these customers choose to simply leave their purchases underground at Cliffside). The only reason for nonproducing customers to buy from the reserve would be for speculation, holding onto it and waiting for the time when the Hugoton-Panhandle field's helium was exhausted. The crude helium in the Bush Dome reservoir could then be sold—at a profit—to the refiners along the pipeline to extend their production lifetime. However, the likelihood of this occurring is completely dependent on the price at which the crude helium can be bought initially.

The information presented in Table 2.1 and Figure 2.2 suggests that significant private helium production is coming from the second element, which is gas fields that do not enjoy access to the helium pipeline. The Rocky Mountain producers (the most important one by far is ExxonMobil) could continue to operate even if Hugoton production was to decline.

Overall, as will be discussed in Chapter 5, the domestic industry appears to be stable and contributes to realistic conservation, especially by using the Bush Dome reservoir as a flywheel. It is not unreasonable to believe that proximity to the Cliffside facility and the size of the helium-bearing natural gas reserves (to be discussed in Chapter 4) will weight heavily in the overall assessment of helium privatization and the impacts it may have.

HELIUM PRIVATIZATION ACT OF 1996

The Helium Privatization Act of 1996 (P.L. 104-273) was signed by President Clinton on October 9, 1996. The act basically mandated that BLM (1) terminate its production and sale of Grade A helium (i.e., 99.995 percent helium or better) by April 9, 1998, which has been done; (2) dispose of all helium production, refining, and sales-related assets within 24 months of closure of the BLM helium refining plant, which has not yet been accomplished, and (3) sell all of the Federal Helium Reserve of crude helium in excess of 0.6 billion scf (17 million scm), which is awaiting the publication of this report and the consequent actions of the secretary of the Interior.

The legislation directs the secretary of the Interior to commence offering for sale, on a straight-line basis, approximately 30.5 billion scf (850 million scm) of the Federal Helium Reserve at any time before January 1, 2005, and to complete offering it for sale not later than January 1, 2015. Furthermore, the act determines a price by dividing the helium program's total debt (about $1.4 billion) by the volume of crude helium in storage. According to the Congressional Research Service, this would establish a selling price of approximately $43 per thousand scf ($1.50 per scm), which is roughly 25 percent higher than the current commercial price of crude helium. The act goes on to use this price as the basis for minimum acceptable bids. Potential problems stem from the pace and price of sales that the act contemplates. The Congressional Research Service points out that straight-line sales of the stored helium, even if begun in 1997, would amount to about 20 percent of current annual consumption. If the sales did not begin until 2005, such sales would amount to more than 40 percent of current domestic consumption. The meaning of the term "straight-line sales" is also not clear. Would, for example, unsold helium from the first year's offer for sale have to be added to the second year's offer? If this were to happen, BLM might find itself near the end of the 10-year sale period with most of its crude helium still on hand. In short, P.L. 104-273's setting of rigid prices and sales volumes could work against the sale of the reserve, or it could attract potential buyers convinced that the asking price must eventually rise.

Some of the crude helium currently residing in the Federal Helium Reserve is already being sold. The legislation stipulates that all pure helium bought by government agencies must derive from government-owned crude helium. Since BLM's refining facilities are being surplused in response to the Helium Privatization Act of 1996, BLM is required to sell the crude helium to private refiners, which then purify the material for sale to the government agencies. The price used for the crude helium is the higher one stipulated by the legislation, which means that government agencies are paying more than the price of commercially available pure helium. Because there is a net storage of privately owned helium, the effect of these transactions is the sale of a portion of the federal reserve to private industry.

As stated at the beginning of this chapter, the legislation requires the government to continue to operate the Cliffside gas field storage system, including the storage field itself and the pipelines needed to store and handle both government and private crude helium. As currently required, the government will continue to collect royalties and sales fees for helium taken from federal lands. The cost of these ongoing activities will be defrayed by allowing the government operator (either BLM or a contractor) to use revenue from helium or other product sales, together with sales of excess property (e.g., helium transportation containers, compressors, and land), to establish a helium production fund. Interestingly, helium-related research money can also be taken from the fund. In the long run, however, the act assumes that all amounts in excess of operational needs will go to the Treasury, first to pay back the indebtedness of the helium program and eventually to the General Fund. The act envisions that after the disposals have been completed, the budget for helium operations will be $2.0 million or less per fiscal year.

The legislation contains a number of specific exceptions not uncommon in privatizations. For example, "the sales shall be at such times during each year and in such lots as the secretary determines, in consultation with the helium industry, to be necessary to carry out this subsection with minimum market disruption." In another instance, the act recognizes that once federal production of grade A helium ceases, federal customers will have to turn to private suppliers. While the implication is that prices might fall somewhat, there is no way to be certain until the market is fully stabilized.

P.L. 104-273 provides considerable additional detail about the liquidation of the Federal Helium Reserve that probably reflects the many concerns that were presented to the Senate Committee on Energy and Natural Resources in 1996, as well as to various other committees and panels throughout the 1990s. Other attempts to reform or eliminate the Federal Helium Reserve had fallen short or failed, and interest groups on all sides were alerted, if not alarmed, by the prospective sale of the Federal Helium Reserve. One result of this concern was the addition of Section 8, which was added to the House version by the Senate committee with a "do pass" recommendation. As stated in the Preface to this report, Section 8 (see Appendix B) of the legislation mandated that the NRC conduct a study and produce a report that assesses whether disposal of the Federal Helium Reserve "will have a substantial adverse effect on U.S. scientific, technical, biomedical, or national security interests." It should be noted that economic interests are not mentioned and that, after the NRC report is transmitted to the secretary of the Interior, the secretary is required to consult with the U.S. helium industry and the heads of any federal agencies deemed to be affected by the legislation. In the event of a determination of "substantial adverse effect," the secretary would be free to make recommendations, including proposing remedial legislation to Congress, that would mitigate the adverse effect.

Although scientific, technical, and security concerns are prominent in the act, and especially in Section 8, it is clear that production and marketing factors will be important in determining if privatization can serve national needs and avoid "adverse effects," since the only assets subject to disposal are the federal crude helium in storage and the extraction, refining, and sales-related assets that produced BLM's grade A helium. To accurately assess the impact of the sale of the Federal Helium Reserve requires a knowledge of helium's uses (Chapter 3), its present and future supply (Chapter 4), and its market economics (Chapter 5).

3

Uses of Helium

The total amount of helium used in the United States grew from about 1.4 billion scf (36 million scm) in 1985 to about 2.6 billion scf (69 million scm) in 1996 and is expected to continue to grow in the foreseeable future (Figure 1.1 showed the trend in helium production and sales from 1960 to 1997). The remarkable fundamental properties of helium (Box 3.1) make it useful for many applications, but few people appreciate the broad range of crucial roles that it plays in industrial processes, military and civilian aerospace applications, medical technologies, and basic research. For example, research using liquid helium has been—and continues to be—at the forefront of science. Although some lines of investigation at the forefront of science may appear to have little impact on society, they could eventually become commercially or militarily important activities.

BOX 3.1 UNIQUE PROPERTIES OF HELIUM

- Helium is the second lightest element.
- It is chemically inert, having essentially no tendency to combine with other elements.
- It has the highest ionization potential (24.587 eV).
- The boiling point of helium is closer to absolute zero than that of any other element, so liquid helium can provide the lowest operating temperatures of any refrigerant.
- Helium remains liquid at atmospheric pressure down to absolute zero and can be solidified only by applying 25 atm. In its solid form, helium is extremely compressible, permitting volume changes of more than 30 percent.
- Liquid ^{4}He undergoes a transition to a superfluid phase at temperatures below 2.18 K (-455.5 °F) and has extraordinary physical properties, including viscosity-free fluid flow and extraordinarily high thermal conductivity (on the order of a million times greater than its conductivity in the normal phase and greater than that of the best metallic conductors).
- The specific heat and thermal conductivity of helium gas are very high.
- Helium is radiologically inert (i.e., it does not easily participate in nuclear processes and does not become radioactive).

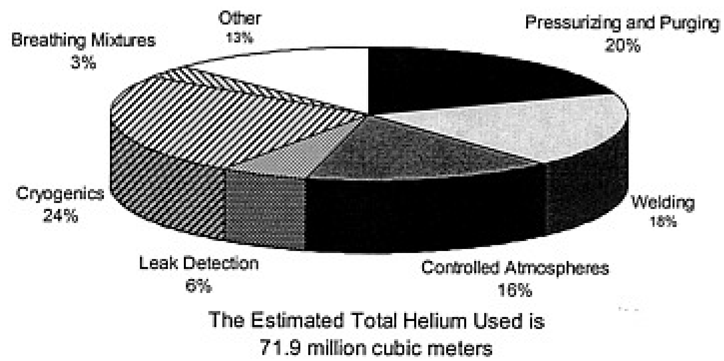

FIGURE 3.1 Estimated helium consumption in the United States by end use in 1996. SOURCE: U.S. Department of the Interior, U.S. Geological Survey. 1996. *Mineral Industry Surveys: Helium.* Reston, Va.: USGS.

This chapter examines the various current and future uses of helium. The current applications are divided into the main categories used by BLM to track domestic helium usage in 1996 (Figure 3.1): cryogenics, pressurizing and purging, welding, atmospheric control, leak detection, breathing mixtures, lifting, and other uses. Each section will discuss the application for which helium is used, the reason for its use, the volume of gas employed, and the prospects for conserving helium or using substitutes. The chapter concludes with a discussion of the potential future applications that may require helium and the overarching issues that surround the tracking of helium usage.

INADEQUACY OF DATA ON HELIUM USE

The U.S. Department of the Interior releases annual reports that discuss the supply and demand for helium. The domestic helium consumption portion of these reports is based on surveys, conducted every 5 years or so, of helium wholesalers. These surveys track domestic use in 18 categories. Although the gross amount of helium exported is known, there is only sparse information on its end uses. Even less is known about foreign production of helium. The last survey of domestic helium wholesalers was in 1995 and the one before that was in 1991. Helium use is estimated using the results of these surveys as a baseline.

One problem that the committee confronted in analyzing the trends in helium usage during the 1980s is that the Department of the Interior reduced the number of categories of helium use it reported from 13 to 7—even though it currently collects data on 18 categories. This aggregation of the data made it difficult for the committee to follow helium use over time within each category. A second problem with the data reported since 1994 is wild variation from year to year in the estimates of the percent of helium consumed in each category. For instance, the percent of helium in the "other" category was reported to be stable at about 11 percent from 1985 to 1993. It jumped to about 22 percent in 1994 and then declined to 18 percent in 1995 and 13 percent in 1996.

CURRENT USES

Cryogenics

The largest current use of helium is for cryogenics. The amount of helium used for cryogenics was about 620 million scf (17 million scm) in 1996. The main cryogenic applications to be discussed in this section are magnetic resonance imaging, semiconductor processing, and large-scale and small-scale fundamental research that requires helium temperatures. Unfortunately, no specific data are available on the quantities used for each of these applications.

It should be noted that the availability of safe, inexpensive helium resulted in the abandonment of liquid hydrogen as a coolant. In a situation of extreme shortage, hydrogen could be used as a refrigerant, with appropriate safety precautions. The lowest temperature attainable with hydrogen, however, is 9 K, which would require a change in magnet wire technology to a niobium-tin alloy or some other high-temperature material. Systems cooled only by liquid hydrogen would also not be able to achieve low enough temperatures to permit a second stage of refrigeration based on ^{3}He. This problem might be resolved by using some of type of magnetic refrigeration as an intermediate stage. Any changes would require a large capital investment in infrastructure, however.

Magnetic Resonance Imaging

The main medical use of liquid helium is for magnetic resonance imaging (MRI) systems. Liquid helium is needed as a refrigerant for the superconducting magnets that are critical components in many of these devices. The availability of helium at a favorable price and the stability of the helium market have contributed to the rapid growth of MRI as a diagnostic tool and have allowed it to make a significant contribution to health care in the United States. There is a large, stable base of superconducting machines in the United States and abroad (>4,000), and this base is expected to grow at 15 percent per year. At least one reason for the abundance of superconducting MRI systems in the United States (approximately 80 percent of the worldwide installed base) is the ease with which liquid helium can be obtained and its relatively low cost.

There is no substitute for helium in this application. Use of high-temperature superconducting wire, while under investigation by several manufacturers, is not likely to be a viable alternative to conventional superconductors in MRI machines. High-T_c superconductors cost 500 times as much as conventional niobium-titanium superconducing wire. Although this cost might decrease in the future, both the mechanical and electrical properties of high-T_c would have to be improved before they could be used economically for this medical application.

However, even with the increasing medical importance of MRI systems, this application's demand for helium is expected to be flat or to grow only slowly. Because it is difficult for them to obtain reliable supplies of liquid helium in other parts of the world, MRI manufacturers have introduced new technologies that dramatically decrease the quantity of liquid helium required. These technologies include improved cryostats with superior thermal efficiency, cryocoolers that recondense the helium, and improved magnet wire and junctions that reduce the size and weight of materials that need to be cooled and lower the small heat load that the magnet itself generates. These systems, which often trade the low cost of electricity for the high price and relative inconvenience of cryogens, have dramatically decreased helium consumption in the superconducting MRI systems that are manufactured today. The newest generation of machines uses 10 times less helium than earlier generations and can operate as long as 3 years between helium fills. Furthermore, while superconducting MRI systems are often the high-end performers, most of the growth in the current U.S. and world markets is for systems at lower magnetic field strengths, which use electromagnets or permanent magnets and require no cryogens.

Semiconductor Processing

Silicon wafer suppliers are the primary users of helium in the semiconductor industry. The process of pulling 12-in. (300-mm) crystals uses helium-cooled superconducting magnets to mechanically stabilize the hot boules of semiconductor material. Other activities in the industry that use helium are plasma etching and vacuum pumping. In the latter, liquid-helium-cooled surfaces cryopump gas contaminants. Recycling techniques could be introduced in each of these processes to reduce helium consumption.

The total volume of helium used by the semiconductor industry is unknown. Nevertheless, it is very important to this key industry. An increase in the price of helium could be accommodated, but if helium were to disappear altogether, semiconductor processing would be severely hampered.

Large-Scale Fundamental Research Requiring Helium Temperatures

The term "large scale" in the context of superconductor-based fundamental research refers to systems that are physically large (e.g., accelerators whose rings are many kilometers in circumference). Superconducting magnets and superconducting microwave and radio-frequency cavities are important components of charged-particle accelerators for nuclear and particle physics and the technology of choice for the highest energy colliding-beam accelerators. All such systems currently employ superconductors that must be cooled by liquid helium. In particular, significant amounts of helium are required to cool the magnets in large particle-storage rings (the circumferences of the Relativistic Heavy Ion Collider at Brookhaven National Laboratory, the Tevatron at Fermilab, and the ring at the Large Hadron Collider at CERN are 5 mi (8 km), 3.7 mi (6 km), and 17 mi (27 km), respectively). The cryogenic plants used at accelerator facilities must be able to provide tens of kilowatts of refrigeration and require tens of megawatts of electric power.

In some systems, especially those using radio-frequency or microwave resonators of large size, the uniquely high thermal conductivity of liquid helium also assures that the superconducting system is kept at the uniform temperatures critical to operation. Since there is no alternative material with comparably high thermal-conductivity properties, helium is the only cryogenic fluid that can be reliably used to reach the low temperatures required for all superconducting electromagnets and radio-frequency and microwave resonators currently in use in large-scale systems. Another use of large superconducting magnets is in specialized particle detectors, and helium is also used to cool accelerator targets to low temperatures.

Like the MRI community, the large-scale fundamental research community is taking steps to increase the efficiency of its systems. The use of closed-cycle systems that reliquefy helium is now commonplace and growing. For example, the new accelerators that are coming on line are extremely efficient, with most of the gas being reused and only small amounts being lost through leakage, maintenance procedures, and failures. Losses should decline further with incremental improvements in recirculation technology.

An important factor in the use of helium in large-scale applications is the possible development of substitutes for metallic alloy superconductors based on high-temperature superconducting compounds. Considerable progress has been made with superconducting transmission lines, to the extent that lines requiring liquid-helium temperatures are no longer seriously considered (e.g., prototype high-T_c lines are currently being installed in the power grid). Prototype superconducting magnets of a small laboratory scale, wound with high-temperature superconducting material, have also been produced, but they are extremely expensive. It would be premature, however, to say that it is inevitable that all large-scale superconducting systems will ultimately be made with high-temperature materials, given the extremely serious materials problems that would first have to be solved.

Large-scale accelerators could absorb a helium price increase because the cost of helium is a small part of their operating costs. However, an increase could reduce the amount of research conducted. If no helium were available, these facilities would cease operation.

The possible use of high-temperature superconductors in high-power radio-frequency applications is also under study at this time, but it is not likely to have any impact on accelerator technology for some time. However, high-temperature superconducting materials are close to commercialization in lower-power applications such as passive microwave filters for cellular telephone ground stations. These systems, which rely on liquid-nitrogen-based cryocoolers, must be able to run unattended for extended periods of time (i.e., years), so that complex, liquid-helium-based cryocoolers are not feasible.

Small-Scale Fundamental Research Requiring Helium Temperatures

Cryogenic-based research has broadened in recent years from its original focus on the properties of liquid and solid helium and metallic superconductors to include a very wide range of materials and phenomena. The fields most heavily involved in the use of helium are materials research, condensed-matter and materials physics, materials science, chemistry, and observational astronomy and astrophysics. The use of helium is absolutely critical to fundamental cutting-edge research in all of these areas, many of which (astrophysics, for one) are potential sources of future technologies.

In chemistry and materials research, both low-temperature measurements and measurements using instruments needing low temperatures for their operation are required to fully characterize new materials. For example, liquid helium is used to cool the superconducting magnets required for nuclear magnetic resonance (NMR), which is a critical tool in structural chemistry. Liquid helium is also frequently used to precool and then sustain the operation of ^3He-^4He dilution refrigerators, which are used to achieve ultralow temperatures (i.e., well below 1 K and down to 0.002 mK). These ultralow temperatures are unattainable by the evaporative cooling of either ^4He or ^3He. Helium is also used to cool samples for various kinds of electrical transport, magnetic, thermal, and spectroscopic studies. The largest steady magnetic fields, such as those available at the National High Magnetic Field Facility, employ combinations of resistive and superconducting magnets that require liquid helium. In many instances investigations conducted in strong magnetic fields involve materials that are also cooled using liquid helium. Many investigations at the frontier of materials research require the use of Superconducting Quantum Interference Device (SQUID) systems for magnetic measurements.

Two kinds of relatively sophisticated low-T_c SQUID systems have been very successful commercially. The first is the SQUID susceptometer, which has been used all over the world in an amazingly wide range of studies. The second is the multichannel system, each channel of which contains between 100 and 300 SQUID magnetometers, used to image magnetic signals produced by the brain. The magnetometers have noise levels as low as 2×10^{-15} T/root Hz. Under favorable circumstances they can locate a magnetic source to an accuracy of 2 to 3 mm, and they have been used for many different studies of the brain.

Astronomy and astrophysics, although not large users of helium, critically depend on liquid helium. Helium is used to cool infrared and other detectors to very low temperatures to reduce mechanical and electrical noise and permit the study of extremely weak signals. Some important research efforts in astrophysics (e.g., investigations of dark matter and the anisotropy of the cosmic background radiation) would not be possible without a supply of helium to cool the detectors.

Liquid helium is also itself a subject of great scientific interest. Liquid ^4He undergoes a phase transition to a superfluid state when the temperature is taken below 2.2 K. The superfluid properties of liquid ^4He are generally believed to be a manifestation of Bose-Einstein condensation, where the entire liquid exhibits macroscopic quantum properties such as quantization of the superfluid flow field. The properties of superfluid helium are unusual. For example, once set in circular flow, it will keep flowing perpetually. Moreover, it can flow up the walls of its container, meaning that a container being filled with superfluid helium can empty itself spontaneously.

For the past 50 years scientists have conducted research on the fascinating behavior of superfluid helium, have used superfluidity to verify theoretical predictions of quantum physics, and have used superfluid helium as a trap for other particles under study. The total amount of helium used in these studies is not well known but is probably relatively small. Needless to say, there is no substitute for helium in studies of the properties of helium itself.

With a limited number of exceptions, liquid helium or helium-based cryocoolers are required for all of the systems discussed above. This instrumentation is either commercial or under development and has nurtured an industry that manufactures cryogenic research equipment in the United States and abroad and that is completely dependent on the use of liquid helium. The efficiency of these systems could be increased by a number of different means, however. For example, an increased use of closed-cycle refrigeration would reduce the helium wastage in some current practices in which helium boil-off gas is expended. For sufficiently large aggregations of research instruments and apparatus using liquid helium, such as might be found at major research universities, recovering and reliquefying helium boil-off gas could reduce helium consumption. This type of operation demands a substantial capital investment in a liquefier, a recovery system, and a helium storage facility, however, and at current helium prices, would be cost-effective only under special circumstances. Consequently, there is little incentive for most universities and laboratories to conserve helium by recovering it. An alternative to recovery and reliquefaction on a large scale would be the use of small closed-cycle coolers. Although this equipment uses helium as a cryogen and, because of inefficiencies and errors, may not eliminate helium loss entirely, a number of commercial suppliers of instrumentation have begun marketing systems equipped with these cryocoolers. For some of the more delicate experimental investigations, the current generation of cryocoolers is mechanically and electronically too noisy, however, and some applications involving very sensitive measurements may require the development of less noisy refrigeration systems.

Pressurizing and Purging

Helium plays a unique and critical role in the pressurizing and purging of primary rocket propulsion systems. It will continue to do so as long as the propellant is a combination of liquid hydrogen and liquid oxygen. First, helium gas is used to pressurize the propellant tanks for the engines. In this application, pressure is provided to prevent pump cavitation and must be sufficient to keep the tanks from collapsing under vehicle-imposed structural loads. Pressure-fed propulsion systems are also used to provide engine-chamber pressurization. Second, helium gas is used for the purging of the propellant feed systems for liquid-hydrogen engines. Helium is used because its normal boiling point is lower than that of hydrogen. Thus it is the only element that can be used without compromising propellant integrity or feed-system function. Other gases would freeze, producing particles that could clog equipment and seize an engine, or react with or dissolve in the liquid hydrogen, reducing engine efficiency, all with potentially disastrous results.

The use of liquid and gaseous helium for pressurizing and purging rocket propulsion systems by the aerospace industry and the National Aeronautics and Space Administration (NASA) amounted to about 470 million scf (13 million scm) of helium in 1996. Large-scale aerospace uses of helium are expected to increase over the next 20 years, as the space shuttle is used to construct and service the International Space Station. There is no question that past successes in space exploration and the associated technology have been partially enabled by access to substantial supplies of helium. Because aerospace use is such a large fraction of overall usage, attention must be paid to developing alternative approaches to helium-based pressurizing and purging or, where there are none, recycling procedures. There has been little incentive thus far to conserve helium in large-scale aerospace use. However, aerospace engineers are focusing their attention on future space access vehicles that do not depend on cryogenic propellants. If the uses of noncryogenic propulsion systems increase, the demand for helium as a pressurant will decrease.

It should be noted that the rocket industry also uses significant amounts of helium for welding, cooling scientific payloads, refrigerating fuel-handling systems to liquid-hydrogen test temperatures, and as a pneumatic control system fluid in spacecraft and other rocket-propelled systems. NASA's current combined use of liquid and gaseous helium for all purposes amounts to the equivalent of 150 million scf (4.2 million scm) of gaseous helium per year.

Welding

Figure 3.1 shows welding as one of the largest categories of helium usage. The amount of helium apparently used in this category was about 470 million scf (13 million scm) in 1996. These data may be misleading, however, because the suppliers of helium for welding also tend to be the leading suppliers of helium for most small-scale, incidental uses (the information on the suppliers of helium for welding is from a report provided to the committee by A. Francis in December 1998). Thus, it is uncertain how much helium is actually used each year for welding and whether this decline is the result of a decline in the use of helium in welding, a decline in other uses reported as welding, or a change in how the other uses are reported. The two uses of helium to be discussed in this section are arc welding and laser welding.

Arc Welding

Gaseous helium is used for gas metal arc welding and gas tungsten arc welding. The helium serves mainly as a shielding gas, preventing atmospheric contamination of the molten metal and stabilizing the arc. It also serves the additional function in gas tungsten arc welding of shielding the red-hot tungsten electrode from the surrounding atmosphere. The unique characteristics of helium in these applications are its high ionization potential and high thermal conductivity, combined with its inertness. The benefits of its use include greater welding penetration in thick joints and in metals with very high thermal conductivity; higher travel speeds, permitting greater productivity; better shielding-gas coverage in vertical and overhead position welds; and flatter surface of root pass when used as a backing gas.

Some weld compositions can tolerate a wide variety of shielding gases, but others are quite demanding. For example, aluminum alloys and other reactive metals require inert shielding. While argon is used in some of the applications that require true inertness, helium or helium mixtures (often 20 percent helium and 80 percent argon) are used to increase the weld pool depth (e.g., penetration) or increase the travel speed. These argon-helium mixtures are quite popular in that they combine the good arc stability and lower cost of the argon with the deeper penetration of the helium. The recycling of helium would entail considerable cost in arc welding applications but would not be impossible. In those activities that are most technologically challenging in welding (i.e., aircraft engines and airframe manufacture), there probably is no substitute for helium. For other applications, argon cover gas might be substituted for helium, as is done in countries where helium gas is expensive, but there would be some loss in productivity.

Laser Processing

Processing with carbon dioxide (CO_2) lasers is a growing activity in the United States. The amount of helium used in these operations is approximately 200 million scf (5.5 million scm) per year and is growing at about 20 percent per year. Helium serves several functions in laser processing: it is primarily a shielding gas for the molten pool in laser welding but is also an important component of the lasing gas in all CO_2 lasers. Carbon dioxide lasers are also used for cutting, drilling, cladding, and heat treatment, although welding is the only process that also uses helium as a shielding gas.

The helium used as a shielding gas in CO_2 laser welding protects the weld pool from oxidation (until the pool cools to temperatures where it does not react with the oxygen and nitrogen in the atmosphere), suppresses plasma formation, and protects the laser optics from damage. Other inert gases can replace helium in protecting the weld from oxidation and in protecting the optics, but the special characteristics of helium are quite important for plasma suppression at very high power densities. For laser powers above about 5 kW, helium is preferred because it is the gas that is least likely to ionize. Shielding and plasma suppression are open-loop processes where the gas flows through a nozzle toward the point at which the laser beam intersects the weldment. Recycling this shielding gas would require substantial investment in equipment to capture and refine the helium after it is contaminated with weld fumes and the surrounding atmosphere.

The smaller but perhaps more critical use of helium in laser processing is as a component of the lasing gas. The gas mixture in CO_2 lasers consists of nitrogen, helium, and CO_2, roughly in the ratio 3:2:1. Helium serves to cool the excited CO_2 molecules in the laser cavity. In theory, it should be easy to recycle the helium gas used in the lasers themselves, since the gas is confined within the laser and is replenished via a closed loop. In reality, recycling is difficult because the CO_2 breaks down during the lasing process and must be replenished and because the reduced pressure in the laser cavity requires a vacuum pump, which can add contamination. Therefore, CO_2 lasers require a regular supply of lasing gas to replenish the losses during operation and after the system is vented for maintenance. The annual operating cost for laser welding is typically dominated by the cost of electrical power, with shielding helium costs typically in second place at nearly 30 percent of the total and laser helium costs typically in third place at about 2 percent of the total. Obviously these percentages will change as helium cost fluctuates.

There are alternatives to laser processing. For example, electron-beam processing can be used, but a vacuum is required to achieve high performance. Nd:YAG lasers (see Appendix D) can also be used instead of CO_2-based lasers, but they are not desirable for most cutting and thick welding processes because they cannot yet achieve the same power densities and they have a much lower operating efficiency.

Atmospheric Control

Helium is used to create an inert atmosphere in many industrial fabrication processes. The amount of helium used in atmospheric control was about 410 million scf (11 million scm) in 1996. This section will examine helium usage in optical fiber manufacture, plasma-arc coating, plasma-arc melting, and heat treatment.

Optical Fiber Manufacture

Fiber-optic technology is a burgeoning field that is becoming increasingly important in modern communications. The manufacture of optical fibers critically depends on the use of helium gas. It involves a number of steps in which a large rod is eventually pulled to form a fiber. The fiber is also coated with several different claddings during the drawing process, which are applied using a modified chemical vapor deposition (MCVD) process. Helium is mixed with the MCVD reactive gases to enhance the thermal gradient and improve the uniformity of the claddings. Helium is also used in the chilling of freshly drawn fiber, where it serves as a nonreacting thermal contacting agent. An additional property of helium that is critical to this activity is that it does not form bubbles in the glass, which would destroy the fiber's transmission properties.

Helium currently accounts for about 1 percent of the total cost of fiber production. The total amount of helium consumed in optical fiber manufacture is not definitively known but is at least 20 million scf (550,000 scm) and is expected to more than double by 2003.

Helium vented during this process could be recycled without much difficulty. The only contaminant is chlorine, which can be removed from the gas by cooling it until the chlorine condenses. However, the current price of helium is too low to make recycling an attractive option. (The information on fiber optics production is from a presentation to the committee by S.-P. Hong in December 1998.)

Plasma-Arc Coating

Plasma-arc coating is a process used in the aerospace industry and other industries to apply wear-resistant coatings to critical components. A mixture of 10 percent helium and 90 percent argon is typically employed. Plasma-arc coatings applied in 100 percent argon atmospheres are not as adherent. Hydrogen could be used as a substitute for helium in this application, but there are concerns about both safety and hydrogen embrittlement of the material being coated.

Plasma-Arc Melting

Plasma-arc melting is used to make specialty metal billets, such as titanium billets for jet-engine components. The process provides superior uniformity and composition control and has effectively replaced electron-beam melting, which used to be the main method. Furnaces operate in a helium atmosphere, with a helium plasma melting the titanium. There are no known substitutes for helium in this application. Argon does not have sufficient specific heat to produce the desired depth of melt. In this process the helium is recirculated during furnace operation but is vented at the end of a run because it is highly contaminated. In principle it should be possible to recover and purify the helium after a run.

Heat Treatment

Some industrial heat treatments are conducted in helium atmospheres because helium's high thermal conductivity allows the cooling of thick sections. For example, nickel-base superalloys are rapidly cooled in helium atmospheres. Helium can be replaced with argon in all but special applications.

Leak Detection

The use of helium for leak detection is a relatively small but critical industrial application. Helium is an excellent leak detector because of its low viscosity and large diffusion coefficient. The amount of helium used for leak detection was about 140 million scf (3.9 million scm) in 1996.

Leak testing using helium-tuned mass spectrometers is the most sensitive method of detecting leaks before they reach a critical stage and thus is ubiquitous in science and technology. It is critical in the manufacture of large rocket engines; the manufacture and maintenance of vacuum equipment in all aspects of industrial processing, including the electronics industry and the advanced materials industry; and in scientific research. Indeed, helium leak detection is the standard in any activity requiring leak-tight systems. Helium leak detectors were developed during World War II and can detect and measure leaks that are thousands of times smaller than the leaks that can be located by other procedures. Equipment can be calibrated to detect leaks that are smaller in volume than the equivalent of one drop of water per year. The usual procedure in leak testing is to spray the area on the outside of the system being tested with helium and then try to detect its presence on the inside, using a vacuum environment attached to a mass spectrometer.

The development of any replacement technology for helium is problematic because its use is based on its combination of unique size and inertness. Inert gases other than argon, which is excluded because it exists in the atmosphere at the 1 percent level, could be used in principle, but comparable sensitivity might require more elaborate mass spectrometers than are currently employed in helium leak-detection systems. Some degree of conservation through gas recovery might be possible using "sniffer" technology. In this approach, helium is introduced under pressure into the device being tested, and a sniffer, connected to a helium-tuned mass spectrometer, detects leaks by sensing helium leaking out of the helium-pressurized apparatus. Helium used in this manner could be recovered.

Breathing Mixtures

Mixtures of helium and oxygen are used as breathing gases for deep-sea divers and for individuals working under high atmospheric pressures for extended periods of time. The advantage of helium over nitrogen in these mixtures is that it is absorbed and released by human tissue faster than nitrogen, making longer dives possible with shorter decompression times. The amount of helium used was about 56 million scf (1.6 million scm) in 1996. Given the diving industry's increasing reliance on robot replacements for humans, however, the amount of helium used for diving is expected to remain relatively stable, or even decline. Each dive consumes very little helium because "rebreathers," which recirculate the gas, are commonly employed.

Lifting

One obvious use of helium is as a lifting gas. Unfortunately, this usage is no longer reported separately, making the amount of helium used for this purpose unknown. Because it is the most visible use of helium, however, it deserves mention in a separate section of this report.

Hydrogen is the lightest gas, but helium's chemical inertness makes it the safest lifting gas. Helium replaced hydrogen for blimps in the 1930s after a number of tragic accidents involving hydrogen-filled airships. Nowadays, party balloons are probably the application with which most people are familiar. Helium is used as well in blimps that bear advertising (e.g., the Goodyear blimp), to detect low-flying cruise missiles, and to carry radar equipment to detect drug smugglers along the nation's borders. Helium-filled balloons are also used in various types of atmospheric and astrophysical research. One future use of helium is as a lifting gas in devices to lift heavy loads for construction.

Other Uses of Helium

Other uses of helium include minor medical uses and uses in lasers not covered in previous sections. The total amount of helium used for these purposes was about 320 million scf (8.9 million scm) in 1996.

POTENTIAL FUTURE USES

This section discusses potentially important applications that could rely on the availability of helium at a low price: magnetic levitation, superconducting magnetic energy storage, energy conversion systems, cryogenic wind tunnels, and superconducting electronics.

Magnetic Levitation

Superconducting magnets could be a central feature of a transport technology involving magnetic levitation (MAGLEV). In this technology, trains are levitated above their tracks, eliminating wheels and permitting very high-speed operation without frictional losses. The Japanese version of MAGLEV is based on the magnetic repulsion between a conducting track and high-power, helium-cooled, superconducting magnets on the vehicle. The highest speed achieved by a full-size test vehicle was 250 mph. A scaled-down, non-passenger-carrying vehicle attained 321 mph (517 kph) in 1979. Although superconducting MAGLEV technology was pioneered in the United States, there has been almost no domestic effort to develop it over the past 30 years.

Superconducting Magnetic Energy Storage

Superconducting magnetic energy storage (SMES) devices store energy in magnetic fields. These systems are highly efficient and could be used for equalizing energy distribution in power systems on small scales, e.g., to keep high-security computer systems running. The devices consist of closed coils of superconducting wires. The coils can be fed and discharged by means of a switch that connects the winding with the power grid. Superconductors are the only appropriate materials for SMES devices because they have no electrical resistance and thus can be operated in a persistent current mode without being connected to a power supply. A SMES device is the only method of storing electrical energy without first converting it to mechanical or chemical energy. The energy density in superconducting coils is comparable with that in flywheels (i.e., higher than that for capacitor banks, but less than that for batteries). Their short cycle times make them competitive with batteries, however. SMES units can be large scale (i.e., 1 MWh to more than 1 GWh) or small-to-medium scale (i.e., a few watt-hours to 1 MWh).

Energy Conversion Systems

Superconducting technology is considered to be an important secondary technology for plasma confinement fusion. Helium would play a critical role in cooling the superconducting magnets that would provide the magnetic containment environment. This kind of fusion technology would become widespread only in the very distant future, if ever. Nevertheless, it is essential to mention it as a potential user of helium as a refrigerant for superconducting magnets, which would probably require liquid-helium temperature refrigeration even if they were made from high-temperature superconducting wire.

A possible nearer-term use for gaseous helium in the energy conversion enterprise is in the high-temperature gas-cooled reactor. This type of fission reactor is fueled with a mixture of graphite and fuel-bearing elements. The coolant consists of helium gas pressurized to about 100 atm. Helium, which is radiologically inert, passes through interstices in the array of fuel and graphite elements. These reactors can operate at extremely high temperatures, as graphite has a high sublimation temperature and helium is chemically inert. The hot helium can then be directly used either as the working fluid in a high-temperature gas turbine or as the heat source to generate steam. The advantages of such a reactor are that it is meltdown-proof, nearly 50 percent more efficient than current water-cooled reactors, more proliferation-resistant since it uses ceramic fuel, and an efficient plutonium burner, and also that it produces less high-level waste. A joint U.S./Russian program is developing and constructing reactors for the destruction of Russian weapons-grade plutonium and is looking at their possible commercialization and marketing. Each reactor would require an inventory of 100,000 scf (2,800 scm) of helium and a reserve of 200,000 scf (5,600 scm). The inventory is expected to be drawn down at 25 percent per year. Depending on scenarios for deployment, the cumulative requirement for helium by 2020 could be as high as 75 million scf (2.1 million scm).

Cryogenic Wind Tunnels

Other potentially important uses for helium are in the operation of high-Reynolds-number wind tunnels, which would facilitate testing the behavior of aircraft and ships, and high-Rayleigh-number Bénard cells, which could lead to the realistic modeling of convective behavior in weather patterns and other studies of turbulent and convective phenomena having astrophysical and geophysical significance. These facilities would require liquefiers of the scale used by the Relativistic Heavy Ion Collider at Brookhaven National Laboratory, so they could become large-scale users of helium.

The Reynolds number is a figure of merit that characterizes the flow of a fluid around an object such as an airplane or a ship. It is proportional to the product of a length of the object, the density of the fluid, and its velocity, and is inversely proportional to the fluid's viscosity. When a scale model is tested in a wind tunnel, the test is realistic only if the flow over the model is the same as the one the real plane would experience in flight. To achieve this, the Reynolds numbers of the real object and the test object must be the same. This can be difficult if the real object is much larger than the model, because the Reynolds number depends on the size of the object under test. One solution to the problem has been to increase the speed of the gas passing over the model. Indeed there are supersonic wind tunnels that use helium gas. There are limits to this approach, however. Building larger models and larger wind tunnels is too expensive, and thus the highest number achieved is typically 10 million. A submarine moving in water can have a Reynolds number as high as a billion. Liquid helium just above its superfluid transition has a very low viscosity and can be used to achieve very high Reynolds numbers.

Standard wind tunnels achieve Reynolds numbers of 10^6. A liquid-helium flow tunnel can achieve values of 10^9. Using cold, gaseous helium, Rayleigh numbers of 10^{16} to 10^{20} can be achieved, depending on the scale. For purposes of comparison, the Reynolds number of a Boeing 747 fuselage is 5×10^8 and that of a nuclear submarine is 10^9. The Rayleigh numbers of the atmosphere, ocean, and Sun are 10^9, 10^{20}, and 10^{21}, respectively.

The Rayleigh number is a figure of merit for convection. Supercold gaseous helium (i.e., helium just above its liquid-gas critical point) can be used in a structure known as a Bénard cell to study convection phenomena. This is possible because buoyancy forces dominate viscous forces in low-viscosity helium gas, leading to high Rayleigh numbers and convective behavior.

Superconducting Electronics

Superconducting electronics systems are being developed for use in radar and electronic warfare. Various switches and analog-to-digital and digital-to-analog converter systems are also being developed for communications applications. Superconducting systems using Rapid Single-Flux Quantum Logic are currently the leading technology under consideration for petaflop computing.

With a limited number of exceptions, liquid helium or cryocoolers using helium are required for all of the systems that are currently commercial or under development. Closed-cycle refrigeration is an alternative to current practices in which helium boil-off gas is expended. After the discovery of high-temperature superconductors, their use in tunneling junctions appeared to be very promising. It was believed that they could lead to a superconducting electronics technology that would not require helium. This may ultimately be possible, but probably not in large computer systems and other applications, such as ultrahigh-speed analog-to-digital and digital-to-analog converters that require large numbers of tunneling junctions on a single chip. The junctions in these systems must have tightly controlled parameters to meet operating margins. It is likely to be a very long time before chips using high-temperature superconductors can be made, and these complicated systems, if they are ever built, will probably require liquid-helium temperatures.

4

Helium Supply, Present and Future

Although the total terrestrial inventory of helium is estimated to be 17,000 trillion scf (470 trillion scm), most of this supply is in Earth's atmosphere at a concentration of only 5 ppm. Atmospheric helium is in dynamic equilibrium between the gain of helium diffusing from Earth's crust (as a product of radioactive decay of elements such as uranium and thorium) and losses of helium into space (Hwang and Weltmer, 1995).

Helium also exists in concentrations as high as 8 percent in certain natural gases. Most U.S. helium-rich natural gas is located in the Hugoton-Panhandle field in Texas, Oklahoma, and Kansas; the LaBarge field in the Riley Ridge area of Wyoming; and the federal facility in the Cliffside field near Amarillo, Texas (Figure 2.2). Generally, natural gas containing more than 0.3 percent helium is considered economic for helium extraction in the United States, although the economics of helium extraction often depend on the other products in a natural gas stream.

This chapter will examine the separation technologies used to produce purified helium, the helium reserves and resources currently identified, and the potential supply and availability of helium over the next 50 years.

SEPARATION TECHNOLOGIES

Although small quantities of helium can be extracted and purified—along with argon, neon, krypton, and xenon—from air,[1] it is mainly extracted from natural gases. In some cases helium is

[1] Air is the only practical source for all of the helium-group gases (argon, neon, krypton, and xenon) except helium. In certain extraction processes for these elements, helium is concentrated and may then be extracted and purified. However, demand for other helium-group gases is insufficient to make air an important source of commercial helium. It has been widely concluded that extraction of helium from air as a primary product is prohibitively expensive and likely to remain so for the foreseeable future (Francis, 1998). If all neon plants were equipped to extract helium, the amount produced would satisfy less than 0.1 percent of the current demand. Furthermore, if all existing air separation plants were upgraded to extract helium, the amount produced would still be less than 1 percent of the current demand.

a natural by-product of the removal of nitrogen from the gas stream to increase its heating value. In other cases, process streams are designed specifically to remove helium.

The processing of helium from natural gas can generally be considered as occurring in two distinct processes, although both processes can and do occur at the same physical location. The first step is the extraction of crude helium (50 to 70 percent by volume) from the natural gas stream. The second step is further refining to purify the helium to commercial grades.

Crude Helium Extraction from Natural Gas

Helium is often separated from natural gases in the course of removing nitrogen to improve heating value. In the United States the lowest practical helium concentration that can economically justify extraction is typically around 0.3 percent by volume. Sometimes, however, the helium is not extracted from high-concentration natural gases and is simply vented to the atmosphere when the natural gas is burned as fuel.

Determining the feasibility of extracting helium from a particular source of natural gas is extremely complicated and is influenced by a combination of technological, logistical, and economic factors. For example, too small a reserve base may disfavor the installation of expensive helium extraction and/or purification facilities. Economic and technical considerations surrounding other products in the natural gas stream and contractual obligations can also affect the economics of helium extraction. All of these factors must be taken into account before a helium extraction site can be planned and established.

Extraction of crude helium from natural gas typically requires three processing steps. The first step is the removal of impurities. Amine and glycol absorption, dry desiccant adsorption, and/or other extraction processes typically remove water, carbon dioxide, and hydrogen sulfide from the gas. The second step is the extraction of the high-molecular-weight hydrocarbons. The third step is cryogenic processing, which removes most of the remaining methane gas. The product is a crude helium typically containing 50 to 70 percent helium, with the remainder being primarily nitrogen along with smaller amounts of argon, neon, and hydrogen.

Purification

Final purification of helium, prior to liquefaction, is typically done using either (a) activated charcoal absorbers at liquid-nitrogen temperatures and high pressure or (b) pressure-swing adsorption (PSA) processes. Low-temperature adsorption can yield helium purities of 99.9999 percent, while PSA processes recover helium at better than 99.99 percent purity (Hwang et al., 1995). PSA can be less costly for gaseous helium but may be more costly where liquefied helium production is desired. The PSA process is widely used to produce specification-pure helium in conjunction with cryogenic enrichment (Hwang and Weltmer, 1995).

TABLE 4.1 Refined Helium Sales Between 1966 and 1996 (bscf/yr)

	Sales			
	1966	1976	1986	1996
U.S. government	0.8	0.2	0.4	0.2
U.S. private sector	0.1	0.4	1.1	2.4
Export	0.0	0.1	0.4	0.8
Total	0.9	0.7	1.9	3.4

SOURCE: Figures for 1966, 1976, and 1986, Campbell (1988) and for 1996, Peterson (1997).

HELIUM RESERVES AND RESOURCES

The United States is the world's largest producer of helium. Table 4.1 summarizes U.S. helium sales over the last four decades. The two most important sources of helium in the United States are the Hugoton-Panhandle field complex, which is located in Texas, Oklahoma, and Kansas, and ExxonMobil's LaBarge field, which is located in the Riley Ridge area of southwestern Wyoming. Most production from the Hugoton-Panhandle complex is connected to or could be connected to the BLM helium pipeline and Cliffside storage facility near Amarillo, Texas. Approximately 2.8 billion scf (78 million scm) of helium was produced from this area in 1996, 2.2 billion scf (61 million scm) of which was sold and 0.6 billion scf (17 million scm) of which was stored in the Bush Dome reservoir. ExxonMobil's Shute Creek processing plant produces approximately 1.0 billion scf (28 million scm) from the LaBarge field, with the remaining 0.2 billion scf (5.5 million scm) coming from other facilities in Colorado and Utah.

ExxonMobil's LaBarge gas field and Shute Creek gas processing facility in Wyoming was originally designed to process approximately 480 million scf (13.3 million scm) per day of natural gas; it entailed an investment of approximately $1.5 billion. The field and processing facility currently produce around 650 million scf (18 million scm) per day of natural gas, with an anticipated upgrade expected to increase the capacity to approximately 700 million scf (19 million scm) per day. Gas produced from the field is 66.5 percent carbon dioxide, 20.5 percent methane, 7.4 percent nitrogen, 5.0 percent hydrogen sulfide, and 0.6 percent helium. The processing facility produces carbon dioxide (for enhanced oil recovery projects), methane, elemental sulfur, and helium. At peak production, the facility could produce as much as 4 million scf (110,000 scm) per day, or 1.4 billion scf (39 million scm) per year of helium.

Although the rate of return on investment has been disappointing, it is clear that ExxonMobil expects the facility to be profitable throughout its projected lifetime. Investments in equipment upgrades (including the helium processing facility) and well drilling in order to maintain deliverability are planned to continue. It was clear to the committee members who visited the facility that the facility is being operated in a manner consistent with ExxonMobil's stated goal of another 50 years of operation.

Helium is produced in small quantities outside the United States. Algeria produced about 0.5 billion scf (14 million scm) of helium in 1998. Much smaller amounts of helium are produced in Russia and Poland, China, and parts of Africa. Although the helium content of the native gas produced at the Algerian facility is only 0.17 percent, economics are favorable since the gas is being converted to liquified natural gas for shipping, and the helium in it is more highly concentrated (Francis, 1998). Algerian helium principally serves the European market.

Categories of Helium Reserves and Resources

Evaluating U.S. helium reserves and resources is the responsibility of BLM. BLM has constructed a 19,000-sample database of helium concentrations, with much of the measuring having been done at its own laboratory in Amarillo. BLM also uses data from a variety of sources for its analyses, including Potential Gas Committee reports (see, for example, Colorado School of Mines, 1995) and data from private producers of helium-rich natural gas.

BLM categorizes helium reserves using a United States Geological Survey classification system that considers both physical uncertainty and economic viability. Physical uncertainty is conveyed by dividing resources into those that are "identified" and those that are "undiscovered." Identified resources are estimated from specific geological evidence, while undiscovered resources are postulated to occur in unexplored areas. Identified resources are further divided into "measured," "indicated," and "inferred" resources. Measured resources are based on production tests and other measurements made during well drilling. Indicated and inferred resources are based on progressively less certain geological data. The combination of measured and indicated resources are referred to as "demonstrated."

Economic considerations are conveyed through a division of the resource into "reserves," "marginal reserves," and "subeconomic reserves." Reserves refer to resources that can be economically extracted. Marginal reserves border on being economically producible. Subeconomic reserves are clearly not economically producible.

The total identified U.S. helium resource base is estimated by BLM to have been approximately 589 billion scf (16 billion scm) as of December 31, 1996, of which 217 billion scf (6 billion scm) is classified as measured reserves. Of this total, 35 billion scf (1 billion scm) is in storage in the Bush Dome reservoir, 4 billion scf (110 million scm) of which is privately owned. The BLM category measured reserves comes closest to the definition of "proved reserves" used by the petroleum industry to signify actual anticipated recoverable volumes of a resource (Society of Petroleum Engineers/World Petroleum Congress, 1997). However, measured reserves are larger than proved reserves because BLM's measured resources numbers include both "nondepleting" reserves (i.e., known but not developed) as well as those from gas that is being produced but from which helium is not being extracted.

The terminology used by BLM makes it difficult to understand how much helium is potentially available. The classification scheme used by the natural gas industry is clearer, and all new helium resources are coming from that industry.

BLM estimates nondepleting measured reserves of helium to be around 53 billion scf (1.5 billion scm) of helium, the bulk of which lie in deposits in the Riley Ridge area (Gage and Driskill, 1998). The Riley Ridge nondepleting reserves are not likely to be produced in the foreseeable future because of poor gas quality. In addition, it is expected that only 60 to 65 percent of helium-rich natural gas is being processed for helium from the Hugoton-Panhandle complex (Gage and Driskill, 1998). Although this number is estimated to approach 75 percent (Gage and Driskill, 1998), a significant portion of these reserves will still be lost when helium-containing gas is ultimately burned as fuel. Accounting for these factors to attempt to arrive at a more realistic proved reserves estimate results in the data presented in Table 4.2.

TABLE 4.2 Estimate of Proved Reserves of Helium in the United States (bscf)

Location	Estimated Proved Reserves
Hugoton-Panhandle complex (except Cliffside)	38
Native gas at Cliffside	4
BLM storage at Cliffside	31
Private storage at Cliffside	4
Total Hugoton-Panhandle complex	77
LaBarge field (ExxonMobil)	67
Other	3
Total	147

At current usage of around 4 billion scf (110 million scm) per year, this reserve represents a reserve/production ratio of over 35 years. Several factors, however, could alter the situation. First, although the Hugoton-Panhandle field is rapidly depleting, operators are initiating programs (e.g., compression) to slow field decline. Such efforts could lead to future increases in natural gas production and thus to increased helium reserves. Second, there is evidence that an increasing fraction of Hugoton-Panhandle gas is being processed for helium. Plans for helium processing plant capacity increases on the storage pipeline suggest that this trend will probably continue. Third, there is evidence that natural gas processors in areas other than the Hugoton-Panhandle are becoming more interested in processing natural gas for helium, where feasible. All of these trends could act to increase helium reserves beyond those indicated above.

Future Helium Supply

A reasonable estimate of future production can be developed from the following observations. First, ExxonMobil is currently producing approximately 1 billion scf (28 million scm) per year from LaBarge, with this quantity anticipated to increase to perhaps 1.4 billion scf (39 million scm) per year in the near future. Further production from this facility is constrained by plant capacity, which is not expected to be increased further. However, such rates should be sustainable for the 50-year anticipated lifetime of the production and processing equipment.

Second, production from fields in the Hugoton-Panhandle complex is expected to decline. However, if it is assumed that the gas currently available at Cliffside (private storage plus public storage plus native gas) is eventually made available, then the lifetime of the helium processing facilities would suggest that production at current rates of around 3 billion scf (83 million scm) per year could be sustained for another 25 years.

Third, production from sources other than the Hugoton-Panhandle complex and LaBarge currently amount to only around 0.2 billion scf per year (5.5 million scm). Plants that are anticipated to come on stream in the near future are expected to approximately double this figure. Although this volume of helium would not make production from outside plants a major source, new plants in the longer-term future could make such outside production far more important.

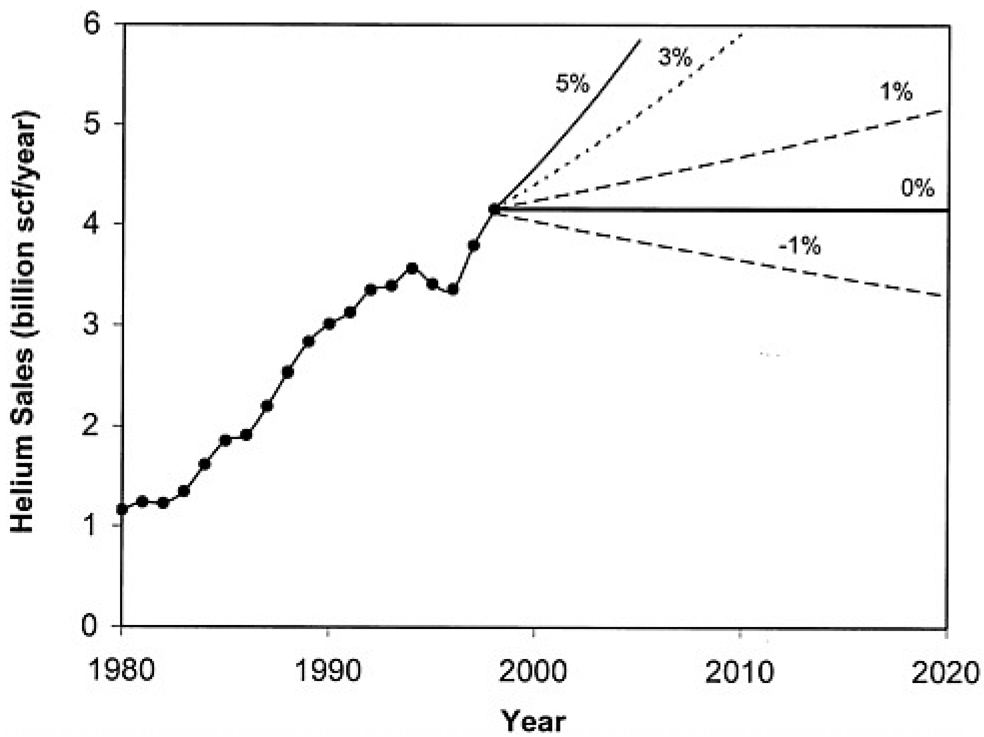

FIGURE 4.1
Historical data on helium sales for the past 20 years as well as scenarios for future sales at various rates of growth.

Forecasting the future supply of natural resources beyond what is currently being exploited is a much more difficult task, given the difficulties of assessing both geologic and economic uncertainty. However, because helium availability is tied to natural gas production and processing, analysis of the natural gas situation may be a useful means of gauging the possibility of future helium supplies.

As of December 31, 1997, proved reserves of natural gas in the United States were estimated to be 167 trillion scf (4.6 trillion scm) (U.S. Department of Energy, 1998a). During 1997, the U.S. produced 19.9 trillion scf (550 billion scm) of gas (U.S. Department of Energy, 1998b), for a reserves/production ratio of 8.4 years. Continued supplies of natural gas are a result of the dynamic natural gas industry in the United States, which is readily replacing produced reserves through new field exploration and improved recovery technology. Were this not so, such a low reserves/production ratio would result in rapid declines in the availability of natural gas. Using the production numbers above as a baseline, the committee generated Figures 4.1 and 4.2 to estimate when the private helium industry will need to buy the government-owned helium. Because the data on helium demand are inadequate for predicting future trends in helium use, the committee considered a range of possible scenarios for growth in helium consumption.

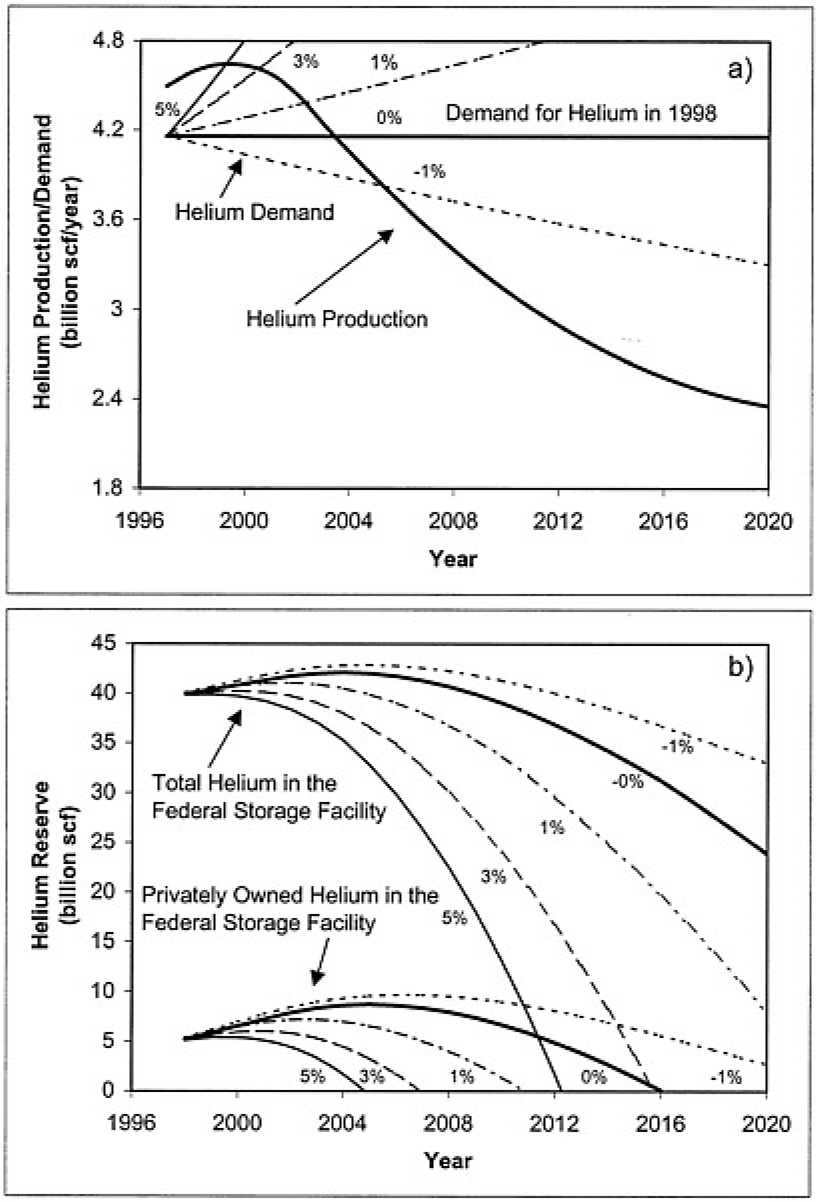

FIGURE 4.2
Part (a) shows scenarios for helium production assuming current trends (solid line) and demand based on the growth rates in Figure 4.1. Part (b) depicts the total and privately owned helium reserves assuming the growth scenarios indicated in part (a).

Figure 4.1 shows the helium sales data for the past 20 years along with curves depicting -1 percent, 0 percent, 1 percent, 3 percent, and 5 percent annual growth in helium sales.[2] Although helium sales more than doubled between 1985 and 1995, the rate of increase has varied and appears to be declining. Thus, although helium consumption will probably continue to rise in the short term, it may flatten out at a level close to the current level or even decline.

For the purposes of this exercise, the committee assumed that no new sources of helium would be discovered. The solid curve in Figure 4.2a depicts this worst-case scenario of helium production vs. time based on current production trends and capacity. The peak in this curve is due to the increase in helium production at LaBarge. The overall decline in helium production is due to the depletion of the fields connected to the Hugoton-Panhandle complex. The other lines in the figure reproduce the consumption scenarios depicted in Figure 4.1.

Figure 4.2b indicates the total amount of helium in the reserve facility (top curves) and the amount of helium in the privately owned reserve (bottom curves), assuming the supply and demand scenarios shown in Figure 4.2a. If helium demand remains constant at the 1998 level, the curves indicate that there will be a net storage of helium until about 2004. At that time, helium suppliers will begin to draw down their private stores, which will be exhausted in about 2015. If helium use increases at 1 percent, 3 percent, or 5 percent per year, the private reserves will be exhausted in about 2010, 2007, or 2005 respectively. If helium use decreases at 1 percent per year, the private reserves will not be exhausted until after 2020. If the amount of helium available is greater than the worst-case estimate used in these scenarios, the private reserve will be exhausted even later.

In scenarios where helium consumption grows less than 3 percent per year, the amount of helium private industry will need to purchase from the government to meet demand will be less than the amount the Department of the Interior is required to offer for sale. In some scenarios the difference is substantial, and it is even larger if more helium becomes available than the committee had assumed.

One might well wonder what additional volumes of helium would become available if more helium-bearing natural gas is discovered. To address this issue, several things need to be taken into consideration. First, the U.S. helium-supply commercial industry is still young, having existed only since about 1960. Second, the industry has primarily been based on sources that were discovered and exploited for other gases (i.e., the Hugoton-Panhandle and LaBarge gas fields). Although helium may play a role in gas field development decisions, companies do not specifically target exploration for helium because its economic status is that of a minor byproduct. As a result, the geological characteristics and processes that form helium-rich gas deposits are not well known, making deliberate exploration for helium difficult. Natural gas producers and operators of natural gas processing plants are becoming increasingly aware of the economic rewards of helium extraction, however. BLM conservation and storage programs have played a large role in getting this industry going and in stimulating interest in extraction. As future uses of helium grow, the awareness of helium extraction is likely to grow, perhaps resulting in a larger percentage of helium being extracted from available natural gas streams or even in deliberate exploration for new sources of helium.

It is estimated that the total U.S. potential resource base of natural gas is an additional 1,100 to 1,900 trillion scf (31 to 53 trillion scm) over the proved reserve base (as of December 31, 1993). With this potential available in the United States, exploration for natural gas is likely to continue for a very long time. As stated above, the reserves/production ratio for U.S. helium is over 35

[2] Helium sales are used as a proxy for helium consumption in this analysis.

years. Although growth in consumption could reduce this ratio in the future, particularly if few new supplies are added to the resource base, the resource base could expand if the very large potential is realized.

In addition, the Riley Ridge area of Wyoming is estimated to contain a nondepleting resource of helium of approximately 47 billion scf (1.3 billion scm) (Gage and Driskill, 1998). This helium is contained in low-quality natural gas that is not currently economic to produce. Should it become so, perhaps as a result of increased helium prices, it would increase the current reserves/production ratio by over 13 years.

Similar observations could be made with regard to worldwide helium supplies. Liquefied natural gas is becoming an important component in the world's energy supplies. Because methane liquefaction concentrates the remaining gas stream, there are potentially other sources of helium throughout the world, even in low-helium-concentration gases (such as those found in Algeria).

5

Economics of the Helium Market

This chapter will examine some special economic factors that affect the helium market, the effect on the market of setting a fixed price for federal helium sales, and the economics of helium storage.

FACTORS AFFECTING THE HELIUM MARKET

The committee's analysis of the helium market was based on a comprehensive framework[1] developed by Scherer (1971) and modified by Radetzki (1978) and Labys (1980) to incorporate special features of mineral commodities. These features include geological uncertainty, depletability, and multistage processing. Analysis of the helium market in particular requires the recognition of four special factors.

First, helium is a nonrenewable, finite resource.[2] This fact leads to concerns about exhaustibility and complicates the optimal allocation of the resource. Scarcity and the variation in resource quality mean that future sources of helium will cost more to exploit. Present consumption from any given source thus forgoes future profits, and the value of the resource is this forgone profit. Theoretically, in a perfectly competitive market, this value will appreciate over time at the discount rate minus the cost escalation rate. Helium prices can be expected to follow this rising path, although the rise may be offset somewhat by the discovery of new deposits or the development and implementation of new technologies (e.g., for conservation and recycling). The rise might also be accelerated somewhat by increased demand. Because helium is a by-product of natural gas, extraction costs are minimal. The appreciation rate is therefore likely to be close to the real market interest rate, currently 2 to 3 percent (4 to 5 percent nominal). If new, plentiful, low-cost reserves were discovered, the situation would become one

[1] The committee was unable to construct a fully articulated economic model of the helium market because historical data on the price of crude helium do not exist and the data on demand are insufficient for that task.

[2] As explained in Chapter 4, only geological sources of helium are in limited supply. Atmospheric helium is plentiful but in such a low concentration that extraction, although technically feasible, is uneconomical.

of perpetual inventory replacement (see Adelman, 1997), with prices increased only by rising exploration and extraction costs, probably less than 1 percent per year. Factors such as the availability of substitutes or the substitution of capital for natural resources can mitigate nonrenewable resource scarcity (Krautkraemer, 1998). Moreover, because every unit of a nonrenewable resource that is produced and consumed today is one less unit available for the future, the value of helium to society may be more than its value to producers.

Second, demand for helium, as for most raw materials, is primarily a derived demand. That is, most consumers of helium use it not as a final product but as an input to the production of other goods and services. Predicting demand for helium thus depends on predicting demand for these other products. Technological breakthroughs in some of the applications discussed in Chapter 3 could result in substantial increases in helium demand. By the same token, other technological breakthroughs could decrease demand. Even for some existing applications, especially those related to national security, future demand is hard to predict.

Third, there is potential for consolidation among helium suppliers. The market has multiple stages, from the extraction and storage of crude helium to the refining, transportation, end use, and recycling of pure helium, but the product changes form only at the extraction and refining stages, and then only in terms of purity. This increases the potential for vertical integration among existing firms. In addition, new firms may be discouraged from entering the market by the dominant role of the natural gas market and the government's strong involvement in helium supply and pricing decisions. For example, the government has often (although not always) sold helium at a price that is below competitive levels.

Fourth, helium is a by-product of natural gas production, so the behavior of the helium market is dominated by conditions in the natural gas market. This fact has many implications, which are, however, not fully understood, because current economic models for the optimal extraction and storage of nonrenewable by-products are inadequate.

THE EFFECT OF A FIXED FEDERAL SALES PRICE

A formula in the Helium Privatization Act of 1996 specifies the future price for sales from the federal helium reserve. Mielke (1997) calculated this price to be $43 per thousand scf (in 1996 dollars). In contrast, the price in the private market is currently about $32 per thousand scf. Chapter 4 suggests that even in the relatively near future, helium producers will have to purchase some federal helium at the $43 price to compensate for production shortfalls (see Figure 4.2b). There are additional implications, however, if the government price remains constant.

First, the government price will eventually act as a cap on private market prices. The time at which that cap becomes relevant will depend on the rate at which private market prices appreciate. As shown in Figure 5.1, if real private prices rise by only 1 percent per year, the cap will not be reached until almost 2030. If they increase at 5 percent per year, the cap will be reached in 2006.[3] At an intermediate appreciation rate of 3 percent, the cap will be reached in

[3] If the appreciation rate was 5 percent, or if a significant risk premium was applicable to investment in the inventory, the implied growth in demand would be greater than that implied by the 3 percent appreciation rate. A 5 percent growth rate might make the reserve attractive to speculators. The 1 percent growth path would reflect mistaken judgement of those who recently invested in private inventories. This scenario would most likely involve choppy price movements rather than the smooth curve depicted in the figure. If the appreciation rate was negative (a scenario not depicted in Figure 5.1), then the price of private crude helium would never reach the $43 per thousand scf federal price.

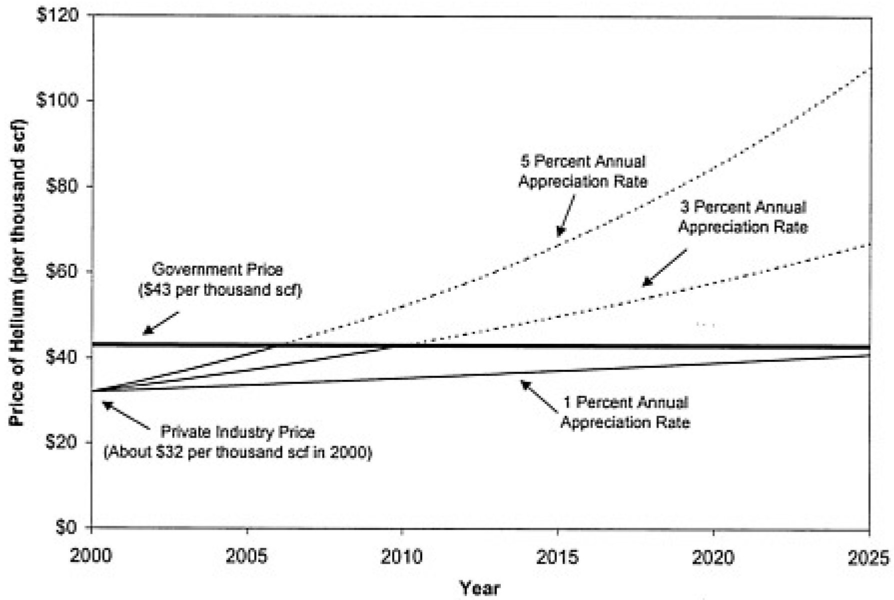

FIGURE 5.1
Trends for real private and government helium prices, assuming various appreciation rates for private sales. (The co mmittee did not consider price decreases for crude helium because that would require developments on the demand or supply side that the committee deems quite unlikely.) The dotted curves indicate private prices that will not actually be attained because the government price will act as a cap. (The three rates shown are not meant to be forecasts; they merely illustrate th e range of rates discussed in the text.)

2010, the midpoint of the projected federal sales period (as can be seen from to figure 4.2a, this rate of appreciation corresponds to a 1 percent per year increase in helium consumption according to the Hotelling model).[4] In any of these scenarios, the private price will eventually appreciate again, once the bulk of the federally owned helium has been sold.

Second, private purchases from the federal helium reserve may accelerate somewhat as the market price approaches the government price. If demand grows substantially and no new high-quality deposits are discovered, the reserve could be drawn down to the target level earlier than expected. Or, speculative private purchases could accelerate the drawing down of the reserve. The latter case would not affect actual helium consumption, but it would shift ownership from the government to the private sector and mean that carrying costs would be borne by industry.

[4] The idea that holders of an exhaustible resource will require a rate of return roughly equal to the real interest rate is the basic Hotelling model. This model implies that competitive private holders of helium inventory would sell all their holdings before the federal minimum sale price of $43 per thousand scf is reached, and provides a connection between the sales scenarios in Chapter 4 and the price scenarios depicted in Figure 5.1 For the scenarios in which the appreciation is close to the real interest rate, the date at which the price reaches the federal minimum price is the date that the private reserve is exhausted.

ECONOMICS OF HELIUM STORAGE

How much helium should be kept in storage depends on several factors. Economists typically give primacy to market efficiency, but other issues may be just as important to policy makers, who must consider societal objectives such as equity and national security.[5] In a normal competitive market, indications of static efficiency include the absence of major shortages or surpluses and a price that is equal to the marginal production cost plus the intertemporal opportunity cost (or user cost). The limited number of helium refiners makes assessment of competitiveness and static efficiency difficult, as does the practical difficulty of measuring user costs. Dynamic efficiency, which is concerned with the optimal time path of extraction and storage, is even more difficult to assess.

Storage is particularly important in the helium market because of the nature of the supply and the contract structure of the industry. The joint-product relationship between helium and natural gas, together with the seasonal fluctuation of natural gas demand, makes helium production quite variable. Events such as maintenance shutdowns can also significantly affect the regularity of supply, both within the United States and internationally. Storage helps to smooth this volatility and thus serves as a sort of insurance policy. Storage also facilitates the conservation of helium when high demand for natural gas would otherwise lead to helium production in excess of demand. In some industries, market institutions provide a similar "insurance" function. As shown in Table 5.1, however, the contract structure of the helium industry allows no futures market and only a limited spot market. The lack of these market institutions, especially the lack of a spot market, increases the importance of inventory holdings in the helium market.

What is the optimal quantity to store? Although the direct cost of helium storage is minimal, an idle asset yields no return on investment and thus has an opportunity cost. From a government perspective, the rationale for storage is usually the maintenance of a critical reserve supply for contingencies. For example, the Strategic Petroleum Reserve was created to insulate the economy from oil-price shocks. From a private perspective, the rationale for storage (of agricultural commodities, for example) is usually the desire to maximize returns as prices fluctuate.

The optimal storage quantity is reached when the marginal cost of additional inventory plus the marginal cost of storage equals the marginal benefit of inventories drawn from the stock (Bohi and Montgomery, 1982).[6] If social costs and benefits are associated with the stored good, then the social marginal costs and marginal benefits must also be balanced. In either case, as noted earlier, the balancing is an inherently intertemporal decision reflecting expectations about future prices as well as the discounting of opportunity cost associated with resource extraction.

[5] Equity is especially difficult to gauge because, unlike economic efficiency, it has no universal definition. For helium, the issue is one of intergenerational equity: whether an adequate supply will be left for future generations. Because helium is nonrenewable, pure sustainability is impossible; we cannot leave as much for future generations as we have today ourselves. The concept of sustainability can reasonably be broadened, however, to permit helium consumption that increases the stock of other assets, so that equal overall assets are left for future generations, even though there will be less helium. Perhaps the greatest complication, though, is that using a discount rate to reflect the time value of money has a negative connotation when considering periods longer than 20 to 30 years, because it implies that future generations are less important than today's.

[6] From society's standpoint, the resource added to the inventory is not actually used up at that time, so the resource cost is not incurred until it is drawn down or used. Also, storage expenses of helium are minimal, so the cost during most of the storage period is the opportunity cost.

TABLE 5.1 Helium Market Institutions

Institution	Existence	Reason
Field sales		
Spot market (1-year contract or specific quantity)	Some	Helium owner is different from extraction company
Futures market	No	Contract may have price change limitations or may specify future price
Long-term contract (multiyear)	Yes	Usually required to accept and pay for all helium produced (standard practice for extraction)
Refinery sales		
Spot market	Yes (very small)	For specific experiment or short-term use
Futures market	No	Contracts may have price change limitations
Long-term contract (1 to 3 years)	Yes (very common)	Typical supply to users who have a continuous requirement
Long-term contract (3 to 15 years)	Yes (less common)	Where supply requires large investment at customer site

A formal model developed by Epple and Lave (1980) provides some approximate results for a particular set of parameters. In that model, storage is usually found to be desirable except when the discount rate is high (e.g., 10 percent).

If storage is determined to be desirable, the next question is whether the private sector will maintain a sufficient quantity on its own. Hitherto, government storage of helium has always been a given, so there is no experience with exclusively private-sector inventories. Epple and Lave (1980) suggest that an appropriate level of storage could be undertaken by the private sector. The optimal inventory size determined by the market could then be smaller than the optimal size determined by social criteria, however. For example, the private sector might undertake too little storage (from society's point of view) if its estimate of future prices understates helium's marginal social value. Even if private storage is smaller and more volatile than is socially desirable, however, there is an incentive, if prices fluctuate, for the private sector to hold precautionary and speculative inventories.

If the policy choice is a combination of public and private storage, the optimal mix depends not only on the factors that prevent private holdings from reaching the socially optimal level but also on the feedback effect of government reserves on the size of private reserves. In general, given information about the size of the public stockpile, the prospects for its sale, and the government's supply policy, including price, the private sector can be expected to adjust its inventory accordingly. Experience with the Strategic Petroleum Reserve demonstrates that government storage can crowd out private-sector storage and that expectations about government pricing and drawdown policy can significantly influence private-sector storage incentives (Bohi and Montgomery, 1996).

The private sector is already storing helium (see Chapter 2), but there is very little flexibility in its inventory decisions. The decision to store appears to be based on the prevailing long-term take-or-pay contracts and a desire to maintain future supplies, as reflected in the development of both spot (immediate to 30-day delivery) and forward markets (delivery approximately one year in the future). Because government helium storage has never been absent, however, it is unclear to what extent the government has crowded out private-sector storage and what has been the effect of expectations about government releases on incentives to store. In other words, it is hard to know whether the quantity of private storage is likely to be adequate to allay legitimate concerns about a potential shortage for "critical" government uses. Even if it is not, the shortfall does not necessarily imply a requirement for government storage (as distinguished from government provision of storage facilities, for example by lease to the private sector). Rather, economic incentives to induce additional private supply could be a viable alternative—e.g., government contracts for purchases of helium or reducing the profit tax rate applied to helium production (Epple and Lave, 1980). It is also important to note that these questions about storage are related to, but nonetheless separate from, provisions in the Helium Privatization Act, which prescribe the pace of disposal and the price at which federal sales are to occur.

Decisions regarding the optimal private and public storage of helium are severely restricted by the current reserve base, the long-term contract structure (including take-or-pay provisions), and the dominance of natural gas extraction. As shown in Figure 4.2, based on current trends the production of helium over the next few years is likely to be in excess of demand, resulting in increased private storage. The rate of helium production will not be reduced to eliminate the temporary supply surplus, because refiners must purchase all the helium by-product generated by natural gas extraction, which is driven by the market for natural gas, not helium. In the near future, however, helium production will fall below helium refiners' demand levels, with the deficit being covered during the first couple of years by private inventories. Thereafter, helium will be purchased from the federal reserve to make up the shortfall. There is little further flexibility in additions to or withdrawals from storage. The levels of public and private inventories will drop continuously unless additional reserves are discovered (or resources are translated into reserves).

6

Impact of the Implementation of the Helium Privatization Act

Having analyzed the history of the discovery and usage of helium (Chapter 1), the structure of the federal and industrial helium establishments (Chapter 2), the uses and supplies of helium (Chapters 3 and 4 respectively), and the market in which helium is produced, stored, and sold (Chapter 5), the committee then analyzed the potential impact of the Helium Privatization Act of 1996 on private producers and users of helium. The results are presented here, in Chapter 6. The chapter concludes with recommendations for follow-on activities to monitor the long-term impact of the legislation and ensure the continued strength and stability of the helium industrial and user communities.

IMPACT OF THE LEGISLATION

The helium community is currently enjoying an extended period of stability. Since the mid-1980s, there have been no drastic increases in the price of helium and no shortages of supply. The industry has also been consistently emphasizing conservation. All the companies on the BLM pipeline store their excess crude helium in the Bush Dome reservoir, and their net storage has led to the accumulation of a private stockpile of approximately 4 billion scf (110 million scm). In the absence of large unforeseen changes, such as drastic increases or reductions in capacity or demand, this stability is likely to continue.

Under the most likely scenarios considered by the committee, the implementation of the Helium Privatization Act of 1996 will have only a modest impact on producers and users of helium over the next 10 to 15 years. First, the price it establishes for the sale of crude helium from the Federal Helium Reserve is approximately 25 percent above the current commercial price for this material. All helium refiners on the BLM pipeline have long-term take-or-pay contracts that require them to buy a negotiated quantity of helium from natural gas producers each year, regardless of whether they store it, refine it, or vent it. Because of these long-term contracts, it is highly unlikely that the refining industry will buy and use gas from the Federal Helium Reserve rather than from private stockpiles or cheaper commercial suppliers. Second, the Helium Privatization Act dictates that the Cliffside storage facility will not be sold or surplused and will continue to be available for the storage of both privately owned crude helium and the 0.6 billion scf (0.017 billion scm) of crude helium that the federal government is mandated to maintain. Thus the current approach to helium conservation will not change in any way that would force private industry to use the crude gas currently contained by the Federal Helium Reserve.

It should be noted, however, that some of the Reserve will be sold during this period for consumption by federal agencies. The Helium Privatization Act mandates that all pure helium used by federal agencies must derive from the crude helium stored in the Federal Reserve. Federal consumption of helium is modest, about 0.2 billion scf (5.5 million scm) per year. Since the price for crude helium mandated by the act is higher than commercial prices, the price paid by the federal government will be higher than the price in the commercial market.

Net private storage of helium at the Cliffside field will probably cease within the next 10 years, for two reasons. First, demand for helium will probably continue to rise somewhat over the next few years, so helium refining will increase to satisfy user needs. Second, the Hugoton-Panhandle gas fields are becoming depleted, meaning that less privately produced crude helium will be available for the plants on the BLM pipeline. To remain in business and satisfy demand, the refining companies on the pipeline will first exploit their private stockpiles at the Cliffside facility. Once these private stockpiles are exhausted, the companies will have no realistic option other than to begin purchasing the crude available from the Federal Helium Reserve. (The only other source is more production, and production is driven by the demand for natural gas, not the demand for helium.) The quantity of crude helium drawn will increase, and refiners will become more and more dependent on this resource. Assuming no dramatic changes in the production and use of helium, however, the Federal Helium Reserve will still last for about 20 years or more, meaning that the federal target of 0.6 bcf will not be attained until approximately 2020 or 2025.

Some changes will occur in the helium industry during the period in which the Federal Helium Reserve is being exploited, but the overall industry will probably remain stable. Although the release of the reserve will probably keep the price of crude helium lower than if no release occurs, there may be a slight increase in the price of refined helium. As the Hugoton-Panhandle gas fields are depleted and the Federal Helium Reserve is exploited, the price of crude helium will rise to the congressionally mandated price. A large portion of the price of refined helium comes from the cost of purifying and transporting the pure gas, however, so a rise of 25 percent in the price of crude helium would probably increase the price of pure helium by only 8 to 10 percent, which is not likely to have a dramatic impact on helium users. A second possible change resulting from the rise in price might be the emergence of investor interest in purchasing helium for speculation, although it is questionable whether the price of helium will rise sufficiently to make it more attractive to speculators than other investments. Even if it does, however, because long-term storage of crude helium is currently possible only at the Cliffside facility, any such investors would eventually have to sell their resources to the refining companies on the BLM pipeline, so the material would remain available.

The only remaining question about the legislation is whether its implementation will result in the repayment of the debt to the Treasury within the stipulated time period. The committee believes that it is unlikely that the Federal Helium Reserve will be sold, and the debt repaid, by 2015, since sales of the stockpile to nonfederal users will probably not begin until about 2010 or 2015. However, the impact on helium users of a failure to repay the debt is likely to be small, because the debt is carried by our entire society.

Finding: Based on the information assembled for this report, the committee believes that the Helium Privatization Act of 1996 will not have a substantial impact on helium users.

The Helium Privatization Act of 1996 requires that the secretary of the Interior, after receiving this report, consult with industry and others and then, if he believes the situation so warrants, make recommendations for legislation to mitigate the adverse impacts. In those consultations, a number of issues are likely to arise that are outside the main scope of the present study. These include concerns such as whether:

- Enacting legislation to reduce the price of crude helium below commercial levels or to sell it in lots at auction could seriously destabilize the helium market by increasing the probability that a single company or individual will purchase all or most of the helium in the reserve, thus creating a helium refining monopoly;
- The total supply of helium produced from wells would diminish if part of the reserve were sold before it was needed to meet the demand for helium. Under such circumstances, suppliers whose principal economic interest is methane would continue that production, forgoing the desirable conservation and storage options currently available. Helium users might also lessen their efforts to conserve and recycle helium and to develop technologies to replace helium in certain applications, even if the benefit of lower prices was relatively short-lived. On the other hand, users might experience little or no reduction in price, depending on the policies of the refiners. Furthermore, selling the reserve before the commercial price reached the "minimum acceptable" $43 per thousand scf might mean that the full debt would never be repaid. In effect, this would excuse at least a portion of the debt;
- The debt repayment schedule is appropriate;
- There are alternative methods for raising revenue if the government is intent on repaying the debt faster than is possible under the current legislation. For example, as stated in Chapter 2, the fees charged industry for storing helium in the BLM facility are currently calculated to offset the facility's direct operating costs and are divorced from any assessment of the economic value of the storage service. This system of setting fees may be limiting the potential income generated by the facility. The federal government might want to investigate a pricing structure that would permit slightly higher fees for helium storage. The increased income might then be used to help pay off the debt as well as to fund the development of superior technologies for location, storage, conservation, recycling, and replacement of helium; and
- The preservation of a viable, unsubsidized helium industry that helps this country to excel in many areas of science, technology, and national security outweighs the method and timing of debt repayment.

Unless new light is cast on these issues during the secretary's consultations with industry and others, the committee can find no reason to recommend seeking changes in the legislation.

FOLLOW-ON ACTIVITIES AND RECOMMENDATIONS

The committee believes that the implementation of the Helium Privatization Act of 1996 will not have an adverse effect on the overall production and use of helium over the next two decades. For the long term, however, a number of research programs and follow-on studies should be considered. These will ensure that the legislation has no adverse long-term effects, beyond 2020, and that sufficient supplies of helium continue to be available after 2020 to satisfy the needs of known and potential users.

Studies

The committee's assessment of the impact of the Helium Privatization Act of 1996 was based on three assumptions about the future. The first was that demand for helium will continue to rise at a steady pace, albeit much more slowly than between 1985 and 1995. Although the committee could not identify any imminent technology that would drive new, large-scale use of helium, the advent of such a technology could have a major impact on the market. An abrupt increase in demand would probably cause an abrupt increase in the price of helium, an acceleration in the rate at which current sources are produced and depleted, and a reduction in the time available to locate new sources and develop technological alternatives.

The second assumption was that there will be no drastic reductions in capacity, such as might occur if a natural disaster, plant disaster, or market decision caused a plant off the BLM pipeline to cease production. Replacing lost capacity would probably require increasing the rate of production at the current reserves. This, too, would increase the price of helium and reduce the time available to locate new sources and develop technological alternatives.

The third assumption was that no new sources of helium will be discovered. The addition of new low-cost sources of helium would serve to extend the life of the Federal Helium Reserve and provide more time to find additional sources and develop technological alternatives.

The Helium Privatization Act of 1996 mandates that its impact should be reassessed in 2015. A mechanism should be developed, however, to ensure that a review can occur sooner, especially if anything happens that would invalidate the three assumptions. The safest approach would be for the helium industry to be reviewed periodically, say, every 5 or 10 years.

Such reviews will require credible data on domestic and international capacity and consumption. The Department of the Interior currently releases annual reports that track supply and demand for helium. These reports provide crucial information on the helium market and are the primary public source of data on helium use. They should be enhanced in two ways to ensure that they register any dramatic changes in the market. First, a credible taxonomy of helium uses should be developed and consistently tracked. In the 1980s, the Department tracked 13 categories of helium use. In the 1990s this was increased to 18, but only 7 were commonly released. Such changes severely hamper efforts to identify trends in helium use that might dramatically change helium capacity and demand. Second, international consumption and production need to be tracked with the same precision as domestic consumption and production to permit the identification of any sudden changes in foreign capacity or demand. The current system tracks foreign demand primarily on the basis of U.S. export data.

Furthermore, the terminology used by BLM to describe helium reserves makes it difficult to understand how much helium is potentially available. The classification scheme used by the natural gas industry is clearer, and all new helium resources are coming from that industry.

Recommendation: The committee recommends that future reviews of the helium industry be commissioned by BLM either (1) in response to drastic increases or decreases in helium capacity or use or (2) regularly, every 5 or 10 years.

BLM should assist this continual review by improving its methods for tracking helium capacity and use. The following improvements would help ensure the timely identification of important shifts in the industry:

- Develop and implement a consistent and credible taxonomy of helium uses.
- Develop and implement better methods for tracking the international helium market.
- Report helium reserves using the natural gas industry's classification scheme.

The Helium Privatization Act of 1996 stipulates that the Federal Helium Reserve eventually stabilize at 0.6 billion scf (17 million scm), which is approximately a 2-year supply at current demand levels. The committee believes that a study is required to determine whether this is an optimal long-term supply and whether this quantity of gas can remain in the Bush Dome reservoir at sufficient concentrations to be available for future refining.

Recommendation: The committee recommends that BLM study the adequacy of the Bush Dome reservoir as the reserves are depleted. The following study tasks should be considered:

- Determine the optimal size of a federal stockpile of crude helium.
- Develop models of gas extraction at the Bush Dome reservoir to predict the helium content of future extracted gas.
- Determine whether the quantity of gas that remains in the Bush Dome reservoir will be adequate to meet future federal needs in the event of a temporary drop in private production.
- Reassess the pricing structure for the storage of helium at the Cliffside facility so that it more accurately reflects the value of the facility.

Research

To ensure the continued supply of helium into the future, research and development should be conducted in three main areas: new geological models and exploration technologies; improved helium storage systems; and enhanced technologies to conserve, recycle, and eventually replace helium.

The first area requiring research and development is the expansion of the information base and the development of methodologies to permit identifying and locating new sources of helium. The characteristics and processes that permit formation of helium-rich gas deposits are not well known, making deliberate exploration for helium difficult. This lack of knowledge has a number of explanations, including the relative youth of the commercial helium supply industry; the reliance of the industry on existing sources (the gas fields in the Hugoton-Panhandle area) and on sources that were discovered and exploited for other gases (the gas fields in the Riley Ridge area); and the economic standing of helium as a minor by-product of natural gas. The producers and operators of natural-gas processing plants are becoming increasingly aware of both the economic rewards of helium extraction and the long-term need for new sources. Research should be begun now to develop a base of knowledge and technology for identifying and locating new sources of helium, so that these capabilities will be available when they are eventually needed.

The second area requiring research and development is the development of long-term storage facilities for helium. The properties of helium that make it the ultimate leak detector (i.e., its high diffusion coefficient and low viscosity) also make it extremely difficult to store and transport. The Cliffside facility is currently the largest facility in the world for long-term storage of crude helium. Its potential as a storage facility was only recognized, however, because it was a depleted field that was known to have previously contained relatively high helium concentrations (about 1.6 percent). The development of improved storage facilities is important because they would allow production facilities off the BLM pipeline to produce and store larger quantities of helium.

The third area requiring R&D is the development of methods to increase efficiency, conservation, and recycling in helium-dependent technologies and eventually to eliminate the need for helium entirely in some applications. For example, a great deal of progress has already been made in the development of cryocoolers and other technologies to recycle liquid helium and reduce the overall amount consumed. Incremental advances in cryogenic technologies continue to be pursued to reduce helium use further. Advances in technologies that require liquid helium temperatures should also be pursued in order to reduce the need for those temperatures (e.g., by employing high-temperature superconductors). This dual emphasis on incremental improvements in recycling and conservation and the eventual development of alternative technologies that do not require helium should be applied to other helium-based technologies (e.g., purging, welding, and other manufacturing processes) to reduce overall helium consumption even further.

Recommendation: The committee recommends that the Department of the Interior conduct research and development to ensure the continued supply of helium into the future. Goals for this research and development should include (1) new geological models and exploration technologies; (2) improved helium storage systems; and (3) enhanced technologies to conserve, recycle, and eventually replace helium.

The following specific research and development tasks should be considered:

- Determine the geological characteristics and processes that permit the formation of helium-rich gas fields and develop methodologies and databases to assist in the discovery of these fields.
- Identify potential sites for natural storage facilities to permit the establishment of new facilities near future major helium producers and to allow an increase in the storage and conservation capabilities of helium users.
- Develop economic models for the extraction and storage of joint-product, nonrenewable resources the production of one of which is dominated by supply and demand for the other.
- Improve the efficiency of technologies that currently depend on helium and develop alternative technologies that do not require helium.

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Appendixes

A Agendas for Meetings of the Committee on the Impact of Selling the Federal Helium Reserve

July 6-7, 1998 Washington, D.C.

Monday, July 6, 1998

8:00 am	Breakfast	
CLOSED SESSION		
8:30 am	Welcoming Remarks	J. Reppy and R. Beebe, Co-chairs
8:40 am	Introduction to NRC	
9:00 am	Discussion: Committee Balance and Conflict of Interest	
10:00 am	Break	
OPEN SESSION		
10:15 am	Briefing: Helium Reserve Facility and Study Origin	Robert Doyle, Department of the Interior
11:15 am	Briefing: Helium Commercial Industry	Arthur Francis, formerly of Praxair and NSF Antarctic Program
12:15 pm	Lunch	
1:00 pm	Briefing: Mineral Resource Economics—Issues and Scenarios	Adam Rose, Pennsylvania State University
1:45 pm	Briefing: Federal Privatization Scenarios and Policy Issues	Tim Brennan, University of Maryland
2:30 pm	Break	

2:45 pm	Discussion: Prioritization of Elements of Study Charge	Reppy and Beebe
5:00 pm	Adjourn	
6:15 pm	Reception	
6:45 pm	Dinner	

Tuesday, July 7, 1998

OPEN SESSION		
7:30 am	Breakfast	
8:30 am	Convene	Reppy and Beebe
8:30 am	Discussion: Report Objective, Scenarios, and Outline	
10:30 am	Break	
10:50 am	Discussion: Topics and Agenda for Helium Reserve Site Visit	
12:15 pm	Lunch	
1:00 pm	Discussion: Topics and Agenda for Helium User Workshop	
CLOSED SESSION		
3:00 pm	Committee Deliberation and Assignments	
4:00 pm	Adjourn	

October 6-7, 1998 Washington, D.C.
Tuesday, October 6, 1998

8:00 am	Breakfast
OPEN SESSION	
8:30 am	Presentations from the Helium Producers/Refiners (details to be set by them)
	Topics: Producers'/Refiners' Views on:
	The Meaning of the Legislation
	Government's Role in the Helium Market and the Reserve
	The BLM Projections of Supply and Demand for Helium
	The Impact of The International Market on the Domestic Helium Industry
	Plans for Future Helium Production
	Other Issues of Concern to Producers/Refiners
Noon	Lunch with Helium Producers/Refiners
1:00 pm	Planning for the Users' Workshop in December
1:00 pm	Identifying Users

2:00 pm	Identifying User Issues
3:00 pm	Workshop Structure
4:00 pm	Draft Agenda
5:00 pm	Adjourn
6:15 pm	Reception
6:45 pm	Dinner

Wednesday, October 7, 1998

7:30 am	Breakfast	
CLOSED SESSION		
8:30 am	Convene	Beebe, Reppy
8:30 am	Outline of Chapter 3, Supply of Helium	M. Miller
9:45 am	Outline of Chapter 4, Marketplace for Helium	M. Macauley
11:00 am	Outline of Chapter 5, U.S. Federal Helium Reserve	Beebe
12:15 pm	Lunch	
1:00 pm	Discussion: Conclusions	Beebe, Reppy
2:30 pm	Discussion: Potential Economic Scenarios	Reppy, Rose
2:30 pm	Overview	Macauley, Rose
3:00 pm	Scenarios: Helium in the Reserve	
	1. Is Sold at or Above the Required Price	
	2. Stays in Federal Hands	
	3. Is Sold to Industry at a Price below Market Value	
	Other Scenarios	
4:00 pm	Adjourn	

December 8-9, 1998 Washington, D.C.
Tuesday, December 8, 1998

7:30 am	Breakfast	
8:30 am	Convene and Introductions	R. Beebe and J. Reppy
8:45 am	Pricing of Helium	Art Francis, AWF Consulting
LARGE-SCALE INDUSTRY USERS		
9:15 am	Leak Detection and Purging of Rocket Engines	Tom Elam, NASA
9:45 am	Leak Detection and Purging of Rocket Engines	Eric Stangeland, Boeing
10:15 am	Break	
10:30 am	Superalloy Quenching, Premium Powder Production, and Welding in the Jet Engine Industry	Scott Walston, GE Aircraft Engines

11:00 am	Laser Welding	Dave Farson, Ohio State
11:30 am	Discussion	
Noon	Lunch	
SMALL-SCALE INDUSTRY USERS		
1:00 pm	Cryogenics	Garry Ferguson, Oxford Instruments
1:30 pm	Fiber Optics Production	Siu-Ping Hong, Lucent
2:00 pm	Magnetic Measuring Systems	Ron Sager, Quantum Design
2:30 pm	Coolant for Nuclear Reactors	Mark Haynes, General Atomics
3:00 pm	Break	
3:15 pm	Semiconductor Fabrication	John Pilot, Intel
3:45 pm	Cryo/Superconducting Electronics	Elie Trak, Hypres Digital Electronics
4:15 pm	Magnetic Resonance Imaging	Phillip Eckels, General Electric
4:45 pm	Discussion	
5:30 pm	Adjourn	

Wednesday, December 9, 1998

7:30 am	Breakfast	
8:30 am	Convene	R. Beebe and J. Reppy
RESEARCH USERS		
8:40 am	Overview	D. Allan Bromley, Yale University
	Inelastic Demand for Helium at a National Accelerator Facility	Claus Rode, Jefferson Laboratory
	Academic Research Needs	Douglas Osheroff, Stanford University
	Future Industrial Needs for Magnets	Hans Schneider-Muntau, National High Magnetic Field Laboratory
	Training of Future Generations of Scientists	Peter Koch, SUNY-Stony Brook
	Ground-Based Astronomy Needs	Morris Aizenman, Astronomical Sciences Division, National Science Foundation
	Small Users in Academia and NSF Recovery Program	Douglas K. Finnemore, Iowa State University
	Relativistic Heavy Ion Collider Project	Michael J. Harrison, Brookhaven National Laboratory
Noon	Lunch	
1:00 pm	Superconductivity Activities in Japan	Don Gubser, NRL
1:30 pm	Adjourn	

February 6-7, 1999 Washington, D.C.

Saturday, February 6, 1999

7:30 am	Breakfast	
8:30 am	Convene	Beebe and Reppy
	Discussion of Chapter 6 of Final Report Draft and Committee Conclusions and Recommendations	
Noon	Lunch	
1:00 pm	Discussion of Preface and Chapters 1 and 2 of Final Report Draft	
5:00 pm	Adjourn	

Sunday, February 7, 1999

7:30 am	Breakfast	
8:30 am	Convene	Beebe and Reppy
	Discussion of Chapters 3 and 4 of Final Report Draft	
12:00 Noon	Lunch	
1:00 pm	Discussion of Chapter 5 of Final Report Draft	
3:00 pm	Adjourn	

B Helium Privatization Act of 1996

Helium Privatization Act of 1996

Calendar No. 477

104th CONGRESS

2d Session

H. R. 3008

[Report No. 104-302]

IN THE SENATE OF THE UNITED STATES

May 1, 1996

Received; read twice and referred to the Committee on Energy and Natural Resources

June 27, 1996

Reported by Mr. MURKOWSKI, with an amendment

[Insert the part printed in italic]

NOTE: The material presented in this appendix has been reprinted from electronic files available on the Internet at <thomas.loc.gov>; and is intended for use as a general reference, and not for legal research or other work requiring authenticated primary sources.

AN ACT

To amend the Helium Act to authorize the Secretary to enter into agreements with private parties for the recovery and disposal of helium on Federal lands, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE

This Act may be cited as the 'Helium Privatization Act of 1996'.

SEC. 2. AMENDMENT OF HELIUM ACT

Except as otherwise expressly provided, whenever in this Act an amendment or repeal is expressed in terms of an amendment to, or repeal of, a section or other provision, the reference shall be considered to be made to a section or other provision of the Helium Act (50 U.S.C. 167 to 167n).

SEC. 3. AUTHORITY OF SECRETARY

Sections 3, 4, and 5 are amended to read as follows:

'SEC. 3. AUTHORITY OF SECRETARY

'(a) EXTRACTION AND DISPOSAL OF HELIUM ON FEDERAL LANDS-

'(1) IN GENERAL- The Secretary may enter into agreements with private parties for the recovery and disposal of helium on Federal lands upon such terms and conditions as the Secretary deems fair, reasonable, and necessary.

'(2) LEASEHOLD RIGHTS- The Secretary may grant leasehold rights to any such helium.

'(3) LIMITATION- The Secretary may not enter into any agreement by which the Secretary sells such helium other than to a private party with whom the Secretary has an agreement for recovery and disposal of helium.

'(4) REGULATIONS- Agreements under paragraph (1) may be subject to such regulations as may be prescribed by the Secretary.

'(5) EXISTING RIGHTS- An agreement under paragraph (1) shall be subject to any rights of any affected Federal oil and gas lessee that may be in existence prior to the date of the agreement.

'(6) TERMS AND CONDITIONS- An agreement under paragraph (1) (and any extension or renewal of an agreement) shall contain such terms and conditions as the Secretary may consider appropriate.

'(7) PRIOR AGREEMENTS- This subsection shall not in any manner affect or diminish the rights and obligations of the Secretary and private parties under agreements to dispose of helium produced from Federal lands in existence on the date of enactment of the Helium Privatization Act of 1996 except to the extent that such agreements are renewed or extended after that date.

'(b) STORAGE, TRANSPORTATION, AND SALE- The Secretary may store, transport, and sell helium only in accordance with this Act.

'SEC. 4.STORAGE, TRANSPORTATION, AND WITHDRAWAL OF CRUDE HELIUM

'(a) STORAGE, TRANSPORTATION, AND WITHDRAWAL- The Secretary may store, transport, and withdraw crude helium and maintain and operate crude helium storage facilities, in existence on the date of enactment of the Helium Privatization Act of 1996 at the Bureau of Mines Cliffside Field, and related helium transportation and withdrawal facilities.

'(b) CESSATION OF PRODUCTION, REFINING, AND MARKETING- Not later than 18 months after the date of enactment of the Helium Privatization Act of 1996, the Secretary shall cease producing, refining, and marketing refined helium and shall cease carrying out all other activities relating to helium which the Secretary was authorized to carry out under this Act before the date of enactment of the Helium Privatization Act of 1996, except activities described in subsection (a).

'(c) DISPOSAL OF FACILITIES-

'(1) IN GENERAL- Subject to paragraph (5), not later than 24 months after the cessation of activities referred to in subsection (b) of this section, the Secretary shall designate as excess property and dispose of all facilities, equipment, and other real and personal property, and all interests therein, held by the United States for the purpose of producing, refining and marketing refined helium.

'(2) APPLICABLE LAW- The disposal of such property shall be in accordance with the Federal Property and Administrative Services Act of 1949.

'(3) PROCEEDS- All proceeds accruing to the United States by reason of the sale or other disposal of such property shall be treated as moneys received under this chapter for purposes of section 6(f).

'(4) COSTS- All costs associated with such sale and disposal (including costs associated with termination of personnel) and with the cessation of activities under subsection (b) shall be paid from amounts available in the helium production fund established under section 6(f).

'(5) EXCEPTION- Paragraph (1) shall not apply to any facilities, equipment, or other real or personal property, or any interest therein, necessary for the storage, transportation, and withdrawal of crude helium or any equipment, facilities, or other real or personal property, required to maintain the purity, quality control, and quality assurance of crude helium in the Bureau of Mines Cliffside Field.

'(d) EXISTING CONTRACTS-

'(1) IN GENERAL- All contracts that were entered into by any person with the Secretary for the purchase by the person from the Secretary of refined helium and that are in effect on the date of the enactment of the Helium Privatization Act of 1996 shall remain in force and effect until the date on which the refining operations cease, as described in subsection (b).

'(2) COSTS- Any costs associated with the termination of contracts described in paragraph (1) shall be paid from the helium production fund established under section 6(f).

'SEC. 5. FEES FOR STORAGE, TRANSPORTATION AND WITHDRAWAL.

'(a) IN GENERAL- Whenever the Secretary provides helium storage withdrawal or transportation services to any person, the Secretary shall impose a fee on the person to reimburse the Secretary for the full costs of providing such storage, transportation, and withdrawal.

'(b) TREATMENT- All fees received by the Secretary under subsection (a) shall be treated as moneys received under this Act for purposes of section 6(f).'.

SEC. 4. SALE OF CRUDE HELIUM.

(a) Subsection 6(a) is amended by striking 'from the Secretary' and inserting 'from persons who have entered into enforceable contracts to purchase an equivalent amount of crude helium from the Secretary'.

(b) Subsection 6(b) is amended—

(1) by inserting 'crude' before 'helium'; and

(2) by adding the following at the end: 'Except as may be required by reason of subsection (a), sales of crude helium under this section shall be in amounts as the Secretary determines, in consultation with the helium industry, necessary to carry out this subsection with minimum market disruption.'.

(c) Subsection 6(c) is amended—

(1) by inserting 'crude' after 'Sales of'; and

(2) by striking 'together with interest as provided in this subsection' and all that follows through the end of the subsection and inserting 'all funds required to be repaid to the United

States as of October 1, 1995 under this section (referred to in this subsection as 'repayable amounts'). The price at which crude helium is sold by the Secretary shall not be less than the amount determined by the Secretary by—

'(1) dividing the outstanding amount of such repayable amounts by the volume (in million cubic feet) of crude helium owned by the United States and stored in the Bureau of Mines Cliffside Field at the time of the sale concerned, and

'(2) adjusting the amount determined under paragraph (1) by the Consumer Price Index for years beginning after December 31, 1995.'.

(d) Subsection 6(d) is amended to read as follows:

'(d) EXTRACTION OF HELIUM FROM DEPOSITS ON FEDERAL LANDS- All moneys received by the Secretary from the sale or disposition of helium on Federal lands shall be paid to the Treasury and credited against the amounts required to be repaid to the Treasury under subsection (c).'.

(e) Subsection 6(e) is repealed.

(f) Subsection 6(f) is amended—

(1) by striking '(f)' and inserting '(e)(1)'; and

(2) by adding the following at the end:

'(2)(A) Within 7 days after the commencement of each fiscal year after the disposal of the facilities referred to in section 4(c), all amounts in such fund in excess of $2,000,000 (or such lesser sum as the Secretary deems necessary to carry out this Act during such fiscal year) shall be paid to the Treasury and credited as provided in paragraph (1).

'(B) On repayment of all amounts referred to in subsection (c), the fund established under this section shall be terminated and all moneys received under this Act shall be deposited in the general fund of the Treasury.'.

SEC. 5. ELIMINATION OF STOCKPILE

Section 8 is amended to read as follows:

'SEC. 8. ELIMINATION OF STOCKPILE

'(a) STOCKPILE SALES-

'(1) COMMENCEMENT- Not later than January 1, 2005, the Secretary shall commence offering for sale crude helium from helium reserves owned by the United States in such amounts as would be necessary to dispose of all such helium reserves in excess of 600,000,000 cubic feet on a straight-line basis between such date and January 1, 2015.

'(2) TIMES OF SALE- The sales shall be at such times during each year and in such lots as the Secretary determines, in consultation with the helium industry, to be necessary to carry out this subsection with minimum market disruption.

'(3) PRICE- The price for all sales under paragraph (1), as determined by the Secretary in consultation with the helium industry, shall be such price as will ensure repayment of the amounts

required to be repaid to the Treasury under section 6(c).

'(b) DISCOVERY OF ADDITIONAL RESERVES-The discovery of additional helium reserves shall not affect the duty of the Secretary to make sales of helium under subsection (a).'.

SEC. 6. REPEAL OF AUTHORITY TO BORROW

Sections 12 and 15 are repealed.

SEC. 7. LAND CONVEYANCE IN POTTER COUNTY, TEXAS

(a) IN GENERAL- The Secretary of the Interior shall transfer all right, title, and interest of the United States in and to the parcel of land described in subsection (b) to the Texas Plains Girl Scout Council for consideration of $1, reserving to the United States such easements as may be necessary for pipeline rights-of-way.

(b) LAND DESCRIPTION- The parcel of land referred to in subsection (a) is all those certain lots, tracts or parcels of land lying and being situated in the County of Potter and State of Texas, and being the East Three Hundred Thirty-One (E331) acres out of Section Seventy-eight (78) in Block Nine (9), B.S. & F. Survey, (some times known as the G.D. Landis pasture) Potter County, Texas, located by certificate No. 1/39 and evidenced by letters patents Nos. 411 and 412 issued by the State of Texas under date of November 23, 1937, and of record in Vol. 66A of the Patent Records of the State of Texas. The metes and bounds description of such lands is as follows:

(1) FIRST TRACT- One Hundred Seventy-one (171) acres of land known as the North part of the East part of said survey Seventy-eight (78) aforesaid, described by metes and bounds as follows:

Beginning at a stone 20 × 12 × 3 inches marked X, set by W.D. Twichell in 1905, for the Northeast corner of this survey and the Northwest corner of Section 59;

Thence, South 0 degrees 12 minutes East with the West line of said Section 59, 999.4 varas to the Northeast corner of the South 160 acres of East half of Section 78;

Thence, North 89 degrees 47 minutes West with the North line of the South 150 acres of the East half, 956.8 varas to a point in the East line of the West half Section 78;

Thence, North 0 degrees 10 minutes West with the East line of the West half 999.4 varas to a stone 18 × 14 × 3 inches in the middle of the South line of Section 79;

Thence, South 89 degrees 47 minutes East 965 varas to the place of beginning.

(2) SECOND TRACT- One Hundred Sixty (160) acres of land known as the South part of the East part of said survey No. Seventy-eight (78) described by metes and bounds as follows:

Beginning at the Southwest corner of Section 59, a stone marked X and a pile of stones; Thence, North 89 degrees 47 minutes West with the North line of Section 77, 966.5 varas to the Southeast corner of the West half of Section 78; Thence, North 0 degrees 10 minutes West with the East line of the West half of Section 78;

Thence, South 89 degrees 47 minutes East 965.8 varas to a point in the East line of Section 78;

Thence, South 0 degrees 12 minutes East 934.6 varas to the place of beginning.

Containing an area of 331 acres, more or less.

SEC. 8. REPORT ON HELIUM

(a) Not later than three years before the date on which the Secretary commences offering for sale crude helium under section 8, the Secretary shall enter into appropriate arrangements with the National Academy of Sciences to study and report on whether such disposal of helium reserves will have a substantial adverse effect on United States scientific, technical, biomedical, or national security interests.

(b) Not later than 18 months before the date on which the Secretary commences offering for sale crude helium under section 8, the Secretary shall transmit to the Congress—

(1) the report of the National Academy under subsection (a);

(2) the findings of the Secretary, after consideration of the conclusions of the National Academy under subsection (a) and after consultation with the United States helium industry and with heads of affected Federal agencies, as to whether the disposal of the helium reserve under section 8 will have a substantial adverse effect on the United States helium industry, United States, helium market or United States, scientific, technological, biomedical, or national security interests; and

(3) if the Secretary determines that selling the crude helium reserves under the formula established in section 8 will have a substantial adverse effect on the United States helium industry, the United States helium market or United States scientific, technological, biomedical, or national security interest, the Secretary shall make recommendations, including recommendations for proposed legislation, as may be necessary to avoid such adverse effects.

Passed the House of Representatives April 30, 1996.

Attest:

ROBIN H. CARLE,

Clerk.

END

C Biographical Sketches of Committee Members

ROBERT RAY BEEBE, *Co-chair*, is former senior vice president of Homestake Mining Company. He has broad expertise in mineral economics and public policy, mineral processing and extractive metallurgical research, and mining and mineral project development and administration. Mr. Beebe is a member of the National Academy of Engineering, the Society for Mining, Minerals and Exploration, and the Mining and Metallurgy Society of America.

JOHN D. REPPY, *Co-chair*, is currently the John L. Wetherill Professor of Physics at Cornell University. Dr. Reppy's research focuses on low-temperature and microgravity physics. He is a member of the National Academy of Sciences and of the American Academy of Arts and Sciences and is a fellow of the American Physical Society, the American Association for the Advancement of Science, the New York Academy of Science, and the Institute of Physics. Dr. Reppy is the recipient of numerous honors and awards, including the Fritz London Award, a Guggenheim fellowship, a Fulbright-Hays fellowship, and an NSF fellowship.

ALLEN M. GOLDMAN is currently head of the School of Physics and Astronomy at the University of Minnesota. A superconductivity specialist, he is an expert on physical phenomena at very low temperatures. His research is in experimental condensed-matter physics. This includes work on superconductivity, electron tunneling, time-dependent effects, fluctuation phenomena in superconductors, superconducting devices and materials, and high-temperature superconductors. Dr. Goldman is a Fellow of the American Physical Society and the American Association for the Advancement of Science.

HERBERT R. LANDER is a member of the staff at Boeing/Rocketdyne. Dr. Lander is a chemical engineer who specializes in jet fuels and jet propulsion, including cryogenic propellants.

MOLLY K. MACAULEY is an economist at Resources for the Future. Dr. Macauley's research interests include public finance; the economics of energy, the environment, and advanced materials; and economic and policy issues related to space.

MARK A. MILLER is a member of the Department of Petroleum and Geosystems Engineering at the University of Texas at Austin. Formerly employed by the Getty Oil Company in reservoir and operations engineering, he has written a long series of technical publications on modeling flow processes in subsurface reservoirs of natural gas and oil. Dr. Miller's research interests are reservoir engineering, natural gas engineering, and naturally fractured reservoirs.

ADAM Z. ROSE is head of the Department of Energy, Environmental, and Mineral Economics at the Pennsylvania State University; he is also head of the Minerals Economics Program at the university. Dr. Rose's research has been primarily in the areas of energy, environmental, and regional economics. He has served as the American Economic Association Representative to the American Association for the Advancement of Science. He is also the recipient of a Woodrow Wilson Fellowship and the American Planning Association's Outstanding Program Planning Honor Award. Among his publications is the book *Forecasting Natural Gas Demand in a Changing World*.

THOMAS A. SIEWERT is a member of the Materials Reliability Division of the National Institute of Standards and Technology. Dr. Siewert is an expert on both the use of helium as a shielding gas component and the cryogenic properties of welds. He is a fellow of the American Welding Society and chairman of the American Council of the International Institute of Welding.

ROBERT M. WEISSKOFF directs imaging development at EPIX Medical, Inc. He is an associate professor in radiology at Harvard Medical School and is on the faculty of the Health Science and Technology Program at the Massachusetts Institute of Technology. He served as director of the High Speed Imaging Laboratory and as research director for Quantitative Therapy Visualization at Massachusetts General Hospital. Dr. Weisskoff is an authority on medical uses of magnetic resonance imaging. He has received recognition and numerous honors in biomedical engineering.

D List of Acronyms and Definitions

BLM	Bureau of Land Management
BOM	Bureau of Mines
boule	a paraboloid single crystal
cryogen	a substance used for cooling
LNG	liquified natural gas
MCVD	modified chemical vapor deposition
MRI	magnetic resonance imaging
Nd:YAG laser	a solid-state laser based on a neodymium-substituted yttrium aluminum garnet crystal
NMR	nuclear magnetic resonance
scf	standard cubic foot (1 scf at 14.7 psi and 60 °F (non-BLM figures) or 70 °F (BLM figures))
scm	standard cubic meter (1 scm at 101.3 kp absolute and 15 °C; 1 scm = 36.053 scf)
SQUID	superconducting quantum interference device