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Determination of Fair Market Value Pricing of Crude Helium

Final Report

for

U.S. Department of Interior's Bureau of Land Management and Office of Minerals Evaluation

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by

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1.0 Introduction

1.1 Purpose

The goal of this project is to provide the Department of Interior (DOI) Bureau of Land Management (BLM) with methods and procedures to establish an economically defensible price for helium for fiscal year 2014 and beyond. We will establish scenarios of the current and future helium market conditions in the United States (U.S.) and Offshore that drive helium pricing.

To establish these scenarios (put them in context), an overview of global helium reserves, capacities, and production; supply chain economics, markets, and forecast market; and capacity growth trends will be provided.

All issues in the body of this report are as outlined in the Contract Statement of Work (SOW) with this report's organization following the sections of the SOW.

An Appendix is provided at the end of each of the main sections for easy reference to material not included in the section itself.

1.2 Key Definitions

The report will use some standard terms, definitions, and measures as defined below

a. Geographic Regions - The analysis will look at the following regions and countries:
   - *Americas:* United States, Canada, Mexico, Central America, and South America
   - *Europe:*
     - *Western Europe* - France, Germany, United Kingdom, Spain/Portugal (Iberian Peninsula), Italy, Ireland, Scandinavia, Benelux (Belgium, Netherlands, and Luxembourg), Greece, Austria, and Switzerland
     - *Eastern Europe* – Russia, Poland, Czech Republic, Ukraine, Romania, Hungary, etc.
   - *Africa/Middle East/India:*
     - *Africa*
     - *Middle East* - GCC States (Saudi Arabia, Kuwait, Bahrain, Qatar, UAE, Oman), Turkey, Pakistan, Afghanistan, Iraq, and Israel
     - *India*
   - *Asia:*
     - *South Pacific Rim:* Australia, New Zealand, Singapore, Thailand, Malaysia, Burma, Indonesia, Vietnam, Cambodia, and Philippines
     - *North Pacific Rim:* Japan, China/Hong Kong, South Korea, and Taiwan

b. Units of Measure and Currency - The analysis of helium will use the following units:

- *Volume Cubic Feet:* Thousands of Cubic Feet (Mcf); Millions of Cubic Feet (mmcf); per day (mmcf/d); and per year (mmcf/year); Billions of Cubic Feet (Bcf); Trillions of Cubic Feet (Tcf).
- *Volume Cubic Meters:* Thousands of Cubic Meters (kcm); Millions of Cubic Meters (mcm); per day (mcm/d); and per year (mcm/year); Billions of Cubic Meters (bcm); Trillions of Cubic Meters (tcm).
- *Crude Helium:* That helium with equal to or greater than 50 percent "contained" helium which is recovered from upstream processing of natural gas to produce natural gas liquids (NGLs) or liquefied natural gas (LNG)
- *Refined Helium:* That helium purified to commercial Grade A gaseous helium
- *Liquid Helium (LHe):* That helium which has been cryogenically liquefied for liquid bulk transport and/or for use as an ultra-low temperature refrigerant
- *English volume measures for gas converted to Metric: 1 standard cubic meter contains 36.053 standard cubic feet*
- *ISO Tanks:* Cryogenic super insulated tanks designed/built under the UN's International Standards Organization code for intermodal and oceanic container transport and shipping
- *Spigot:* Referring to Capacity or Production of helium volume free on board (fob) at the plant.
- *Nameplate Capacity (NPC):* Capacity designed into a specific production plant including how it has been upgraded to higher capacity
- *Effective Plant Capacity (EPC):* Nameplate Capacity adjusted for planned or unplanned plant maintenance, crude availability, etc. (i.e., Plant Capacity at the Spigot)
- *Maximum Deliverable Production (MDP):* Spigot Plant Capacity available for sale as adjusted for inefficiencies in supply management such as shipping schedules weather, container availability, and container residual
- *Years:* Generally Calendar unless otherwise specified
- *Value:* All values will be in $U.S. unless otherwise specified
- *Prices, Costs, and Unit Market Valuations:* $U.S./thousand cf (Mcf)
- *APR:* Asia Pacific Region

Note: Due to rounding, subtotal numbers may not add to the exact totals in tables and figures.

2.0 Executive Summary

2.1 Background

The Department of Interior (DOI) Office of Minerals Evaluation (OME) contracted with J. R. Campbell & Associates, Inc. (JRCI) to provide the Bureau of Land Management (BLM) with the methods and procedures to establish an economically defensible end-user market based crude helium price for FY 2014 and beyond. This task was driven by the DOI Office of Inspector General (OIG) report of November 2012. With the passage of The Helium Stewardship Act of 2013, the BLM is required to continue offering crude helium for sale and by auction.

The original project assignment was to determine a BLM crude price based on 4 defined scenarios of the current and future helium market conditions in the U.S. and Offshore that drive refined global end-user helium pricing. On further research, definition, and agreement by BLM and the OME, it was decided that a single U.S. Scenario was what was required to accomplish the project assignment. It was determined that the other 3 scenarios/conditions would not impact the U.S. market until after BLM reached the end of it operating life, about 5 years at maximum production capacity.

- Offshore implications
- Conservation
- Closure

This assignment develops the methodology to determine a fair market price for BLM's crude helium price based on end-user helium market prices. That price does not include other factors that could add to the market based price component such as the recovery of future capital investment costs, helium conservation, and funding for future BLM system's closure. These necessary expenditures will be addressed in a separate report by BLM.

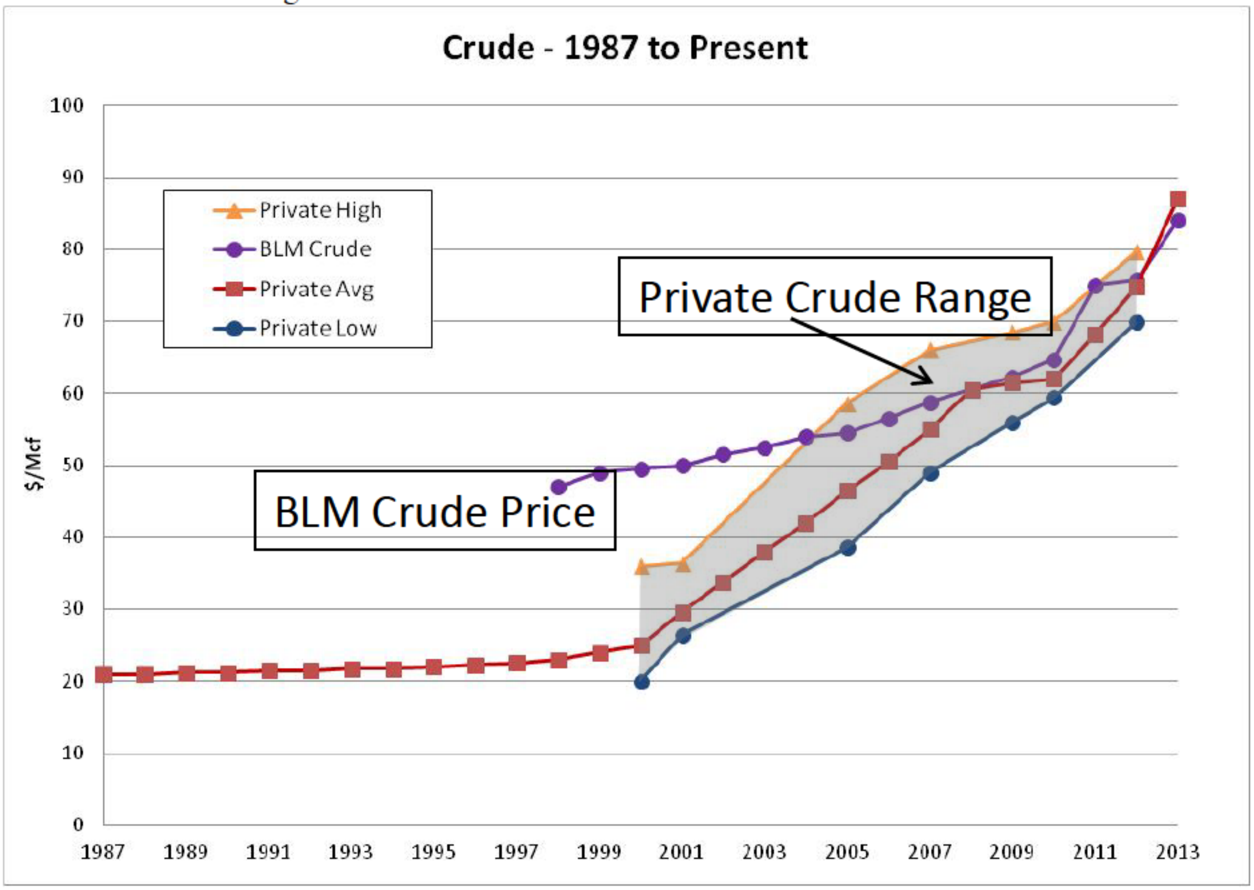
2.2 History of Crude Prices and Values

Upon the cessation of the 1960 Helium Recovery Program in 1968, the U.S. Private Sector (USPS) crude helium suppliers sold crude to the USPS refining businesses starting at $10-$11/Mcf. That price increased slowly to $23/Mcf when the new Privatization Act of 1996 was passed. That Act eliminated the refining, delivery and service for/to U.S. Government (USG) helium customers, enabled the sale of BLM crude to the USPS refiners from the BLM reservoir and pipeline system, and established the delivery of helium refined from BLM crude to USG agencies and contractors. The crude price was established in 1996 and set at $47.00/Mcf for 1998 sales. That price plus minimum escalation terms were set to pay off the Treasury debt by 2015 based on straight-line crude withdrawal and sales rates. That BLM price was also set significantly higher than the USPS crude price so as not to interfere with the USPS helium business.

By 2000, the USPS crude suppliers began to increase their crude prices to USPS refiners to close the gap with BLM. By 2008 the average USPS crude price had closed that gap, and by 2013 the

USPS crude price exceeded BLM by as much as 5%. Fig 2.2.A below shows this crude price development.

Fig 2.2.A BLM and USPS Crude Prices – 1987 to Present

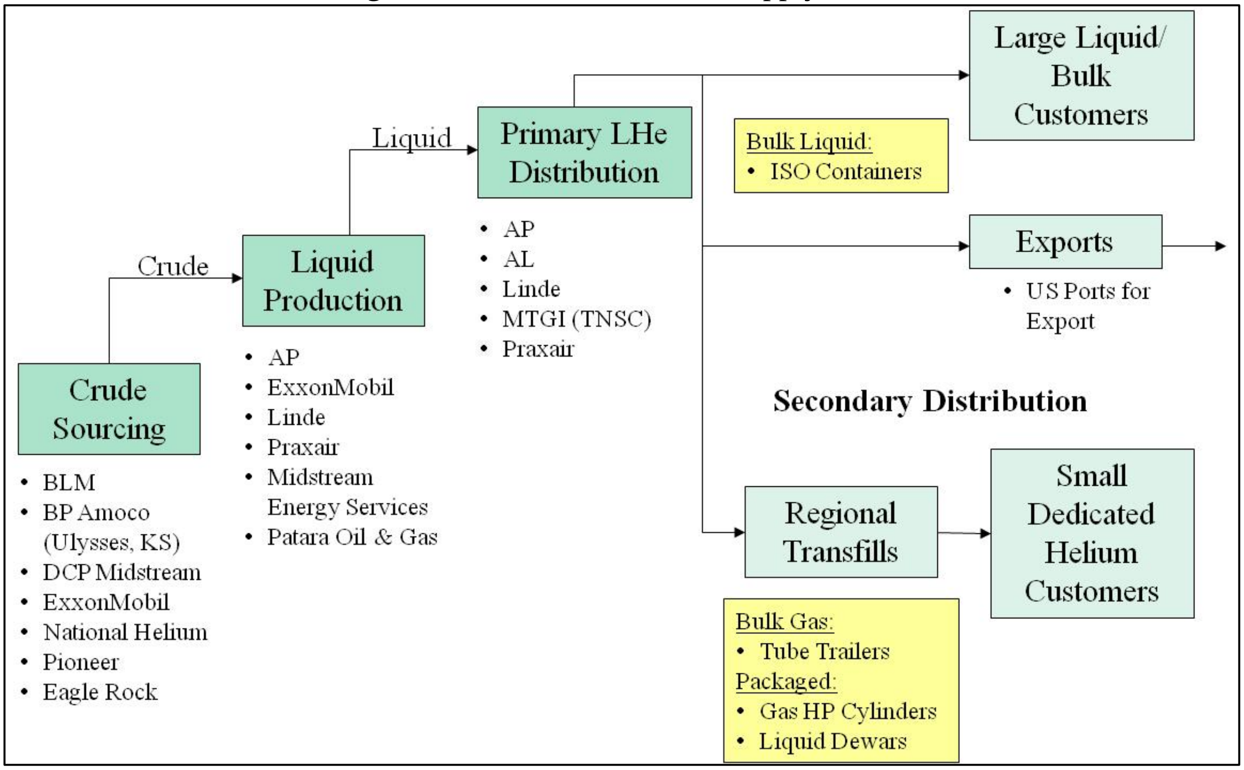


The early USPS crude prices were negotiated on a highly confidential basis between crude suppliers and refiners. On the other hand, helium producers like [redacted] had internally generated crude from a "straight-through helium production process" whereby the crude was recovered without a significant crude cost (or price). In [redacted] case, liquid is sold at the spigot (fob plant) using an assumed "value" for crude. The spigot price from this type of operation becomes the base value of helium for the refiners who are also the primary distribution companies shown in figure 2.3.A. The new offshore helium plants have the same internally generated crude helium and a cost/pricing model at the spigot similar to [redacted] with much of the spigot value closely related to BLM's price for crude.

2.3 The U.S. Helium Supply Chain from Crude to End-User Market

The sourcing for U.S. helium starts with crude fed to production of pure gas and liquid, which is delivered by Primary distribution to large customers, to Secondary redistribution depots for repackaging and further delivery to medium and smaller customers, and to export terminals located on the East, West, and Gulf coasts. Large customers and redistribution depots and helium for export have bulk liquid helium delivered in 11,000 gallon specially designed and very expensive cryogenic tanks. Medium and smaller customers are delivered by bulk in high pressure tube trailer and by packaged helium in high pressure cylinders and liquid dewars. Fig 2.3.A below shows that supply chain again, separating the bulk from the packaged helium, important in developing the container delivery price model for this assignment.

Figure 2.3A The U.S. Helium Supply Chain



The four important helium distribution modes are by:

- Bulk - in liquid ISO container and Tube Trailer gas, and
- Packaged – in high pressure gas cylinder, and liquid in dewars

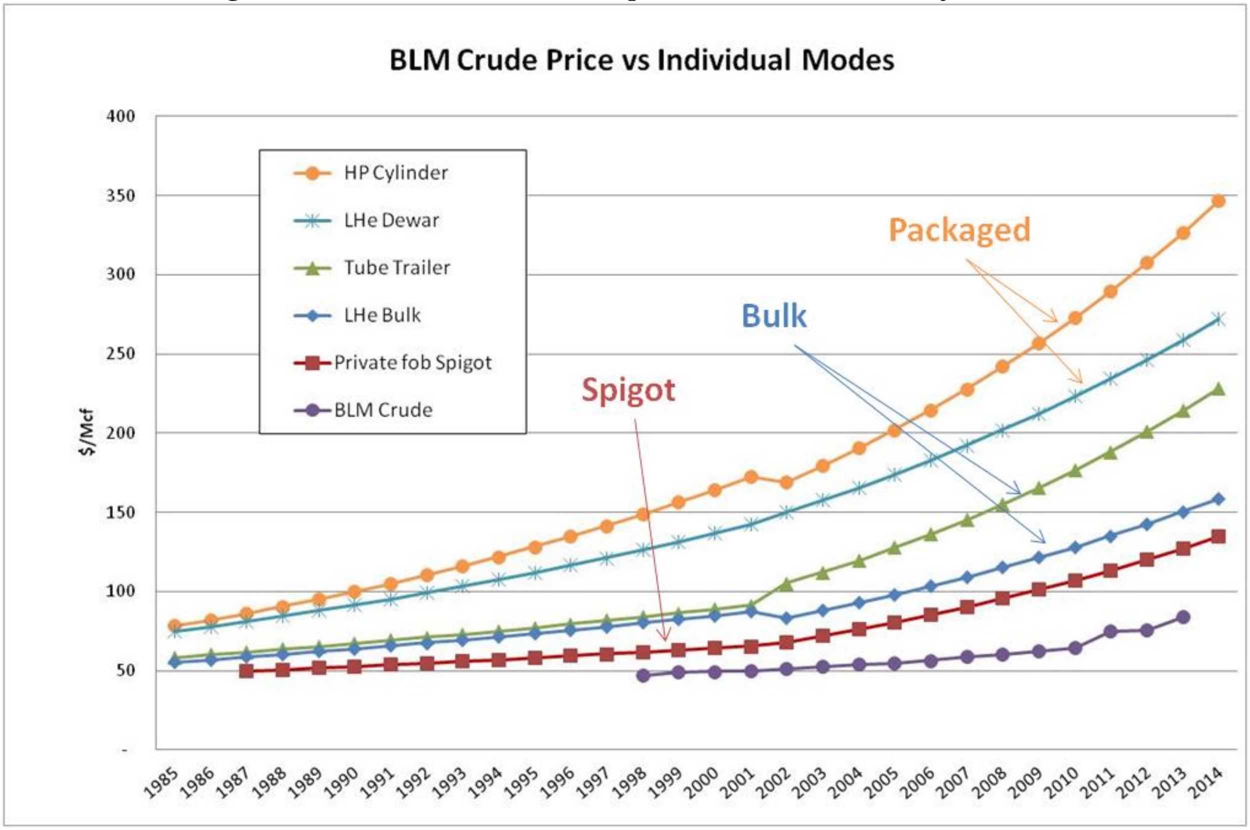
These modes are highlighted in yellow above.

The helium prices as delivered to end-users in supplier owned containers are unique to these four modes because of the significant differences in the costs due to volumes and distances delivered, and the use of supplier owned equipment cost. These cost/price factors are totally dependent on primary distance from plants and from the widely varying distribution and container cost factors, with nothing to do with crude costs down-stream from the producing plant.

2.4 End-user Refined Helium Price Development from 1987 to 2013

Fig 2.4.A below shows the development of end-user prices for refined helium for the four significant container/delivery modes which drive the cost/ price for delivering pure gas and liquid helium to customers' sites. This figure also compares those four prices with the price of BLM crude and the "value" of spigot helium. Detail on customer uses and the distribution of those uses and the modes of delivery are detailed in this Report.

Fig 2.4.A BLM Crude Price Compared to Helium Delivery Modes



As with helium's physical supply chain, we have grouped the four helium distribution modes into Bulk (liquid ISO container and tube trailer gas) and Packaged (liquid dewar and HP cylinder gas) to create two primary categories for pricing that reflects pricing unique to those categories. As noted above the price differences in bulk and packaged helium is primarily in the significant increases in container investment, its cost of capital including return, and the operating costs for delivery of very different volumes and distances to be travelled both from the plant and in the secondary distribution system. The expanding difference over time shown above indicates a logical increase in cost price that reflects the actual increasing costs and preservation of margins experienced by the gas industry in delivery bulk and packaged helium, with the value/price of crude held constant.

2.5 BLM Fair Market Value Price Methodology

The crude helium fair market price model has been developed based on the collection and analysis of historical and recently collected helium supply chain mode volumes and prices. The helium delivery mode price data included investment and distribution operating costs and minimum and average profit margins. The volume data by delivery mode included volumes to market applications of liquid and gaseous helium to obtain the share of helium delivered by each Mode.

Figure 2.5.A provides a summary of the modeled increase in the Market Reflected FY 2014 prices derived from the Price Options described.

Figure 2.5.A Summary of Three Price Options

Option Prices ($/Mcf)	2013	2014	% AGR '13 - '14
Private fob Spigot - Option 1	127.19	134.62	5.8%
Weighted Bulk Helium - Option 2	172.83	183.22	6.0%
Weighted Helium All Modes - Option 3	253.66	268.74	5.9%
BLM Crude			
Option 1	84.00	88.91	5.8%
Option 2	84.00	89.05	6.0%
Option 3	84.00	89.00	5.9%
Calculated % (Crude of Market) - Option 1	66%	66%	
Calculated % (Crude of Market) - Option 2	49%	49%	
Calculated % (Crude of Market) - Option 3	33%	33%	

The above application of the BLM Pricing Model options shows a tightly clustered price set of FY 2014 market prices very close to $89/Mcf. It also shows the logical reduction in the % of BLM crude as the container/delivery mode increases in cost with margin preserved. The result is that maintaining a 5.8% to 6.0% crude price increase from FY 2013 to FY 2014 does not change much between the three Options for price relevancy between Spigot, Bulk and all four container/delivery modes. This model demonstrates that as the mode prices are properly weighted within market segments, and by mode and then logically grouped, the resulting weighted prices of the container/delivery modes at a point in time are consistent. The difference in mode prices are consistent with price recovery of increased distribution costs and preservation of margins, and have little to do with the price of crude or the resulting cost/value of production.

2.6 BLM Fair Market Price Conclusions

Given the tight clustering of the prices as derived from the price model, the choice of which Price Option comes down to the reliability, feasibility, and cost of implementing that methodology on a continuing basis for FY 2015 and beyond. This is considered in the advantages and disadvantages of each option below.

Option 1 – Spigot Price

These prices are contractually confidential, and are really a "cost" in the helium supply chain and therefore not really reflective of "market" which is the delivered price of helium. Currently, and so long as BLM posts a minimum crude price level, all private crude prices and therefore production costs/values, will continue to reflect BLM's price. Although crude is the major part of the production cost stack, it does not really reflect “market” as it is too far removed from the customers.

Option 2 – Bulk Price (from ISO Liquid and Tube Trailer Gas)

This aggregated and weighted price of Bulk represents 40% of the U.S. end-user customer volume sold. There are less than 100 ISO liquid helium customer locations in the US, some of which are USG customers, with tightly and fairly easy to survey.

There are less than 2,500 tube trailer helium customers in the US with relatively similar applications and uses. Because of the homogeneity of those customers, including their supplying distributors this group would also be fairly easy to survey.

The combination of these two bulk customer groups would provide a representative and reflective part of the market and be relatively easy to survey.

Option 3 – Bulk & Packaged (combining the properly weighted four modes)

This represents 100% of the U.S. helium end-user market, with over 100,000 customers, and would be the most reflective of the total market, if it could be sampled properly. The addition of Dewar liquid and HP cylinder customers would add significant planning, organization, time, and money to achieve a quality sample of market reflective helium pricing. The capture of HP cylinder and dewar prices for this project results in significant pricing variation. The addition of 60% of the total U.S. market would yield only a marginal increase in the accuracy of market pricing, and would far exceed the cost of the survey result.

Our Recommendations

1. We highly recommend Option 2 as the method to implement to set a market reflective crude price for BLM. Replicating this model for future years will be relatively easy and of significantly lower cost than Option 3 while providing the same quality of pricing analysis.
2. We recommend that BLM include extra surcharges for new project and infrastructure costs to be made transparent but separate from the base end-user market reflective crude price component. Those surcharge justifications can be separately explained and warranted with market rationale modified when useful or necessary. The separation also tends to put less emphasis on the circular roll-up of crude price in the U.S. and probably dampen the circular route of increased crude price, to increased refined price, back to increased crude price. That continued action puts the USG in a peculiar position of setting worldwide helium prices.
3. We recommend that the In-Kind price be set to 80% of the new end-user market reflective component of BLM’s crude price, with a decision on how the In-Kind federal users participate in additional surcharges.

3.1 BOM/BLM Pricing Policies 1985 to Present

Task

Describe BOM/BLM pricing policies and actual pricing of applicable kinds of helium in the supply chain from 1985 to present.

Purpose of this Section

Summarize the development of U.S. helium demand and supply, including the conditions and national issues, and the development of U.S. demand, supply and pricing for both raw and crude helium and the resulting refined gaseous and liquid modes.

Include a history and explanation of BOM/BLM crude and refined helium pricing in a timeline and cover their operations, private sector operations and pricing, and the interfaces and relationships between BLM and the private sector's marketing, operations, and strategies. That historical development will explain how BLM's crude helium pricing has gained its current position in the U.S. and international helium supply schemes. It should also provide some background and insights into future BLM pricing options and strategies to meet crude pricing objectives.

The costs and prices of each helium purity level vary significantly. There are also important cost price differences between the gas and liquid delivery and storage systems. Each of these states has different price levels which should be described in detail against their position in the helium supply chain.

This section also explains the development of BOM/BLM crude and refined helium pricing on a historical timeline related to:

a. BOM/BLM Operations,
b. Private Sector Operations and Pricing.
c. The Interfaces and Relationships between the above two supply systems.

3.1.1 Historical BOM/BLM and Private Sector Operations and Helium Pricing

From the early days of the USG’s helium development, that activity was under the management of the Bureau of Mines, Department of Interior of the Executive Branch of USG. It’s responsibilities included the assay and development of the U.S.’s helium resources and the servicing of the early helium needs of the USG and US private sector needs as well as those of allied nations with helium needs consistent with US foreign and commercial policies and practices.

With the recognition that helium existed in the large volumes in the large Hugoton natural gas fields of KS, OK, and TX and the needs of developing those resources for the US’s space, military and scientific needs, the Helium Act of 1960 was passed. It enabled the recovery of crude helium via the processing of natural gas for its NGL contents which also contained crude helium. That crude was stored in a special reservoir from 1960 to 1973 via recovery processing contracts with private sector players. By the end of 1970, the debt on the reserve had grown to $210 million.

From 1967 on, the US industrial gas and related industries were developing its private commercial helium business in the Hugoton while the BOM was storing excess crude recovered and not processed into pure helium gas for sale. The US BOM had built its own USG owned helium facilities to produce and deliver to USG agencies their needs for Grade A and liquid helium. With the development of defense, nuclear, and space requirements for helium the BOM capabilities expanded rapidly with helium volumes delivered by high pressure tube railcars, tube trailers, and gas cylinders and by liquid Dewar. By 1985, this had become a substantial business for BOM that included export sale of helium and some sales of helium to the US commercial customers. BOM and the private helium refiners located on BOM's crude helium pipeline provided most of the world's helium with some helium coming from Poland and Russia into Eastern and Western Europe.

By the early 1980's BOM was producing and selling tube trailer, cylinder, and dewar helium to USG agencies and their contractors, and some helium to private sector industrial gas players for resale to their customers.

In the early 1980's [redacted] decided to develop the helium contained in its large methane and carbon dioxide reserves in the [redacted] near [redacted], [redacted] This became a significant source for high purity helium gas and particularly liquid with plant, brought on stream in 1986, was the largest helium production plant in the world. Because of its large capacity of liquid which could be shipped in high vacuum, super-insulted ISO containers around the U.S. and internationally, the [redacted] (now [redacted]) plant quickly became a strategic source for large volumes of helium in the then rapidly growing applications of MRI, welding, deep water diving, leak detection, etc. Relevant prices projected from [redacted] new spigot sourcing prices were competitive with the BOM helium. [redacted]s new high volume production and spigot prices, when trucked in new 11,000 gallon ISO containers provided lower cost cartage of 950,000 cf payloads of helium gas equivalent.

Also in the mid 1980's and under the Reagan administration, the debt incurred by the DOI/BOM for helium recovery had increased to $1.33 billion because of hyper inflation and high interest rates, and was getting attention from its line item budget status in the yearly federal budget. After realizing that the BOM helium operation was not saleable to the private sector, and finding that BOM helium pricing was lower than private sector helium pricing, BOM decided to increase its prices stay at or above private sector price levels. Shortly after that, administration interest increased in shutting down BOM's gas/liquid helium production and distribution operations, which was later mandated by the Helium Privatization Act of 1996. By 1998 the remaining crude reservoir and crude pipeline had been reorganized under the BLM and crude helium was being sold to private helium refiners to process and deliver their requirements to USG agencies and their contractors. The crude price was established in 1996 and set at $47.50/Mcf for 1998 sales. That price plus with minimum escalation terms were set to pay off the Treasury debt by 2015 based on straight-line crude withdrawal and sales rates. Meanwhile helium demand in the U.S. and worldwide was increasing with the effect that BLM crude became more valuable as a primary source of crude to the private helium players as an offset to the ongoing depletion of large Hugoton field's recovery of native helium to crude.

Because the few crude helium supply contracts between the private oil/gas companies and their customers were highly confidential and originally set as levels of a by-product from their natural gas (NG) and natural gas liquids (NGL) businesses, the private crude prices were considerably less than the crude price set yearly for auction by the BLM. Figure 3.1.A below shows the relative position and increases in crude price level from the private crude players as they renegotiated their crude contracts to achieve parity with the BLM price level. By 2010, the private crude prices had reached levels within 10% of BLM crude price. (This figure was originally developed by JRCI for the 2010 NRC Helium Report).

In addition to these developments in the U.S., new offshore helium supply players began to index their spigot price "values" to the publicly available BLM crude "values" integrating those values in their pricing strategies and decisions. This was particularly true with [redacted] in its pricing negotiations for their [redacted] helium plant brought on stream in 1987; their [redacted] helium plant started in 2007; and the [redacted] helium operation in [redacted] started in 2005; and a new Australian plant in 2010.

Figure 3.1.A Historical and Future Crude Helium Price (Fiscal Year Pricing)

Source: NRC 2010 report: "Selling the Nation's Helium Reserve," subsequently modified by JRCI

The above tracks the development of private sector crude helium pricing (the shaded area with min/max pricing) from the independent Hugoton based NGL gas players to helium refiners. It compares that price range with the BLM open market pricing from 2000. While the original graph was developed in 2009 based on actual data to that year and projections to 2014, updated data shows actual prices set by BLM for 2009 through 2013. This was an important document for that study.

This information has been updated and integrated into our analysis to form the relationships between crude pricing and end-user market pricing, the purpose of this project.

3.1.2 Relationship Between BLM and Private Sector Marketing and Operations

As noted above, the primary relationship between the BLM Helium operations and the private sector turnkey helium service is that BLM is an important supplier of crude helium from its Cliffside, TX crude reservoir to the 13 refining plants located on and near the BLM crude pipeline. In 2012, BLM supplied about 32% of the 6.1 Bcf of helium supplied worldwide. BLM crude is supplied to the 3 primary helium players with refining facilities on the crude pipe (CRLP), or 42% of the U.S. total supply of crude to serve U.S. and export helium requirements.

3.1.3 Role of BLM Crude Helium Price in the U.S. and Internationally

That development from 1997 to its current price is shown graphically in figure 3.1.A, together with its relationship to our estimates of other aggregate crude prices charged by the natural gas (NG) and natural gas liquids (NGL) players from their supply of crude to the 3 refiners on BLM's crude pipeline.

The refiners on the crude pipe can only refine crude which is supplied to them from BLM and/or the Hugoton based NG and NGL players which recover the crude helium as a by-product from NGL processing. There are other refining plants in the U.S. (and internationally) which recover and process the raw helium molecules as part of a single train, straight-through recovery/refining process. That system does not generally have an internally calculated crude helium cost or price. Therefore, those companies, principally [redacted] in the U.S., can decide on a crude value as part of the aggregate fob spigot price for liquid that they sell to the primary distribution players. As the main international liquid helium plants located in Algeria, Qatar, and Australia also recover helium as a by-product from LNG production under a single train recovery/production process system, those players have the same relationship between the value of the crude helium and its final liquid helium price as [redacted] does at its [redacted] plant.

Because the BLM crude price has been publically set by BLM through its volume auction process with prices set by BLM in accordance with helium Legislation, the helium industry has adopted that price as primary basis for valuing and pricing liquid helium sales fob plant to the primary distribution customers, noted in section 3.3, figure 3.3.B. In addition, the remaining, if depleting role, of the crude-only players in the Hugoton have over the past 13 years renegotiated their crude price to the refiners to be at or very close to the BLM posted price from crude. Moreover, virtually all the integrated helium recovery/production players which do not have separate crude supply, have set the escalation formulas for future price changes of the fob liquid to change by formula as the BLM crude price changes.

This crude helium price/value system has therefore resulted in the BLM crude price becoming the defacto crude price, both in fact and in valuation for the world's supply of both the helium molecule as it sits in the ground, and as it increases in value through the recovery and production of liquid helium fob plant. The price of the refined liquid or refined gas as it moves through the U.S. and international supply chain increases in cost/price as costs and profit margins are added at each stage of the rather complex supply system of various modes of delivering and varying volumes of helium liquid and Grade A gas.

3.1.4 Differences in Costs Between Gas and Liquid Delivery and Storage Systems

In section 3.2, figure 3.2.J shows the U.S. helium supply chain from the sourcing of crude helium, through primary distribution:

- To large volume helium customers are generally served directly with 11,000 gal ISO containers (with payloads of about 950,000 cf) where the container can serve as stationary/swapped plant storage vessel or by 15,000 gal tankers delivering to ISO container storage. These liquid ISO containers move interdependently between U.S. customers and into export for service to offshore markets, therefore the ISO configuration of these tanks which are the workhorses of the world's primary distribution of helium. The containers currently cost between $650,000 and $1.0 million depending on design, performance and supplier, of which there are only three.

- To regional helium transfill facilities which repackage the liquid, delivered by ISO container, into tube trailers, high pressure (HP) cylinders or liquid dewars – all for regional/ local delivery to helium customers requiring this type of smaller volume service. The tube trailers vary in size from 50,000 to 180,000 cf of capacity and cost from $100,000 to $250,000 depending on size and performance specs. The liquid dewars cost $5,000 to $15,000, and the high pressure cylinders cost from $80 to $175. From this range of equipment costs one can imagine the complexity of delivery options available to suppliers to service customers over a very wide range of volume requirements, distance from supply points, and the unit costs for various methods of supply. This equipment is generally rented to the customer which charges are separate from the price of the gas.

- By ISO liquid container to transfill depots adjacent to ISO container ports for final servicing and then loading onto container ships for ocean shipping to offshore markets. The primary ports for this type are located on the U.S. East, West and Gulf Coasts, the most used parts being Newark, NJ and Long Beach, CA.

The helium cost/pricing model is described in section 3.3, and indicates the costs and prices for the transfer of helium at each stage of the helium supply chain as noted in figure 3.2.J. As the industrial gas industry provides total delivery and storage equipment as part of their service arrangements and contracts, they prefer to rent equipment to customers. Therefore rental rates are important to determining total supply chain costs.

For purposes of this study we have grouped the above equipment as modes of distribution by ISO container and tube trailer into bulk delivery to large volume customers, and packaged helium in liquid dewars and high pressure cylinders for delivery to smaller/medium sized customers. These two groups have very different cost and price characteristics, with ISO container bulk and tube trailers being of different use, also depending on volume requirements and distance from source to customers. The difference between the bulk and the packaged helium group is more in whether the application of helium is as a gas (in HP cylinders) or as a liquid (in liquid dewars).

3.2 Helium Supply and Demand

Task

Provide a macro and micro analysis of helium crude capacity, refining, and production capacities (supply), demand, primary distribution, and the resulting demand/supply balance of U.S. and worldwide helium volumes from 1985 to 2012.

Purpose of this Section

This section must provide analyses that address raw helium in known geological structures through the supply chain to worldwide customer segments. Describe the helium supply chain from important sources, with distribution to important re-distribution depots in the U.S., and from the U.S. to important offshore redistribution depots. This analysis should further describe the analysis at a micro level and should be illustrated in map format.
Provide important background on the key issues of refined helium demand and supply by defining, quantifying, and forecasting when applicable:

a. known global raw helium reserve structures, volumes and availability for future for future processing.

b. crude helium processing capacities and their interfaces with efficient and reliable raw helium sourcing.

c. production of refined pure helium gas and liquid and its interfaces with competitive primary distribution.

d. the structure of primary and secondary helium distribution and delivery structures and systems which provide the U.S. and worldwide delivery of liquid and gaseous helium. This will include the distribution and transportation of helium gas and liquid to key large helium customers and to redistribution and transfill depots in the U.S. for further delivery to the many smaller users of helium.

This section will also describe the distribution of liquid helium from U.S. liquid production plants to U.S. ports with international ocean-shipping operations, for further transport to offshore redistribution and transfill depots.

This section will provide BLM with a better understanding of its current role in the complex international helium supply chain and BLM's important role in that supply chain. This information and analysis will be made at a micro detail level with graphics to enhance the presentation and discussions.

3.2.1 Worldwide Current and Forecast Helium Reserves (Natural Gas Formations with Proven Helium Reserves, etc.)

This will be done by indicating the world's known major natural gas reserves, many of which are known to contain helium, with a primary "parent gas" content of methane or carbon dioxide. For those countries with natural gas this section will detail by country, and for areas/regions within the country, helium reserve information on volumes, contained helium and other relevant information on the level of "proven" versus other qualifications and comments on the helium reserves. For each significant helium reserve area, current, planned, or suspected development of the helium will be noted.

An important part of this section will be a detailed description of the helium reserve information for the U.S. so that further assessments can be made of the role the U.S. is expected to have during the study period as a primary supplier to the world's helium demand and to that of helium users within its market boundaries.

At a more primary level, it is well known that helium is generally considered to be a by-product of the decay of uranium and thorium. Experience and relevant geological studies suggest that in some/many cases, "where there is uranium there is helium." According to the WISE Uranium Project documentation, updated in August 2012, the top 18 countries with identified uranium reserves, in the order of known uranium deposit volumes, are: Australia, Kazakhstan, Russia, Canada, Namibia, United States, Niger, South Africa, Brazil, Ukraine, China/Mongolia, Greenland, India, Uzbekistan, Botswana, Tanzania, Jordan, and Argentina. While it is noted that many of these countries have helium, further discussion on uranium's connection to helium is beyond the scope of this study.

The top six countries with proven helium resources, per the United States Bureau of Land Management (U.S. BLM), that currently have helium production plants are: U.S. 142 Bcf (3.9 Bcm), Qatar 365 Bcf (10.1 Bcm), Algeria 296 Bcf (8.2 Bcm), Russia 246 Bcf (6.8 Bcm), Canada 72 Bcf (2.0 Bcm) and China 40 Bcf (1.1 Bcm).

3.2.2 Overview of Current Known Helium Sources by Region by Country

Worldwide natural gas reserves are presented in figure 3.2.A, which shows the region and country, the country's estimated volume of NG reserves, the % of the NG reserve that is likely to contain meaningful helium volumes, the estimated % of contained helium, and a characterization of the existence/status of helium within each country. While the percent of helium bearing NG and % contained helium are from several sources, effort has been made to gain referenced information on both of those statistics from the NG and helium trade literature and from various publications of the U.S. Government (USG). In figure 3.2.A, the characterization of helium is an estimate based on the % probability of initial or further development of the helium reserves by country. This estimate is a matter of experience and judgment by JRCI.

Figure 3.2.A Worldwide Natural Gas Reserves and Contained Helium by Region by Country

Region	Country	Proven Natural Gas NG Rsrv (Tcm)	NG Rsrv (Tcf)	Charaterization Of Existance/Status of Helium	Est % Cntnd Helium
North America	U.S.	8.4	304.6	Yes, Significant, Developing	0.35%
	Canada	1.9	68.2	Yes, Moderate, Not Developed Yet	0.10%
	Subtotal	10.3	373		
South America	Argentina	0.3	11.7	NA	
	Venezuela	5.4	195.1	NA	
	Brazil	0.4	14.0	NA	
	Chile	0.1	3.5	Yes, Limited, Not Developed	NA
	Subtotal	5.8	209		
Europe	Russia	46.8	1688.2	Yes, Significant, Developing	NA
	Norway	2.0	73.1	NA	
	Poland	0.1	3.2	Yes, Moderate, Developing	0.10%
	Subtotal	48.9	1,765		
Afr/MidEast/Ind	Iran	32.9	1187.0	Yes, Significant, Not Developed	0.04%
	Qatar	24.7	890.0	Yes, Significant, Developing	0.04%
	Saudi Arabia	8.0	287.8	Yes, Limited, Not Developed	0.18%
	Turkmenistan	7.4	265.0	NA	
	UAE (Abu Dhabi)	6.0	215.0	NA	
	Algeria	4.4	159.1	Yes, Significant, Developing	0.19%
	Iraq	3.1	111.5	Yes, NA, Not Developed	0.04%
	Kazakhstan	2.4	85.0	NA	
	Libya	1.5	54.6	Yes, Significant, Not Developed	0.10%
	India	1.2	43.8	Yes, Not Significant, Not Developed	0.01%
	Pakistan	0.7	24.0	NA	
	Subtotal	92.2	3,323		
APR	China	3.4	124.2	Yes, Not Significant, Developed	0.02%
	Indonesia	3.0	108.4	Yes, Significant, Not Developed	0.04%
	Australia	1.2	43.0	Yes, Significant, Developing	0.31%
	P New Guinea	0.2	5.5	NA	
	Subtotal	7.8	281		
Total Worldwide (Calculated)		164.7	5,937		
Total Worldwide (Total Estimate)			6,707		

Sources: U.S. Energy Information Administration (EIA), International Energy Statistics, Proved Reserves of Natural Gas, 2013 and Oil and Gas Journal, Survey of Natural Gas Reserves, January 1, 2013.

Worldwide natural gas reserves, measured (proven) helium reserves and total helium content by region by country are provided in figure 2.1.B. Since proven and potential helium reserves are where the helium development efforts are focused, JRCI does not include detail for speculative helium reserves in this figure.

Figure 3.2.B Worldwide Proven and Potential Helium Reserves and Contained Helium by Region by Country

	Proven Helium		Total Helium		Contained Helium	
Region/Country	**Bcm**	**Bcf**	**Bcm**	**Bcf**	**Field(s)**	**%Contained**
North America						
US	3.9	142	20.6	744	Various	0.35%
Canada	2.0	72	NA	NA	Various	0.10%
Subtotal	5.9	214	20.6	744		
Europe						
Poland	0.0	1	NA	NA		0.08 - 0.45%
Russia	6.8	246	7.1	256		NA
Subtotal	6.8	247	7.1	256		
Afr/MidEast/India						
Algeria	8.2	296	NA	NA	[redacted]	0.19%
Qatar	10.1	365	NA	NA	North Field	0.04%
Iran					North Field	0.04%
India						0.01%
Libya						0.10%
Subtotal	18.3	661	NA	NA		
APR						
Australia	0.2	8	NA	NA	Timor Sea	0.31%
China	1.1	40	NA	NA		0.02%
Indonesia					Timor Sea	0.04%
Subtotal	1.3	47	NA	NA		
TOTAL	32.4	1,169	NA	NA		

Sources: Helium Proven Reserves: BLM/U.S. Geological Survey (Mid-Continent & Rocky Mountain Regions only) and JRCI estimates.

3.2.2.1 Overview of Current Known and Forecast Helium Sources in the U.S. by Region

The world's commercial merchant helium business started in the U.S. in the 1920's based on finding easily available helium in the Texas panhandle. The U.S. will continue to be an important international factor in sourcing, markets and use/applications development, and in the development of new over-the-horizon technologies that could use significant volumes of helium in 25–50 years.

Of immediate interest and consequence is the disposition of the U.S. BLM's still very large crude helium reserve at BLM's Amarillo, TX Helium Operation's Cliffside, TX reservoir. The recently passed U.S. Legislation (Helium Stewardship Act of 2013) modifies the previous BLM pricing system to include a more market reflective BLM crude price. It also includes a provision for an increasing allocation of crude helium for auction. The Legislation states that the system will continue until the Federal Helium Reserve is 3 Bcf. The BLM posted crude price will continue to occupy a prime position in establishing new producer spigot liquid helium pricing until the reserve reaches the 3 Bcf. The Secretary of Interior has authority for USG helium operations and the responsibility to issue regulations governing the implementation of the new Legislation and the detail of BLM's helium operations. To some extent, the USG's current efforts are being guided by the deliberations and conclusions of the National Academy's committee work of 2009/2010 on most of related helium issues, including the future cost/price structure of crude helium.

As noted in figure 3.2.A, the U.S. has one of the world's largest concentrations of raw helium located primarily in two key regions, The Rocky Mountains and Mid-Continent, with a total estimated volume of 142.2 Bcf (3.9 Bcm) based on BLM measurements in their publication, "*Helium Resources of the United States – 2007, Technical Note 429, December 2008*." It also has a large and highly skilled management and work force in the oil and gas patch, with high skilled entrepreneurial investors in natural gas and its derivatives including helium. That experience in helium is also highly integrated from the discovery and recovery of helium through its entire supply chain from crude to liquid, through primary and secondary distribution, to a wide variety of uses and applications. All of this has been applied for many years in the U.S. and is currently a preferred model for offshore operations because of the magnitude of its exports and follow-on support.

The majority of the proven helium reserves are located in the Mid-Continent and Rocky Mountain regions of the United States where most of the helium extraction occurs. Most domestic extracted helium comes from the Hugoton field in Kansas, Oklahoma, and Texas; the Panoma field in Kansas; the Keyes field in Oklahoma; the Panhandle West and Cliffside fields in Texas; and the Riley Ridge area in Wyoming.

Figure 3.2.C shows the estimated helium reserves by U.S. region for Proven and Potential of estimated volumes, developed by the BLM, in their Technical Note 415, of June 2004 with 2003 volume estimates. Appendix to this section provides the BLM definitions for proven (measured), potential (probable), possible, and speculative resources. Note that the Mid-Continent and Rocky Mountain regions contain the highest percent contained helium and 91% of the total helium volume.

The BLM study goes to some lengths to analyze the known/suspected helium reserves as Depleting versus Non-depleting, and as Marginal versus Sub economic, under conditions of current costs/prices at the end of the helium supply chain.

Adding proven and probable helium reserve measures displayed on p.5 of the Technical Note 415, suggests a demonstrated helium reserve of 309.6 Bcf (8.6 Bcm), including 14.6 Bcf (405 mcm) in the Cliffside reservoir (Mid-Continent and Rocky Mountain only). While JRCI understands that these measures of helium reserves are probably estimated quite differently than other helium volumes in the world, the reserves are significant. They also suggest that helium is likely to be available in the U.S. for at least its own domestic consumption for quite some time to come. This assumes that the U.S. cost/competitive position is not totally out of sync with offshore supply/demand economics.

The Potential Gas Committee (PGC) reports estimates of natural gas resources for seven regions of the United States. These estimated natural gas resources are used to evaluate the potential helium resources of the United States. The total helium resources of the United States are estimated to be about 732 Bcf (20.3 Bcm). These include 157 Bcf (4.2 Bcm) proven (measured) helium reserves, 193 Bcf (5.2 Bcm) of probable helium reserves, 215 Bcf (5.8 Bcm) of possible helium reserves, and 185 Bcf (5.0 Bcm) of speculative (most likely) helium reserves.

Figure 3.2.C Estimated U.S. Helium Reserves and Resources (Bcf/mcm)

	Helium Reserves					
	Proven		Potential		Total	
Region	(mcm)	(Bcf)	(mcm)	(Bcf)	(mcm)	(Bcf)
Mid-Continent						
The Helium Fields (1)	1,018	36.7	11.1	0.4	1,029	37.1
BLM (Res & Stored) (2)	406	14.6	-		406	14.6
SubTotal	1,424	51.3	11.1	0.4	1,435	51.7
Rocky Mountain						
Wyoming	1,689	60.9	1.4	49.6	1,691	110.5
Four Corners	50	1.8	0.1	4.0	50	5.8
Arizona/New Mexico	11	0.4	0.0	0.2	11	0.6
SubTotal	1,750	63.1	1.5	53.8	1,752	116.9
Total Regions	3,174	114.4	12.6	54.2	3,186	168.6

(1) While the Mid-Continent has proven reserves of 1.77 Bcm (65.7 Bcf) of helium, The Helium Fields that serve the helium producers on the BLM crude pipeline have 1.0 Bcm of crude contained helium and are located in the Hugoton fields and those of the East & West TX Panhandle.

(2) Approximately 301.4 mcm (10.9 bcf) of Conservation Crude, 36.9 mcm (1.3 Bcf) of Privately Owned crude, and 67.5 mcm (2.4 bcf) of native gas contained helium at 1.8%.

Sources: Helium Reserves: Helium Resources of the United States – 2007, Technical Note 429, December 2008, Table 1 (Mid-Continent & Rocky Mountain Regions only), and JRCI assessment by state.

U.S. Reserves Under Consideration for New Capacities and Production

Mid-Continent (Hugoton)

The Field Reserve: is the aggregate of the Hugoton NG field structures and reserves bounded by the states of KS, OK, and TX. The Hugoton field map is shown in the Appendix on figure 3.2-1. It was established in the early 1900's and at the time was the large known concentration of NG in the world. The field has been supplying NG from Denver, CO east to Pittsburgh, PA for many years, and is now depleting at a rapid rate. It contains about 0.35% helium, consistently, which is extracted from the NGL components extracted in NGL processing plants at strategic junctions among the large NG pipeline systems from the gathering points in the Hugoton. The helium reserve is now estimated at 51.3 Bcf (1.4 Bcm) of contained helium at about 0.35% of total gas volume.

It is estimated to be at a level of .037% of contained helium by 2020, with field wells running then at marginal recovery pressures.

BLM's Cliffside Crude Helium Reserve: was started in mid-1964 with an input of about 8 Bcf/year until those contracts were cancelled in 1973, achieving a conservation inventory of 35 Bcf during that period. After 1973, the then USG operator was the U.S. Bureau of Mines (BOM), which was supplying the USG military, defense and space and other parts of the USG and its contractors with Grade A helium from the reservoir. At the time the Cliffside reservoir was being used to store excess crude helium for the private sector refiners who build plants along the USG crude pipeline used to pipe crude from the NGL conservations plants to their refiner plants to produce Grade A helium gas and liquid.

With the continuing depletion of The Field supply of crude helium, the refiners' crude supply started to shift at an accelerated rate to the now BLM's reserve to the point in 2007 when the BLM had become the first and last resort in crude helium supply to a declining production rate from the refiners' Hugoton based plants.

As described above, the disposition of the remaining BLM crude helium was addressed in The Helium Stewardship Act of 2013.

<u>Rocky Mountain NG and Helium Area</u>

This is a large area and for purposes of NG containing helium is made up of the States of [redacted], [redacted], and the states of CO, UT, AZ, and NM, which make up what is called the Four Corners area. It is known that this large area of three distinct sub areas contains significant NG, crude oil and CO_2 reserves, some of which contain helium which can be recovered with the recovery of CO_2 for enhanced crude oil recovery, or in some few cases with the production of LNG. Therefore this area of the U.S. is getting significant attention for future increase in its already demonstrated helium potential.

[redacted] is currently a significant source of crude helium from is large reserves of CO_2/CH_4 and contained helium in the range of 0.35% helium, and a potentially more important supplier of crude helium with an estimated total helium reserve of 110.5 Bcf (3.1 Bcm). The Riley Ridge gas field can be seen on the Map in figure 2.1-1in the Appendix.

The Riley Ridge gas field is supplying [redacted] with about 1.4 Bcf/year (38.8 mcm) of effective production from the USG owned from the Mississippian Madison CO_2, CH_4, H_2S, and helium containing from the Mississippian Madison formation. [redacted] is producing liquid helium at its [redacted] plant in [redacted] for sale to several primary helium players.

The second and new player in the Riley Ridge area is [redacted]., a very large gas, oil, and Enhanced Recovery player specializing in EOR with CO_2. It has recently bought a major share of [redacted] $CO_2/CH_4/He$ reserves in Riley Ridge for its CO_2 and helium values. In a related purchase of mineral rights from another oil/gas player, [redacted] supports the helium plant with an initial capacity of 200 mmcf/year (5.5 mcm/year) (expandable to 400 mmcf/year (11.1 mcm/year)) with sales for liquid helium scheduled 50:50 to [redacted] and [redacted] (a subsidiary of the Japanese company [redacted]). That plant is scheduled to start supplying liquid in 3Q13. This may be delayed for a few months as [redacted] litigation problems are resolved – which do not involve either [redacted] or [redacted]

It is estimated that the [redacted] in Wyoming contains proved reserves of 250 Bcf (6.9 Bcm) of natural gas, 8.9 Bcf (247 mcm) of helium, and 1.4 Tcf of CO2 net to the interest to be acquired. It estimates other acreage at a probable 250 – 300 Bcf (6.9 to 8.3 Bcm) of gas, 9.5 – 11.5 Bcf (264 to 320 mcm) of helium, and 1-1.2 Tcf of CO2 net to the interest being acquired. [redacted] net interest totals 4.5 Tcf of the gross 6.1 Tcf of total proved and probable CO_2 reserves.

Riley Ridge expected to start flowing methane and helium in late 2011, but there have been delays. Wells are being completed and separation plants built to extract methane and helium from the raw well stream, which is 65% CO_2, 19% gas, 6% helium, 5% hydrogen sulfide, and the rest other gases. [redacted] will re-inject CO_2 and H_2S until a CO_2 pipeline can be laid.

<u>Four Corners</u>
Is a large mineral sourcing area with much of the land and mineral rights owned by the USG. With 5.8 Bcf (50 mcm) of proven and potential helium reserves contained within anticipated economically viable CO_2, methane, and EOR development and extraction projects, it is very likely that helium recovery will fit into those projects. There are several projects in preliminary planning with the potential of producing at least another 600 mmcf/year (16.7 mcm/year) of liquid helium by 2020. Current and forecast helium by product cost/prices suggest an 80% probability of realization by 2020.

<u>Arizona and New Mexico</u>
Arizona and New Mexico have relatively rich helium reserves and by product values in conjunction with CO_2 recovery for enhance oil recovery. This is particularly so with [redacted] described above, purchasing the mineral and development rights to the gas formation, centered in [redacted] AZ. This CO_2 can be used to great advantage for EOR in the Permian Basin in West, Texas. The main hurdle appears to the significant pipeline expense from St. John's to West, TX. With an estimated reserve volume of 0.6 Bcf (11 mcm) and an average 0.20% contained helium in the main gas stream, the co-product value of 600 mmcf/year (16.7 mcm/year) of liquid helium is given a 25% probability of success by 2025.

In Summary

From the vantage of helium reserves, there are very good prospects for the U.S. in the Mid-Continent and Rocky Mountain areas to be able to replace at least a part of the crude volume that will eliminated from the current helium supply chain. This does not count a significant increase in [redacted] production at [redacted] or an aggressive program by the USG to replace its BLM reserve by extending the radius of action of its current NG pipeline recovery, capturing part of the depleting and non-depleting contained helium currently beyond the system.

3.2.2.2 Overview of Current Known Helium Sources by Region by Country, Outside the U.S.
The following is a short discussion of the NG and helium reserves noted in figure 3.2.A.

- Of primary relevance to the U.S. BLM helium source are the sources directly related to countries with established helium reserves with current/potential relevance to future supply. Qatar, Algeria, and the U.S are important as current and future sources of helium. Future potential sources include Russia (Eastern Siberia), Australia, China, and Indonesia, which are part of the Asia Pacific Region, the region of fastest growth in helium demand. The U.S. was covered separately in section 3.2.2.1.

  - **East Siberia, Russia:** Russia has one of the largest reserves of helium-containing natural gas, most of which are concentrated in Eastern Siberia. NG produced in Chayandinskoye field contains high-density helium, at 0.58 per cent. It has estimated proven helium reserves of 246 Bcf. [redacted] plans to build up gas pipeline from [redacted] to [redacted] via [redacted] in order to transport gas produced from the Chayandinskoye field, allowing large-scale gas processing development in Eastern Russia. A new helium production facility in the vicinity of [redacted] is planned.

  - **Australia:** has helium rich NG with significant plans to produce LNG with bi-product helium after 2020. Australia is blessed with many NG formations which have proven or potential helium deposits in the fields known as Canning, Kimberley, Gunnedah, Mereenie, Woodada, and Coonarah onshore, and the Woodside Field offshore. The new [redacted] [redacted] complex with by-production helium is fed with NG from the offshore Timor Sea Fields. Central and Western Australia is where much of the ne NG projects are located, including the Northwest shelf offshore NG reserves. Major developers of the NG to LNG potential in Australia wherein crude and refined helium is being considered include [redacted] [redacted] [redacted] etc. These projects are long term with helium not expected in production before 2025.

  - **China:** has NG, but much of this is from shale with little helium. It also has its own small source of crude or purchased helium to feed its small (30+ mmcf/year (<1 mcm/year)) liquid helium plant in Sichuan province. Sourcing from Australia, the U.S., Qatar, and Russia (when ready) and possibly Indonesia could prevail in the intermediate term in the growth in the Chinese market and supply. However conventional wisdom suggests that if the Chinese should get the opportunity to produce their own helium they will do that for their own strategic advantage. This is considered unlikely before 2030 and could be obviated with significant NG, NGL, and helium dealings with Russia assuming they are successful.

  - **Indonesia:** has significant NG with 0.04% contained helium. While LNG production and export has been considered for some time, the location of same with little to no container traffic would make helium export difficult and therefore a low probability of happening before 2030.

- **Qatar:** has one of the largest concentrations of NG in the North Field part of The Gulf with its NG structure extending out from its land extending into The Gulf. This NG is already well onto very significant development with more LNG trains planned together with more helium recovery and liquid helium production. Qatar has two helium trains with a nameplate capacity of 1.8 Bcf/year (51.3 mcm/year) on-stream in 2013, and with enough crude left from its existing LNG capacity to load another helium extraction and liquid train. It is possible that [redacted] or [redacted] will consider installing another 600 mmcf/year (16.2 mcm/year) of liquid helium before 2020.

- **Algeria:** also has very large concentrations of NG rich in helium and is heavily invested in its recovery, processing, and sale of liquid helium at its two locations, [redacted] and [redacted] currently has reduced demand for its pipeline NG into Spain and Italy which has also reduced their LNG demand. That, combined with difficulties with their two clusters of old LNG trains at [redacted] and the reduced crude capacity at [redacted] to feed that liquid helium plant, has reduced their ability to supply adequate crude helium to both the [redacted] operation at [redacted] and the [redacted] plant at [redacted] The new LNG trains at [redacted] are coming on-stream now and will resolve the lack of crude feed to the helium plant. While thinking has been given to expanding [redacted] crude helium to feed to increase liquid helium, it is more likely that new replacement LNG investment will be required at [redacted] before that were to occur. With the pace of decision making in [redacted] it is unlikely that additional liquid helium will be available from either [redacted] or [redacted] before 2025.

  Notwithstanding the above, [redacted] has very significant NG potential from its [redacted] operation in the Southern Algerian desert which could eventually be employed to significantly increase their helium export business. Unless helium prices are considerably increased during the next 15 years, the likelihood of that is small.

• Other helium reserves:

  - **Canada:** has significant NG reserves, located in the Western provinces of Saskatchewan, Alberta, and British Columbia. Most of that gas is non-helium bearing. The are a few helium recovery projects which have been under evaluation for several years, but have questionable feasibility because of the marginal volume of helium which is most probably below the critical volume required to pay back the required investment, particularly when any such project would be competing with the proximity and scope of large existing and potential helium projects across the U.S. border.

  - **South America:** has considerable NG but has very limited locations with critical mass concentrations of helium. While a helium opportunity in Chile has been evaluated, it was evaluated at below investment grade and abandoned. At this time there does not appear to be any viable opportunities for basic helium development in South America under current and anticipated cost/rice scenarios.

- **Iran:** has the South Pars side of the North Field in The Gulf, offshore from its land. While there may be LNG and therefore helium bi-product strategies in preliminary planning, it does not appear that Iran could develop either the financial or technology bases to affect those plans.

- **Saudi Arabia:** has significant gas reserves with fields containing 0.11-0.24% helium. While this has had some analysis interest from helium players it appears that the Saudi's other crude oil and derivatives and its other gas interests have left helium related opportunities at a low level of priority. This is unlikely to change before 2020.

- **Iraq:** while it has significant NG reserves with some helium, other requirements for economic and political redevelopment are unlikely to allow or support investment in recovering and monetizing helium.

- **Libya:** has NG and meaningful helium and the potential for developing that resource. While Richard Clarke of the Cambridge University Helium Team gives Libya a 30% probability of developing that resource, most in the helium business give that option little chance of success during the study period given the other international helium development potentials.

- **India:** has some NG with very modest contained helium and is interested in being self-sufficient in its own helium supply. JRCI believes that with Qatar and other relatively easy and economical import sources, India will not develop its own significant position in helium.

3.2.3 Current Helium and Pure Gas and Liquid Plants

The following section covers definitions and current helium and pure gas and liquid plants.

3.2.3.1 Sourcing Definitions and Notes

Crude Feed vs Integrated Crude Feed Helium Plants - The U.S. helium business started in the 1960's with the USG's helium conservation program described in the 2.2 Appendix. It's cessation resulted in that program's crude production being redirected to private sector pure gas and liquid producer/refiners buying that crude under long term, arms length supply contracts under terms and prices totally divorced from the price of the pure gas and liquid produced and sold by the refiners. JRCI refers to those plants and players as "crude feed" representing the separation of crude economics from "integrated crude feed" plants which is the new norm for current and prospective helium production. In this "integrated crude feed" scenario, the real cost of the crude can be and is handled in a variety of ways set by the player and reflecting how that player wants to account for his costs and investment.

When BLM came into existence, they set a very high price for crude compared to the industry because it was based on the debt to be paid back to the federal government, not the market. Once the BLM published their crude price, all crude values began to reflect the BLM set price. Differences became very apparent in the economics of supply between the “crude feed” and “integrated crude feed” plants.

The following is how JRCI defines and describe capacities, which is applicable to this BLM project.

Nameplate Capacity (NPC) – is that production volume of pure helium gas and/or liquid which the plant was designed and built to produce and is generally considered the absolute maximum production available from the plant. It is also what was originally and “publicly” announced as millions of cubic feet or millions of cubic meters of produced volume per year – (mmscf/year, or mcm/year) as if the purification/liquid production unit were running 365 days/year with unlimited crude feed. On occasion, this capacity figure is adjusted to reflect what JRCI understands to be increases in max production volume based on significant ream-outs or modifications to the plant. The NPC is generally considered to be not limited to crude helium feed volumes.

Effective Production Capacity (EPC) – is considered a more accurate description of real production capacity, achieved in normal operations, and which accounts for scheduled and unscheduled outages in both the pure/liquid plant <u>and</u> in the often less reliable crude helium supply. While this is a very useful production metric, it now falls short of describing what is actually available to markets and customers which are at the end of an increasingly long and complex helium supply chain.

Maximum Deliverable Production (MDP) – is a relatively new term which JRCI has developed and results from our experience in the helium suppliers underestimating the delays and slippages in the long distance and complex transport of ISO container deliveries of liquid helium to national and growing offshore markets. JRCI now uses MDP to estimate the forecast volume that’s available to the customer at the end of the primary distribution channel, and accounts for the increasing complexity, inefficiencies, and transport delays in serving the global helium markets. This “capacity” accounts for the reduction in Effective Production Capacity to volumes which are actually available to meet customers’ demand at the end of the “primary distribution” component of the supply chain, including:

- Erratic helium ISO container ocean shipping schedules, often weather related;
- Container availability after transport delays and extraordinary service requirements;
- Container “dwell times” at transfer points during ocean shipping, e.g. Singapore;
- Container “dwell time” at large customers and at domestic and offshore transfill depots and;
- The normal difficulties in matching plant production and storage to the varying overland and ocean distribution scheduling, container servicing and maintenance, particularly when containers become “hot,” last minute changes in container ship schedules, loading priorities, and switching times.

Because of the transport efficiencies developed in the U.S. from many years of experience, JRCI estimates the EPC and MDP are about equal with little loss between the two. On the other hand, for ocean shipping from the U.S. and from non-U.S. plants, JRCI estimates the loss between the two at between 7 and 10% depending on which plant is serving which market. While the Secondary Supply Chain is not analyzed in this study, it is generally operating with virtually no loss between EPC and MDP because the accounting and invoicing for returned residual volumes are making up for actual operating volume losses, if any.

With the world short on helium production and short on ISO containers, and in the face of longer and more complex distribution of helium, the use of the above definitions in planning and forecasting is becoming more important.

Figures 3.2.E and 3.2.F describe U.S. and Non-U.S. liquid helium production plants with approximately 8.9 Bcf/year (246 mcm/year) of NPC.

U.S. Plants

The United States is currently the major producer of Helium with NPC of 6.4 Bcf/year (178.3 mcm/year) and EPC of 4.9 Bcf/year (136.7 mcm/year). There are 13 liquefiers on the BLM Pipeline and Storage System operating at six sites with 4.1 Bcf/year (112.6 mcm/year) of NPC and 3.4 Bcf/year (95.1 mcm/year) of EPC. [redacted] with 1.7 Bcf/year (47.2 mcm/year) of installed NPC at their [redacted] facility and 1.4 Bcf/year (38.8 mcm/year) of EPC, is the second largest single producer with four liquefiers. The remaining NPC of 670 mmcf (18.5 mcm/year) is in Mid-Continent and Rocky Mountain states.

- The BLM System (Mid-Continent and Hugoton Natural Gas Fields) is nearing the end of its useful life. Figure 3.2.D provides the BLM system EPC before and after the July 2013 NITEC capacity revisions. The table provides a view into the precipitous reduction projected by BLM. The NG Field wells' depletion rates are accelerating with a reduction in crude helium output of about 7%/year. Those crude sources are connected to the BLM crude pipeline permitting supply to be connected to private sector liquid helium plants owned by [redacted], [redacted] and [redacted].

Figure 3.2.D BLM System Reduction – Revised Projection

Effective Nameplate Capacity	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total BLM System (6/13)	2,177	1,880	1,350	1,384	1,215	1,026	836	722	609
Adjusted Total BLM System	2,177	1,880	1,350	1,193	1,039	902	766	600	600
BLM System Reduction	-	-	-	(191)	(176)	(124)	(70)	(122)	(9)

- The second source of U.S. crude is from plants not connected to the BLM crude pipeline (Non-BLM System). These plants are integrated crude to liquid facilities so that their liquid production is limited to crude supplied from a single integrated source. Several of these plants, including [redacted] at [redacted], [redacted] and [redacted] at [redacted] UT, are primarily bringing in tube trailer crude for processing. [redacted] still has some limited crude production.

Figure 3.2.E U.S. Helium Extraction and Refining Plants – NPC and EPC's - 2012

US Plants							
		Crude Feed/			mmcf/yr	EPC (mmcf/yr)	
Plant Owner/Operator	Location	Integrated	Crude Source	Primary Customer	NPC	2007	2012
BLM System (Hugoton)							
[redacted]	[redacted]	Crude Feed	[redacted], TX)	Supply Chain	450	124	100
[redacted]	[redacted], KS	Crude Feed	[redacted] KS)	Supply Chain	1,010	1,300	1,050
AP Subtotal					1,460	1,424	1,150
[redacted]	[redacted] KS	Crude Feed	[redacted], KS)[2], [redacted], KS)[6]	Supply Chain	350	290	308
[redacted]	[redacted], KS	Crude Feed	[redacted], KS) [redacted]) & [redacted] K [redacted], KS)[5]	Supply Chain	1,020	846	897
[redacted] Subtotal					1,370	1,136	1,205
[redacted]	[redacted] KS	Crude Feed	[redacted] TX & [redacted] KS)	Supply Chain	1,050	925	900
[redacted]	[redacted], OK	Crude Feed	BLM Tolling	[redacted]	180	138	172
Subtotal BLM System					4,060	3,623	3,427
Non-BLM System							
[redacted]	[redacted], [redacted]	Integrated	Own CO2 Based	[redacted], & [redacted]	1,700	1,400	1,400
[redacted]	[redacted] CO	Integrated	Own & TT Crude	[redacted]	450	44	44
[redacted]	[redacted], UT	Integrated	TT Crude	[redacted]	150	23	23
[redacted]	[redacted], NM	Integrated	Own Crude	[redacted]	50	24	24
[redacted][1]	[redacted] KS	Integrated	Own Crude	Supply Chain	20		9
Subtotal Non-BLM System					2,370	1,491	1,500
Total US (mmcf/year)					6,430	5,114	4,927

1 Plant came online May 2009.
2 Plant did not produce helium during 2010.
3 [redacted] purchased plant from Nathaniel Energy in March 2009.
4 [redacted] Helium Plant did not produce helium during 2010.
5 Output is piped t[redacted] for purification.
6 Plant started in 2002 and shut down April 2009.

- The third source of U.S. crude is that made available from BLM's crude helium reservoir near Amarillo, TX under quarterly auction of crude volume with prices set annually by the BLM. That crude reserve had a 2012 ending inventory available for future sales of 10.9 Bcf (301.4 mcm/year), reported in the BLM Statistical Report for December 2012. Total inventory in the reservoir, including privately owned helium yet to be withdrawn is 12.2 Bcf/year (338.2 mcm/year). The current withdrawal from the reservoir is now less than 2.0 Bcf/year (55.5 mcm/year), limited by the management of the reservoir's "crude cloud" to preserve long-term future recovery. The withdrawal rate will decline to about 600 mmcf (16.6 mcm/year) in 2020 as Nitec Annual Helium Conference Bush Dome Helium Reservoir report of July 23, 2013. This equates to an average annual decline of -10 percent per year. By 2020, the volume remaining in the reservoir will be 3.2 Bcf/year (83.2 mcm/year) about the volume required by the new U.S. Legislation on the management of the BLM reservoir and disposition of that crude reserve.

<u>Non-U.S. Plants</u>
As shown in figure 2.2.B, [redacted] has NPC of 1.25 Bcf/year (34.7 mcm/year) and EFC of 525 mmcf/year (14.6 mcm/year) extracted from LNG tail-gases at two locations with a total of three liquefiers. [redacted] with feed gas supplied from the tail-gases of their liquefied natural gas (LNG) plants is the next largest producer of liquid helium, currently with NPC of 600 mmcf (16.6 mcm/year) NPC and 552 mmcf/year (15.3 mcm/year) of EPC. Now that the [redacted] facility is on-stream (July 2013), total [redacted] NPC will reach NPC of 1.9 Bcf/year (53 mcm/year) when the facility is fully operational in 2015.

The remainder of the world's NPC totals 575 mmcf (16 mcm/year) at one site in Russia with five small liquefiers, at one site in Poland with a new liquefier, and at one site in [redacted] Australia with one liquefier.

Figure 3.2.F Non-U.S. Ownership and Location of Helium Extraction and Refining Plants - 2012

Non-US Plants							
		Crude Feed/			mmcf/yr	EPC (mmcf/yr)	
Plant Owner/Operator	Location	Integrated	Crude Source	Primary Customer	NPC	2007	2012
[redacted]	[redacted], Algeria	Integrated	Own Field Crude	[redacted]	650	581	350
[redacted]	[redacted] Algeria	Integrated	Own Field Crude	[redacted]	600	135	175
Subtotal Algeria					**1,250**	**716**	**525**
[redacted]	[redacted] Poland	Integrated	Own Field & TT Crude	Supply Chain	125	81	113
[redacted]	[redacted] Russia	Integrated	Own Field Crude	Supply Chain	250	180	180
[redacted]	[redacted]	Integrated	Own Field Crude	[redacted]	600	540	552
[redacted] [1]	[redacted], AU	Integrated	Own Field Crude	[redacted]	200		170
Total Non-US					**2,425**	**1,517**	**1,540**
1 Plant came online March 2010.							

NOTES: on the above table of Non-U.S. Helium plants

- Algeria's [redacted] plant is a joint venture between [redacted] and [redacted]. [redacted] is a joint venture between [redacted] and [redacted]. The plant is located near [redacted] on the Western Algerian coast. [redacted] has NPC of 650 mmscf/year (18 mcm/year), based on two modular process/liquid trains designed/built by [redacted] EPC, limited by LNG production and crude feed due to the recession in Europe and LNG plant problems, is about 350 mmscf/year (9.7 mcm/year) for delivery fob plant to the JV of [redacted] and [redacted]

- Algeria's [redacted] plant, a joint venture between [redacted] ([redacted] and [redacted] ([redacted] is located in [redacted] That plant's NPC is 600 mmscf/year (16.6 mcm/year), in a single train plant with crude feed from [redacted] LNG plant. As with the [redacted] plant, EPC is limited by LNG production and crude feed due to the recession in Europe. EPC is estimated at 175 mmscf/year (4.9 mcm/year). The LNG plant has been replaced, and when it is fully online, crude feed will improve [redacted] EPC to about 540 mmscf/year (15 mcm/year) by 2014.

- Poland's western helium plant is owned by [redacted] and is located in [redacted] NPC is 125 mmscf/year (3.5 mcm/year) with a new liquefier installed in January 2012. EPC is estimated at 113 mmscf/year (3.1 mcm/year). Current estimates of field reserves by the Polish Geological Society indicate this field will be fully depleted by 2020 at current EPC production rates. The [redacted] has noted to JRCI that they are perusing new sources and production to continue past 2020.

- Russia's western helium recovery is from [redacted] natural gas fields. NPC is 250 mmscf/year (6.9 mcm/year) with current EPC at 180 mmscf/year (5.0 mcm/year), and EPC declining to 135 mmcf (3.8 mcm/year) by 2020.

- NPC at [redacted]'s [redacted] natural gas - LNG complex, just north of [redacted] is 600 mmscf/year (16.6 mcm/year). The plant has a single train plant built by [redacted] that came on-stream in 2006 with full production in 2009 due to start-up problems. EPC is estimated at 552 mmscf/year (15.3 mcm/year). Qatar #2 is on-line and described below.

- [redacted] is now online and in commercial production with a published NPC of 1,300 mmcf/year (36 mcm/year), with an estimated EPC of 1,170 mmcf/year (32.5 mcm/year). The total [redacted] complex helium NPC will reach 1,900 mmcf/year (52.7 mcm/year) and an EPC of 1,722 mmcf/year (47.8 mcm/year). JRCI estimates that the roundtrip days from [redacted] through Singapore to markets east of Singapore (Tokyo, Shanghai, etc.) is about 90 days. JRCI estimates that over 1,200 additional ISO deliveries per year will be required to load the new production from Qatar #2's EPC 1,170 mmcf/year.

  Assuming that the average of all deliveries from [redacted]s new EPC can be cut to 80 days (4.5 turns/year/ISO), that suggests the need for [redacted] customer/distributors to shift from other global transport routes or to acquire an additional 300 ISO containers to provide service to Qatar's expanded markets, most of which is to the east of Singapore.
  The above described expanded operational scenario is a challenging task, particularly when added to the job of managing current production and distribution operations for [redacted]

- [redacted] plant in [redacted] Australia has a NPC of 200 mmscf/year (5.5 mcm/year). It came online in 2011, with an EPC estimated at 170 mmscf/year (4.7 mcm/year). This plant has the distribution challenge of not being located near a port with large container traffic.

3.2.4 Worldwide Helium Supply and Demand by Region by Market Application

The following two sections provide historical helium supply (MDP) and demand by region followed by a description of helium market segments and applications

3.2.4.1 Historical Worldwide Helium Supply (Maximum Deliverable Production) by Region from 1985 to 2012

Figure 3.2.G provides the helium production volumes produced worldwide by U.S. versus Offshore supply. Prior to the [redacted] Algeria helium plant coming on-stream in 1993, the only offshore supply was the relatively small helium plants in [redacted] Poland and [redacted] Russia. In 1985, the US supplied 96 percent of the world's helium.

Figure 3.2.G Historical Worldwide Supply (MDP) Volumes from 1985 to 2012

Helium Supply (mmcf)	1985	1990	1995	%AGR '85-'95	2000	2005	2010	2012	%AGR '85-'10
US Supply	1,940	3,060	3,255	5.3%	3,870	4,895	4,710	4,800	1.8%
Offshore	80	100	495	20.0%	940	890	1,355	1,390	3.3%
Total WW Production	**2,020**	**3,160**	**3,750**	**6.4%**	**4,810**	**5,785**	**6,065**	**6,190**	**2.1%**

3.2.4.2 Historical Worldwide Helium Demand by Region

Figure 3.2.H provides a demand volume perspective on worldwide helium demand by region for 1985 and 2012 from our historical tracking of this data. While the U.S. represented 75% of the world's demand in 1985, its share is currently only 32% of global demand, while supplying 78% (4.8 Bcf) of the world's total demand, or 6.2 Bcf as shown in figure 3.2.G.

What is striking from figure 3.2.H is the sharp decline in U.S. demand from its peak in 2005 to 2012. JRCI has highlighted this because the experience of that period in future planning is instructive. JRCI has determined that that sharp decline in volume demand happened for the following reasons:

- While industry in the U.S. did not realize that the economic bubble here was about to burst, helium demand was reaching its historical peak along with that in Europe, and from an extraordinary increase in demand from Asia, albeit from a smaller base. This peak occurred as helium supply was tightening very hard against demand, which was completely absorbing the total capacity of both production and transport. This tightness drove substitution, recovery, and recycle in the U.S., as well as the rising prices associated with reduced supply.

Figure 3.2.H Worldwide Historical Helium Demand by Region (mmcf) – 1985 and 2012

Helium Demand (mmcf)		1985	1990	1995	%AGR '85-'95	2000	2005	2010	2012	%AGR '85-'10
Americas										
	US	1,510	2,165	2,465	5.0%	2,815	2,815	1,970	2,000	-2.8%
	Other Americas	55	90	195	13.5%	190	270	560	625	10.4%
	Total Americas	1,565	2,255	2,660	5.4%	3,005	3,085	2,530	2,625	-1.1%
Europe		310	565	580	6.5%	950	1,470	1,435	1,350	3.0%
Afr/MidEr/Ind		15	25	45	11.6%	170	160	355	345	6.1%
Asia		135	310	470	13.3%	960	1,040	1,740	1,870	5.7%
Total WW Demand		**2,025**	**3,155**	**3,755**	**6.4%**	**5,085**	**5,755**	**6,060**	**6,190**	**1.7%**

- The recession of 2008, that really started late in 2007 and lasted into 2010 in many U.S. market segments, resulted in the sharpest drop in the U.S. economy since the depression of the 1930, crippling many companies and reducing demand for a large number of industrial gases, including helium.

- Operation of the helium plants on the BLM pipeline experienced unusually high downtimes in 2008 and 2009. Also, the crude feed from both BLM and the field crude sources feeding those plants was reduced from the effects of lower pressure in the NG reservoirs, and because of the sharp decline in NG demand caused by the abruptness of the recession's downturn.

- While [redacted] at [redacted] did not have significant operating problems, some overlap in their maintenance schedules and those of BLM caused some serious production shortages during the summer of 2009, backing up ISO filling for several weeks.

- The extended partial shutdown at [redacted] late in 2012 for maintenance (approximately eight weeks) significantly aggravating the supply shortage. The whole situation caused the four major helium players to announce helium supply allocations at 50% to 75% of "last year's volume take" by customer, depending on their delivery schedules.

- Exacerbating the U.S. supply problems in 2012, Algerian production was reduced because of the continuing lack of crude at [redacted] and reduced crude feed to [redacted] due to the recession in Europe (e.g., LNG demand down). This required shifting supply from the U.S. to Europe on an allocation basis.

Note that some of these conditions, while not as bad as during the most difficult times of the five year period, still exist today. Some further notes on other regions of the above figure include:

- Canada/Mexico did not experience the same downturn as the U.S. and actually kept growing, but at a slower rate than before. But the use of helium in both those markets grew much faster than their economies because of an across the board pent-up manufacturing demand carryover from their part in the recent recession, and the continuing migration of manufacturing from the U.S. across its northern and southern borders. Much of that continued growth was due to high activity levels in MRI, leak detection, and party balloons in Mexico, which is considered a good growth market for helium.

- Western Europe's manufacturing decline was delayed behind, and slower than, the U.S. decline.

- Africa and the Mideast economies were growing at normal rates, but the U.S. military, a significant user of helium in Iraq and Afghanistan, was slowing its use of helium in Iraq.

- India experienced high economic growth with helium demand experiencing the same, but from a small base. In the latter part of the period (2010 – 2012), India began to receive more helium from Qatar production with supply from a wider base of new helium customer/distributors through trades with [redacted] and [redacted].

- While China was booming, Japan's economy was flat to down, and its helium demand was in decline. Korea and Taiwan economies were moderating, feeling the effects of the electronics downturn in the U.S. and Japan. The South Asia country economies fared well and grew moderately fast from a small base.

During this period of helium decline in the U.S. and Asia's continued economic growth, Asia reached the same helium demand level that the U.S. has sunk to, i.e. each at about 30% of world demand. The continuation of Asia's high growth rate compared to the U.S.'s forecast of flat growth will be shown later.

Before forecasting helium volume demand by region and country, we'll discuss the helium's uses and applications by Market Segment.

3.2.4.3 Current Helium Demand by Market Application

Over the years JRCI has segmented the uses and applications of helium into liquid use and gaseous use. From there JRCI segments the liquid use into its primary two markets, and the gas use into its nine primary markets. We have found over the years that forecasting the use of gases, including helium, is more accurate and useful when forecasting regional and local volumes. In addition to providing a better forecasting methodology, it provides the opportunity to assess volume sensitivity, price elasticity, and in helium's case today, the stimulus of short/constrained supply for conservation, recovery, and recycling of spent helium back into that segment's processing and use.

<u>Liquid Applications</u> - Applications of Liquid Helium to 3° K temperature levels, mostly to achieve superconductivity, include:

- **MRI** - cooling of superconductive magnets for MRI sites for medical imaging and diagnosis. There are about 25,000 MRI units in the world today with all requiring LHe for the testing and shipment of the units "cold" with their inventory of about 2,000 liters of liquid helium, and kept cold while in service with periodic replenishment of LHe depending on the level of supplementary mechanical cooling installed.

This segment is the world's largest market for helium and has reached that position in less than 30 years of extraordinary growth. During this recent period of constrained supply, particularly the allocation of deliveries by its major suppliers and the significant shift in supply to higher "spot" priced supply to offset the lower allocations of contracted supply, the major MRI players have accelerated their plans toward more efficient systems design including more supplemental in-unit cryogenic refrigerators, investment in more spent helium recovery & recycle, and to developing higher temperature (liquid nitrogen) cooling to support their future superconducting magnet designs. The combination of supply reliability and higher price has significantly affected the future growth rate of helium use in this segment. (JRCI has been involved in this market segment since 1985)

- **Science/Engineering** - cooling of superconducting industrial and research magnets for government institutions and private industrial/commercial firms, and cooling of other Research and Development (R&D) and scientific components and media for a wide variety of R&D projects. This segment also includes particle accelerator use of liquid helium, i.e. the Large Hadron Collider at CERN in Switzerland. JRCI has been involved in parts of this segment since the late 1980's.

  This segment has also been affected in similar fashion to the MRI segment, though to a lesser extent as it is government funded and includes a few very large investments where the refrigeration use systems are closed with large internal refrigeration systems at less than 4^{o} K, with make-up LHe required periodically. The extraordinary use of LHe in this segment is not likely to be affected by price changes, either up or down.

- **Other –** miscellaneous liquid uses. These are small and specialty uses, and is a catch-all category which rounds out our demand and forecasting estimates.

Gas Applications - Applications for gaseous helium (GHe) generally involve its attributes of inertness, high heat conductivity, and lightweight, for:

- **Electronics/Semiconductors –** for the inert and heat conduction and cooling properties of GHe in semiconductor wafer and chip fabrication, together with a number of developing applications. A part of this segment is the use of GHe in monitor screens and LEDs, and has been extended into some parts of PV development and fab.

  Again, this large volume use of helium with excellent growth potential is more sensitive to constrained supply than to price. With more reliable steady supply this segment is likely to increase its potential growth rate. But that supply reliability will have to be demonstrated, not just publicized which will take some time. At the present time only argon seems to be a marginal substitute. So far, there has not been much development of recovery and recycle systems because current fab systems aren't capable of recycling helium and can't be modified easily. For sustainability purposes, many of the chemicals and gases used in next generation fabs will need to be recovered/recycled, including helium.

- **Fiber Optics –** Gaseous Helium (GHe) is used as the cooling gas in the strand spinning operations in the manufacture of fiber optic cables. This is a large use segment for helium which has developed significant and efficient recovery and recycle systems during the past 10 years, reducing its need for make-up feed. This segment's use, therefore, will grow more slowly than the segments output of fiber optics systems.

- **Leak Detection –** uses helium's small atom to check for leaks in an expanding array of containers, pressure vessels, process equipment and control, etc. It is another of the special applications that is amendable to recovery and recycle of helium used. These systems are in an accelerated development mode which is reducing the net cost of helium and spurring the growth of the application. It has already been affected by constrained supply and price, particularly in Asia/China where the manufacturing capacity requiring leak detection is growing very fast. Hydrogen is continually being evaluated as a substitute but is not likely to succeed until H_2 becomes a much more widely used product.
- **Analytical/SpecGas/Labs –** is a large and steadily growing use of helium, both as a pure gas, and in mixtures with other gases in a very wide variety of applications for analysis of materials, for calibration of instruments, etc. It is the most ubiquitous use of helium, though not currently the highest segment user. Because of its large, wide and varied use in relatively small transactions, this segment is not affected significantly in price, at least as far as JRCI sees retail prices for helium developing.
- **Pressure/Purging/Aerospace –** used as a purging and/or pressurizing gas where its inertness, lightness and ultra-low temperature are advantageous. Aerospace, defense, and nuclear industries are heavy users of helium for those attributes. One of the largest periodic users of helium has been the space agencies of National Aeronautics and Space Administration (NASA) and Ariane in engine testing and missile flight, particularly when the fuel is liquid hydrogen. These specialized uses of helium are in use with very significant projects where the price/cost of helium at virtually any foreseeable price is not significant enough to decrease its use. However, where recovery and recycle are feasible it is likely to be developed as part of the total cost of the last projects involved.
- **Controlled Atmospheres –** is a process atmosphere or in gas mixtures for process control, particularly when its absolute inertness is necessary. These uses, generally with a substitute of argon, have been affected by price and will continue to be flat in volume development.
- **Diving Gas –** is the primary inert and small molecule component in breathing gas in deep sea diving for divers' installation and repair of underwater equipment, particularly for offshore oil and gas recovery. This use, particularly in deeper ocean operations, is being affected by the increased development of underwater positioning, welding, and cutting with newly automated systems and robotics, particularly as oil, gas, and minerals recovery is performed at greater depths and beyond the human endurance for deep water and high pressures. When helium is required and therefore used, it is relatively insensitive to price.
- **Welding –** has been a common and steadily growing use for helium as a welding-shielding gas in mixtures with argon, CO_2, and O_2, in TIG welding, and in new laser welding technologies. This application was particularly prevalent in the U.S. because of its low cost, abundance, and performance in a high labor cost economy. With significant increases in price, constrained supply, and the development of more automated and

higher performing welding processes that use helium are now in decline and will continue to do so.

- **Balloons –** is the lifting gas for promotional, recreational, and “party” balloons. This segment is surprisingly big, has increased dramatically over the last 10 years in the U.S., and is now developing around the world as the #2 user of helium. With wider marketing by balloon manufacturers, and a wide variety of retails stores and shops, it has an excellent growth future when supply becomes more reliable and when the balloon use is not competing with other higher priority uses, e.g. MRI, etc. The current use of helium has actually declined because it is not a priority use under the current system of allocations and severely constrained supply. Fundamentally balloon use of helium is more dependent on a growing middle class and increasing disposable income, and not particularly affected by price. The marginal use of air and/or nitrogen as a mixture with helium is being tried in many balloon venues out of desperation. When helium supply is restored and balloon use of helium is no longer a “useless” activity, worldwide use, and particularly APR use will increase significantly.
- **Airships –** is a lifting gas for promotional, industrial, and military lifting of stationary and mobile dirigibles and has been slower than anticipated in development. While Airships has been slow to develop, it is likely to become more useful as supply increases and supply becomes more reliable. However, it will always be subject to replacement by hydrogen when that product is in wider use.
- **Other –** miscellaneous gaseous uses. Again, a catch-all segment for rounding up demand to our forecast totals.

3.2.4.4 Shifting of Market Demand with Changes in Modes of Delivery

JRCI has performed a detailed analysis of the applications for helium by major worldwide region, including the significant markets of the U.S. That analysis has provided the basis for analyzing the key market segments for the U.S. by the four modes that service each market segment. From that we can calculate the various relevant combinations of “market price” from the production spigot, through the primary distribution channel, further through the secondary distribution channel to the medium and smaller users of helium who pay a higher price.

Based on surveys and our historical understanding of markets, both by segment and by mode of delivery, we have modelled each of the above applications by the four modes to achieve a current and historical development of the share of the U.S. helium market by mode to weight our aggregate price intelligence by delivery mode. Figure 3.2.I provides the JRCI estimate of U.S. helium volumes by delivery mode into market applications for 2013.This has allowed us to achieve a weighted average helium price for:

- bulk deliveries to larger low priced customers for liquid by ISO container and by tube trailer, and for
- medium and smaller customers served by liquid dewars and gas in cylinders, with less volume and a higher specific investment in volume delivered.

Figure 3.2.I Helium Volumes by Delivery Mode into Market Applications for 2013

Primary Application/ Mode	MRI	Sci/Eng /Oth	Elec/Semi /Fiber	Leak Det	Analy/Spec /Labs	Pres/Purg /Aero	Cntl Atmos	Diving	Welding	Lifting	Other	Total Volume	Share by Mode
	Liquid					Gaseous							
Bulk													
LHe Bulk	71%	7%	14%			7%		1%				527	26%
Tube Trailer		3%	16%	9%	21%	3%	3%	19%	6%	17%	3%	284	14%
Subtotal												810	40%
Packaged													
LHe Dewar	72%	15%	2%		9%	1%					2%	344	17%
HP Cylinder		3%	2%	9%	24%	1%	3%	1%	17%	37%	2%	871	43%
Subtotal												1,215	60%
Total Volume Share - Spigot	612	128	147	106	303	51	40	73	164	368	32	2,025	2,025
% Share by Application	30%	6%	7%	5%	15%	2%	2%	4%	8%	18%	2%		

Figures 3.2.Ja and 3.2.Jb depict how the share of helium sourced by mode has changed over time, influenced by changes in the market segment demand.

Figure 3.2.Ja U.S. Historical Helium Demand Share by Mode (mmcf) – 1985 and 2012

US Demand -Share by Mode	1985	1987	1998	2000	2007	2010	2013
Bulk							
LHe Bulk	150	205	605	680	725	515	525
Tube Trailer	530	555	760	735	390	275	285
Subtotal	680	760	1,365	1,415	1,115	790	810
Packaged							
LHe Dewar	75	90	305	360	470	335	345
HP Cylinder	755	825	1,365	1,425	1,195	845	870
Subtotal	830	915	1,670	1,785	1,665	1,180	1,215
Total Volume (mmcf)	1,510	1,675	3,035	3,200	2,780	1,970	2,025
Total BLM Volume (mmcf)			110	1,075	2,180	1,840	1,860

The following chart shows the % share of total for each of the mode/years quantified in the above table, figure 3.2.Ja.

Figure 3.2.Jb U.S. Historical Helium Demand Percent Share by Mode – 1985 and 2012

US Demand -Share by Mode	1985	1987	1998	2000	2007	2010	2013
Bulk							
LHe Bulk	10%	12%	20%	21%	26%	26%	26%
Tube Trailer	35%	33%	25%	23%	14%	14%	14%
Subtotal	45%	45%	45%	44%	40%	40%	40%
Packaged							
LHe Dewar	5%	6%	10%	11%	17%	17%	17%
HP Cylinder	50%	49%	45%	45%	43%	43%	43%
Subtotal	55%	55%	55%	56%	60%	60%	60%
Total Volume Share - Spigot	100%	100%	100%	100%	100%	100%	100%
BLM % Total Volume			4%	34%	78%	93%	92%

Note that BLM has a historically important share of U.S. demand. While the U.S. demand volume has increased from 1.5 Bcf in ’85 to 2.0 Bcf in 2013, or at the rate of 1.1%/yr, the modes of delivery have changed substantially because of the way the significant markets have grown in different ways.

- 1985 was before [redacted] came on stream with their very large liquid helium capacity which output was sold from on-stream to 3 major players who were then engaged in meeting very fast growing demand for large volumes of LHe to a very few MRI and fiber optics customers where bulk liquid was the least costly way of transporting helium to those customers. As that mode of delivery increased very fast and dramatically lowered the cost of transportation, the mode also increased to supply an increasing number of regional helium transfill depots where in primary delivery was by liquid ISO container, with secondary transportation shifting to tube trailers and cylinders of gas and dewars of liquid. Volumes for bulk liquid in ISO’s increased from 150 mmcf/yr in 1985 to 530 mmcf/yr in 2013, at 4.5%/yr.

  From 1985 to 1998 there were a series of developments which drove bulk ISO liquid deliveries up at fast rate, including the rapid development of U.S. MRI manufacture and service, fiber optics, NASA’s space and shuttle program, increased primary liquid helium distribution to an increasing number of helium redistribution depots, etc. From 2000 and with the two recessions of ’01 – ’02 and from ’07 to ’10, bulk liquid distribution development slowed with the cut back in U.S. demand in most of the market sectors using large volumes of helium.

- This resulted in reducing the use of tube trailers in hauling large volumes of helium in primary transportation to many customers before 1985 to using tube trailers for shorter distances in the secondary and shorter distances including distributors for filling cylinders. This shift in tube trailer delivery volumes decreased from 530 mmcf/yr in1985 to 280 mmcf/yr in 2013, for a -2.2%/yr.

  This delivery mode peaked in 1998 then declined rapidly to the present as bulk liquid took over much of what was originally transported from plant to customer and to transfill depots. The main current use of tube trailers is for local deliveries to end-use customers and to gas distributors filling cylinders, and who have taken on the main share of customers' cylinder helium demand.

- Another effect was in the dramatic increase in dewar deliveries, primarily for local transportation of small volumes of liquid to service the new MRI facilities growing fast in U.S. regional markets. This mode of delivery increased from 75 mmcf/yr in 1985 to 200 mmcf/yr in 2013, or at a rate of 3.6%/yr.

  Liquid dewar demand great at a relatively fast rate from MRI unit demand as the number of MRI units grew rapidly, then peaked in the early 2000's as the maintenance of MRI magnet refrigeration shifted to mechanical LHe temperature levels with onboard refrigerators. Further dewar demand is expected from a wider variety of R&D type applications which will sustain and probably increase current levels for dewar helium.

- Finally while the use of high pressure gas cylinders continued to increase in total mode volumes 750 mmcf/yr in 1985 to 870 mmcf/yr in 2013, for an increase of 0.5%/yr, but a decrease in share of mode from 50% to 43%.

  The cylinder helium mode was the most common method of delivery as demand was made up of a large number of small volume users and applications like welding grew in importance in U.S. fabrication, particularly of aluminium and stainless steel. Applications for these type markets has weakened significantly with the globalization of manufacturing demand, and with the price of helium for which substitution, recovery and recycle have become possible.

The above described changes in market demand and in the changes in delivery modes to provide lower delivered costs by using the least expensive available delivery vessels and vehicles, has significantly shifted the average price of helium to large sized supply schemes with lower costs and prices. These changes are important to the calculation of average helium price, which has helped to dampen the large increases in the cost of merchant helium from increases in the crude feed stock.

3.2.5 Primary Distribution of Production through the Supply Chain with Distribution to Important Re-distribution Depots in the U.S., and from the U.S. to Important Offshore Ports/Markets

This section will present and discuss the structure and of supply from crude through primary distribution to important re-distribution depots in the U.S., and from the U.S. ports to important offshore ports/markets.
The first step is to describe the various components of activity. For purposes of this study, the primary customers are the:

- domestic in-country large liquid/bulk customers serviced from 11,000 gallon ISO containers or 15,000 gallon liquid tankers, each specially designed and very costly

- in-country transfill depots where liquid helium is repackaged into high pressure gas cylinders and tube trailers, and liquid dewars, for sale and service to the distributors and customers that make up the structure of market for the secondary distribution channel

- in-country seaports from which ISO liquids are shipped to offshore receiving and transfill depots, e.g. [redacted] Japan for primary and secondary service to that region of Japan in similar fashion as shown in the Secondary Distribution part of the below diagram.

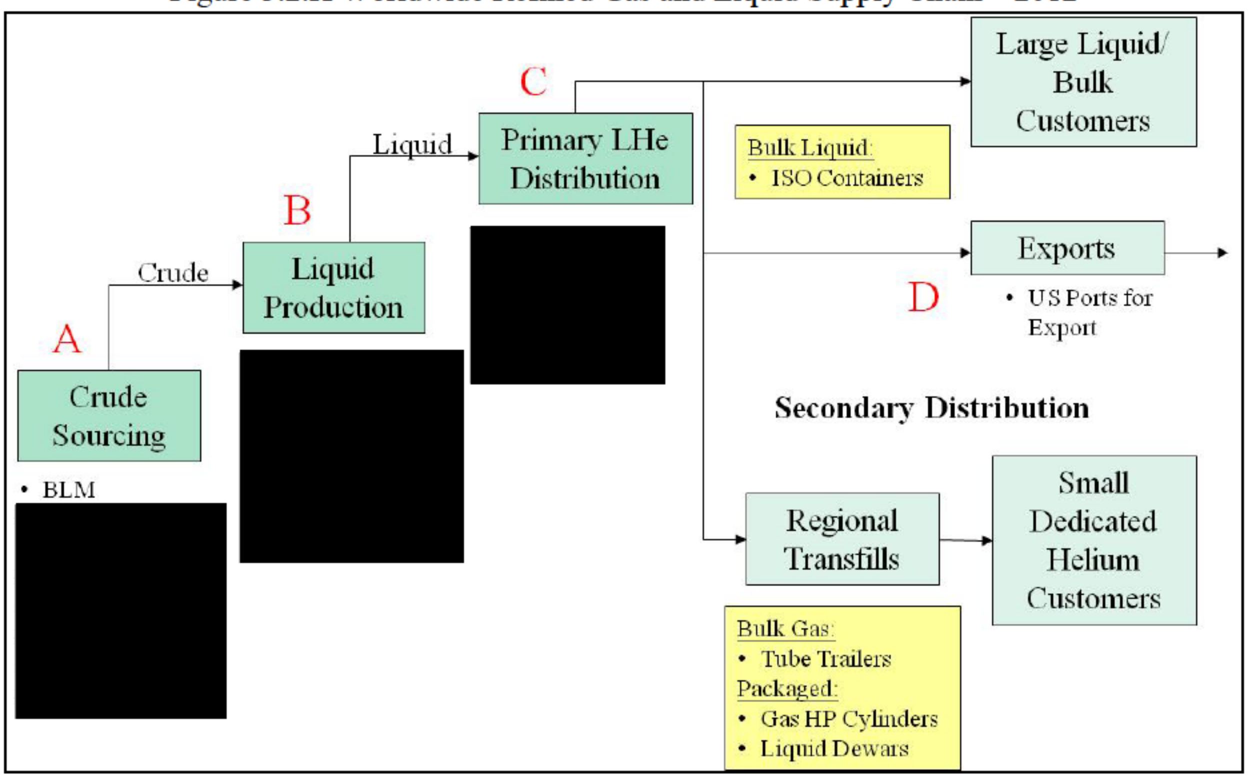
The second step is to quantify the cost/prices of helium along the supply chain. This step is included in section 3.3 of the report.

Figure 3.2.K., the diagram of the helium supply chain reflects what has been developed in the U.S. over the past 75 years and is basically the model used by the major players in their strategic planning and management of their helium businesses for many years.

3.2.5.1 Crude Helium Feed (Point "A" on Figure 3.2.K)

The sourcing of crude from natural gas reserves via the NGL or LNG route, at point "A" on the diagram below, was covered in sections 3.2.2.1 and 3.2.2.2.

Figure 3.2.K Worldwide Refined Gas and Liquid Supply Chain – 2012



3.2.5.2 Gas and Liquid Helium Production (Point "B")

While practically 100% of the sourcing of pure merchant helium is produced and delivered as a liquid at least through the primary distribution part of the helium supply chain, some is produced and distributed as a gas. Some of the major helium plants in the world have an off-take of pure gas which is distributed within a practical radius of action from the plant in cylinders and tube trailers. Moreover in the U.S. and with the shortage of helium some independent entrepreneurs are developing low quality sources of helium from helium rich natural gas in the Rocky Mountain area, purifying the gas by adsorption to 98-99% helium, which is attractive at the present time and at high prices to those customers that do not need the high purity of liquid, mostly party balloon wholesale and retail distributors.

3.2.5.3 Primary Distribution (Point "C")

As noted above in figure 3.2.K., Primary Distribution connects the liquid helium plant spigot to large customers, the Secondary Distribution system described below, and on-shore ports from which liquid in ISO containers are shipped to offshore receiving transfill and redistribution depots, e.g. [redacted] Japan, for repackaging and inland transport to the Kansai region of Japan.

ISO liquid helium containers are very special triple wall vessels with the outer annulus being a super-insulated, high vacuum space, with the inner annulus filled with liquid nitrogen. These ISOs are principally designed and built by [redacted]' subsidiary, [redacted], and cost anywhere from $850k to over $1mm. The former has a 30 day hold time with a maximum pressure before venting of 64 psig; the higher priced unit has a 40 day hold time and can reach 175 psig before venting. These containers are highly specialized, single use containers and are the primary means of transporting LHe overland in country/region overland, and by sea container ship to offshore markets. The payload of an 11,000 gallon ISO is generally estimated on average to be 26.4 cm (950,000 cf). These containers are owned by the primary helium player and are paid as part of the selling price either as a rental (about $400/day of round trip use time), or factored into the price of the delivered helium. The ISO is designed for dual service: over-the-road and shipment aboard container ship. This permits the flexible interchangeability and use to maximize the efficiency of the players transport system, a very important attribute of the Primary helium players' performance. Note that some LHe is transported in the U.S. and in Western Europe in over-the-road tankers, specially designed for helium transport with similar performance as the ISO containers. In these cases, the over-the-road tanker makes fast turnarounds and usually offloads at the transfill or large customer location into a stationary ISO container.

3.2.5.4 Secondary Distribution

The Secondary Distribution system is operated by most of the major helium players on a direct basis, or through their subsidiary JVs offshore, and by a few of their largest independent distributors in the U.S. The facilities transfill helium from the ISOs into high pressure cylinders and tube trailers and into industrial, scientific, and MRI liquid dewars. This equipment is owned by the major players and their distributors and customers, and is filled and delivered by the gas players as part of their whole multi-product industrial, medical, and specialty gases local, regional, or national businesses. Prices for these services vary greatly depending on volume, distance from the service location, the number, volume, and variety of products served, and the customer density and competition dynamics of the area. Prices for helium in the widely varying modes differ greatly within the local areas, and certainly around the world. However with helium, there is a very different national cost base depending on where the helium is produced, how it gets to the regional market for its production source common, and the scale of business enjoyed by the supply chain.

3.2.5.5 Export Side of Helium Primary Distribution (Point "D")

As helium markets are great distances from helium sources, the transportation from liquid helium plants to those foreign markets has become the largest part of the current and forecast helium business and supply chain. Complicating the inherent complexities of shipping is the very expensive perishable product (helium) in a very expensive ISO, placed on the deck of a container ship (with no stacking allowed). In addition, the container ship's schedules and routes can change quickly, making excellent distribution performance quite a challenge. Today 66 % of the helium produced in the world is transported by container ship to its final country of use. With the expansion of Asian demand, JRCI estimates that that figure will increase to 75% by 2030.

3.2.6 Redistribution/Transfill Depots

These facilities have become a very important part of the total U.S.(and international) helium supply chain by transitioning the lowest distribution sourcing cost for helium from high efficiency ISO liquid trucking, to the lowest cost local delivery systems provided by a few small tuber trailers, several thousand liquid dewars and a large number of high pressure cylinders. These facilities have been an important part of developing a highly efficient U.S. helium distribution system which system has become the basis for serving the world's helium requirements, both on the export/import side of supply and in the world's intra-country distribution systems.

Figure 3.2.L Worldwide Transfills by Company by Region

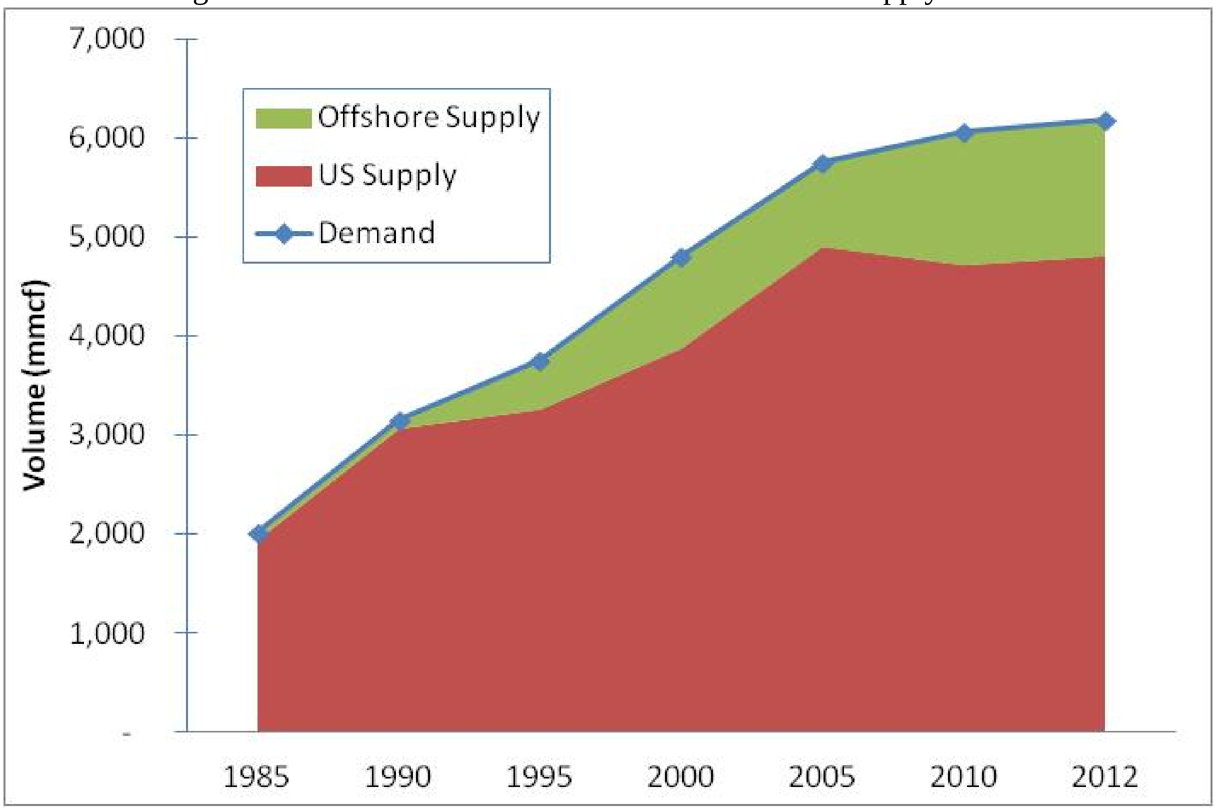
Company	NoAM	SoAM	Eeuro	Weuro	Afr/ME/Ind	NoPac	SoPac	Total
[redacted]	8	-	3	6	6	5	2	30
[redacted]	17	1	1	10	5	7	4	45
[redacted]	1	-	-	-	-	-	-	1
[redacted]	18	3	2	4	5	10	8	50
[redacted]	1	-	1	4	1	-	-	7
[redacted]	5	-	-	-	-	-	-	5
[redacted]	15	2	-	2	1	6	3	29
[redacted]	-	-	-	-	1	-	-	1
[redacted]	6	-	-	-	2	8	2	18
[redacted]	-	-	-	-	2	1	3	6
[redacted]	-	-	-	-	-	5	2	7
[redacted]	-	-	2	-	-	-	-	2
Total	71	6	9	26	23	42	24	201

We estimate that there are about 1,000 ISO containers at work in the world's primary supply channel of which over 200 are employed in the world redistribution in secondary channels of helium distribution.

3.2.7 Historical and Current Demand/Supply Balance of Worldwide Helium Volumes

Figure 3.2.M shows graphically the worldwide demand and supply of helium from 1985 through 2012 as developed and presented above in figures 3.2.G and 3.2.H. This figure represents a %AGR growth in WW demand from 1985 to 2012 of 4.2%/year.

Figure 3.2.M Historical Worldwide Helium Demand/Supply Balance



3.2 APPENDIX

A. HELIUM RESERVE DEFINITIONS PER THE U.S. BLM

Total Helium content includes measured (proven), probable, possible and speculative helium reserves/resources. JRCI defines "potential" helium reserves as the sum of probable and possible reserves. Definitions of measured, probable, possible and speculative helium reserves/resources found in the U.S. Department of Energy/Energy Industry Association (DOE/EIA) publication, "*U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves 2006 Annual Report*" (November 2007), and from the Potential Gas Committee (PGC) definitions in previous helium resources reports are as follows:

- Measured Reserves – The estimated reserves, which geological and engineering data demonstrate with reasonable certainty to be recoverable in future years from known reservoirs under existing economic and operating conditions. Petroleum engineering and geological judgment are required in estimating proved (measured) reserves; therefore, the results are not precise measurements.

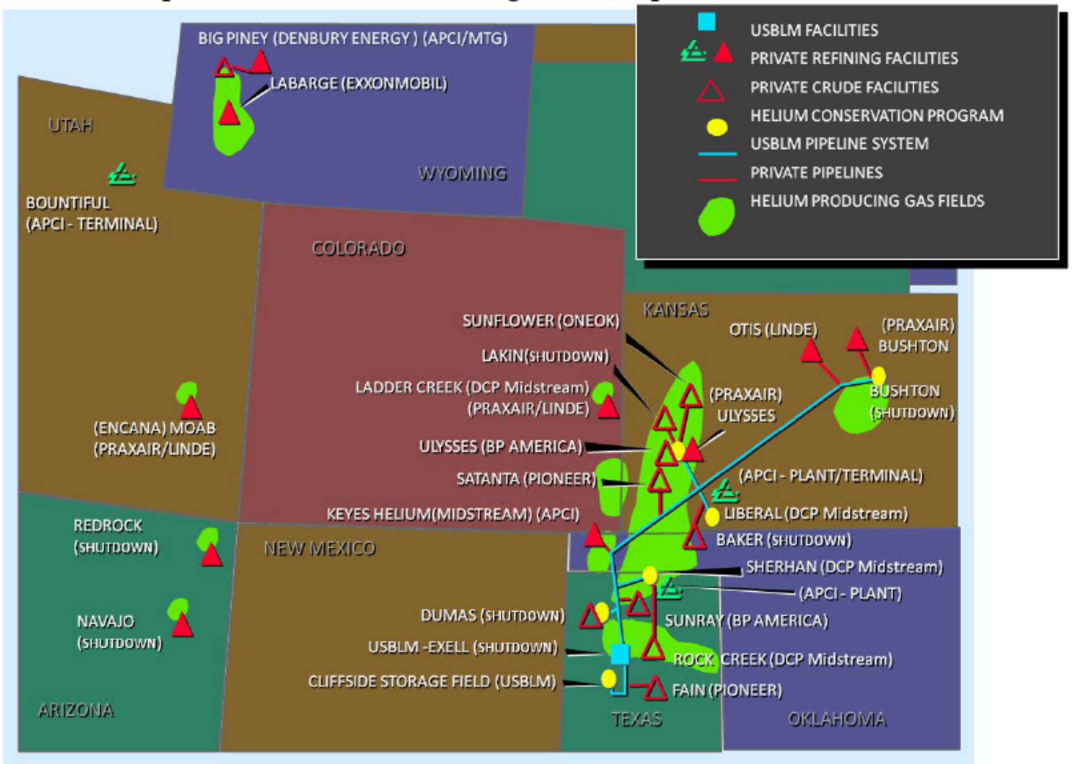
- Probable Resources – Those resources associated with known gas fields which are most likely to be produced. Substantial geologic and engineering data are available on this type resource. Probable resources bridge the boundary between discovered and undiscovered resources. The discovered portion includes supply from future extensions of existing pools in known productive reservoirs. The pools containing these resources have been discovered, but the extent of the pools has not been completely delineated by development drilling. Therefore, the existence and quantity of resources in the undrilled portion of the pools is unconfirmed. The undiscovered portion is expected to come from future new pool discoveries within existing fields either in productive reservoirs in those fields or in other formations known to be productive elsewhere in the same geologic province or sub-province.

- Possible Resources – Those resources that are less assured because they are postulated to exist outside of known gas fields, but are associated with a productive formation in a productive province. Their occurrence is indicated by a projection of plays or trends of a producing formation into a less well-explored area of the same geologic province or sub-province. The resources are expected to be found in new field discoveries, postulated to occur within these trends or plays under both similar or different geologic conditions.

- Speculative Resources – Those resources that are expected to be found in formations or provinces that have not yet proven to be productive. Geologic analogs are developed in order to ensure reasonable evaluations of these unknown resources. The resources are anticipated from new pools or new field discoveries in formations not previously productive within a productive geologic province and/or from new field discoveries within a geologic province not previously productive.

B. Maps Relating to the U.S. Significant Helium Bearing Reserves

Figure 3.1-1 Map of U.S. Helium Producing Fields, Pipelines and Facilities



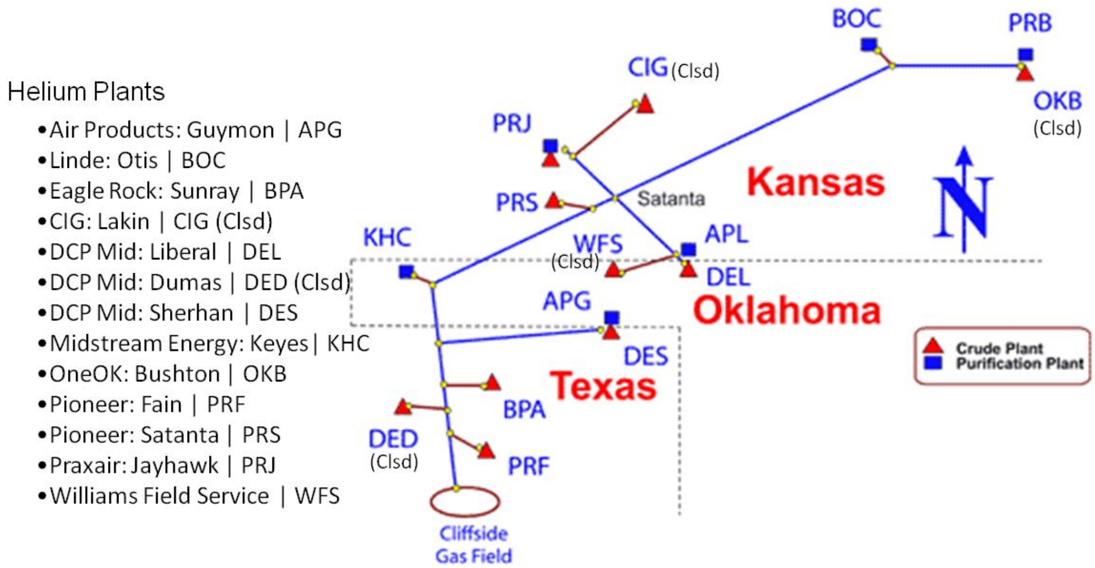
Crude helium is recovered from the natural gas fields (shown on the map as green shaded areas) by the crude recovery plants (shown on the map as a red hollow △ or blue □) and either piped directly to the refined helium production plants (shown on the map as a red ▲), or put into the crude pipeline for future refining.

On the map, the players which own/control each facility are noted (in parenthesis) right after the name of the towns in which the facilities are located. Plants outlying from the Hugoton and which do not have access to the BLM crude pipe/reservoir and reserve include:

- [redacted]
- [redacted]
- [redacted]
- [redacted]
- Other (In planning – not announced)

These facilities are not connected to the BLM crude pipeline/ reservoir system, and therefore must be self sufficient in their supply of crude helium feed to their refined helium production.

Figure 3.2-2 U.S. BLM Helium Pipeline and Storage System



The map in figure 3.2-2 illustrates the importance of the Cliffside crude helium reservoir and the BLM system that connects it to the crude helium processing facilities and to the refined helium production plants located along the pipeline. The combination of the pipeline and reservoir serves as online crude storage critical to U.S. and offshore helium supply. The figure shows the U.S. BLM production system from the perspective of:

- plants which recover and process crude helium from NRU plants, tied to the large natural gas recovery system in the Hugoton
- the BLM crude helium storage reservoir at Cliffside Field near Amarillo, TX, together with the BLM crude helium pipeline which operates between the Cliffside reservoir in the south and the Bushton field in the north
- the various private sector refined helium plants located along the BLM pipeline & storage system
- other helium plants located outside the Hugoton gas fields, the most important of which is the very large crude recovery and refined helium production plant [redacted] owned and operated by [redacted] at [redacted], [redacted]

3.3 Helium Cost/Price Relationships in the Supply Chain

Task

Provide an explanation of the helium cost/price relationships from the raw molecule contained in the primary reserve gas, through the supply chain, to end users worldwide (by region) – from 1985 to 2012.

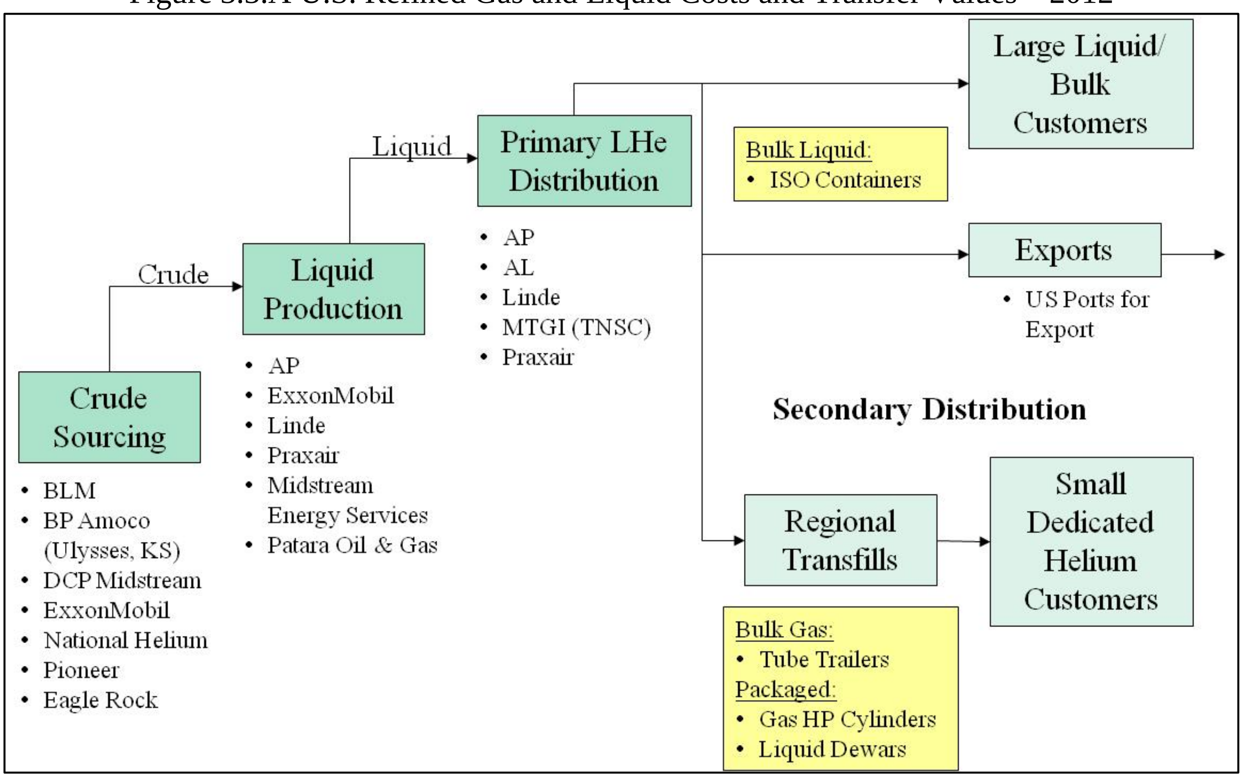
Purpose of this Section

Develop volumes, investments, operating costs, and prices for key stages and at key transfer points in the helium supply chain and how those economic factors have developed from 1985 to 2012. Discuss how that has impacted BLM's crude operations and economics during the period. This section must provide a detailed description of current and anticipated cost structure, investments and related price structure for liquid helium (LHe) from important regional sources, with distribution to important regional re-distribution depots.

3.3.1 Supply Chain Physical and Cost/Price Structures

In section 3.2.5 we explained the physical structure of the helium supply chain. It is repeated here in figure 3.3.A as a basis for discussing current cost structures, actual average costs, and the development of prices from those costs.

Figure 3.3.A U.S. Refined Gas and Liquid Costs and Transfer Values – 2012



The costs and relevant values and prices are noted in the appendix of this section and will be explained below.

3.3.2 Crude Helium and Its History Including Pricing from 1985 to 2012

The first instance of crude helium pricing was occasioned by the Helium Act of 1960 which started the helium recovery by the USG from the Hugoton natural gas fields into the Cliffside storage reservoir. While the contractors where paid for that helium in a fee for turnkey service, the amount of helium recovered of 38 Bcf had an initial cost in the order of $270 million (?) or the equivalent of $.007/Mcf. (That cost was significantly escalated from the cessation of that recovery program in 1970 to about $1.33 billion by the enactment of the Helium Act Amendment of 1996, because of the hyperinflation of the US economy and extraordinarily high interest rates compounded during that 26 year period.

Meanwhile in 1961 at the start of the recovery program and during initial BOM Helium operations the USG helium price fob its small scale facilities was raised from $15.50/Mcf to $35.00/Mcf to allow the fledgling US private helium business to start vigorously developing its private sector helium business including distribution of helium to USG departments and agencies. That pricing to the private sector for filled in private tube trailers, HP cylinders a few liquid dewars remained in effect until the ‘80’s when it was raised to $37.50/Mcf for service to USG operations, and to $42.50/Mcf from private sector purchases for sales to private sector customers. By 1989 the total sales of helium in the US to both USG and private user had a volume of 1.66 billion cf plus exports of 700 million cf for a total supply from US helium operations of 2.36 Bcf.

During this period the private sector helium refiners of the BOM crude pipeline were paying in the order of $10 - $12/Mcf for crude from the crude helium extractors which had stopped recovering crude for the USG’s recovery program, which price reached an average of about $25/Mcf by 2000. In 1998 the BLM promulgated its implementation helium operations CFR which included its first implementation of its auction process and its first crude price set for that year of $48/Mcf. The subsequent BLM’s crude price development is graphically shown in figure 3.3.B, which also shows the development from 2000 of the US private sector crude value/price to reach the BLM crude price levels by 2009. The current 2013 BLM Open Market crude price is now $84/Mcf, with an approximately $5.00/Mcf in additional BLM service fees. The history of the BLM Open Market and In-Kind crude base pricing is in the Appendix to this section.
We note that while the US crude helium supply from the Hugoton natural gas fields of KS, OK and TX has depleted significantly, the BLM supply, though fast depleting, has become a major factor in US crude feed to those refiners on the crude pipe.

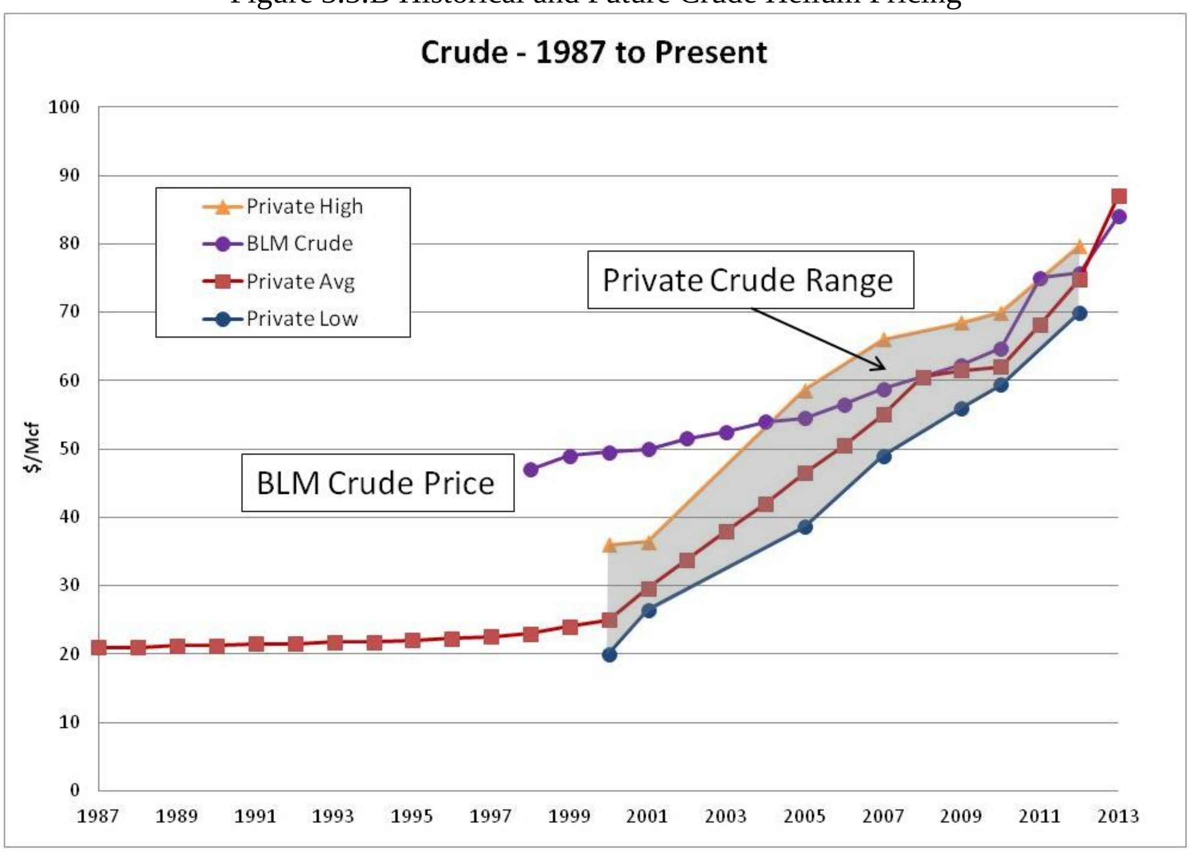
Figure 3.3.B is based on work that was originally developed by JRCI as part of work with the National Academy Committee on helium completed in 2010. It has been further developed and shows the value/price development of crude helium from 1987 to 2013, and the relationships between actual crude pricing from private crude suppliers in 2000, the convergence of those prices to the BLM posted prices in 2009, and the estimates of the continuing relationships developing from 2009 to 2013.

It should be noted that that major increased by BLM from 2010 to 2011 and again from 2012 to 2013, as they were carried through the adjustments in spigot costs and through the primary and secondary supply chains to end-user prices resulted in some significant increases in those end-user prices. The effect was even greater in the offshore markets as the effect was carried through the offshore primary and secondary distribution systems experienced significant increases in spigot prices.

It should also be noted that, because of the medium to long term supply contracts with the biggest end-using customers and distributors, the ability to pass these costs increases through the supply chain is difficult because of restricted price increase terms of the supply contracts.

We now move up the helium supply chain into the cost pricing of fob spigot helium pricing, starting with the historical and current pricing of crude helium. In section 3.1 a graph used by the NAS helium committee was shown with detailed crude pricing starting in 2000. From a different angle the following graph goes further back to 1987 when BOM (predecessor to BLM) was operating its own helium refining plant and was transferring crude from its "crude books" to its refining books at $10.50/Mcf , which compared with the US private sector paying $21/Mcf from its crude from NGL players. The BLM got into the business for selling crude to the refiners on the crude pipe as a result of BLM exiting the refining business and then selling crude to the refiners in 1997 at $47/Mcf.

Figure 3.3.B Historical and Future Crude Helium Pricing



The following table, figure 3.3.C, provides to the crude prices shown in the above graph, placing them in the benchmarked years for purposes of model development with follows.

Figure 3.3.C Historical and Future Crude Helium Price

Historical US Crude Helium Price	1987	1998	2000	2007	2010	2013
US Private Industry	21.00	23.00	25.00	55.00	62.00	87.00
BOM/BLM		47.00	49.50	58.75	64.75	84.00
Average Crude Price*	21.00	35.00	37.25	56.88	63.38	85.50
* Not weighted for volume						

Figures 3.3.B and 3.3.C also show the convergence trend of the lower priced private sector crude price from 1998 to the higher BLM crude price with virtually full convergence by 2009. That was not only convergence in the U.S. with the crude price from the independent crude players, but convergence of crude "values" by the integrated helium producers with internally recovered crude, became a key component in those players price of liquid helium as they sold it at their spigots. With the increasing and sometimes acute shortages of crude helium to feed the refiners in the US, crude from the independents has actually increased to the point that that crude price exceeds BLM crude by at least 3%.

Section 3.3.7.2 of this study describes the methodology for the development of helium prices by mode using regression analysis to analyze the JRCI database of raw helium prices from 1985 to 2013/3014. The results of this analysis are presented in the following sections.

3.3.3 Liquid Production – Spigot Pricing

Figure 3.3.D plots the private sector spigot price/values for the benchmarked years of this study against the BLM open market crude price.

Figure 3.3.D Historical Helium Spigot Pricing Compared to BLM Crude ($/Mcf)

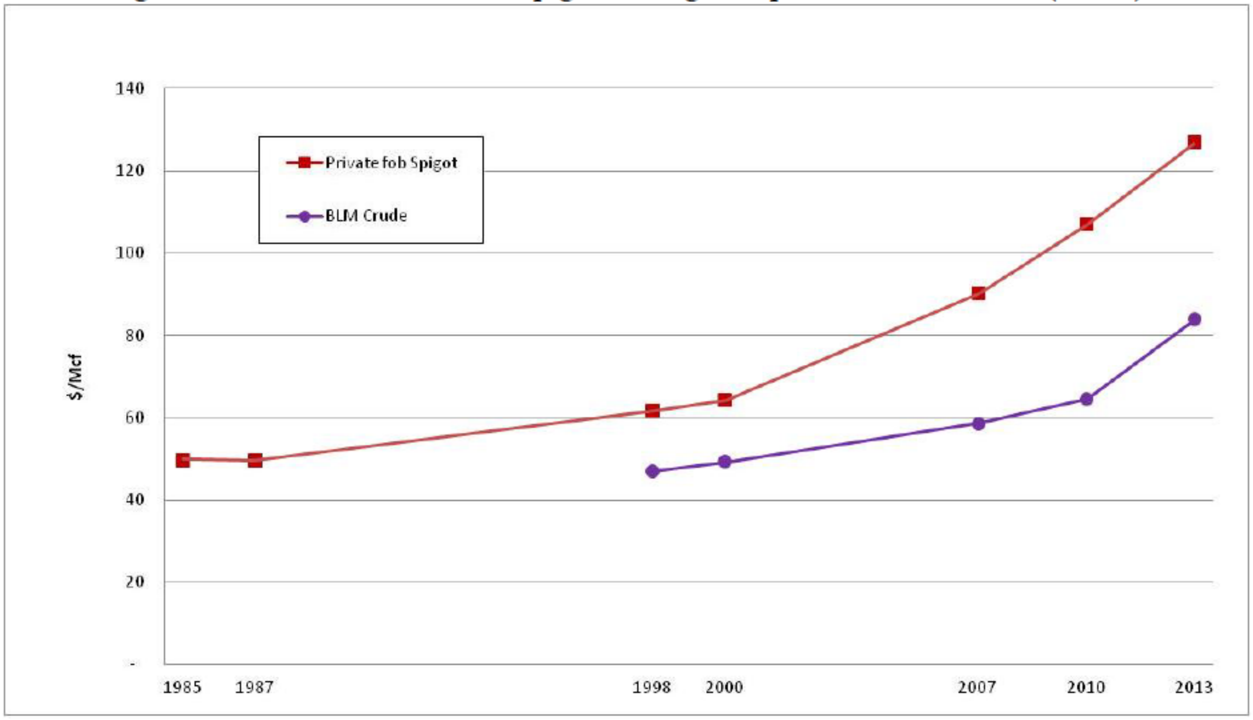


Figure 3.3.E below indicates the actual prices represented in figure 3.3.D. Note that the BLM crude cost until 1987, was $10.50/Mcf as a transfer cost from BLM's crude accounting to its refining accounting as a component cost of total refined pricing.

Figure 3.3.E Historical Helium Spigot Pricing Compared to BLM Crude

Pricing By Mode ($/Mcf)	1985	1987	1998	2000	2007	2010	2013
Private fob Spigot	50	50	62	64	90	107	127
BLM Crude			47	50	59	65	84

The U.S. refiner spigot price directionally tracks to price of BLM crude, but the price different expands due to the increase in rapidly increasing cost component of private crude as it converges from its lower levels to meet the BLM crude price, and from the modest inflationary increases in other plant operating costs, i.e. labor, maintenance and energy costs.

A note on [redacted] which entered the U.S. world helium scene in 1987

Until [redacted] came on stream with their [redacted] plant in 1986, helium was not sold at the spigot except by BLM for fob pick-up in tube trailers, cylinders and dewars. While refiners on the crude pipe and at a few of the minor locations were selling increasing volumes of helium, it all was being sold as delivered helium at the terminus of the primary or secondary part of the supply chain above. As [redacted] was a very large producer of liquid helium (and some tube trailer helium at the time) it sold that liquid to [redacted], [redacted] (now [redacted] and [redacted] (with part of their commitment taken by [redacted] under long term take-pay contracts. Those prices where and still are confidential. That plant, which started out at a nameplate volume of 800 mmcf/yr has been expanded and now produces 1.4 Bcf/yr.

The [redacted] helium business model became to strategic base for most if not all the current liquid helium producers ([redacted] [redacted] etc) which operate totally integrated crude/ pure liquid process plants which sell fob plant to [redacted] [redacted] [redacted] [redacted] and [redacted] all under long term take-pay contracts with very closely held fob pricing and price escalation systems, bound by strict confidentiality agreements. As 45% of the world's helium produced currently is sold under those circumstances, and as there is not market price attached to those suppliers, the only crude prices existing are those where the crude sales transaction is a separate transaction from the selling value of helium fob plant. The notable exception to that is BLM's sale of crude to the refiners on their crude pipe which is a well known public price. In 2012, from the 6.2 Bcf produced and in the world, the split of crude sourcing volumes is:

- Hugoton Field – 1.4 Bcf, 23% total
- BLM – 2.0 Bcf, 32%
- Integrated Process – 2.8 Bcf, 45%

It is anticipated that, at least as long as BLM is selling crude at a posted publicly known price, two things are quite certain.

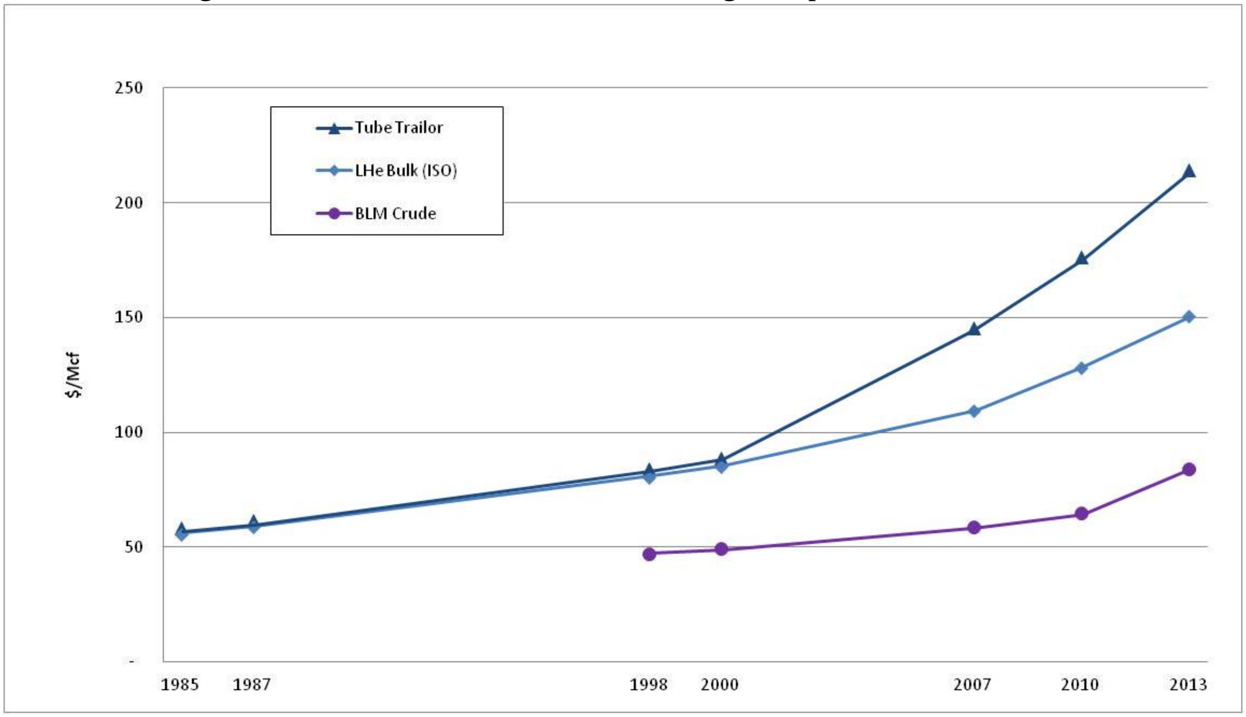
- Any crude only supplier will develop new capacity based on selling it at or above the BLM posted price
- Any new integrated crude/pure liquid process capacity will develop pricing where the "value" of the helium molecule is closely related to the BLM price. Because of this that player will have a significant profit advantage because of his discount in crude value compared with his competitor buying crude at an inflated market price.

As crude values and pricing do have a value system relationship with the retail pricing system which is semi-known outside the specific helium primary players, ratios of retail to crude values can be determined and therefore used in crude price evaluation and strategies.

3.3.4 Primary Distribution and Pricing - Bulk Helium

Our second case and crude price option compares the weighted average price of helium delivered by bulk delivery modes with BLM crude prices. This case is presented in figure 3.3.F and quantified in the price table in figure 3.3.G. The bulk share is made up of all ISO liquid and tube trailer gas delivered directly from plants to end-using customers.

Figure 3.3.F Historical Helium Bulk Pricing Compared to BLM Crude



This bulk mode group is closer to the end-user market because it services a relatively small number of U.S. customers, particularly when compared with the packaged gas group which comprises case and Option 3. The bulk ISO liquid is the lowest cost delivery mode servicing the largest customers like the major MRI players at the lowest of all end-user prices because of very large requirement volumes at those players MRI manufacturing factories, e.g. [redacted] [redacted] and [redacted]

Figure 3.3.G Historical Helium Bulk Pricing Compared to BLM Crude

Pricing By Mode ($/Mcf)	1985	1987	1998	2000	2007	2010	2013
LHe Bulk (ISO)	55	59	80	85	109	128	151
Tube Trailor	58	62	84	89	145	176	214
BLM Crude			47	50	59	65	84

ISO liquid helium containers are very special triple wall vessels with the outer annulus being a super-insulated, high vacuum space, with the inner annulus filled with liquid nitrogen. These ISOs are principally designed and built by [redacted]' subsidiary, [redacted], and cost anywhere from $850k to over $1mm. The former has a 30 day hold time with a maximum pressure before venting of 64 psig; the higher priced unit has a 40 day hold time and can reach 175 psig before venting. These containers are highly specialized, single use containers and are the primary means of transporting LHe overland in country/region overland, and by sea container ship to offshore markets. The payload of an 11,000 gallon ISO is generally estimated on average to be 950,000 cf (26.4 cm). These containers are owned by the primary helium player and are paid as part of the selling price either as a rental (about $400/day of round trip use time), or factored into the price of the delivered helium. The ISO is designed for dual service: over-the-road and shipment aboard container ship. This permits the flexible interchangeability and use to maximize the efficiency of the players transport system, a very important attribute of the Primary helium players' performance. Note that some LHe is transported in the U.S. and in Western Europe in ISO containers and over-the-road tankers. In these cases, the over-the-road tanker makes fast turnarounds and usually offloads at the transfill or large customer location into a stationary ISO container.

When making long trips like from [redacted] at [redacted] through Long Beach, CA to connect to a container ship bound for [redacted] checking the tank pressures and LIN inventories in Long Beach and then again in Japan is very important to maximizing the hold time to the specifications of container performance. An 87 day round trip from/to [redacted] will require at least three service checks so that the container returns to [redacted] "cold" with some residual LHe. If it returns "hot," that could add another 2-4 weeks of container downtime, a very expensive event when ISO's are short, as is the current case.

The cost/value details of the LHe roundtrip between liquid plant via destination with return to plant is a very important part of the pricing of LHe at the spigot. The performance and profitability of this activity is usually as important if not more so to the Primary helium players than is the plant operations to produce the LHe itself.

3.3.5 Secondary Distribution and Pricing - Packaged Helium

Our third case and analysis option is based on including the packaged gas group of delivery modes with that of the bulk group. The graph in figure 3.3.H shows the historic smoothed prices of dewar liquid and cylinder gaseous helium and compares it with the BLM crude price

Figure 3.3.I provides the values shown in the above graph. Note that while dewar liquid is more expensive to produce, the much higher volume of helium per container for about the same cost of delivery for the full container provides a delivery cost advantage for the customer. In addition a high share of total dewar volume is delivered to hospitals and clinics employing MRI and being services under long term contracts with the major MRI players in behalf of their MRI customers.

While there are many large customers for cylinder helium, the majority of volume is delivered to a large variety of small users and in as a blended carrier gas for mixtures of specialty gases.

While the packaged helium group is a very large and is the largest group of helium customers, the spread of pricing and the integration of rental charges and values as part of the buy/sell transaction complicates the use of this group in comparing packaged helium to BLM crude helium. The rental and service costs for the containers, and large part of the total integrated price of this group, both liquid and gas, is not included in this analysis.

Figure 3.3.H Historical Helium Packaged Pricing Compared to BLM Crude

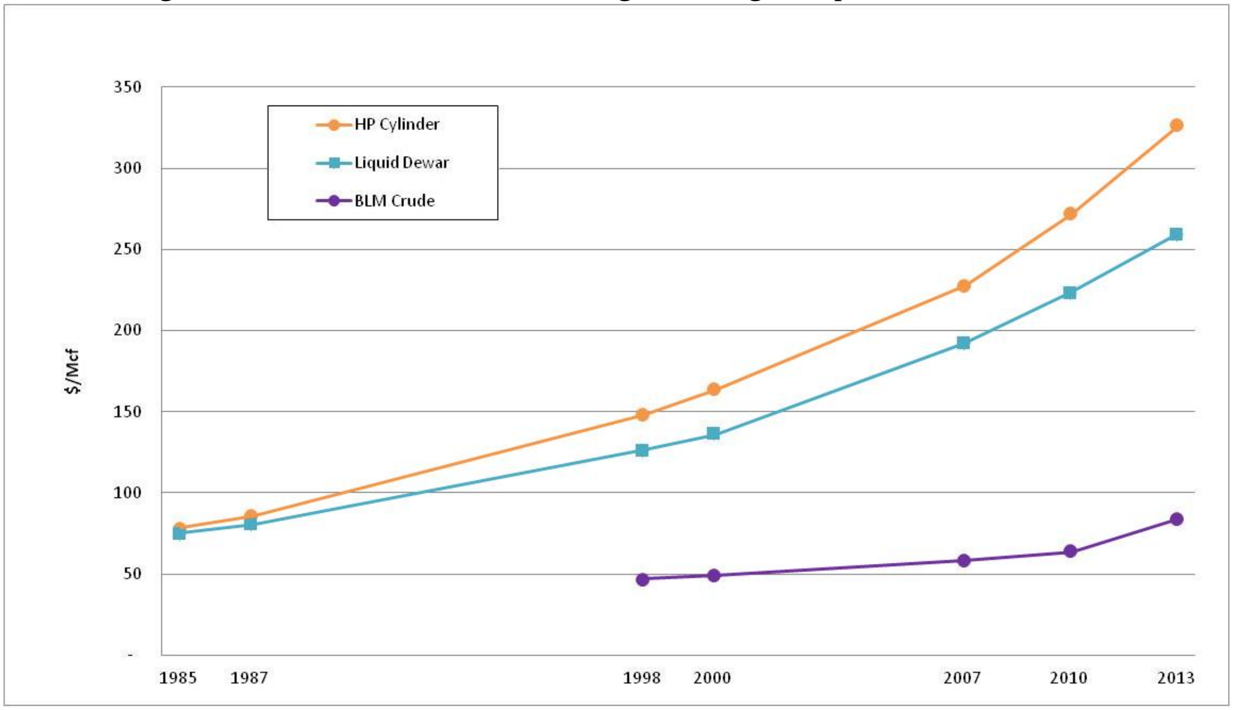


Figure 3.3.I Historical Helium Packaged Pricing Compared to BLM Crude

Pricing By Mode ($/Mcf)	1985	1987	1998	2000	2007	2010	2013
Liquid Dewar	75	81	126	137	192	223	259
HP Cylinder	78	86	149	164	228	273	327
BLM Crude			47	50	59	65	84

3.3.6 Summary of Helium Pricing Along the Supply Chain

Figure 3.3.J summarizes the prices of the four U.S. individual helium delivery modes together with the price of spigot and BLM crude, comparing them to crude and to each individually.

Figure 3.3.J Historical Helium Pricing by Mode

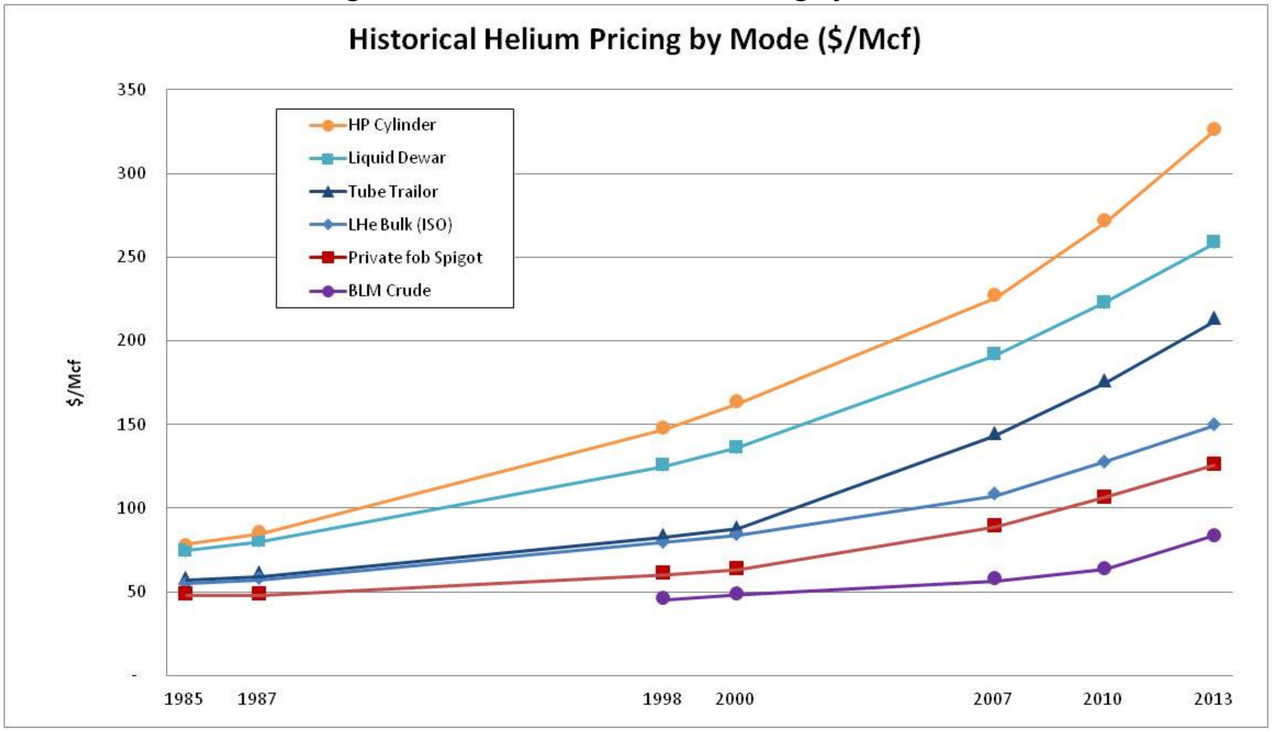


Figure 3.3.K provides the table of data shown in the figure above.

Figure 3.3.K Historical Helium Pricing by Mode

Pricing By Mode ($/Mcf)	1985	1987	1998	2000	2007	2010	2013
HP Cylinder	78	86	149	164	228	273	327
Liquid Dewar	75	81	126	137	192	223	259
Tube Trailor	58	62	84	89	145	176	214
LHe Bulk (ISO)	55	59	80	85	109	128	151
Private fob Spigot	50	50	62	64	90	107	127
BLM Crude			47	50	59	65	84

The above data and analyses provide the basis for comparing their price relationships over time and a discussion of the Options developed for this modeling. This and the following will provide for discussion of the most advantageous price option for determining the FY 2014 and subsequent BLM crude helium prices.

3.3.7 BLM Crude Helium Price Model Based on End-User Market Pricing

This section of the report provides the basis and development of the end-user market price model to support the development of a pricing strategy for BLM crude. Given the current acute shortage of helium supply in the world, it should be safe to assume that:

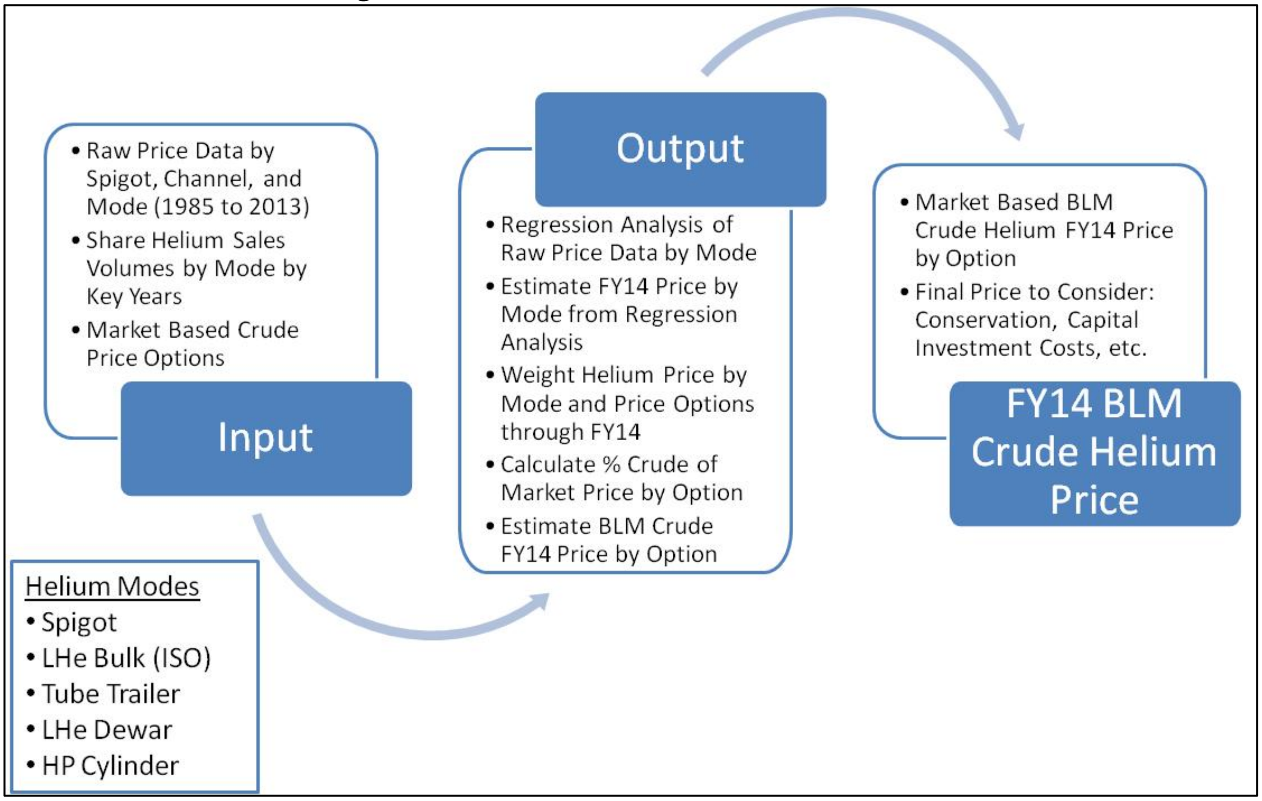
- End-use helium markets will tolerate increases in BLM crude price,

- A crude price reduction in setting the next base price (for FY 2014) would be inconsistent with the acute helium shortage and might put into question new investment plans for more helium capacity,
- Sensitivity by customers to changes in helium price in different markets is due to:
    a. Price's relationship to use volume and helium's share of the total cost structure of the customers products and business,
    b. the availability, performance and cost of substitutes, and
    c. the prospects for conservation, together with recovery and recycle of spent helium.

3.3.7.1 The BLM Crude Helium Price Model

Figure 3.3.L provides a schematic of the BLM Crude Helium Price Model, highlighting the input and output data to arrive at a fair market price for BLM crude helium derived from end-user market pricing.

Figure 3.3.L BLM Crude Helium Price Model



Below is a simplification the pricing model developed for this project:

- Collect raw helium pricing data from 1985 to 2013 (28 years) from the variety, mix and levels of helium product by delivery modes, excluding container rental, and recognizes the significant differences in price levels between the various kinds of delivery modes:
    a. fob liquid at the spigot sold to major industrial gas companies,
    b. liquid bulk by ISO container for very large customers where the cost and availability requires large volumes frequently delivered,
    c. high pressure bulk by tube trailers for medium and smaller customers that can benefit from bulk gas deliveries,
    d. liquid dewars for smaller customers or use sites that require helium as a liquid, and
    e. high pressure cylinders for medium and smaller customers.

- Assess the momentum and trend of the raw price data using regression analysis for each delivery mode over time and determine the price curve line equation that best fits the raw data with the highest coefficient of correlation (R^2), the measure of how well the regression line represents the data. The price curve equations are used to calculate a smoothed helium price curve by mode from 1985 to 2014. In most cases, the price data exhibited a different trend from 1985 to 2001 and 2002 to 2013. Therefore, a best fit price curve equation for the whole period was determined by combining the regression curves from the two separate time frames. The discontinuities in periods of the price data were due to major changes in helium activity and economic factors described in section 3.3.7.2.

- Three cases and BLM price options have been developed using the calculated helium market prices by mode to track the relationships between BLM crude helium price and the relevant end-user prices. The three price cases which form the basis for the options are:

    1. The average spigot value/price of liquid helium where the cost crude component is a percent of the spigot value of helium in the U.S. This is the easiest comparison to make with BLM crude as the data is the easiest to get and the difference from the mean of that scattered data is clustered quite tightly.

       As previously noted, integrated refiner production where recovery of crude is processed straight-through to refined liquid helium, may have only a very low if any accounted for cost of crude and therefore probably has an imputed “value” indexed or related to the posted price of BLM crude.

    2. The weighted average of the price of bulk liquid helium in ISO’s to the end-user plus gaseous tube trailer helium.

    3. The weighted average of the price of the four delivery modes noted above and grouped as bulk and packaged:

        – Bulk

i. ISO liquid
ii. Tube Trailer
- Packaged
i. Dewars
ii. HP Cylinders

This pricing model has been developed from a high level of understanding the helium business both within BLM and JRCI, and with a good sampling of prices from all modes of delivery from 1985 to 2013.

At this point a legitimate question: "is there another model that's relevant to this task and more commonly used to determine a 'market reflective price' for BLM's crude helium?" After considering this, we believe the answer is no.

Crude helium is the raw material for refining to pure helium gas and liquid. Helium has few crude suppliers, few refiners and no publicly available price intelligence for either crude or refined helium, except for the publicly quoted and available pricing to USG agencies and contractors, and the very well known crude price determined and published by BLM for each fiscal year since 1998.

Having intentionally set the original crude price in accordance with the 1996 Helium Act significantly above the private U.S. crude price which was generally known to BLM, it then used the USG published increase in Consumer Price Index (CPI) to calculate and establish the following year's crude price. The fact that each new price was public enabled those few private crude suppliers to raise their price over time to roughly equal BLM's crude price. That convergence occurred in 2008.

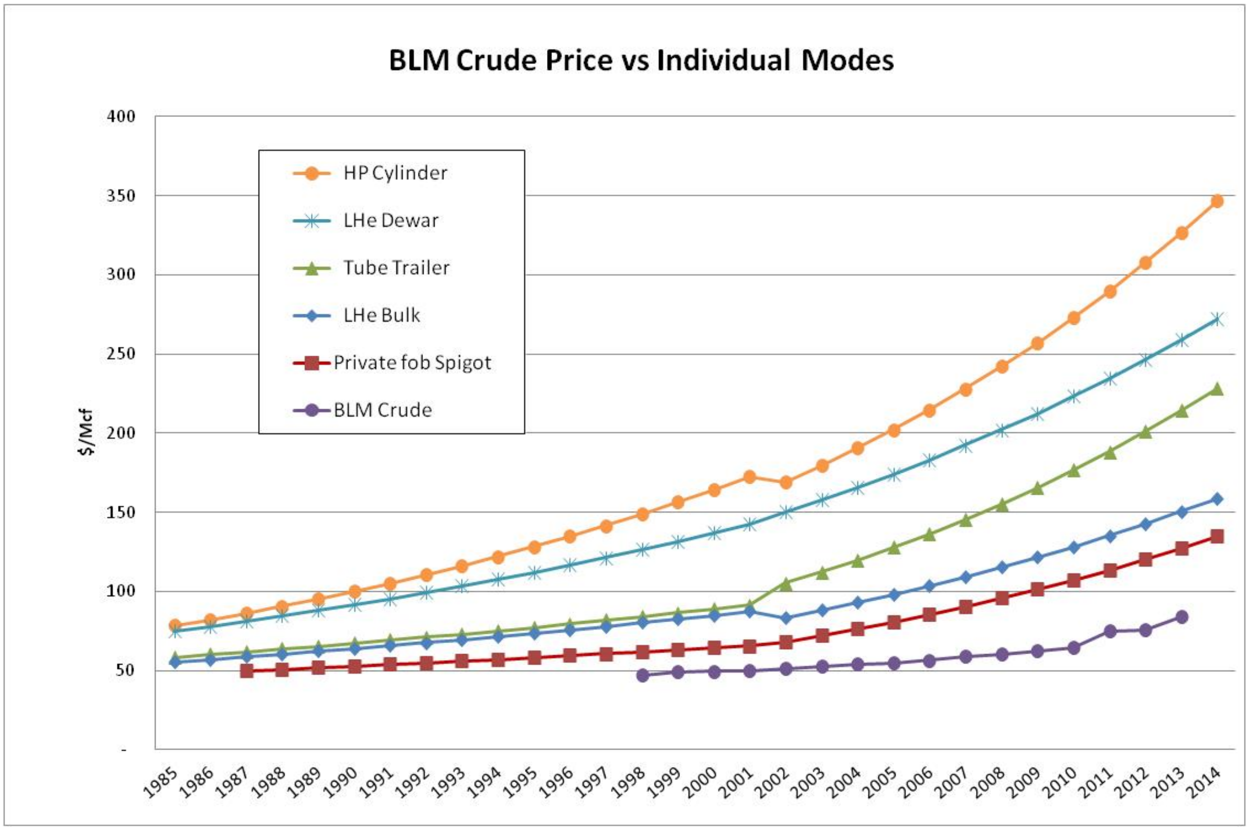
The related U.S. and international energy sector has daily published oil, gas and hydrocarbon prices which are analyzed, reported and forecast on a daily basis. That plenitude of price data makes the setting for market reflective pricing relatively easy, but is not applicable to pricing the U.S. or world's supply of crude or pure liquid helium.

3.3.7.2 Development of Helium Prices by Mode Using Regression Analysis

The scatter plots of raw helium price data by mode is used in the regression analysis to calculate helium prices by mode and are included in the 3.3 Appendix. The calculated/smoothed helium prices from 1985 to 2014 based on the regression analyses were presented in sections 3.3.3 to 3.3.6.

The detailed smoothed historical prices for the three case and option modes, plus those of BLM crude are shown in figure 3.3.M below. This graph tracts the data for benchmark years in which important changes in the role of delivery modes occurred in the U.S. helium supply chain and had some impact on mode pricing and its share of the total U.S. supply chain.

Figure 3.3.M Historical BLM Crude Helium Price vs Raw Average Individual Mode Prices



While we have a time series for all this above raw data, the key years that we have used to show this info are:

- 1985 – the first year of experience for this study with BOM (now BLM)
- 1987 – a base year for comparing BLM refined production and the private helium refiners economics for crude and refined helium gas and liquid; the beginning of the USG's strategy to exit in the refining and distribution part of its helium business (JRCI's first BOM/BLM helium study.)
- 1998 – the last year of BOM helium production; the first year of the private refiners' purchase and use of BLM crude
- 2007 – just before the peak of U.S. business, before the recent deep recession; a year of high production and demand for U.S. helium; a year of accelerating offshore demand for U.S. helium and exports
- 2010 – the depth of the recession; a period of increased depletion of crude; the slowing beginning of the decline in U.S. helium demand. It was the year in which the BLM departed from its CPI crude price indexing and set the first significant big crude price increase for 2011.
- 2013 – the current helium situation with worldwide and US demand severely constrained by lack of supply, combined with a crude price factor which has increased at rate of 10%/year from 2000. That crude price increase has been difficult for the helium supply players to pass through to its helium customer base, particularly with "bundled supply" to large customers using large volumes of other gases and services, and with contract

purchasing terms permitting only limited price increases for delivered helium to many large end-users.

Helium price data used in this study has been collected and tallied confidentially by JRCI over several years from helium producers, end-users, published studies, helium contracts publically available, etc. Due to the confidential nature of this price data, it will not be provided with this study. However, the regression equations developed from this data are provided by primary and secondary helium distribution modes described below. If more than one period was analyzed to best represent discontinuity in data over time, it is noted below. These tools along with historical data points are replicable. The new helium survey price data required by the Helium Stewardship Act of 2013 can be added to the model.

Private Industry fob Spigot Price – For the period 1987 to 2001, the best equation to fit to the price data was $y = 48.74e^{0.0198x}$ with an $R^2 = 0.97$. For the period 2002 to 2013, the best equation to fit the price data was $y = 64.333e^{0.0568x}$ with an $R^2 = 0.96$.

Bulk ISO liquid – For the period 1985 to 2013, the best equation to fit to the price data was $y = 54.036e^{0.0283x}$ with an $R^2 = 0.67$. For the period 2002 to 2013, the best equation to fit the price data was $y = 79.131e^{0.0536x}$ with an $R^2 = 0.83$.

Bulk Tube Trailer – For the period 1985 to 2001, the best equation to fit the price data was $y = 56.851e^{0.0279x}$ with an $R^2 = 0.62$. For the period 2002 to 2013, the best equation to fit the price data was $y = 98.662e^{0.0646x}$ with an $R^2 = 0.88$.

Packaged Dewars – For the period 1985 to 2013, the best equation to fit the price data was $y = 71.105e^{0.0415x}$ with an $R^2 = 0.77$. For the period 2002 to 2013, the best equation to fit the price data was y = $y = 142.76e^{0.0497x}$ with an $R^2 = 0.72$.

Packaged cylinders – For the period 1985 to 2014, the best equation to fit the price data was $y = 75.157e^{0.0484x}$ with an $R^2 = 0.80$. For the period 2002 to 2013, the best equation to fit the price data was $y = 159.76\ e^{0.06x}$ with an $R^2 = 0.51$.

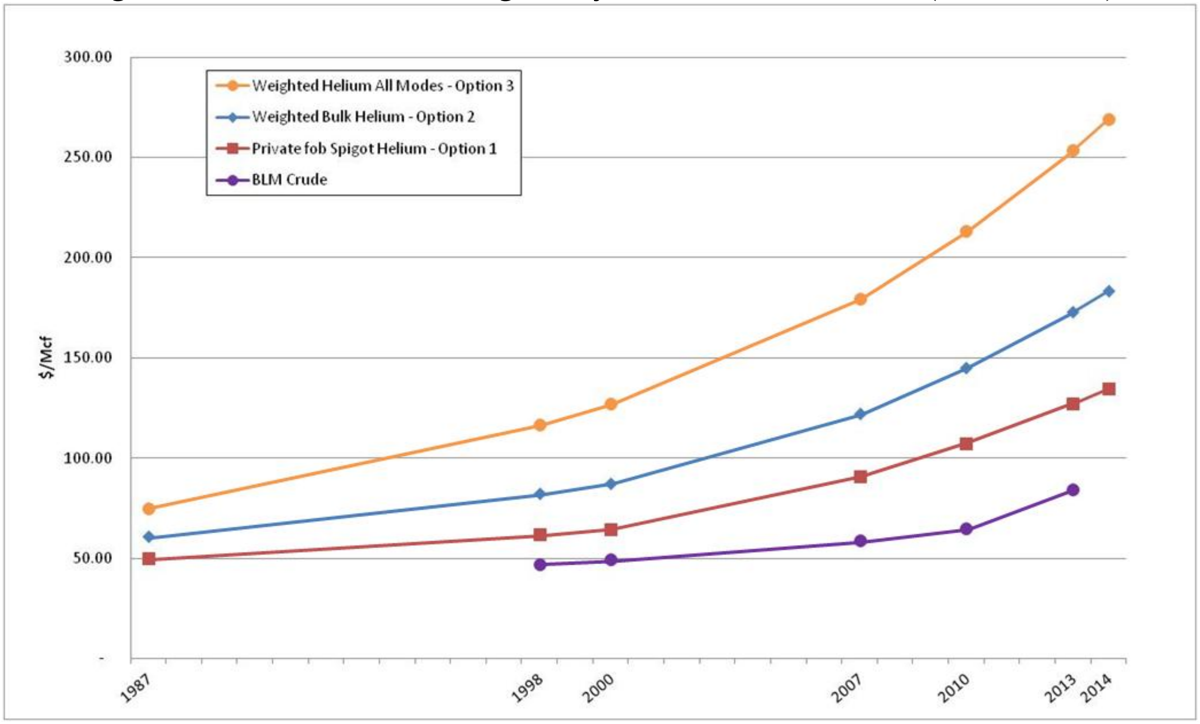
3.3.7.3 Weighting of Helium Prices by the BLM Crude Pricing Options

This section provides the analysis and results of the three options described in 3.3.7.1 to derive helium end-user market prices to calculate the future FY 2014 BLM crude helium price.

Weighting of Helium Prices – Helium prices are weighted based on the share of volume by modes as shown in figure 3.2.Jb in section 3.2. Figure 3.3.N provides the comparison of each Price option based on the weighting.

The rate of growth in helium prices for all modes of helium, including crude, has been higher growth since 2000 as is evident in figures 3.3.N and 3.3.M. Growth in crude helium has averaged 4.2%/yr over 2000 to 2013. Over the same period, growth in Private fob Spigot averaged 5.4%/yr, growth in Bulk Helium averaged 5.4%/yr, and growth in All Modes (excluding crude) averaged 5.5%/yr.

Figure 3.3.N Helium Prices Weighted by Mode vs Crude Helium (1987 to 2014)



Option 1: Private Industry fob Spigot Price - As shown in figure 3.3.O, the average spigot value/price of liquid helium where the cost crude component is about 66% of the spigot value of helium in the U.S. This is the easiest comparison to make with BLM crude as the data is the easiest to get and the difference from the mean of that scattered data is clustered quite tightly.

Figure 3.3.O Option 1 Price Model

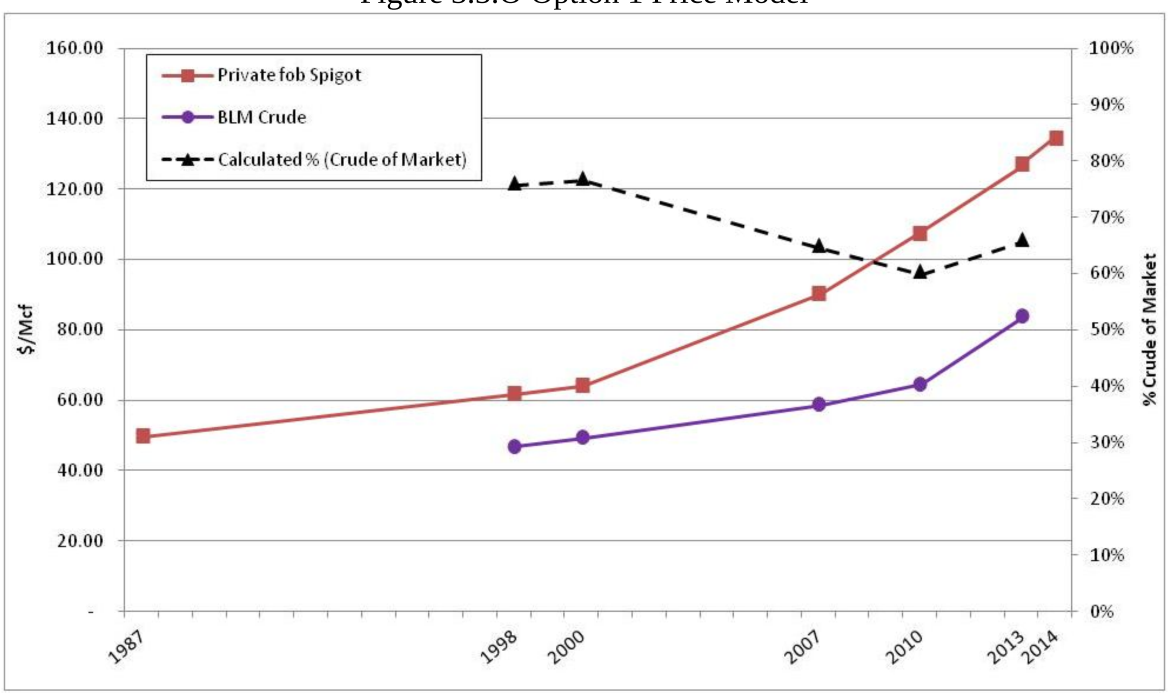


Figure 3.3.P demonstrates a BLM crude price increase of 5.8 percent, $4.91/Mcf, would yield a Crude to Market ratio in line with the trend.

Figure 3.3.P Option 1 Price Analysis

Option 1 Prices ($/Mcf)	1987	1998	2000	2007	2010	2013	2014
Private fob Spigot	49.71	61.81	64.31	90.46	107.26	127.19	134.62
BLM Crude		47.00	49.50	58.75	64.75	84.00	
Calculated % (Crude of Market)		76%	77%	65%	60%	66%	
Calculated Multiple (Market to Crude)		1.3	1.3	1.5	1.7	1.5	

Option 2: Weighted average price of Bulk Helium - As shown in figure 3.3.Q, liquid in ISO's plus tube trailer helium , currently about 40% of the total volume of helium delivered by those two modes, has a crude cost of 49% of the weighted average value. The regression analysis provides a FY 2014 weighted average price that the crude cost fraction can be applied to determine the FY 2014 BLM crude helium price.

Figure 3.3.Q Option 2 Price Model

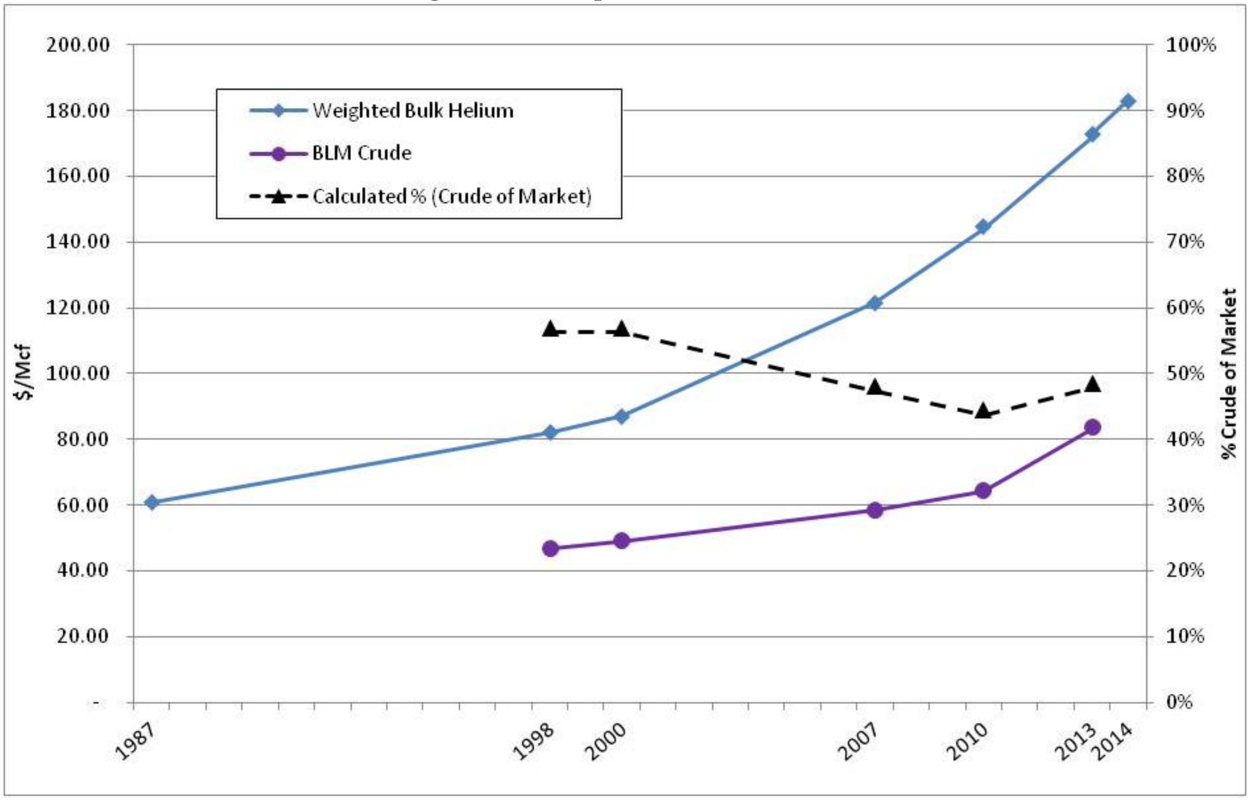


Figure 3.3.R demonstrates a BLM crude price increase of 6.0 percent, $5.05/Mcf, would yield a Crude to Market ratio in line with the trend.

Figure 3.3.R Option 2 Price Analysis

Option 2 Prices ($/Mcf)	1987	1998	2000	2007	2010	2013	2014
Weighted Bulk Helium	60.99	82.34	86.96	121.83	145.08	172.83	183.22
BLM Crude		47.00	49.50	58.75	64.75	84.00	
Calculated % (Crude of Market)		57%	57%	48%	45%	49%	
Calculated Multiple (Market to Crude)		1.8	1.8	2.1	2.2	2.1	

Option 3: Weighted average price of the four delivery modes - As shown in figure 3.3.S, the cost of crude is 33% of the weighted average value of the four delivery modes. Again, the regression analysis provides a FY 2014 weighted average price that the crude cost fraction can be applied to determine the FY 2014 BLM crude helium price.

Figure 3.3.S Option 3 Price Model

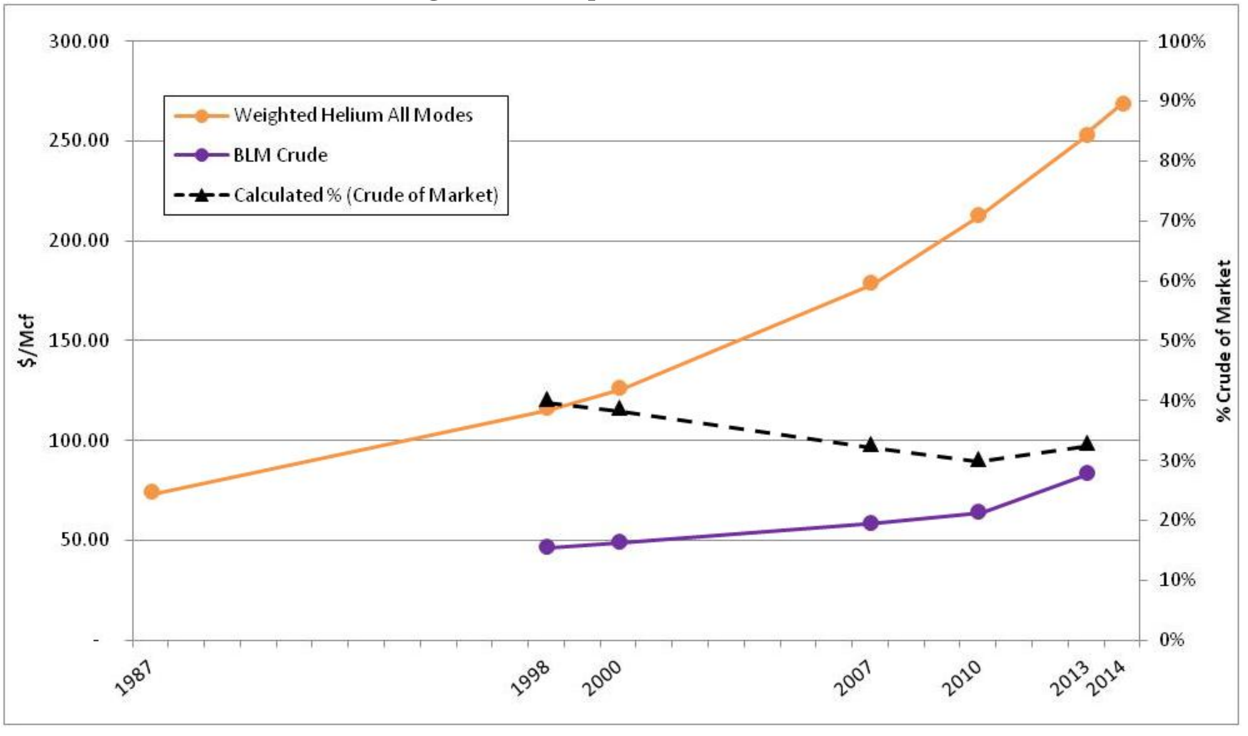


Figure 3.3.T demonstrates a BLM crude price increase of 5.9 percent, $5.00/Mcf, would yield a Crude to Market ratio in line with the trend.

Figure 3.3.T Option 3 Price Analysis

Option 3 Prices ($/Mcf)	1987	1998	2000	2007	2010	2013	2014
Weighted Helium All Modes	74.63	116.62	126.92	179.43	213.32	253.66	268.74
BLM Crude		47.00	49.50	58.75	64.75	84.00	
Calculated % (Crude of Market)		40%	39%	33%	30%	33%	
Calculated Multiple (Market to Crude)		2.5	2.6	3.1	3.3	3.0	

A summary of the weighted/average price for all three options was presented in figure 3.3.N. Figure 3.3.U provides the comparison of the Calculated % Crude to Market for the three price options. The trend in the Calculated % Crude of Market price trended down from 2000 to 2010. However, the allocation supply issues driven by private plants (U.S. and international) and the BLM plant has caused pricing to trend back up as a natural market reaction to supply and demand balance. With new supply coming on in 2014 and beyond, but with uncertainty beyond 2017, we expect that the trend in Calculated % Crude to Market to remain flat to increasing in the near future.

Figure 3.3.U Comparison of Weighted/Average Price for the Three Pricing Options

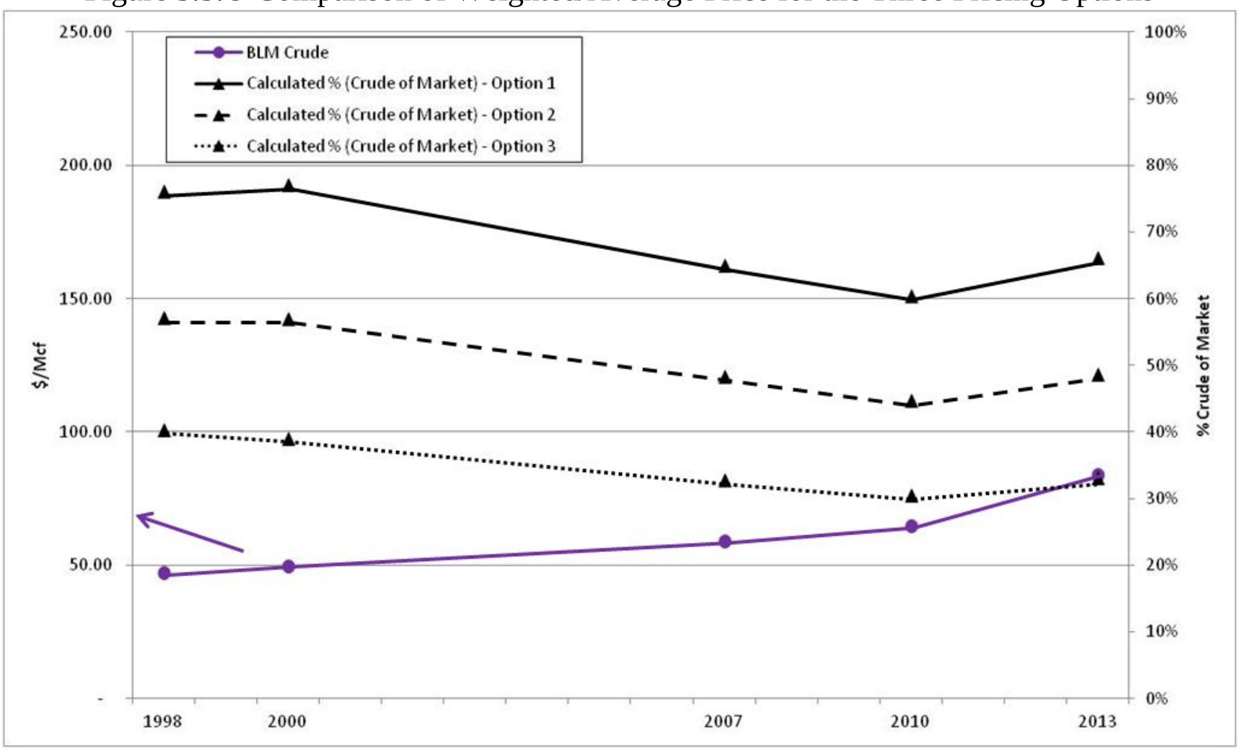


Figure 3.3.V provides the output from the modelling for BLM to decide which of the above options can be used to calculate a FY 2014 price for open market crude helium solely based on end-user helium market prices. This model is used in section 3.4 to calculate price for each scenario.

Figure 3.3.V Comparison of the Weighted/Average Price for the Three Pricing Options

Option Prices ($/Mcf)	2013	2014	% AGR '13 - '14
Private fob Spigot - Option 1	127.19	134.62	5.8%
Weighted Bulk Helium - Option 2	172.83	183.22	6.0%
Weighted Helium All Modes - Option 3	253.66	268.74	5.9%
BLM Crude			
Option 1	84.00	88.91	5.8%
Option 2	84.00	89.05	6.0%
Option 3	84.00	89.00	5.9%
Calculated % (Crude of Market) - Option 1	66%	66%	
Calculated % (Crude of Market) - Option 2	49%	49%	
Calculated % (Crude of Market) - Option 3	33%	33%	

3.3.8 Structuring Spigot Pricing Into the Future

Currently, the structuring of pricing under new helium supply contracts, or under the conditions of exercising the reopening price clauses of existing supply contracts, is made up of pricing components which combine:

- the total costs of production, including fixed and variable operating costs at capacity and often under turndown conditions
- the anticipated competitive pricing of the regions to be served by customer/supplier's using a "netback" method of calculating and assessing the total transportation costs including overland, ocean shipping, related fees, and the round-trip value of ISO container including the destination dwell time
- the profit expectation for investment returns consistent with the producers all in plant investment and hurdle rates
- an integrated price escalation system including a formularized price change mechanism and associated terms.

Most current valid spigot-based liquid helium prices have been adjusted to reflect the BLM posted price for crude helium as an important cost component, whether or not there is a corresponding real cost for the producer's crude. That price is currently $84.00/Mcf ($3.03/cm), effective 1 October 2012. That price is expected to increase again for the 2014 USG fiscal year. At this point that new price has not been determined.

In addition to having played an important role in establishing current liquid helium spigot price levels, the BLM is referenced in many of the existing supply contracts as an index upon which, in whole or in part, changes in those spigot prices change on a yearly or other period basis. It is commonly accepted that the BLM posted crude price is the only existing indication of the value of the raw molecule producing liquid helium, adjusted for the relationship of market demand versus primary channel distribution helium availability. The recently passed U.S. Legislation modifies the previous BLM pricing system to include a more market reflective BLM crude price. It also includes a provision for an increasing allocation of crude helium for auction. The Legislation states that the system will continue until the Federal Helium Reserve is 3 Bcf. The BLM posted crude price will continue to occupy a prime position in establishing new producer spigot liquid helium pricing until the reserve reaches the 3 Bcf.

The dilemma for the world's helium producers is what is likely to happen after the end of BLM crude helium availability to the private sector. There are several options which may be considered and which are likely to include:

- the USG continuing royalty arrangements with extraction of natural gas or CO_2 containing helium long after the removal of the BLM reserve from use. There could be a different basis for the USG/BLM to establish a new system of valuing the crude helium molecule for the use by at least the U.S. helium production business;

- the helium industry, or some critical mass part of it, possibly establishing an annual or periodic survey of helium crude pricing or of helium retail pricing with net-backs calculated back to crude values;

- the world's helium suppliers possibly abandoning any group established price for crude (as the world's sourcing for helium becomes limited in scope of by-product availability to sourcing like LNG and CO_2 for EOR), with all helium produced by integrated suppliers of the raw helium molecule through final pure processing to liquid. From this option it is likely that some entity would create a helium price index that would become a new base for understanding helium pricing.

3.3.9 U.S. Global Helium Supply Chain Logistics and Costs

As shown in figure 3.3.A, the Primary Supply Chain component is mainly performed by specially designed/built ISO containers which are triple walled high vacuum containers of stainless steel that provide a 30 to 45 day holding time for -452 degree F liquid helium with little loss during that time. These containers have a price of from $850,000 to $1.2 million depending on performance and have efficient interchangeable between over the road, rail and ocean going container ship transport.

The transport cycle is shown in the supply chain schematic and the in- country US average transport cost model provided in the Appendix. Large customers like the major MRI, electronics and fiber optics customers require direct shipment in the US by road of ISO's with high frequency deliveries and large volumes delivered per month. These requirements are priced by liter with significant extra charges for storage and insitu piping and applications systems, and more recently recovery and recycle of spent helium systems.

The Secondary Supply Chain system is much more complicated with service generally from by the Primary players from their regional transfill systems and by their helium distributors. The Secondary Distribution system is operated by most of the major helium players on a direct basis, and by a few of their largest independent distributors in the U.S. The facilities transfill helium from the ISOs into high pressure cylinders and tube trailers and into industrial, scientific, and MRI liquid dewars. This equipment is owned by the major players and their distributors and customers, and is filled and delivered by the gas players as part of their whole multi-product industrial, medical, and specialty gases local, regional, or national businesses. Prices for these services vary greatly depending on volume, distance from the service location, the number, volume, and variety of products served, and the customer density and competition dynamics of the area. Prices for helium in the widely varying modes differ greatly within the local areas, and certainly around the world. However, with helium, there is a very different national cost base depending on where the helium is produced, how it gets to the regional market for its production source common, and the scale of business enjoyed by the supply chain. It is for this reason that our analysis focuses on the relative costs from various production and debarkation ports to the primary receiving ports around the world. From those offshore supply points the Secondary Distribution economics fit into a common model but with very different energy, material, and labor cost bases and different treatment of economics. This is why the industrial gas business is known as such a "locally based business."

The following table shows the variety of helium users by the kind of customer they are, irrespective of the unique use requirements arising from the kind of market segment business the customer is in.

1. U.S. Government (USG)
    a. USG Users – For In-Kind Price & Service Though Private Primary & Secondary Supply Chains
        i. Departments/Agencies: Department of Defense (DOD), DOE, NASA, National Labs
        ii. Contractors: Universities, R&D Contractors
        iii. Other

2. U.S. Private Sector
    a. Majors Players – the buyers of crude and/or spigot LHe
        i. On Crude Pipe : Are BLM Buyers – [redacted]
        ii. NOT on Crude: Are BLM Buyers – [redacted]

    b. Primary Chain Buyers From Majors – Direct
        i. Liquid
            1. ISO/Tanker – MRI: GE, Siemens, Philips, Corning
            2. Dewar – MRI: GE, Siemens, Phillips
        ii. Large Tube Trailer (Supplier Owned vs Customer Owned)
            1. Large Industrial Gas Distributors – Norco, Nexair
            2. Large Direct End Users – Babcack Wilcox
            3. Buyer Coops – Independent Welding Distributors Cooperative (IWDC)

iii. Liquid - GE, Siemens, Philips, Corning
iv. Key Privately Owned Distributors

3. International Customers – Through U.S. Exports

These customer groups fit into a number of market segments which have been analyzed and discussed in section 3.2 of this report. A key from point for this study and the pricing side of same is the tolerance for price increases which helium customers can accept without reducing or eliminating significant purchasing volumes is part of the determination of price:volume elasticity at the end-user level of the helium market, as that market aggregate in influenced by the large helium supply chain cost component , BLM crude helium. This is covered in some detail later in this section.

3.3.10 U.S. Helium Exports, a Significant Part of the Offshore Supply Chain and Its Costs

Helium markets are great distances from helium sources; the transportation from liquid helium plants to those foreign markets has become the largest part of the current and forecast helium business and supply chain. Complicating the inherent complexities of shipping is the very expensive perishable product (helium) in a very expensive ISO, placed on the deck of a container ship (with no stacking allowed). In addition, the container ship's schedules and routes can change quickly, making excellent distribution performance quite a challenge. Today 66 % of the helium produced in the world is transported by container ship to its final country of use. With the expansion of Asian demand, JRCI estimates that that figure will increase to 75% by 2030.

Because the spigot value of liquid helium is so influenced by the volume development of Asia and the cost of moving the liquid from the U.S., the Mideast/Africa, and the prospects for exports from Russia, the economics of helium exports across ocean boundaries is very important.

3.3 APPENDIX

Figure 3.3-1 BLM Historical Open Market Price

Fiscal Year	Effective Price Range	$/mmscf	% AGR
2013	(OCT 2012-SEP 2013)	$84.00	10.9%
2012	(OCT 2011-SEP 2012)	$75.75	1.0%
2011	(OCT 2010-SEP 2011)	$75.00	15.8%
2010	(OCT 2009-SEP 2010)	$64.75	4.0%
2009	(OCT 2008-SEP 2009)	$62.25	2.9%
2008	(OCT 2007-SEP 2008)	$60.50	3.0%
2007	(OCT 2006-SEP 2007)	$58.75	4.0%
2006	(OCT 2005-SEP 2006)	$56.50	3.7%
2005	(OCT 2004-SEP 2005)	$54.50	0.9%
2004	(OCT 2003-SEP 2004)	$54.00	2.9%
2003	(OCT 2002-SEP 2003)	$52.50	1.9%
2002	(OCT 2001-SEP 2002)	$51.50	3.0%
2001	(OCT 2000-SEP 2001)	$50.00	1.0%
2000	(OCT 1999-SEP 2000)	$49.50	1.0%
1999	(OCT 1998-SEP 1999)	$49.00	4.3%
1998	(OCT 1997-SEP 1998)	$47.00	

Figure 3.3-2 BLM Historical Open Market Price

Fiscal Year	Effective Price Range	$/mmscf	% AGR
2013	(OCT 2012-SEP 2013)	$67.75	3.4%
2012	(OCT 2011-SEP 2012)	$65.50	1.2%
2011	(OCT 2010-SEP 2011)	$64.75	0.0%
2010	(OCT 2009-SEP 2010)	$64.75	4.0%

Figure 3.3-3 Private Industry fob Spigot Price Regression Analysis

[redacted]

[redacted]

Figure 3.3-4 LHe Bulk Price Regression Analysis

[redacted]

[redacted]

Figure 3.3-5 Tube Trailer Price Regression Analysis

[redacted]

[redacted]

Figure 3.3-6 LHe Dewar Price Regression Analysis

[redacted]

[redacted]

Figure 3.3-7 HP Cylinder Price Regression Analysis

[redacted]

[redacted]

3.4 BLM Crude Helium Pricing Scenarios

Task

Provide and explain some BLM crude helium pricing scenarios based on modeling of future U.S. and Offshore Helium Crude Sourcing and Liquid Production Cases.

Purpose of the Section

Use the information, analyses, and data developed from previous sections to finalize and discuss the Options for BLM to set prices for FY 2014 and subsequent to the final crude inventory levels when crude sales to the private sector cease.

Background from the Study

- The history of BLM's (and BOM before it) crude pricing has been discussed in section 3.1.
- The development of the U.S. and international helium markets and supply chains were discussed in section 3.2.
- The background of BLM development of crude pricing since the Helium Privatization Act of 1996 was developed in section 3.3, together with that of crude and refined helium by the private sector helium business, including market segments and delivery modes and their impacts on refined pricing.
- Those activities and performance factors and their relationships to BLM crude pricing from 1985 was also covered in section 3.3, ending with the U.S. private sector delivered prices and comparisons with 3 evaluation cases. Those cases will serve as the three pricing option methods from which to choose BLM's FY 2014 crude helium open market price together with the application of those one or a combination of those options for subsequent price adjustments.

This has been done to create a method for U.S. helium market reflective pricing.

It is noted that until the pricing decisions made in 2010 for FY 2011, BLM pricing was based on cost increases with a minimum increase at the rate of the previous year's CPI increase. It is further noted that significant operating and investments are required to maintain a satisfactory withdrawal rate from the Cliffside reserve to sale to the private players under a new auction scheme.

While this study has been restricted to developing a market reflective crude pricing scheme, financial prudence suggest that the end game in BLM pricing should include both the crude's price relationship with the end-user market and a stipend for project investments.

It is finally noted that, from a preliminary review of BLM's financial and operational statistics, the mandatory sales of BLM crude have exceeded the ability to withdraw and deliver that volume resulting in an increased inventory of previously paid for crude helium amounting to a volume exceeding 2.0 Bcf (FY13), to be delivered prior to cessation of Cliffside operations. This could complicate the crude price structure contemplated by this study. The economics of this situation should be included in the final selection of the crude pricing system for FY 2014 and afterwards.

3.4.1 Scenario 1 – US Only Production and Resulting Crude Helium Prices

Project Task : Include the existing U.S. only Hugoton (BLM Reservoir and Field "sourcing" connected to the pipeline) and Non-Hugoton sourcing volumes (e.g., [redacted] based on 3-4 BLM helium production (reservoir depletion) cases developed by BLM. A resulting crude helium cost will be developed for each production case.

The basis of this section will be the primary task of relating the BLM crude helium price and price structure to market prices in order to achieve a relevant relationship of BLM's crude price to the end-user helium pricing.

3.4.1.1 BLM Crude Helium Price Model Based on End-User Market Pricing

We have developed the basis of the End-User Market Price Model for BLM to use to calculate the open market crude helium price for FY 2014, which process and options was developed in section 3.3.7.

Figures 3.4.A and 3.4.B provide the output from the modeling for BLM to consider in deciding on the price structure and actually pricing for Open Market crude for FY 2014.

That model showed the relevant Options developed as based on the comparison of private sector refined helium pricing through three cases of price bases for the six benchmarked years from 1987 through 2013 described in section 3.3, for:

- **Option 1:** Private sector spigot pricing
- **Option 2:** Bulk helium delivered to end-users by ISO liquid containers and tube trailer gas
- **Option 3:** The addition of packaged liquid by dewars and gas by high pressure cylinders, aggregating to the whole of the U.S. helium market of 2.0 Bcf for 2013.

Figure 3.4.A Comparison of the Weighted/Average Price for the Three Pricing Options

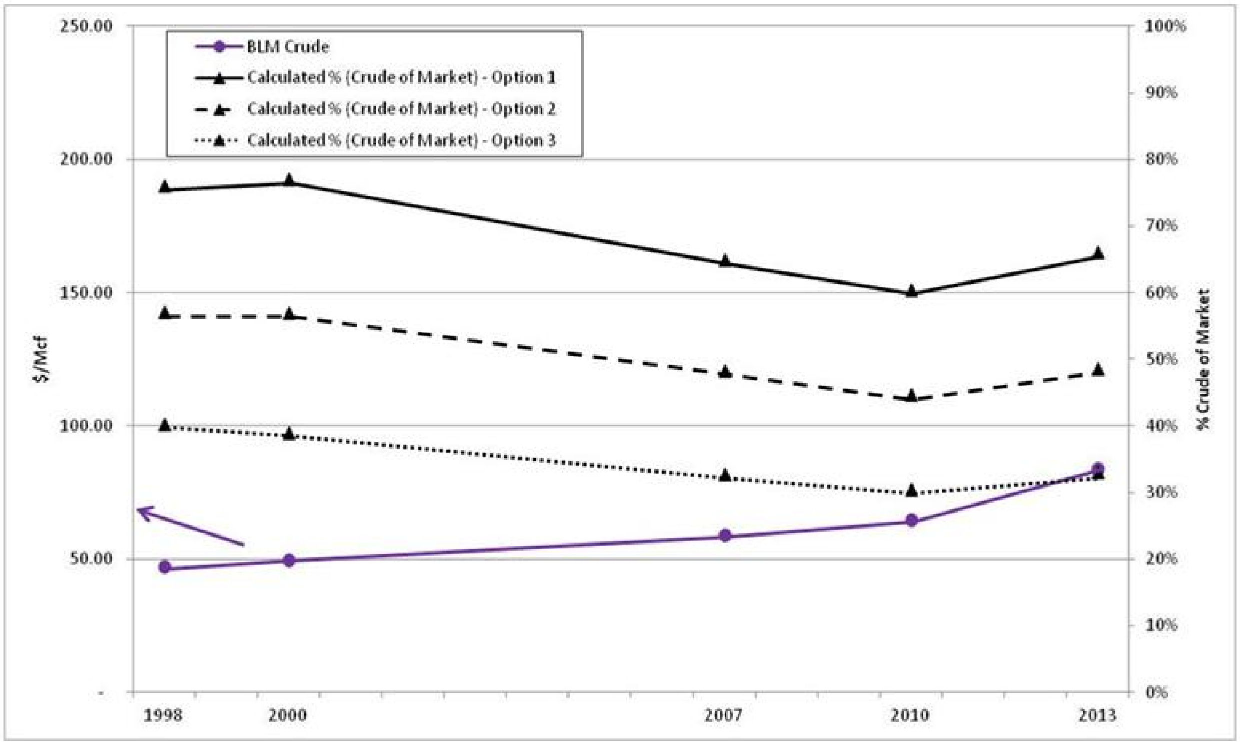


Figure 3.4.B Comparison of the Weighted/Average Price for the Three Pricing Options

Option Prices ($/Mcf)	2013	2014	% AGR '13 - '14
Private fob Spigot - Option 1	127.19	134.62	5.8%
Weighted Bulk Helium - Option 2	172.83	183.22	6.0%
Weighted Helium All Modes - Option 3	253.66	268.74	5.9%
BLM Crude			
Option 1	84.00	88.91	5.8%
Option 2	84.00	89.05	6.0%
Option 3	84.00	89.00	5.9%
Calculated % (Crude of Market) - Option 1	66%	66%	
Calculated % (Crude of Market) - Option 2	49%	49%	
Calculated % (Crude of Market) - Option 3	33%	33%	

This model suggests a price increase of about 6 percent based on the options presented as the market reflective component for the price increase from FY 2013 to FY 2014, or an increase in the open market crude price of about $5.00/Mcf based on figure 3.4.B. That would mean a new open market price for crude in FY 2014 of $89.

This model and these price options are strictly from a reasonable mathematically modeled price based on reasonably accurate market inputs and should be easily accepted for continued purchases of BLM crude for the foreseeable future. These prices do not consider other factors affecting a reasonable price from BLM such as conservation and new project capital investments or extraordinary service fees, which already amount to approximately $5.00/Mcf and which could be increased to absorb the other costs/benefits above.

As far as picking the basis for the increase, if the above rationale would be acceptable, we recommend the best and most reasonable basis, consistent with market reflectivity, as Option 2. It is reasonably reflective of a large volume of the end-user market for the U.S. of 2.0 Bcf, would be relatively easy to acquire market data to continue that system for the time remaining for the reserve. It would also be justifiable to the private industry as market reflective. Option 2 also has the advantage of large bulk deliveries of liquid dampening the ups and downs of spigot pricing from potential significant price moves at the spigot. It is also much easier to gain credible data than using Option 3 which has wide variation of pricing, including potential arguments that surround the eventual use of container rentals in the calculation models. (Our Option 2 does not include equipment rental that can significantly skew pricing on the upside and provide very different price variations between U.S. regions.)

On the negative side, Option 1 would not be market reflective and could be subject to more downside risk than upside benefit as new spigot helium comes on in the U.S., Middle East, and Russia. Option 3, while more market reflective would be much more difficult of gather and evaluate data to provide reasonable justifications to affect justifiable increases.

As a matter of judgment, and for FY 2014, we suggest that the FY 2014 increase should be no more than $10.00/Mcf. More than that could put the buyers in a position of demanding more of their paid for inventory before paying for new withdrawals. We also suggest that anything more than a $6.00/Mcf increase be in the form of dollar surcharges along the lines of what makes up the $5.00/Mcf extra service charges currently in effect.

There are 3 other price scenarios/situations in the scope of work, which are addressed in the following short sections

3.4.1.2 In-Kind Helium Pricing to Federal Users

In 2011, BLM established an “In-Kind” price for Federal Users which was the same as the Open Market price of $64.75/Mcf. While that Open Market price was increased in FY 2011 to $75.00 (by 15.8%), the FY 2012 In-Kind price remained at $64.75/Mcf. This was in part a response to the NRC helium study of 2000 which strongly recommended BLM provide a legitimate discount for Federal Users as an incentive to continue to perform important USG sponsored helium using research and development (R&D) to benefit the long term strategic interest of the U.S.

After consideration and discussion of the future of In-Kind pricing, we have determined with BLM that the In-Kind pricing should be established with a discount of 20% from each year’s Open Market pricing, keeping the In-Kind price at 80% of the Open Market price. This will continue the incentives for USG R&D strategic interests, establish some in forecasting stability for In-Kind helium pricing, and will provide the private sector companies which In-Kind helium to those USG agencies and contractors with acceptable margin incentives to maintain quality service.

Three additional scenarios were part of this project's assigned tasks and are noted below. In discussions with DOI OME and BLM it was determined that, given the changing conditions of BLM Helium Operations and of the new Helium Stewardship Act of 2013, these three issues had little if any relevance to the U.S. demand and supply situation and BLM's very important role in it. Moreover the decision was made by DOI OME and BLM to direct JRCI to concentrate on Scenario 1 and its recently increased complexities arising from the acute shortages of helium in the U.S. and offshore.

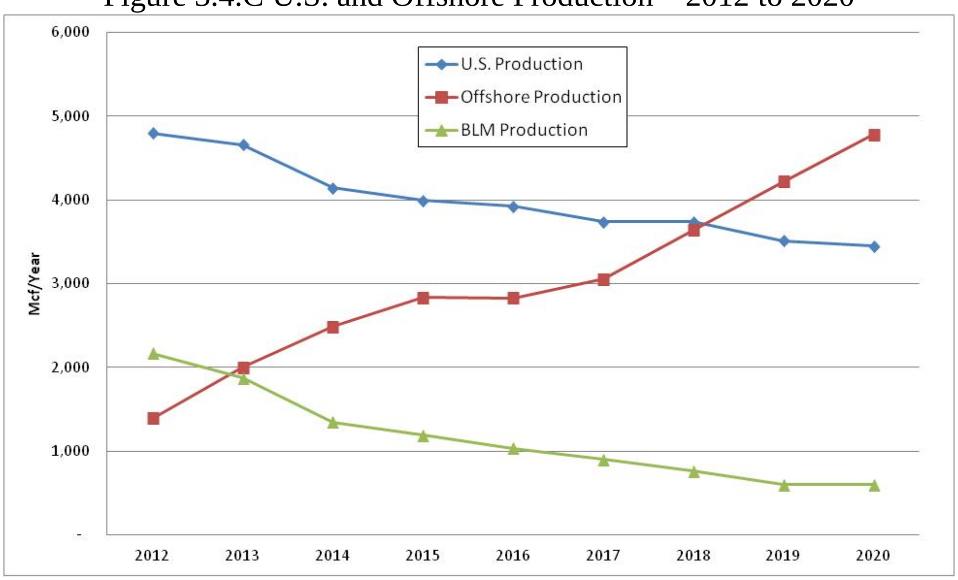
3.4.2 Scenario 2 – US and Offshore Production and Resulting Crude Helium Price

<u>Project Task</u> : to add the U.S. and competing Offshore Helium sourced volumes to develop a combined production Scenario of the worldwide supply in which BLM will continue to operate until the reserve is exhausted. Offshore Helium production cases should be developed.

Extensive description of the current and anticipated offshore developments in Demand, Capacity and Production of pure liquid helium was provided in sections 3.2 and 3.5. This will provide BLM with a much better understanding of its position in these important worldwide helium positions. However positioning BLM's crude price in the international end-user pricing systems, beyond its impact on the U.S. current and forecast export volumes, in the face of BLM's current very important position in U.S. demand including its contribution to export volumes was considered irrelevant for the probable time remaining for its crude helium production and supply.

Figure 3.4.C provides the U.S. and Offshore helium production that is the basis for U.S. helium, and BLM specifically, becoming less of a factor after 2018.

Figure 3.4.C U.S. and Offshore Production – 2012 to 2020



Moreover the delays in offshore investments and capacity on-stream dates and times noted in this study clearly showed the international relevance of maximizing BLM's crude output in the short term as a bridge to that delayed investment and new capacity. While it is well known and acknowledged that virtually all offshore helium spigot prices reflect the posted price of BLM crude helium, the much higher delivery, container and service costs and prices of offshore delivered helium prices lacked any utility in price analyses and decision making impacts on this projects BLM crude pricing concerns, conclusions or recommendations.

3.4.3 Original Assignment and Scenarios 3 and 4

The original project assignment was also to address two other tasks:

Scenario 3 - BLM Helium Reservoir Conservation, to include BLM helium reservoir conservation as a possibility.
While this Scenario contemplated a longer term outlook, changes in BLM supply plans particularly in the acceleration of depletion rates and the need to increase reservoir pressure with increases compression capacity made analysis of this scenario irrelevant with respective to crude pricing options.

Scenario 4 – BLM Closure, to include closing the BLM helium crude system, and its impact on crude helium pricing.
This scenario contemplated elimination or mothballing of the reservoir's and its impact on helium prices in the U.S. and offshore helium markets. As this also had no relevance in BLM's current and anticipated operations given the passage of The Helium Stewardship Act of 2013, this scenario was dropped from consideration.

Note: The above actions were taken in consultation and at the direction of DOI's OME and BLM.

3.4.4 A Survey Of End-User Helium Prices, FY 2015 BLM Crude Price

The Helium Stewardship Act of 2013 envisions establishing a BLM crude helium price that reflects the end-user helium price. This project recommends a process to do that, particularly for the new base crude price for FY 2014. That model and pricing system has been described above and recommends a base end-user market reflective price component of $89.00/Mcf for the FY 2014 crude price, a 6% increase from FY 2013.

That price was determined in part from a survey of end-user prices for the period 2010 through 2013, together with analysis of the end-user price increase data and development trends from 1985 to 2010.

In order to continue this price adjustment system from FY 2014 price to FY 2015 and beyond, it will probably be useful, if not necessary, to conduct a survey of U.S. helium end-user prices, particularly for the same types of delivery modes as was used to establish the Open Market price for FY 2014, i.e. bulk helium delivered by ISO liquid container and by high pressure tube trailer gas.

It is recommended that the survey is designed and conducted by a qualified agency or contractor with no conflicts of interest, and that the outside contractor have excellent credibility in protecting the confidentiality of the price information they gather and analyze. Without that credibility and expertise, the survey will not produce useful results.

More specifically the survey should include an independent and qualified firm with industrial gas experience, and a firm with an excellent reputation in gathering, analyzing, and reporting sensitive commercial intelligence. A high quality accounting or legal firm with this experience is recommended. An action program for this survey would include the following:

- The team and BLM would agree on the contents of a simple questionnaire to be sent to a select group of helium end-users whose helium was delivered by the four delivery modes described in this report, but with emphasis on collecting price data on bulk liquid helium deliveries. An important component of the design of this survey would be its relationship with the Allocation and Bid process for establishing the crude pricing system to be established in the early part of FY 2014 for effect by 1 October 2014; to establish the crude price, boundaries and terms of that Auction Process.

- The team would create the list of end-users to be surveyed (probably between 200 and 400 end-users) primarily of ISO liquid and tube trailer helium gas end-users, and large helium distributors, from the private sector and from federal In-kind users.

- The questionnaire would solicit the volume and price for each of the last 5 calendar years, of delivered helium, not including equipment rental, and aggregate that information into summaries that were designed as part of the organization of the survey to statistically develop the conclusions agreed to in the assignment.

- The team would then analyze the data, arrive at the boundaries of price and a recommended crude price for BLM, considering the many economic, market and competitive factors that are involved in effecting the “price population,” and how and why the price data and aggregated value had changed from the FY 2014 price.

The result would provide guidance to BLM in setting the market reflective crude helium price component, plus other market information of use to BLM in better understanding the U.S. helium market for future purposes and projects.

3.5 Forecast Worldwide Supply, Demand, and Demand/Supply Balance - 2012 to 2020

Task

Provide a macro analysis and forecast for 2012 to 2020 of crude capacity, refining (purification and liquefaction) capacity, demand, supply (production and primary distribution), and demand/ supply balance of worldwide helium markets.

Purpose of this Section

Provide quantitative forecasts of these performance factors and supply/demand balance in enough detail to enable BLM to develop its supply strategy and crude pricing options. Understanding the rest of the world's helium supply system through 2020 will be important to BLM. This will be done so as not to compromise confidential data and plans of those players and supply schemes that are not a matter of public record.

Provide a macro analysis and forecast for 2012 to 2020 of crude capacity, refining (purification and liquefaction) capacity, demand, supply (production and primary distribution), and demand supply balance of worldwide helium markets. The BLM understands that this analysis may use confidential data and does not expect the contractor to divulge this information.

3.5.1 Prospective Helium Production Projects and an Evaluation of Feasibility

Figure 3.5.A provides prospective helium production projects worldwide. A description of each project and the probability analysis is provided following the figure.

Probability Assessment Scheme – Probabilities are assigned for prospective helium plant projects based on an evaluation of their feasibility. Feasibility criteria considered include: quality and source of information on project status, status of project financing, viability and status of co-product project (e.g., EOR), location of helium plant, etc. Based on these criteria, probabilities will be assessed as follows:

Probability Assessment	Criteria
0 %	Helium exists, project considered, no financing
25%	Project considered, no financing, co-product project viability questionable but still under consideration
50%	Project considered, financing committed, co-product viability questionable but under strong consideration
75%	Project financing committed, co-product financing committed, may be some delays to plant
100%	Project financed and built, co-product financed and built, waiting start-up

All projects with a probability assessment of 50 percent or higher are included in the global helium forecast of capacity and effective production volumes.

Figure 3.5.A Prospective Worldwide Helium Production Projects and Probability Assessment

New Sources	NPC		Est Date	Est Probability
Plant/Project	mmcf	mcm	On-stream	of Success
[redacted]	200	5.5	2013	100%
[redacted] [redacted]	1,300	36.1	2013	100%
[redacted]	550	15.3	2013	100%
[redacted] (U.S.)	10/42/48	0.3/1.2/1.3	2013/2014/2015	100%/75%/25%
[redacted] CO	240	6.7	2016	100%
[redacted]	650	18.0	2018	25%
[redacted] [redacted] [redacted]	200	5.5	2018	50%
[redacted] [redacted]	2,100	58.2	2018	75%
Other U.S.	600	16.6	2019	0%
[redacted], AZ	600/600	16.6/16.6	2019/2025	25%/25%
Canada ([redacted]	300	8.3	2019	25%
Australia [redacted]	150	4.2	2025	25%

NOTES: On the Helium Prospective Plant Projects and Feasibility

[redacted] [redacted] [redacted] - the helium plant is built, ready for start-up, and is waiting on crude supply. The delay is being caused by issues between [redacted] and [redacted] on some complex issues surrounding the Riley Ridge field. However, because the helium project's JV partners, [redacted] and [redacted] (sub of [redacted]) maintain the plant will be on-stream by the end of 2013, our feasibility assessment is a 100% probability of the project coming on-stream.

[redacted] **Algeria –** The LNG replacement plant with crude feed to the helium plant is in start-up now with an estimated project feasibility of 100%. Once fully on-stream, the EPC for helium is estimated to be 540 mmcf/year (15 mcm/year), providing the plant with the originally planned crude feed.

[redacted] **U.S. –** [redacted] has three projects currently operating in [redacted] KS, [redacted] UT, and several others in various stages of planning and financing. These projects produce lower purity gaseous helium suitable for balloon consumers. The volumes are small (approximately 10 – 50 mmcf/year) (as they are extracted based on [redacted] proprietary, non-cryogenic helium recovery units that extract and purify helium directly from natural gas. Only the projects which are in start-up or have financing are rated with 75 – 100%.

[redacted]**, CO** – is an EOR CO2 based project, with helium as a by-product. The helium project is in development with [redacted] by an industrial gas company (identity confidential). [redacted] is a very well managed and financed player in EOR with CO2. From confidential sources, JRCI forecasts the plant to be online in 2016, with a 100% probability of success.

[redacted], AZ – is another [redacted] EOR CO2 recovery project with by-product helium. Because this project requires a $500mm CO2 pipeline to the West Texas Permian Basin, the project has many challenges. JRCI assesses the feasibility of this project with a 25% probability of success in 2019 with an expansion in 2025. The helium side of the project is an important credit to the more important EOR project. Assuming the project happens, [redacted] has an existing contract to develop the helium side of the project. This project has the potential to add NPC of 600 mmcf/year (16.6 mcm/year) in 2019 and another 600 mmcf/year (16.6 mcm/year) in 2025.

[redacted] – Once [redacted] is on-stream, it is likely that it will be expanded with at least another NPC of 200 mmcf/year (5.6 mcm/year) in 2018. JRCI assesses a probability of 50% as the current plant liquefier is configured to expand and produce this volume with just additional compression.

[redacted] Russia – [redacted] announced its final investment decision on pre-development of the Chayandinskoye field, construction of the [redacted] – [redacted] – [redacted] gas trunkline, as well as gas processing facilities in [redacted] in December 2012. The project plans to refine the gas at a helium plant in [redacted] The rest of helium will be retained and injected back into the reservoir directly at the Chayandinskoye field. JRCI estimates a total of 2,100 mmcf/year (58 mcm/year) of NPC will be incrementally installed from 2018 to 2020. JRCI assesses a probability of 75% as [redacted] has announced the final investment decision on pre-development.

Other U.S. Plants – At least one more [redacted] plant is confidentially under serious consideration with crude from CO2 EOR sourcing to produce NPC of 600 mmcf/year (16.6 mcm/year) in 2019. Currently financing has been redirected to other projects, giving this plant a feasibility assessment of 0%.

Canada – There appears to be interest recovering helium from the [redacted] British Columbia LNG project. However, no financing has been committed so JRCI has assessed a project feasibility probability of 25%.

Australia [redacted] – There appears to be less Australian market potential beyond the loading of the first [redacted] helium plant in [redacted] While [redacted] is a difficult export location for helium, additional capacity there is assessed a 50% probability, but not until after 2025.
The recent [redacted] interests in the Northwest shelf project to some new locations give more credibility to possible new helium capacity in Australia. The difficulties will continue to be operational, particularly the reliability of supply for exports.

3.5.2 Global Forecast Capacity and Effective Production Volumes

Figures 3.5.B and 3.5.C show significant global helium plants for 2012 and forecasts 2015 and 2020.

Figure 3.5.B provides the current and forecast Nameplate Capacity (NPC) of refined helium based on figures 3.2.D, 3.2.E and 3.2.F, and adding the NPCs based on the on-stream schedule outlined in figure 3.5.A. Worldwide NPC is expected to expand from 9.4 Bcf/year (261 mcm/year) in 2012 to a maximum of 11.1 Bcf/year (307 mcm/year) in 2020.

Figure 3.5.B Worldwide Nameplate Refined Helium Capacity 2012 – 2020

				[redacted] (mmcf)		
Region	**Country**	**Owner/Operator**	**Location**	**2012**	**2015**	**2020**
Americas	**US**	**BLM System**				
		[redacted]	[redacted] TX; [redacted] KS	1,460	1,460	1,460
		[redacted]	[redacted], KS; [redacted], KS	1,370	1,370	1,370
		[redacted]	[redacted] KS	1,050	1,050	1,050
		[redacted]	[redacted] OK (1)	180	180	180
		Total BLM System		**4,620**	**3,459**	**2,214**
		Non-BLM System				
		[redacted]	[redacted] WY	1,700	1,700	1,700
		[redacted] (2)	[redacted] UT	140	140	140
		[redacted] (2)	[redacted] CO (3)	450	450	450
		[redacted] (2)	[redacted] NM	50	50	50
		[redacted]	[redacted] KS	20	62	62
		[redacted]	[redacted] ([redacted])		200	400
		[redacted]	[redacted] CO			240
		Total Non-BLM System		**2,360**	**2,602**	**3,042**
	Total US			**6,980**	**6,061**	**5,256**
Total Americas				**6,980**	**6,061**	**5,256**
Europe						
	Algeria	[redacted]	[redacted]	650	650	650
		[redacted]	[redacted]	600	600	600
	Total Algeria			1,250	1,250	1,250
	Poland	[redacted]	[redacted]	125	125	125
	Russia	[redacted]	[redacted]	250	250	250
Total Europe				**1,625**	**1,625**	**1,625**
MidEast	**Qatar**	[redacted]/[redacted]	[redacted]	600	1,900	1,900
Asia	**Australia**	[redacted]	[redacted], AU	200	200	200
	Russia	[redacted]	[redacted], RU			2,100
	Total Asia			200	200	2,300
Total Non-US				**2,425**	**3,725**	**5,825**
Total Worldwide				**9,405**	**9,786**	**11,081**

(1) Crude helium sold to [redacted]

(2) Depleteing resources with Tube Trailer Crude helium brought in through 2020 to maintain supply

(3) Refined helium sold to [redacted] and [redacted]

Figure 3.5.C provides the current and forecast Effective Production Capacity (EPC) of refined helium based on figures 3.2.D, 3.2.E, and 3.2.F. Worldwide EPC is expected to expand from 6.5 Bcf/year (174 mcm/year) in 2012 to a maximum of 8.6 Bcf/year (240 mcm/year) in 2020.

Figure 3.5.C Worldwide Effective Refined Helium Production Capacity 2012 – 2020

				EPC (mmcf)		
Region	**Country**	**Owner/Operator**	**Location**	**2012**	**2015**	**2020**
Americas	**US**	**BLM System**				
		[redacted]	[redacted], TX; [redacted] KS	1,150	850	472
		[redacted]	[redacted], KS; [redacted] KS	1,205	890	495
		[redacted]	[redacted], KS	900	665	370
		[redacted]	[redacted], OK	172	127	71
		Total BLM System (6/13)		3,427	2,532	1,408
		BLM System Reduction		-	(191)	(9)
		Adjusted Total BLM System		3,427	2,341	1,399
		Non-BLM System				
		[redacted]	[redacted], WY	1,400	1,400	1,400
		[redacted]	[redacted], UT	23	23	23
		[redacted]	[redacted], CO	44	44	44
		[redacted]	[redacted], NM	24	24	24
		[redacted]	[redacted], KS	9	34	34
		[redacted]	[redacted] ([redacted]		186	372
		[redacted]	[redacted], CO			223
		Total Non-BLM System		1,500	1,711	2,120
	Total US			**4,927**	**4,052**	**3,519**
Total Americas				**4,927**	**4,052**	**3,519**
Europe						
	Algeria	[redacted]	[redacted]	350	350	580
		[redacted]	[redacted]	175	540	540
	Total Algeria			525	890	1,120
	Poland	[redacted]	[redacted]	113	113	78
	Russia	[redacted]	[redacted]	180	180	138
Total Europe				**818**	**1,183**	**1,336**
MidEast	**Qatar**	[redacted]	[redacted]	552	1,722	1,722
Asia	**Australia**	[redacted]	[redacted], AU	170	170	170
	Russia	[redacted]	[redacted], RU			1,890
	Total Asia			170	170	2,060
Total Non-US				**1,540**	**3,075**	**5,118**
Total Worldwide				**6,467**	**7,127**	**8,637**

3.5.3 Forecast of Worldwide Deliverable Production Volumes by Plant from 2012 to 2020

Figure 3.5.D provides the current and forecast Maximum Deliverable Production (MDP) of refined helium based on figures 3.5.B and 3.5.C, and adding the NPCs based on the on-stream schedule outlined in figure 3.5.A. MDP is an important metric because it is how JRCI defines supply (see section 3.2.3 for a complete definition.) Worldwide MDP is expected to expand from 6.2 Bcf/year (172 mcm/year) in 2012 to a maximum of 8.2 Bcf/year (228 mcm/year) in 2020, dropping off thereafter due to the expected loss of the U.S. BLM Cliffside Reserve and declining reserves in the Hugoton Field and Eastern Europe.

Figure 3.5.D Worldwide Maximum Deliverable Refined Helium Production 2012 – 2020

				MDP (mmcf)		
Region	**Country**	**Owner/Operator**	**Location**	**2012**	**2015**	**2020**
Americas	**US**	**BLM System**				
		[redacted]	[redacted], TX; [redacted], KS	1,229	908	505
		[redacted]	[redacted], KS[redacted], KS	1,161	858	477
		[redacted]	[redacted], KS	854	631	351
		[redacted]	[redacted], OK	171	126	70
		Total BLM System (6/13)		3,415	2,523	1,403
		BLM System Reduction		-	(190)	(7)
		Adjusted Total BLM System		3,415	2,333	1,396
		Non-BLM System				
		[redacted]	[redacted], WY	1,287	1,358	1,358
		[redacted]	[redacted], UT	22	22	22
		[redacted]	[redacted], CO	43	43	43
		[redacted]	[redacted], NM	23	23	23
		[redacted]	[redacted] KS	9	33	33
		[redacted]	[redacted])		180	361
		[redacted]	[redacted] CO			217
		Total Non-BLM System		1,384	1,659	2,057
	Total US			**4,799**	**3,992**	**3,453**
Total Americas				**4,799**	**3,992**	**3,453**
Europe						
	Algeria	[redacted]	[redacted]	317	317	553
		[redacted]	[redacted]	167	514	514
	Total Algeria			484	831	1,067
	Poland	[redacted]	[redacted]	107	107	75
	Russia	[redacted]	[redacted]	162	162	135
Total Europe				**753**	**1,100**	**1,277**
MidEast	**Qatar**	[redacted]	[redacted]	517	1,574	1,574
Asia	**Australia**	[redacted]	[redacted], AU	120	160	160
	Russia	[redacted]	[redacted], RU			1,767
	Total Asia			120	160	1,927
Total Non-US				**1,390**	**2,834**	**4,778**
Total Worldwide				**6,189**	**6,826**	**8,231**

3.5.4 Forecast Worldwide Helium Demand

3.5.4.1 Worldwide Helium Demand Forecast by Region

Figure 3.5.E provides the detailed growth in helium demand for 2012, 2015, and 2020 by important worldwide region and sub-region. JRCI forecasts that worldwide demand volume will grow at 2.6 percent per year from 2012 to 2020, or from 6.2 Bcf to 7.6 Bcf/year (210 mcm/year). In 2020, the U.S. will comprise 29 percent of global demand, or 2.2 Bcf (60 mcm/year), down from 32 percent of global demand in 2012. JRCI believes this is consistent with the result of constrained demand driving growth in helium recycle/recovery and substitution. The important assumptions and modeling behind this forecast include:

- that crude helium will increase as an attractive co-product natural gas processing where helium is a part of the input process gas, and that projects with helium potential will be part of the initial planning so as not to lose time in project development;
- that the current industrial player mix will broaden to engage more management and innovation in the production and distribution of helium in its current complex distribution systems;
- that ISO container and other important helium distribution design/build capacity will increase to handle the forecast increases in that equipment utilization, and the replacement of obsolete equipment;
- that crude helium primary distribution pricing models will maintain the delicate balance between supply and demand so that large unwarranted price increase snuff demand, and that price are held high enough to stimulate added and larger capital investments.

Figure 3.5.E Worldwide Helium Demand by Region by Sub-Region - 2012 to 2020

DEMAND SUMMARY (mmcf)					**%AGR**
Americas		**2012**	**2015**	**2020**	**'12-'20**
US		2,002	2,063	2,168	1.0%
Canada/Mexico		393	404	469	2.2%
Total NoAM		2,395	2,467	2,637	1.2%
SoAm		228	246	292	3.1%
	Total Americas	**2,623**	**2,713**	**2,929**	**1.4%**
Europe					
Eeuro		124	136	158	3.0%
Weuro		1,226	1,263	1,395	1.6%
	Total Europe	**1,350**	**1,399**	**1,552**	**1.8%**
Afr/MidEr/Ind					
Afr/MidE		202	217	246	2.5%
Ind		144	162	201	4.3%
	Total Afr/Ind/MidE	**346**	**379**	**447**	**3.3%**
Asia					
NoPacRim		1,609	1,813	2,302	4.6%
SoPacRim		260	291	353	3.9%
	Total Asia	**1,869**	**2,104**	**2,655**	**4.5%**
TOTAL WW DEMAND		**6,188**	**6,594**	**7,583**	**2.6%**

Regarding the older developed economies of the U.S., Europe, and Japan, JRCI is showing either flat (U.S.) or slow growth (Europe) until at least 2020. JRCI commented on the dynamics of this flat/slow growth earlier, with the observations on the dynamics of helium use. While our comments are directly related to our many years of U.S. helium use and applications, they are similar in Europe and Japan.

3.5.4.2 Worldwide Demand Forecasts and Constrained Supply

There have been demonstrated effects on demand from price actions in market application and for product use during the recent past. Market demand has also seen significant impact of constrained supply, the impact on price, and the effect on demand from substitutes and recovery/recycle of spent helium. JRCI believes (and this belief is shared by many close observers of helium supply-demand) these impacts are actually accelerating to the point where there will not be the significant growth in annual helium demand that was experienced in the period from 1970 to 2010. JRCI analysis demonstrates that the aggregate effect of a major conservation of helium effort between now and 2020 could be depressing demand by at much as 0.4%/year with substitution and recovery/recycle of helium. That would suggest that demand will have been depressed from 2012 to 2020 by about 470 - 500 mmcf (13 – 14 mcm), the equivalent of adding almost another Qatar #1 helium plant EPC to the world's supply system. So while the %AGR growth rates may be small compared with the extraordinary growth rates in helium use during the past 50 years, higher growth rates in demand than forecast (which may happen) will frankly be a big challenge to supply. This is particularly true when considering that:

- helium is a by-product of energy supply which has its own economics and priorities, and that it's a perishable product with virtually no significant, readily available inventory, in-the-ground or at-the-spigot;
- helium's markets are far from its sources, in fact shiploads away;
- that helium is very capital intensive and expensive to transport;
- there does not appear to be a new significant use of helium perceived, even over the horizon that would dramatically affect the demand growth rate forecast.

On the other hand, it is possible that demand growth could become lower to flat if developments in superconductivity were to yield HiTC superconductive electrical systems whose refrigeration requirements could be supported at liquid nitrogen temperatures. That could potentially wipe out a big part of existing and planned use of LHe.

3.5.5 Forecast Demand/Supply Balance of Worldwide Helium Volumes from 2012 to 2020

Figure 3.5.F shows the worldwide demand against existing and forecast Maximum Deliverable Production supply of helium from 2012 through 2020 as developed and presented in the table, figure 3.5.E. This figure shows our base worldwide demand supply forecast and represents a 2.6% AGR in worldwide demand from 2012 to 2020. The rationale behind demand was covered in the earlier part of this section.

Worldwide Helium Supply Surplus/Deficit

Figure 3.5.F shows the forecast demand and supply (based on forecast MDP) appears extremely tight until well after 2018, with demand in a deficit position in 2016 and 2017. By 2020, the U.S.

BLM system will most likely only contain crude helium available to In-kind U.S. federal buyers with the private sector refining plants located on the pipeline unable to purchase crude for sale to the private sector users. This scenario also assumes that there will be no new crude within pipeline proximity that could replenish the Federal Helium reservoir. Therefore, the natural demand would be constrained by lack of supply, slowing the long term growth of helium demand unless new sources of helium were developed.

Figure 3.5.F Worldwide Helium Demand/Supply Balance

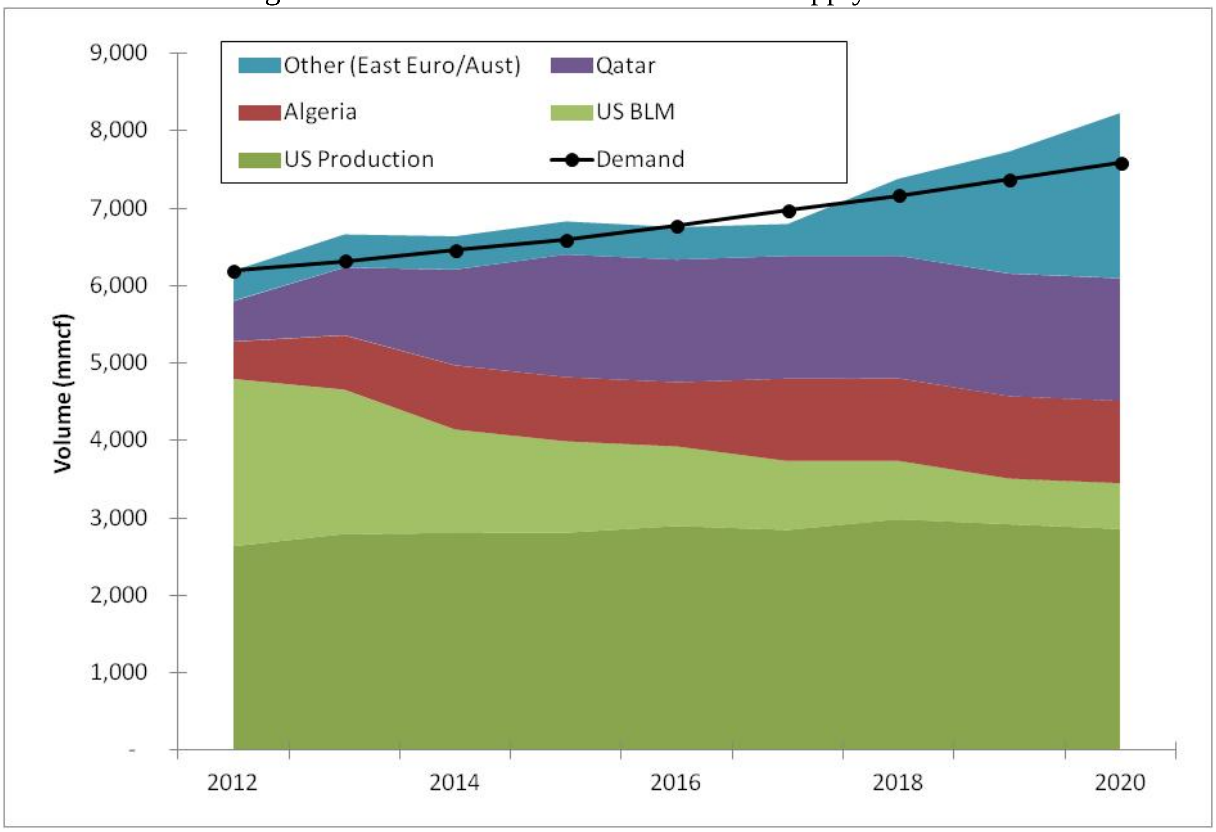


Figure 3.5.F also shows the significant decline of the U.S. position in worldwide refined helium capacity resulting from the lack of adequate crude capacity replacement for BLM's depleting crude reserve. The major offset to that depletion is forecast to come from offshore with marginal increases from Algeria and Qatar, and significant increases of helium capacity from Russia's Eastern Siberian natural gas, LNG, and helium projects. This offshore increase in capacity should supply the increase in Asian demand by 2020. Of concern to U.S. strategic technology interests will likely be this shift in helium capacity from the U.S. and its safe supply to those technology developments, to distant parts of the world with risky capacities and long supply chains.

Figure 3.5.G shows more clearly the marginal difference between forecast supply and demand, particularly in 2016 and 2017, with no spare capacity/production in the face of significant forecast declining crude supply from BLM.

Figure 3.5.G Worldwide Helium Demand, Supply, and Surplus/(Deficit)

Figure 3.5.H provides more specific volume data behind the above graphs. In Asia, helium shortages could affect those economies significantly where relatively fast growing natural helium demand results from higher rates of technology development and growth in per capita income.

Figure 3.5.H Worldwide Helium Surplus/Deficit – 2014 to 2020

WW Helium Estimates (mmcf)	2014	2015	2016	2017	2018	2019	2020
Demand	6,455	6,594	6,778	6,969	7,166	7,371	7,583
MDP	6,633	6,827	6,753	6,793	7,378	7,732	8,229
Surplus/(Deficit)	178	232	(26)	(175)	212	361	646
Surplus/(Deficit) % Demand	2.8%	3.5%	-0.4%	-2.5%	3.0%	4.9%	8.5%

An important conclusion is drawn from the surplus/deficit analysis is the forecast surpluses do not cover short and intermediate term crude and refined helium operating difficulties or the likely delays in bringing on new crude capacity to feed to refining capacity worldwide. While not much can be done about this in the short term, the U.S. and international private sector helium industry must begin to build into their capacity and investment planning the facility to have online, or in standby, more "spinning reserve" helium. This reserve will become much more important as the BLM crude reserve continues to deplete and is eventually not available for private sector use.