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Helium – Macro View

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Fragility of supply/demand picture to continue

Elemental analysis

Oil & gas/Industrials

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After three years of oversupply, 2017 has seen a notable tightening in the helium market caused by plant outages and the Qatari blockade, triggering price increases from major industrial companies. Despite an opaque picture making forecasting difficult, we believe the balance is weighted towards a tightening market, as little new supply will come online to offset declines elsewhere, in spite of large additions from mega projects in Qatar and Russia planned from 2020 onwards. Assumed annual demand growth of 1.5% will continue to put pressure on the supply/demand balance in the longer term and should support prices, motivating further development and helium exploration. If the mega projects are delayed (very possible), the picture could deteriorate further, pushing the market into substantial deficit.

Supply constrained, deficits likely

Helium is a vital and irreplaceable element in many critical modern components industries.The era of supply being underwritten by the drawdown of US strategic reserves is nearly over, and replacing the supply is not straightforward. New (medium-term) supply is largely as a by-product of planned oil and gas mega projects that are open to delays. While a number of companies have appeared in recent years (mostly in the Western US and Canada) almost all are at the pre-drill stage or focused on projects with limited potential. Many have announced grand plans, but few have progressed to proving up gas resources, which will take time.

Opaque & oligopolistic supply impedes easy analysis

Five major fields/facilities (BLM storage, LaBarge, Hugoton, Algeria and Qatar) supply around 80% of global upstream helium. A similar number of large players control the distribution, which is often executed on privately negotiated contracts. Data on current supply/demand/prices are therefore not widely disclosed and create uncertainty around exact estimates. However, our analysis of project developments suggests a lack of new supply to satisfy increasing (price-inelastic) demand. We think news from large market participants lends some credibility to our conclusions (eg Air Products contracted to buy over 75% of the 2018 volumes in the July 2017 auction and Praxair has reportedly increased its prices from 2018).

Demand steady, prices should be supported

We have little information on demand, but see a continued increase backstopped by helium's lack of substitutes in its main markets of MRIs, high-end science/ engineering, pressure/purge applications and semiconductors. We can try to infer the balance of the market from price reports. A well documented shortage in 2011-13 forced price spikes. New supply (based on LNG plant start-ups) then came online and prices returned to more normal levels. However, we believe the supply-constrained picture we see in the near to medium term should see continued support for pricing and may see marked increases. Our analysis indicates an increasing shortage in the market in 2018-21 and possibly beyond, especially if the mega projects at Qatar and particularly Russia (Amur) are delayed, which we think is very likely given delays seen in similar-sized projects historically.

Report summary

Helium is a vital element in the manufacture of MRIs, semiconductors as well as being critical for space exploration, rocketry and high-level science. We examine the supply/demand picture for helium, examining key supply sources in the US and globally. We also summarise the reserve situation for helium and look for pricing guidance.

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This report has been commissioned by North American Helium as a third-party review of global helium supply and demand

Summary

In this report, we detail our views on **supply and demand** for helium over the next 10 years, examining major sources in the US and globally. Few projects will come online in the next three to four years, putting increased stress on the market as the sale of stocks held in the US strategic reserve finally ends (held in the Cliffside field, operated by the Bureau of Land Management, BLM). We review the key sources of current and future supply to examine critical components.

Helium supply is structurally fragile, as an outage of one (of the limited number of) supplier could have outsized effects. The impact of the Qatar blockade seems to have been contained as a new route was found quickly, but the underlying tensions in the region remain. Other majors sources (such as Hugoton or the BLM storage) are now at/towards the end of their lives and it is not clear how the reservoirs will react to increasingly low pressures. It is possible that the fields will decline far faster than we model and that the reserves estimates will not be recovered fully.

Algeria supplies over 10% of the market, but supplies of helium are dependent on the volumes of LNG produced, which are of secondary importance to piped gas to Europe. The gas explosion in Austria in mid-December 2017 (causing Italy to issue a state of emergency) could easily mean that Algeria increases its piped gas to the detriment of LNG (and therefore helium) supplies.

All fields/plants will need to go down for periodic maintenance. As the information is not publicly disclosed, it is possible that one of the large suppliers may reduce volumes markedly in coming periods, which could affect the market.

There are few ways in which this picture could improve; there is little potential for existing projects to expand materially and although a number of small helium exploration companies have announced grands plans, few have proven reserves of the size that would materially move the needle in the event of delays from Qatar and Russia.

We then summarise the **reserves** picture. While it is estimated that there is plenty of helium in the world, the accessibility and commerciality of these reserves are more complex. Reserve replacement of helium has been very poor and hampered by a number of factors:

- Helium is scarce and generally found within conventional natural gas reservoirs in small concentrations (<0.5%), making helium a valuable by-product as long as the gas is profitable to extract. In the past, this has meant that upstream companies had no strong incentive to negotiate high prices for helium, while in recent years depressed gas prices (particularly in the US) have discouraged development of conventional natural gas fields.
- Prices of helium have arguably been kept artificially low by the large-scale, well-publicised sell-off of the US strategic reserve to a limited number of buyers that gave mid/downstream companies a reliable supply over the last 10 years.
- Helium has traditionally been traded on confidential long-term private contracts, keeping pricing opaque and reducing incentives for helium exploration.
- Due to its properties, helium cannot be stored/produced from shale. Helium therefore has to be sourced from conventional natural gas reservoirs, which currently hinder its economics. Helium associated with CO_2 will also suffer from currently low oil prices.

Finally, in light of these factors, we look to examine the **price history** and see if comparison to oil prices over time may be useful. In our view, helium will likely be subject to steady, price inelastic demand growth. Hampered investment in supply led to a shortage of supply in 2011-13. In the resulting price rise, many industries sought to replace (or recycle) helium, where possible. However, its unique properties (lowest boiling point, small atomic size and weight, unreactive nature, high thermal conductivity) mean that it is irreplaceable in many applications. The demand destruction

seen in the industry in the spike of 2011-13 may have left the rump of demand more inelastic to price movements. Indeed, despite the current looser supply/demand dynamics, pricing has not retreated and BLM auction prices rose around 10% in July 2017 (vs previous year).

Appendices include a history of the BLM and some notes on the Helium Extraction Act 2017.

Fragility of supply/demand picture to continue

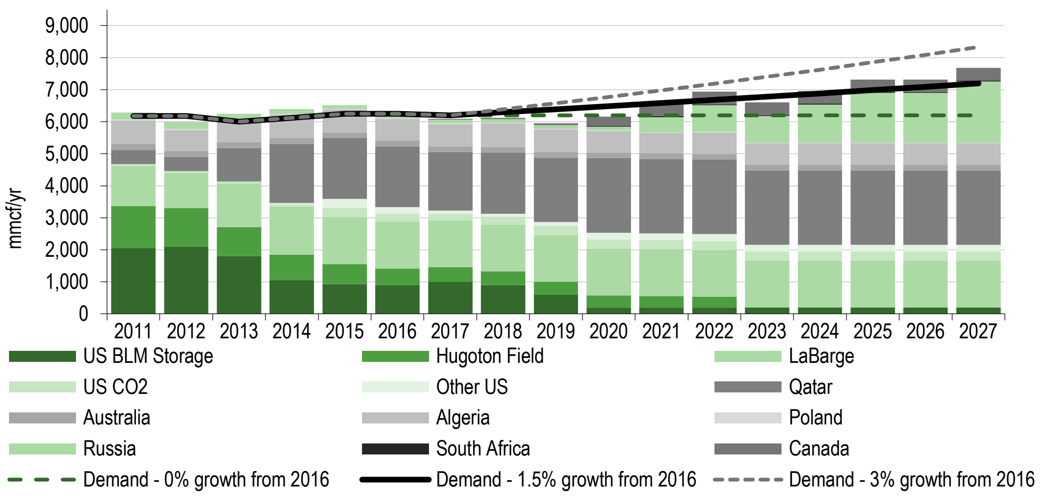
The helium industy is an opaque one, with oligopolies of large companies and nations controlling upstream and downstream supply. There are no independent authorities that accurately trace supply and demand as seen in other industries (eg the IEA, in the case of oil). The vast bulk of production is not disclosed publicly, either because the players are so big that helium production is not relevant to investors (ExxonMobil's LaBarge facility, or Linde/Air Products businesses) or because entities are not listed (for example, the Qatari/Algerian LNG production). As a result, there is no clear picture of supply or demand. Additionally, estimates on key variables such as helium concentration, productive capacity or timelines for expansion often vary between two forecasters for the same facility. Outages in productive capacity are rarely reported widely or on a timely basis, while many future projects will likely be dependent on the level of natural gas prices to be sanctioned or expanded.

We do know that supplies from major sources (Hugoton and the BLM storage facility) are definitely declining. New sources of supply are limited and will not offset these falls, meaning near-term supply will certainly decrease, and the only projects that could reverse this picture are mega projects (Qatar III and Amur in Russia), which are liable to delays. Our study of other large oil and gas developments worldwide shows material delays are commonplace, so the 2021 start-up of Amur may be at risk, we think. If this is delayed it will have a significant effect on the helium market.

The demand side is equally difficult to pin down accurately, but there have been no reports of sharply increasing prices of the type seen in 2012 (despite the Qatari blockade in mid-2017), suggesting the market was broadly in balance in 2017.

In the longer term, major additions such as Helium III (Qatar, 2020) and Amur (Russia, 2021) will create material new helium sources, but the next few years are likely to bring little new incremental supply to cover reducing supply from existing sources and any demand increases (which we assume will be 1.5% pa, in line with historical increases). There is, therefore, potential for a deficit before then, which would be exacerbated by any downtime (such as further issues with Qatar or unexpected downtime in other major producers).

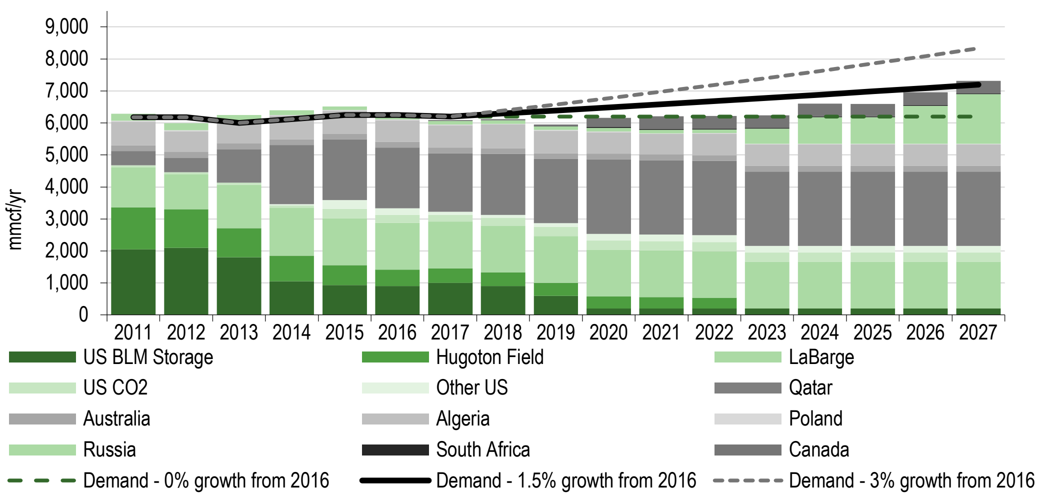
Exhibit 1: Estimated global supply/demand forecast, mmcf/year



Source: JR Campbell & Associates report for BLM Office of Minerals Evaluation, public and private company data, Edison Investment Research, various

Our base case sees a deficit building from 2017 onwards, only (partially) offset by increased production from Qatar's Helium III in 2020, but more importantly the volumes coming from Amur Gas development in 2021/2022 onwards. While we currently model Amur's volumes coming online in mid-2021 (as currently forecast by GazProm), the effect of possible delays would be very material on the supply demand balance. For example, if we were to delay the Amur volumes by 24 months (industry studies show an average delay on projects of 20months), the picture become one of severe deficit out to 2027, as seen below. Indeed, under this scenario, the market would only be in balance with no demand growth whatsoever, which we see as very unlikely.

Exhibit 2: Estimated global supply/demand forecast under a delayed Amur scenario (24months), mmcf/year



Source: Source: JR Campbell & Associates report for BLM Office of Minerals Evaluation, public and private company data and Edison Investment Research, various

If readers were to assume a 3% demand growth, deficits would grow even if Amur and Qatar came online as currently expected, while any delays would leave the deficit at around 1bcf/yr by 2027.

We have seen some action from some market participants that may indicate their preparation for shortages to cover possible market gaps (for example, Air Products bought 75% of the recent BLM auction for 2018 volumes). The market remains very susceptible to supply disruption.

Key supply sources/projects

Our analysis of major production facilities globally indicates little new (guaranteed) supply will come online in coming years (DBK, Tenawa), with incremental supply primarily going towards offsetting declines eslewhere (BLM, Hugoton). We review the major sources below.

United States

The US has been the key source for helium for decades. However, the depletion of the strategic reserve (and other major fields), together with the new supply from Qatar has lessened its role.

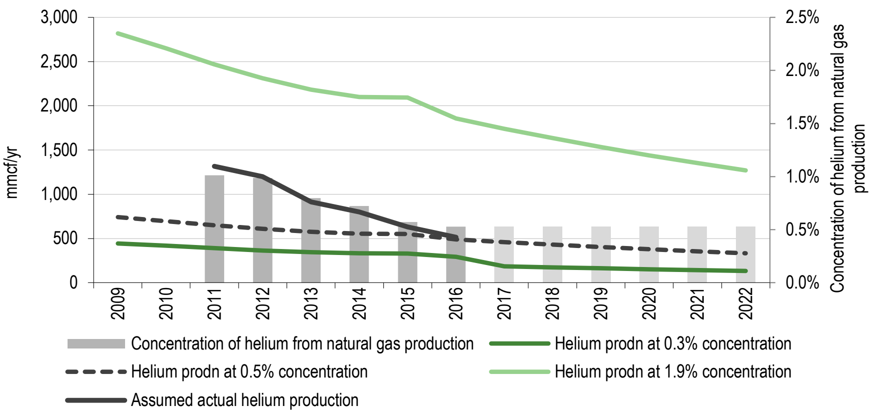
BLM – the strategic reserve will be fully depleted by 2021 (except for 3bcf of strategic reserve, which is to be used only when critical, and some privately held reserves). After auctions in July 2017 (and the conservation sales), production in 2018 will be around 900mcf/yr, leaving only around 400mmcf/yr to be sold in 2019,[1] to keep within the federally mandated 3bcf limit of strategic reserves. As of October 2017, reserves of helium in the system were 3.475bcf (government) and 3.642bcf (private). After this limit is reached, only the private storage will be released. As a result, we assume 200mmcf/yr will be released each year from private sources.

Hugoton field – the Hugoton field is one of the largest gas fields in the US. It has produced nearly 27tcf of natural gas to date and has a high helium concentration (0.3-1.9%). As such, it has been a substantial contributor of helium supply in the US for many years. Reports suggest there may be another 3-4tcf of natural gas left to be produced.

Hugoton produced 97bcf of natural gas in 2016 and has declined at a five- to 10-year CAGR of around 6-7%. We assume the entire field continues to decline at this rate. Using the field production data (from Kansas) and applying the ranges of helium content suggests helium production consistent with concentrations of around 0.5%. The data certainly suggest that the 1.9% upper end of the range is not a relevant figure to use (although it may have been in parts of the field some time ago).

Actual helium output from Hugoton is not available, but we have used the estimates of historical data from JR Campbell and Associates from 2011-15, which imply helium concentrations of production fell from 1% in 2011 to around 0.5% in 2015. If true, this is a concern and suggests that our base assumption of a 6.1% decline in helium production (in line with field declines) will be too optimistic. If the trend of falling helium concentration continues, it may be uneconomic to continue to produce helium at Hugoton in the medium term.

Exhibit 3: Possible Hugoton helium production, mmcf/yr



Source: Kansas Geolgical Survey, Edison Investment Research. Note: We use the 0.5% helium concentration as a forecast guide for 2017 onwards.

1 www.gasworld.com/blm-completes-fy-2018-crude-helium-auction/2013150.article

LaBarge field – LaBarge is a large natural gas field in Wyoming with high concentrations of CO_2 and a relatively high concentration of helium (0.6%). The field economics rely on the efficacy of the CO_2 in enhancing oil production in surrounding oil fields as LaBarge is only 21% methane (the lowest methane content of any gas field globally)[2] and is 65% CO_2 (as well as 5% hydrogen sulphide and 0.6-0.7% helium).

The Shute Creek facility separates out the gases, reinjecting the hydrogen sulphide (and some CO_2) into the reservoir, liquefying the helium and piping the rest of the CO_2 to surrounding fields in Wyoming and Colorado. The facility has a helium production capacity of 4mmcf/d, or 1.46bcf/yr, making it a substantial contributor to global demand (around 23%).

According to Exxon, all the gas was contracted for sale since the start of operations in 1986, but long-term sales averaged only half-capacity for much of this time, as the CO_2 enhanced recovery market did not develop as fast as anticipated, partially as a result of the distance to the fields. Higher oil prices from the 2000s onwards made project economics more attractive. We assume that the facility continues to produce at its capacity over the forecast period (of 4mmcf/yr or 1.46bcf/yr).

Big Piney, US (Matheson & Air Products) – Big Piney was designed to extract helium from sour gas at rates of 200mmcf/yr, expanding to 400mmcf/yr. The helium-rich natural gas and CO_2 feed gas was due to come from the LaBarge field via Denbuy's Riley Ridge processing plant, Wyoming. Denbury's interest in gas was 1.2tcf of CO_2 with 0.6% helium. Indeed, Gage and Driskill (1998) estimated helium resources of 47bcf, and peak production from the LaBarge field as a whole was envisaged at 1.4bcf/yr. However, design issues meant there were delays to the start-up (in late 2013) and the plant was shut-in in 2014 after additional issues (caused by sulphur build-up in gas supply wells) hampered production. The plant remains shut in and was fully written off by Denbury in its 2016 annual report. We therefore do not expect any helium from this plant.

Doe Canyon, US (**Air Products**) – a helium separation plant from CO_2 feed was proposed to start in 2015 with a capacity of 400mmcf/yr, but we understand this was quickly reduced to 230mmcf/yr after start-up and that production has declined to 140mmcf/yr currently, due to lack of demand for the CO_2 feed gas. We model that the plant continues to produce at this rate during the forecast period, although sharp increases in oil prices could motivate greater CO_2 and therefore helium (we do not forecast this).

DBK expansion (IACX) – NASCO, a German-listed player, is planning to expand its DBK facility in Arizona. We model production increases from 70mcf/yr in 2013 to around 150mmcf/yr in 2019.

Other – Industry sources indicate that new supply from an existing cryogenic plant in the mid-continent US is possible over the next few years. Very little has been made public at this stage, but we have modelled supply of 100-150mmcf/yr starting in late 2019/early 2020.

Miscellaneous – we do not have access to the production data of the other production facilities in the US, so we assume that together they contribute around 100mmcf/yr in 2017, declining slowly over the forecast period. These include projects by IACX (and partners) targeting helium depleted fields and lower pressure extraction techniques. We do not see a material future contribution from such projects.

Worldwide projects

Qatar – the start of the Helium I and II projects had a major impact on helium supply and contributed to a surplus in 2014-16 after the shortage of 2012. The USGS estimates that Qatar produced 1.8bcf of helium in 2016, up from 468mmcf in 2012. In theory, the helium produced

2 CO_2 Management at ExxonMobil's LaBarge Field, Wyoming, USA. P E Michael E Parker et al, *Energy Procedia* 4 (2011)

should continue at the peak plateau rates (of around 2bcf/yr) as the production is dependent on plateauing LNG production.

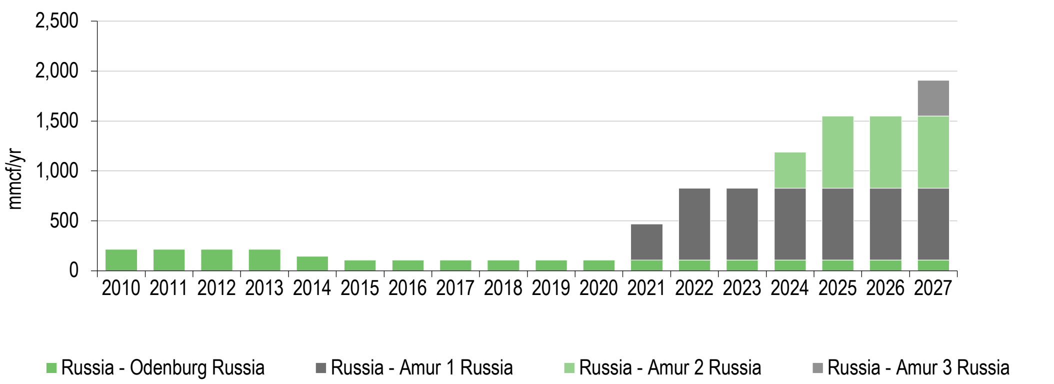
Despite the large volumes produced, estimates are difficult as no public information is available. Indeed, in 2017 the USGS revised its 2015 production estimate from 40m cubic metres (given in 2016) to 49m cubic metres. Estimates of 2017 production are made more difficult by the recent blockade.

The Helium III development, located in the Barzan facility, was planned to come online in 2018, adding a further 425mmcf/yr. However, issues in the upstream mean that this may be delayed. Such issues are often complex to fix and take some time (especially given the size of the development). We therefore assume production comes online in Q419.

Qatar supplies c 25% of global demand and helium was exported from the UAE (via Saudi Arabia), but this route was blocked in mid-2017. Helium production was suspended in June 2017 but restarted in July after a new route was organised.

Russia is currently a small contributor to helium production (the USGS estimates production of just under 110mmcf/yr in 2016) and has seen production decline steeply in recent years, as seen below. With no further information, we assume Odenburg continues to produce at this rate, although this could be optimistic.

Exhibit 4: Russian helium production



Source: USGS, Edison Investment Research. Note: 2017 onwards are Edison estimates.

However, the massive Amur gas development has the potential to help Russia rival Qatar as the largest helium producer in the world by 2030. Planned to produce 42bcm of natural gas per year (contributing to a 30bcm pa export of gas to China over 30 years), the staged development could produce as much as 60m cubic metres of helium per year (2.2bcf/yr) – equating to 0.15% helium concentration.

Data on the development is not easily found, but we assume helium plants come online in the middle of 2021, 2024 and 2027, each of 720mmcf/yr. We would caution that as massive, complex projects, it is entirely possible that the developments see delays – albeit that intense pressure will be on managers to hit the targets given the strategic importance of the project to Russia and China of such massive volumes of natural gas. The Amur complex will be one of the largest gas/chemicals plants in the world. We also do not know how the constructrion of the plant will be affected by western sanctions or exactly how it will be funded (we understand China has yet to provide some of the substantial loans required to build the complex). The gas plant alone is currently scheduled to cost €11.5bn.

Studies of projects by industry observers found that (i) 78% of upstream mega projects faced either cost overruns or delays;[3] (ii) 73% of projects are delayed[4] – indeed of the 20 largest projects examined by an Ernst & Young study, only seven were on budget;[5] (iii) large oil & gas, mining and infrastructure projects run on average 20 months late and cost 80% more than budgeted; and (iv) the Oil and Gas Authority (in the UK) stated that fewer than 25% of new projects were delivered on time over the last five years.[6]

The impact of any delays would be very material for helium balance, as we described earlier in this report.

Algeria supplies helium when gas from its massive Hassi R'Mel field is exported via LNG. While the helium concentration is low (0.17%), the field accounts for c 60% of Algerian gas exports so economic extraction is possible (no other fields have commercial helium extraction). Historically, estimates have put helium production at around 900mmcf/yr, but we believe recently production has been lower.

We believe Algeria prioritises its pipeline gas exports to Europe, with LNG a less critical component. LNG volumes can therefore suffer if demand in Europe increases or gas supply in the country is not as high as hoped.

As the crown jewel of the Algerian gas industry, the Hassi R'Mel field has taken the brunt of delays or under-production of other fields (In Amenas, Ohanet and Reganne to take just three examples) meaning that it has been used to fill-in these production gaps. The consequence is a reduction in the recycling of some gas (reinjecting dry gas and stripping the liquids for sale, keeping pressure up for longer-term reservoir management), inability to mitigate possible water production and fall in capacity.

This is bad for helium markets as it possibly reduces ultimate recoverable helium in the long term but also means that this in-filling of near-term gas production goes through the pipeline to Europe, bypassing the LNG system and helium extraction. We do not know the statistics for production of helium from Algeria directly, but instead we look to the BP Energy Review to see how LNG exports have progressed, using rules of thumb to derive production volumes since 2010. This indicates lower production from LNG (and consequently helium over 2010-16). Our calculated volumes (Exhibit 4) are different to some other sources (which put exports at around 900mmcf/yr). This is a major source of uncertainty for our analysis. For modelling purposes, we assume a 5% decline pa in production of helium.

As the source of so much revenue, Algeria has made strides to try to better conserve the field (and capture more gas elsewhere). It is possible that the decline in volumes in LNG may flatten out in the near term. More work is required to maintain long-term volumes.

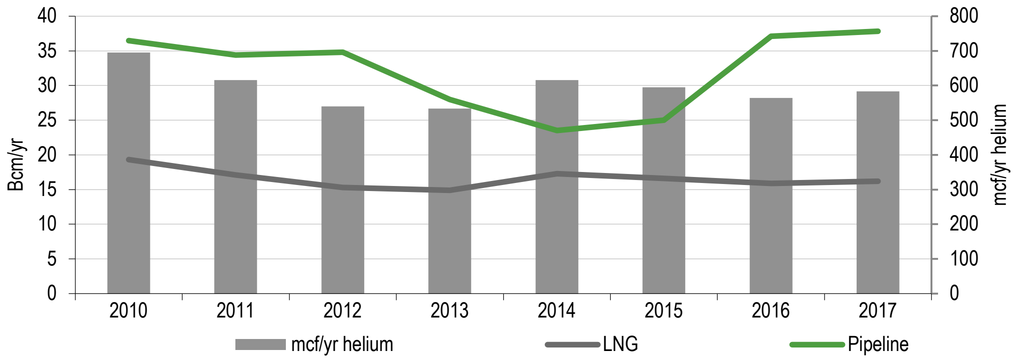
[3] Independent Project Analysis (IPA), 2011

[4] Spotlight on Oil and Gas Megaprojects, Ernst & Young

[5] HIS Global Insight

[6] Lessons Learned from UKCS oil and gas projects 2011-2016, The Oil and Gas Authority

Exhibit 5: Algeria gas volumes by export route

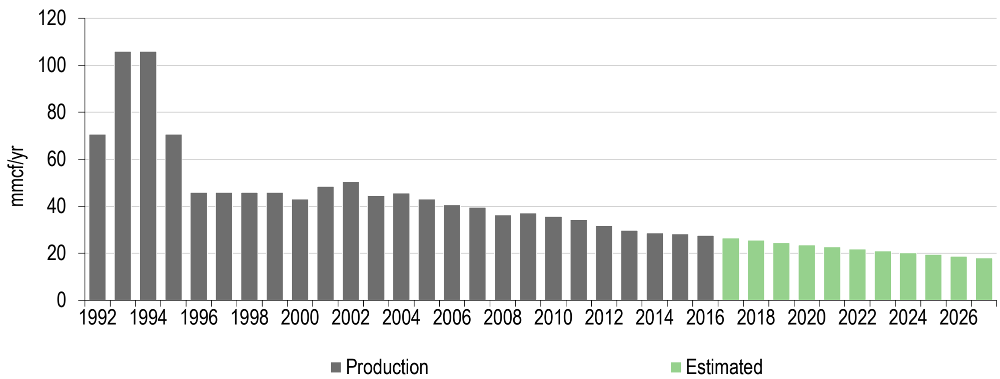


Source: BP, Edison Investment Research, various

Poland is one of the minor players in global helium, but the only European producer. According to the Polish Geological Institute, there are 16 helium fields in the country (situated in the Zielona Góra-Rawicz-Odolanów area) of which 14 are producing. Reserves and production are dominated by two fields that make up almost 60% of production. The reserve life of the complex is over 30 years. For 2016, the combined resources were estimated[7] to be 25.09m cubic metres and production was 0.78m cubic metres.

This is notably different from the USGS estimate of 2m cubic metres. We take the Polish Geological Institute figures, which show an average (10-year) yearly decline of 3.8% and assume production continues to decline at this rate for the foreseeable future.

Exhibit 6: Polish helium production



Source: Polish Geological Institute and Edison Investment Research

Other new (possible) sources

Renergen operates a natural gas field in the Virginia field in Free State in **South Africa**, which has high helium concentrations (of between 2-4%) and 9.2mkg of 2P reserves (corresponding to 1.96bcf). A project to extract the natural gas over a phased development has started, but the helium cannot be extracted until a pipeline network and central processing facility have been completed. The latest (May 2017) estimates for this development put the helium start-up in 2019, although delays are very possible. We currently expect the helium capacity to be around 30mmcf/yr at peak. We note South Africa is extremely short of energy, so there are strong incentives to develop any gas (and associated helium) over time.

Iran – the South Pars field is the same field as Qatar's North Field and therefore could be a massive source of helium as/when it is developed; some estimate it to contain 350bcf of helium.

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7 http://geoportal.pgi.gov.pl/surowce/energetyczne/hel/2016.

Total's deal with Iran (signed in July 2017) for phase 11 of South Pars envisaged 2bcf/d of natural gas. Initial gas flows are believed to start in 2021 (for domestic market); large-scale export volumes by pipeline/LNG may be some time after. The field already has a pipeline network so we would think additional supplies will be exported via this infrastructure, negating the need for LNG facilities (and therefore helium extraction plants). For LNG facilities to be built we would likely need a large increase in LNG pricing, which we think is unlikely in the near term. Given the low concentration of helium (0.05%) it is likely that helium production from South Pars will have to wait many years before sufficiently large LNG facilities are built to allow commercial extraction of helium.

In this vein, on 20 November, the National Iranian Oil Company signed a contract with IFLNG to produce floating liquefied natural gas (FLNG). The press release mentions first LNG could be supplied before the end of 2018. Given the small volumes and the complexity of the FLNG vessel being employed, we think it is extremely unlikely that any helium will come from this LNG supply.

There are a number of projects in **Canada** of differing maturities. Exploration for helium in Canada could be very promising given proven deposits of helium in deeply buried traps, often with little associated CO_2 or other gases (other than nitrogen) making extraction and liquefaction cheaper.

Weil Group is currently producing 35-40mmcf/yr from its Mankota plant, and Medicine Hat has announced plans to commission a facility in 2019 (of unknown helium capacity).

There are a number of players exploring (or planning to explore) for helium in Canada. North American Helium is a private company operating in Southern Canada and has accumulated a large property position (>500,000 acres) within a known helium province. It is seeking to further expand its proven resource base in the Greater Battle Creek. It has so far drilled six wells, finding helium in concentrations of around 1% (within a majority nitrogen reservoir, which makes commercialising cheaper than if it was in a natural gas reservoir). Given the proven helium resources in the location, we include volumes from 2020 onwards at this point.

Royal Helium Corporation is a listed vehicle focused on exploring in Canada. The company holds 399 sections (255,400 acres) of crown helium land; approximately 45% is held as helium leases on 21-year terms with the remainder held as helium exploration permits. Royal's assets are associated with Saskatchewan's highest known helium concentrations. The company believes its targets have concentrations of 1.1-2.8% helium and it was planning on re-entering a well in November 2017 to prove up its G&G analysis.

Thor Resources names five helium projects of varying maturities (from well tested to much earlier stage). The Knappen project is believed to contain over 1bcf of helium (management estimates) and is in development with Weil Group. We have found one source to indicate that this will be commissioned in 2017, so timelines are uncertain at this time.

Tanzania – Helium One is a private company seeking to explore for helium in Tanzania after traces of helium were detected in geothermal springs. According to Helium One's website, Netherland Sewell and Associates has estimated P50 unrisked prospective recoverable helium volume of 98.9bcf, across 28 leads (as seen on 2D seismic).

Until exploration wells are drilled, we remain cautious on the potential for commerciality of the area – many geothermal waters around the world contain helium so this in itself is not a major indicator of commercial traps. Indeed researchers posit that identifying the ratio of isotopes of helium ^{3}He and ^{4}He from many such sites could be an indication for good locations for geothermal energy plants.[8] Historical wells by Amoco detected helium, but reservoir quality still has to be proven. Additionally, the site is remote and the economics of liquefying and exporting the product may be challenging.

8 Flow of Mantle Fluids Through the Ductile Lower Crust: Helium Isotope Trends, B Mack Kennedy, Matthijs van Soest, 2007 (Science)

Global reserves

There is no clear picture of global helium reserves/resources and relatively little written publicly. Many papers and books reference papers that are decades old and there are no global authorities that publicly release data on helium in the same vein as seen in other industries.

In 2013, this uncertainty led US congress to request the USGS to perform a national and global helium gas assessment. Given the scarcity and niche nature of helium, the USGS expects this to take many years. However, the BLM expects to update its view on helium resources in the US in a shorter timeframe. Discussions with the USGS indicate a report may be published by end 2018, but this is uncertain.

Intermediate results (from January 2016) are shown in Exhibit 7. Assuming 7.0bcf/year demand (foreseen in 2019), this would translate to 23 years of proven reserves for the US, moving out to over 200 years including probable reserves in the US and the rest of the world. While this may superficially seem generous, these resources have to be developed, and this is not a given. Development of the helium is hugely dependent on the development of the gases that it exists alongside.

Transparent reporting of reserves and resources is not helped by the tiny concentrations found in many natural gas fields. It exists in such small quantities in many natural gas reservoirs that it is often overlooked given the small volumes/revenues it may represent vs natural gas. Helium has largely been a profitable by-product but not valuable enough to justify standalone developments (nor in the US of a statute to allow federal land lease).

In most fields, large quantities of natural gas (or CO_2) have to be extracted for commercial volumes of helium to be separated, and as a result, the commerciality of a helium project largely rests entirely away from the helium itself. As natural gas prices have declined in recent years (particularly in the US), projects have become less attractive and fewer projects have been sanctioned.

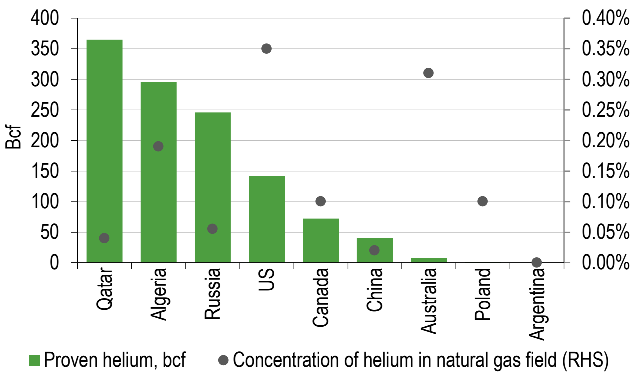
- The current surfeit of LNG supplies (and low prices) has led to postponement of large LNG projects (such as Browse) from which other helium could have been recovered.
- The low oil prices also mean that CO_2 flooding (from which helium can be extracted) has become less economic, reducing the demand for CO_2. A number of projects have been put on hold.
- Shales cannot trap helium, which means that supplies have not benefited from the massive shale boom in the US, and the economics of shale gas production have the potential to price out conventional natural gas development (which may contain helium) in the US in the medium term.

In the US therefore, helium development may have to be driven by helium economics, necessitating higher helium prices to incentivise investment.

Kinder Morgan has a JV with Air Products (announced in 2013, started in October 2015) at Doe Canyon to extract helium from the CO_2 stream going to EOR projects (the plant is designed to produce 230mmcf/year of helium but is probably producing closer to 140mmcf/yr now), while IACX has a number of plants extracting helium from a number of small natural gas fields. Standalone helium separation (of the type that Canadian companies are contemplating for example) requires high helium content to be commercial (which is around 0.5%, but is highly dependent on gas volumes and other gases in the stream).

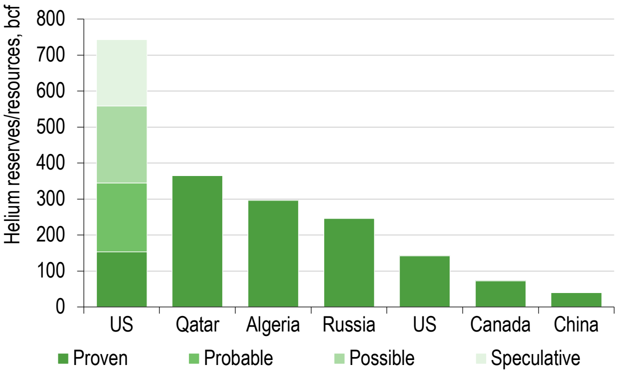
In the rest of the world, helium production comes from large LNG schemes in Qatar and Algeria. A planned development of a massive Russian gas field, Amur (with material associated helium), has a risk of delays, we think.

Exhibit 7: Reserves of helium globally, including from natural gas fields



Source: BLM "BLM – Determination of fair market value pricing of crude Helium." Note: Proven helium reserves are given in bcf. Estimates made in 2013.

Exhibit 8: USGS summary of global helium resources (intermediate findings)



Source: USGS Mineral Commodity Summaries, January 2016. Note: Converted using a 36cf/m ratio.

Pricing context (BLM-era to future)

The US government-mandated sell-off of the helium reserve was designed to recoup the investment (plus interest) on the helium reserve and get the government out of the helium market. Initially the price set on the crude from the reserve was purely to cover the costs of the US$1.33bn debt, and was well above the prevailing crude helium market price at the time, as can be seen in the years 2000-05 (Exhibit 9). Helium was a profitable by-product of natural gas production, and as such prices had little reference point, while its private nature meant price discovery was difficult.

With the advent of the BLM auction process, a partially market-driven price became public and a reference point for private contracts. It is clear that the private spigot prices are materially above the BLM crude pricing, with bulk liquid helium well above this level (not surprisingly given the refining that is required). Unsurprisingly, prices rise the closer you get to the consumer, with HP cylinder prices 2.5x the private spigot (wholesale) price.

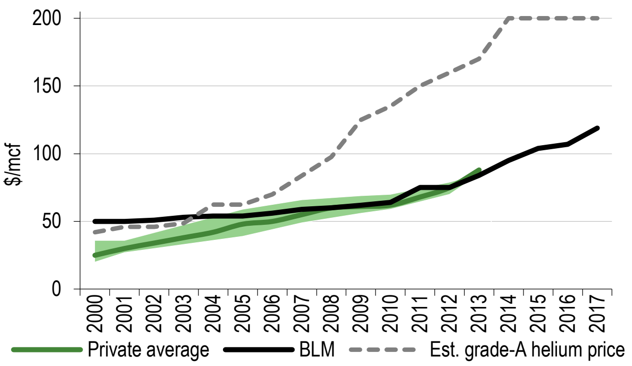
Recent price history

BLM prices are increasingly less informative given that the auctions will shortly end as the reserve is depleted and as helium is actually traded at much high purities. However, for reference, prices for BLM crude have risen substantially, at an average rate of over 6% since 2007 (or over 9% in the last four years).

Cargoes are usually sold at a 99.999% purity or Grade 5, for which we have little pricing information. The lower Grade-A (or 99.99% purity) helium prices are estimated by the BLM to be $200/mcf.

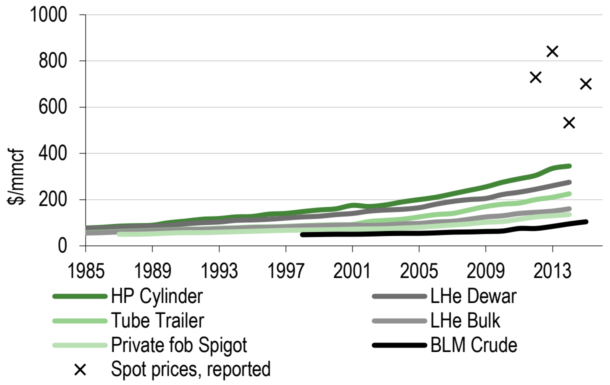
On 15 November 2017, Praxair announced that it will increase the price of helium from 1 January 2018 by 10% (on 1 January 2018, or by contract).

Exhibit 9: Wholesale prices of private crude helium converged towards rising BLM pricing



Source: USGS. Note: All prices are for crude helium The green range is the low to high estimates of private crude helium, and estimates past 2012 are not available

Exhibit 10: Prices for different customers, from wholesale (BLM and private spigot at the bottom) to retail



Source: USGS, "Determination of fair market pricing of crude helium", assorted sources for spot prices

Deriving a possible price trajectory from historical relationships

We could also refer to historical price relationships to give an indication as to how prices may move in future. The charts below show a very strong relationship between US demand and pricing since 2000, though we think it is unlikely that these are causal and therefore indicative, given the long-term offshoring of demand (mostly to Asia). We would also point out that prices (Exhibit 10) indicate that BLM pricing is not necessarily the best indicator of end-user pricing.

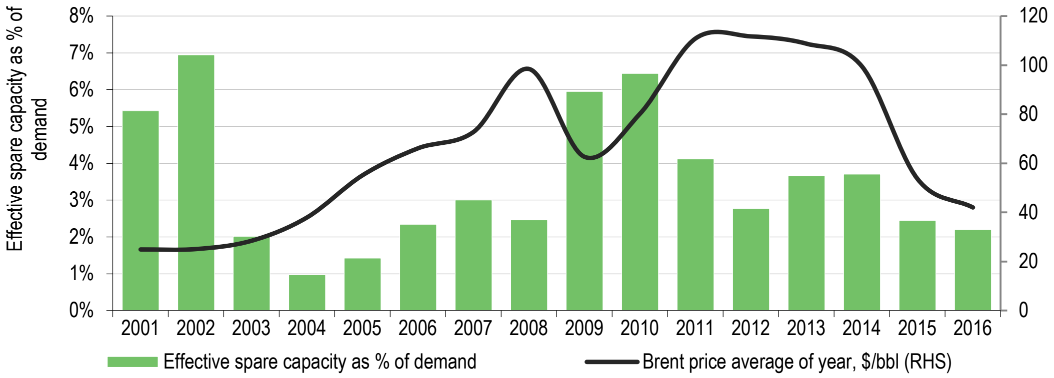
Another way to look at prices is that they have risen at around a 6% CAGR since 2000.

Drawing analogies from other industries suffering supply constraints

It seems likely that, should the supply/demand balance tilt as strongly to undersupply as we believe it may, there is strong potential for upward movement to curb demand (essentially a top-down, demand-driven pricing mechanism). This would replicate the circumstances seen in the 2011-13 shortage that led to price spikes.

While we cannot forecast prices in this scenario, it may be worth drawing an analogy to the course of oil prices in the 2000s as spare capacity shrank and prices rose strongly from US$25/bbl in 2001, peaking to over US$140/bbl in mid-2008. The global financial crisis then intervened, adding further impetus to declining demand. It took up to 2014 (from 2004) for the industry to react with enough innovation and capital to end the cycle with a powerful enough supply response.

Exhibit 11: Demand-led undersupply in 2000s caused a material move in the oil price.

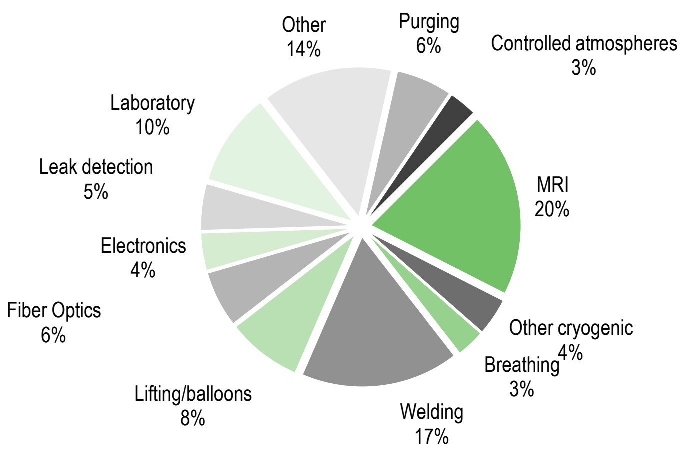


Source: IEA, Bloomberg

In this scenario, the price would therefore be determined by the marginal price of demand, defined by the maximum price users will be willing to pay for it. In the case of helium, this is very difficult to estimate, but substitution and budgeting considerations will be key.

Looking at the uses of helium, there are areas that are obvious candidates for reduction in demand – either because helium is substitutable with other gases, or because demand is more elastic to price. Unfortunately, we do not have sufficiently granular detail to see clearly which industries were most/least responsive to the 2011-13 price increases.

Exhibit 12: Demand constituents



Source: Kornbluth consulting: www.kornbluthheliumconsulting.com/

According to the USGS, US use declined by 30% in 2013-14 and had not rebounded back to 2013 levels in 2015, despite a greater supply. This suggests a level of permanent demand destruction as industries switched or became more efficient with supplies (many have built more effective helium recycling facilities for example). We would flag that MRI scanners, 20% of global demand, have seen some innovations that may reduce/negate the use of helium for super-cooling the magnets. This is clearly a risk should these become mainstream, although it will take time for the replacement cycle to kick in (US MRI life spans are 12 years). The comparative full-life costs of the ever more helium-efficient technology are not yet clear and we would imagine a gradual adoption cycle as long as helium prices do not spike in the near term.

To counter this, the pricing spike and demand destruction in 2011-13 may have left a (growing) rump that is even less price sensitive.

Appendices

US Helium Extraction Act 2017

The Helium Stewardship Act (2013) set a timetable for the release of the US national helium reserves to be steadily sold off, but did little to incentivise longer-term helium exploration. It arguably had the opposite effect; by selling a large percentage of global demand per year to a small number of players, it may have reduced prices below the market equilibrium. With only a few years to go before the reserve is exhausted, steps are now being taken to motivate helium exploration again (on federal lands).

Currently, the Mineral Leasing Act (1920) only allows companies to retain acreage if they are extracting oil or natural gas. The Helium Extraction Act of 2017 is intended to extend these rights to companies looking to extract helium, thereby taking a further step towards allowing focused helium exploration. As the sponsor of the bill (Paul Cook: R-CA) stated in the House on 1 November 2017, "[u]nder existing law, the Mineral Leasing Act only permits helium extraction as a by-product of an existing oil or natural gas lease. As a result, if oil and gas production on a Federal site is not economically viable, the lease will expire, regardless of the revenue brought in by helium sales. The Helium Extraction Act of 2017 would correct this error and authorize helium production activities where economically viable."

The act was passed by the house (committee) without amendment in January 2017. The next step will be to go to the Senate before being approved by the president. We do not expect this to have a material effect on helium for a number of years, but it is nevertheless a positive step.

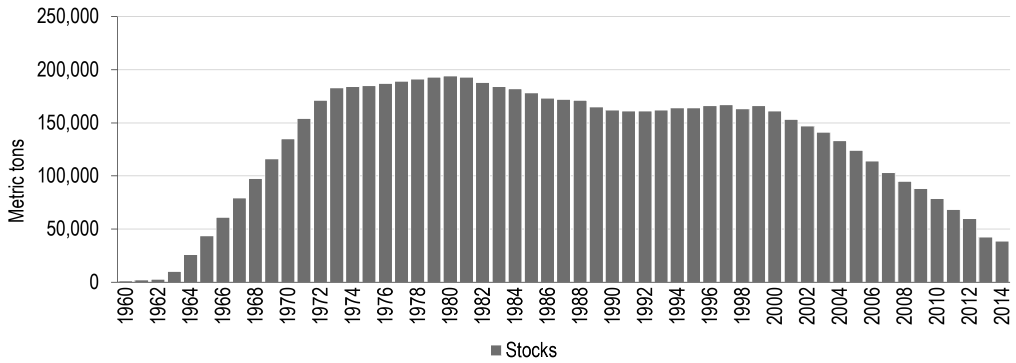
History of the BLM and the Federal Helium Reserve

In 1925, the US government started to store helium in the Bush Dome Reservoir in Texas (also known as the Cliffside field), in order to retain reserve and flexibility on the scarce resource. Initially set up as a strategic supply for airships, the focus moved to space exploration. As more gas was required for the reserve, the 1960 Helium Conservation Act allowed for a 425 mile pipeline to be built connecting a number of natural gas fields in Texas, Kansas and Oklahoma with high helium content to the Cliffside field, where it was injected for storage. The act also funded construction of five large natural gas processing facilities that produced crude helium as a by-product for sale to the US Bureau of Land Management (BLM). Later, the government looked to increase the stockpile further, and this resulted in the huge growth of reserves over the next decade, as seen in Exhibit 13. During this period, the government was the major buyer of helium.

This growth was funded by a debt to the US government, which had grown (with help from high interest rates and inflation) to US$1.33bn by 1996. With the 1996 Helium Privatization Act, Congress sought to recoup this amount through a controlled sale of the resource to the market, starting a gradual depletion of the resource since then. As can be seen in the supply/demand charts, this is a significant percentage of global supply.

It is clear that this supply will be exhausted soon. In October 2013, Public Law 113-40 (Helium Stewardship Act) was passed, requiring the BLM to auction volumes off (to any qualified bidder), a revision to the previous set sales price approach. In 2019, or once the resources gets to 3bcf, this process will stop (the 3bcf will be reserved for government use). Once privately owned crude helium has been delivered, the world helium market will no longer have the flexibility that was historically provide by the BLM reserve.

Exhibit 13: Stocks of helium in US strategic reserve



Source: USGS