

Article

Helium Production and Possible Projection

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Abstract: The future availability of helium has been raised as an issue in the literature. However, a disaggregated projection of helium production has not been attempted, presumably due to the difficult nature of accessing disaggregated historic production data to test the accuracy of this issue. This paper presents collated and estimated historic helium production statistics from 1921 to 2012 for each helium producing country in the world and by U.S. state. A high and regular growth projection of helium has been created. It is found that helium resources are sufficient for the near future, with the projected production plateauing in 2060–2075 and 2090–2100 for the high and regular growth scenarios, respectively. As long as natural gas deposits with helium are appropriately managed, there is little likelihood for helium shortages to occur in the short term due to geologic constraints.

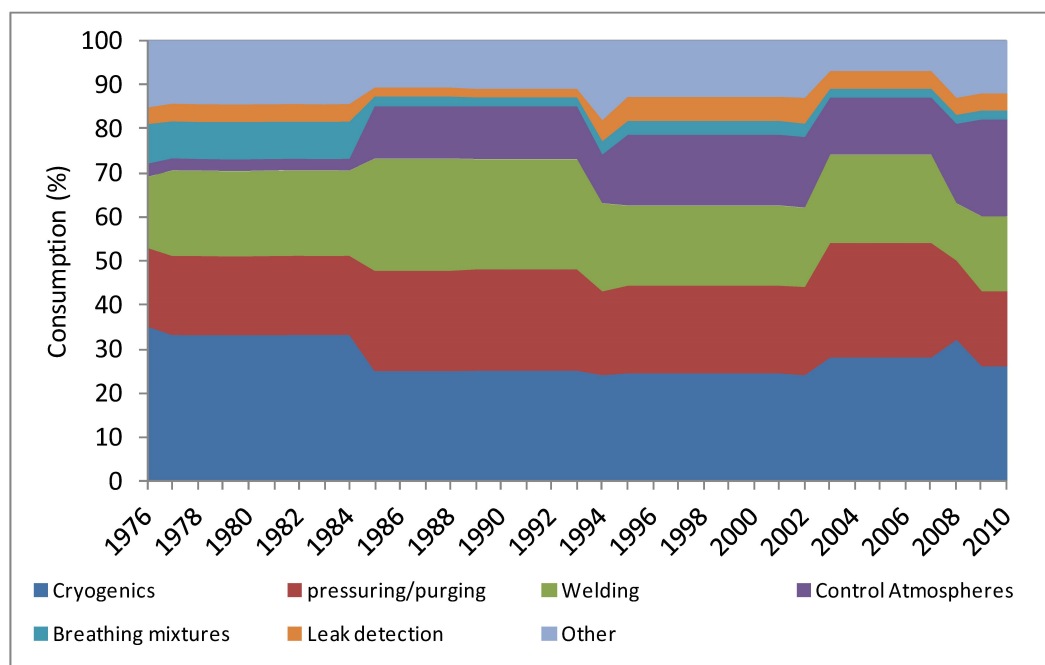
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1. Introduction

Helium is an important element for applications requiring very cold temperatures, and currently, 20% of helium consumption is used in Magnetic Resonance Imaging (MRI) scanners [1]. It is also used for welding, controlled atmospheres and other uses, such as a lifting gas; see Figure 1 [2]. During the Second World War, helium was an important gas for inflating blimps, weather balloons and magnesium welding [2]. Helium has been produced in commercial quantities since 1921 [2].

In the future, large quantities of helium may be required for nuclear fusion reactors [3,4]. Since the early 1960s, the U.S. government has stockpiled helium in the federal reserve [2,5]. In 2012, helium taken out of the stockpiled reserve accounted for over one third of global helium supplies, primarily as a response to legislation to shut the federal reserve by 2015 [5]. Legislation passed in late 2013 overturns the closure of the federal reserve and is intended to ensure that helium from the reserve will be drawn down at a slower rate and at higher prices, to facilitate a smoother transition [6]. Currently, leading researchers have predicted of looming helium shortage [7]. This issue of a possible helium shortage was addressed by *Cai et al.*, who examined world resources and modeled world helium supplies using a systems dynamic approach and concluded that there were no supply issues until at least 2060 [8]. Afterwards, *Glowacki et al.*, modified the input parameters of the *Cai et al.*, model and indicated that helium consumption could peak with a long plateau period around 2030 at 10,000 million cubic feet per year (47 kt/year), assuming a high demand scenario [9]. The issue of helium shortages was brought to widespread attention by the *Nuttall et al.*, article in Nature [10]. The helium shortage occurred due to the decision in the USA to sell off helium from the federal reserve in preparation for its then planned shut down in 2015; this resulted in years of artificially low helium prices, which provided a disincentive to recover helium from natural gas waste streams. At the same time, there was strong growth in helium demand, particularly from Asia [10]. One of the major issues of helium production is that a large amount of helium is lost, due to the venting of helium rich gases in the natural gas industry [10].

Figure 1. Helium consumption in the USA [2].



Other than from gas wells helium's only other possible source on Earth is from the atmosphere, where helium is present at 5.2 parts per million [3,11]. This potential backstop solution could potentially supply some helium in the future; however, there would be significant engineering challenges, as it would take more than a hundred cubic kilometres of air to produce the current helium demand [11].

A possible reason for the differences in helium availability is that the projections have been applied to world helium supply rather than making projections on a disaggregated regional basis. For example, most recent work on peak oil apply disaggregated projections to improve the accuracy, e.g., [12–14]. A disaggregated approach is made difficult, as the USA helium production statistics by state and world helium production by country for the entire time that commercial quantities of helium have been produced has not been collated. Only the USA and world total production data is readily available from [2,5,15].

The aim of this paper, therefore, has three components. The first aim is to conduct an exhaustive search of the literature and determine, as best as possible, the historic helium production by world by country. Second, as the USA historically and currently dominates the production of helium, USA production will be determined by state. This compilation and estimation of historic production is a major stumbling block to more disaggregated projections of helium. The third aim is to use this more detailed production data and project helium production by individual countries and USA regions to see if a helium shortage is likely.

2. Historical Helium Production

This section describes how historical production data has been collated for each individual country or state. The dataset compiled is for helium production, namely the amount of helium—the mass of helium atoms—in either Grade A or raw production streams) extracted from the ground and either sold to consumers or stored in the federal reserve. This is not including the production of helium from the extraction of helium from the federal reserve. It includes helium produced from either dedicated helium wells or extracted as a by-product from natural gas wells. The individual country or state helium production is sourced as a by-product of the natural gas industry, unless stated otherwise. It does not, however, include helium extracted from natural gas fields, which is subsequently vented to the atmosphere as a waste stream. For certain time periods, only the raw production of helium from the ground (including some vented helium) could be quantified, and the amount of helium lost to venting/extraction losses are unknown. At other periods, the production is estimated from sales data, as production data is unavailable. The collated production data has, where possible, been obtained from the literature or regulatory authorities. However, for certain time intervals and regions, helium production has been estimated, as statistics were not found. The collated and estimated helium production statistics are available as an excel file in the electronic supplement.

2.1. Australia

Australia has one helium extraction plant in Darwin. However, the source helium comes from the Bayu Undan natural gas field in the Timor Sea, part of the Joint Petroleum Development Area, where the East Timorese are entitled to receive 90% of the oil and gas royalties [16]. Whilst the production and resources from this basin will be attributed to Australia, realistically, 90% if not all (if the median line were applied to the disputed area, then the Bayu Undan gas field would belong to East Timor [17]) could perhaps alternatively be attributed to East Timor. The helium plant in operation in Australia was commissioned in early 2010 [18]. The production numbers for Australia could not be sourced,

either from Australian agencies, such as the Bureau of Resources and Energy Economics, the Australian Bureau of Statistics or via contacting the gas plant operator directly. Production for Australia is therefore assumed to be the capacity of this plant at 941 t of helium per year [18].

2.2. Poland and Russia

Production numbers for Poland and Russia are difficult to determine, due to [United States Geological Survey](#) reporting production between 1971 and 1985 as from the two countries combined (and at times, as the rest of the world component, which is assumed to be Poland and Russia) [2]. No production data can be found from 1986 to 1988. As a result of these difficulties, the production for the region is generally unreliable prior to 1994, and an attempt has been made to estimate the production in the two countries. Specifically:

- 1971–1976: The production number for Russia is stated in [United States Geological Survey](#) [2]. Poland was not producing helium during this time [2].
- 1977–1979: The production for Poland and Russia combined is known [2]. It is assumed that Russia continues to produce 100 million cubic feet per year (≈ 470 t/year), which corresponds to the Russian production in 1976, and the rest of the production is attributed to Poland.
- 1980: The Polish production plant was damaged in December, 1979, and came online late in 1980; hence it is assumed that all production for the non-free world in [2] is attributed to Russia.
- 1981–1985: The production for Poland and Russia combined is known from [United States Geological Survey](#) [2]; it is assumed that the Poland to Russia production ratio is 10:12.
- 1986–1988: No production numbers can be found in the literature. It is assumed that production is 100 million cubic feet per year (≈ 470 t/year) for Poland and 120 million cubic feet per year (≈ 360 t/year) for Russia, based on the production numbers before and after this period.
- 1989–1993: The Polish production numbers were obtained from [Czapigo-Czapla](#) [19]. Production numbers for Russia could not be determined and were estimated to be 120 million cubic feet per year (≈ 360 t/year) based on the production numbers before and after this period.
- 1994–2012: The Polish production numbers are from [Czapigo-Czapla](#), and the Russian production was from [United States Geological Survey](#) [5,19].

2.3. Canada

The historic production of helium from Canada was assumed to be the production capacity [2]. Production numbers from Canadian sources could not be located.

2.4. France

Production from France was obtained from [United States Geological Survey](#) [2].

2.5. Algeria

Production was obtained from [United States Geological Survey](#) [5].

2.6. Qatar

Production was obtained from [United States Geological Survey](#) [5].

2.7. USA

2.7.1. Arizona

Both the annual raw gas production from helium producing wells and the helium concentration of the wells have been collated by the Arizona Geological Survey [20]. Helium production from Arizona was from dedicated helium wells. The production of helium from Arizona has assumed to be the raw gas multiplied by the average helium concentration. This is likely to cause a slight overestimation of actual production, due to losses in the refining process. These losses are expected to be small, however, as the raw gas was exploited for its helium content and, hence, was unlikely to have been vented.

2.7.2. Colorado

Virtually all helium in Colorado has been produced since 1990, with only a very small amount of helium produced in 1929 and 1930 [2].

- *1929–1930*: During 1929 and 1930, 14 t of helium were produced [2], and this has been proportionally divided by each year based on the months of operation.
- *1990–1997*: Production data between 1990 and 1997 could not be sourced and, hence, have been estimated. It is believed that during this period, the Archer plant was operating, and the following estimates were assumed: 1990, 469; 1991, 469; 1992, 469; 1993, 469; 1994, 376; 1995, 329; 1996, 235; 1997, 188. These numbers were assumed to give the Archer plant a production profile similar to the EnCana plant in Utah and the Ladder Creek plant in Colorado.
- *1998–2012*: Since 1998, sales of helium from the Archer helium plant and Ladder Creek gas plant are available from [Colorado Oil and Gas Conservation Commission](#) [21]. The data is the monthly reporting data from the individual gas plants [21]. For the Archer helium plant, the sales included the units of the numbers. For the Ladder Creek plant, the sales data do not include units; as a result, the conversion of sales data to kilotonnes of helium produced was based on the knowledge that 9.7 kt of helium was produced in 2005 [22]. It is assumed that sales data are a good approximation to the production data, as the plants are not connected to the U.S. federal reserve pipeline [9].

2.7.3. Kansas and Texas

Separate helium production data for Kansas and Texas could not be found in the literature for all years. Up to 1976, production data are available/or can be deduced and readily split into Texas and

Kansas production. Post 1976, the distinction between Texas and Kansas production must be estimated. Although an attempt has been made to split the data in Texas and Kansas production individually, this is done with caution, and the production for the combined region is also provided in the electronic supplement. The data sources and method of estimated production for Kansas and Texas have been split into numerous time periods:

- *1921–1950*: The production in Kansas came from the two small gas plants operating during 1927 to 1930 and 1943 to 1946. The cumulative production for these plants were known [2], and annual production numbers were estimated by proportioning production into the different years based on the months the plants operated. The production for Texas during this time was taken to be total USA production minus Kansas and Colorado production, as these were the only three states engaged in helium production.
- *1951–1973*: During this time, annual helium production is available [22]. However, between 1959 and 1962, total USA production of helium from [United States Geological Survey](#) [22] is higher than from [United States Geological Survey](#) [2]. Helium production in Texas and Kansas in 1962 is available [2] and was used for 1962 production numbers. The production numbers from [United States Geological Survey](#) [22] between 1959 and 1961 for Texas were scaled to account for the discrepancy in total USA production from the two sources. The production numbers for Kansas were not scaled, as the 1962 for the two sources agreed.
- *1974–1976*: During this period, production data for Texas is known [22], and Kansas production is taken as the difference between USA production and all other states' production.
- *1977–1981*: As production data is withheld for 1977–1981, the production for Kansas plus Texas is determined by the USA total minus all other states, and the proportion of production assigned to Kansas and Texas is determined by a linear extrapolation between the ratio in 1976 and 1982.
- *1982–1983*: As crude production in Texas is withheld, the production for Kansas plus Texas is determined by the USA total minus all other states, and the proportion of production assigned to Kansas and Texas is determined by the ratio of the high purity production in those states [22].
- *1984*: The production data in [United States Geological Survey](#) [22] includes production from stored production; hence, this data cannot be used directly. As a result, production in Kansas is taken as the ratio of increase in high purity plus crude production between 1983 and 1984 [22]. The production for Texas was assumed to be the USA total minus all other states' production.
- *1985–1992*: As production data is withheld for 1985–1992, the production for Kansas plus Texas is determined by the USA total minus all other states, and the proportion of production assigned to Kansas and Texas is determined by a linear extrapolation between the ratio in 1984 and 1993.
- *1993–1995*: The production data in [United States Geological Survey](#) [22] includes helium from stored production; hence, the production for Kansas plus Texas is determined by the USA total minus all other states, and the proportion of production assigned to Kansas and Texas is determined by the ratio of the crude production in those states from [United States Geological Survey](#) [22].

- *1996–2000*: As crude production data is withheld for 1996–2000, the production for Kansas plus Texas is determined by the USA total minus all other states, and the proportion of production assigned to Kansas and Texas is determined by a linear extrapolation between the ratio in 1995 and 2001.
- *2001*: For 2001, the crude production of helium for Texas and Kansas individually is known and is within a 1% difference of the USA minus all other states' production. As a result, the crude production values have been used.
- *2002–2012*: The total production in Kansas and Texas was known by taking the USA total production minus all other states' production. Further, in 2001, Kansas produced four times as much crude helium as Texas [22]. Texas's and Kansas's individual productions were estimated by assuming the four-to-one ratio remains the same. This is likely to lead to large errors in helium production for either Kansas or Texas; however, the combined production for the two states is correct.

2.7.4. New Mexico

New Mexico production has been split into four distinct time periods: 1944, 1953–1970, 1975–1991 and 2001–2009.

- *1944*: The production of 10.5 t of helium occurred at Shiprock, New Mexico, for the war effort [2].
- *1953–1970*: Annual helium production statistics are available [22].
- *1975–1991*: The production of helium occurred in each year between 1975 and 1991, with the exception of 1979 [2,22]. The production volumes of helium for these years were withheld [22]. It is known that the Beautiful Mountain and Big Gap Organ Rock reservoirs were discovered in 1975 and 1980, respectively. Both the cumulative production from these reservoirs and the helium content are known [23]. Helium production was estimated by assuming that Beautiful Mountain produced between 1975 and 1978 and Big Gap Organ Rock produced between 1980 and 1991. Annual production for these years was approximated by taking the total production to be the raw gas multiplied by the average gas content and assuming a typical gas reservoir production profile (sharp increase to a plateau followed by exponential decay, as indicated by Utah, Oklahoma and Colorado).
- *2001–2009*: Annual production statistics from helium producing wells were obtained from [New Mexico Tech](#) [24]. The helium content of these wells is known [23], and hence, the raw helium produced could be estimated. Although actual production statistics could not be sourced, these wells contained only trace amounts of hydrocarbons and were dedicated helium wells; hence, actual production is likely to be similar to raw production.

2.7.5. Oklahoma

Helium production in Oklahoma was estimated for two distinct time periods: 1959–1981 and 1995–2012.

- 1959–1981: During this time, annual helium production is available [22], with some exceptions: first, in 1977, the production numbers are withheld (hence, the production in that year was estimated), and between 1959 and 1962, the total USA production of helium from [United States Geological Survey](#) [22] is higher than from [United States Geological Survey](#) [2]. Helium production in Oklahoma in 1962 is available [2] and was used for 1962 production numbers. As with Kansas and Texas, the production numbers [22] between 1959 and 1961 were scaled to account for the discrepancy in the total USA production from the two sources.
- 1995–2012: The production of helium in Oklahoma resumed in 1995 [2,22]. Monthly raw gas production data by individual gas wells was obtained from [Oklahoma Corporation Commission, Oil and Gas Division](#) [25]. Between 1995 and 2008, the buyer of the raw gas was available, and the raw gas going to two gas plants that refined helium could be estimated. Between 2008 and 2012, the production for DCP Midstream Energy was obtained [25], and this company operated the only helium gas plant operational in Oklahoma during this time. These two sources agree well for the monthly production numbers in 2008 and were combined to obtain the raw gas produced in Oklahoma. The average helium content of the gas was estimated to be 1.85% [23]. As a result, the raw helium produced could be estimated for Oklahoma between 1995 and 2012. It is likely that actual helium production is lower than the raw helium production, as the helium produced is a by-product of natural gas; hence, some of the helium may have been vented.

2.7.6. Utah

Monthly helium sales are available by individual gas plant [26]. Based on the United States Geological Survey (USGS) data [2], Utah helium production is limited to the EnCana Lisbon/Moab gas plant. Utah's production statistics have been assumed to be the helium sales from the Lisbon plant. As Utah is not connected to the Federal Gas Reserve, it is assumed that the difference between helium sales and production in Utah is minimal.

2.7.7. Wyoming

Monthly helium sales and raw gas production statistics are available by individual gas plant [27]. Based on USGS data [2], Wyoming helium production is restricted to the Exxon Mobil Shute Creek gas plant. Production numbers for Wyoming are the helium sales from the Shute Creek plant. As Wyoming is not connected to the Federal Gas Reserve, it is assumed that helium production is very similar to the sales statistics.

3. Helium Projections Using Country and Regional USA Data

The projections of helium by USA regions and the world by country were achieved by using the field component of the geologic resource supply-demand model [12]. This model has been described in full detail [12], and a general overview of the field component has been described [28]. This model requires historic production and estimates of the ultimately recoverable resources (URR). The URR is the total amount of the resource that is extracted over all of time. That is, it is the sum of all historic

production and all future production. The model generates projections of the resource using a bottom-up approach of adding production from idealised fields that are brought online over time. This model is freely available [29], and the specific parameters used and the model are presented in the electronic supplement. The estimate for the URR of helium is described below.

3.1. Helium URR

The URR has been estimated by combining cumulative production with helium resource estimates. Ideally, helium resources by U.S. state would be used to create projections of individual states. Unfortunately, the only detailed resources of helium are broken down into regional area [30]. The resources of helium in the USA by region and the world by country have been obtained from literature sources (see Tables 1 and 2). The estimates for helium URR have been calculated to be 4178 kt He for the USA and 9064 kt He for the world and are shown in Tables 1 and 2, respectively.

4. Results and Discussion

Helium production for the world by country is presented in Figure 2, and the production by U.S. region is presented in Figure 3. There are two projections: a high growth scenario aimed at replicating the high demand for helium in Glowacki *et al.* [9]; and a regular growth scenario shown in Figures 4 and 5. In particular, the supply of helium in the projection reaches 48 kt He/year in 2030 for the high growth scenario, which is similar to the high demand scenario in Glowacki *et al.* [9] of 47 kt He/year. The projections indicate that production can continue to grow until reaching plateaus in 2090–2100 and 2060–2075 in the regular and high growth scenarios, respectively. This finding is in agreement with the work of Cai *et al.*, who indicated no supply issues out till 2060 [8]. In comparison, the results presented here contradict the work of Glowacki *et al.* [9], who indicated that helium supplies could enter a long plateau in 2030.

Table 1. The cumulative production, resources (from [30]) and ultimately recoverable resources (URR) of helium in the USA by region (kilotonnes of He).

| Region | Cumulative Production | Resources | URR |
|-----------------|-----------------------|-------------|-------------|
| Mid Continent | 518 ¹ | 1629 | 2146 |
| Rocky Mountains | 169 ² | 1533 | 1702 |
| Atlantic | 0 | 156 | 156 |
| Gulf Coast | 0 | 76 | 76 |
| Alaska | 0 | 45 | 45 |
| North Central | 0 | 34 | 34 |
| Pacific | 0 | 19 | 19 |
| USA | 687 | 3491 | 4178 |

Notes: ¹ Kansas, Oklahoma and Texas; ² Arizona, Colorado, New Mexico, Wyoming and Utah.

Table 2. The helium resources of the world by country.

| Country | Cumulative Production | Resources (kt He) | Reference | URR |
|--------------|-----------------------|-------------------|------------------------|-------------|
| USA | 687 | 3491 | [30] | 4178 |
| Qatar | 14 | 1710 | [5] | 1723 |
| Algeria | 47 | 1388 | [5] | 1435 |
| Russia | 26 | 1151 | [5] | 1177 |
| Canada | 2 | 339 | [5] | 340 |
| China | 0 | 186 | [5] | 186 |
| Poland | 10 | 5 | [19] | 15 |
| Australia | 3 | 5 | Estimated ¹ | 8 |
| World | 789 | 8275 | | 9064 |

Note: ¹ The Bayu Undan field has estimated resources of 4 trillion cubic feet (tcf) of natural gas [31], and the helium content is estimated at 0.025% based on the annual production capacities of the associated helium production plant (0.941 kt He) and the liquefied natural gas (LNG) plant (3710 kt natural gas) [18,31].

Figure 2. Helium production for the world by country.

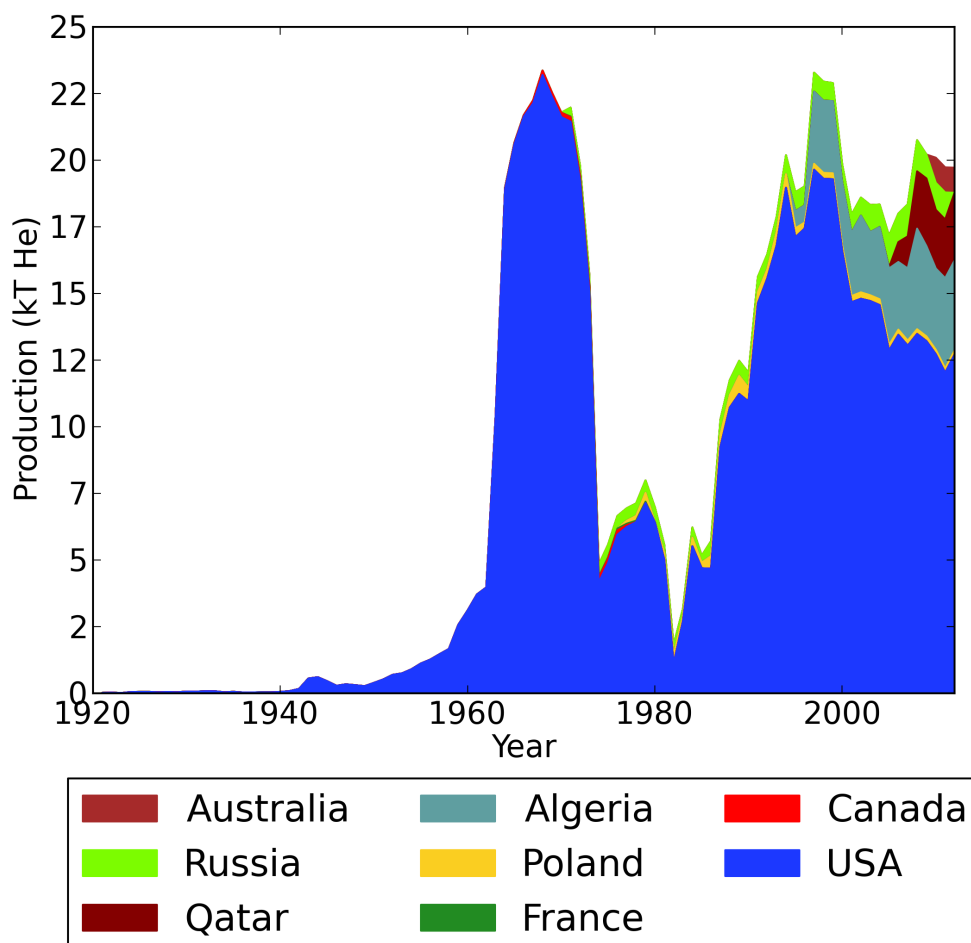
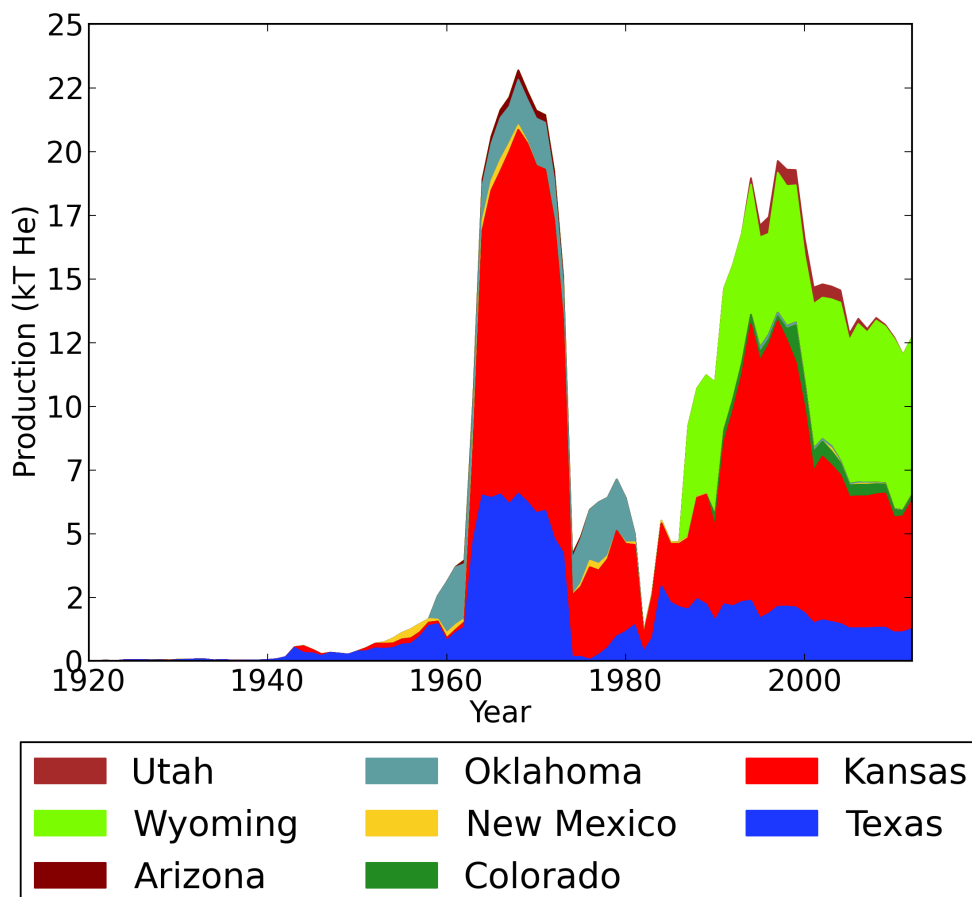


Figure 3. Helium production in the USA by state.

Although, on paper, the resources of helium should ensure sufficient helium production until at least 2060, and more likely to 2090, it is important to note several factors that may cause helium scarcity. First, world helium production is in a current state of flux, with USA helium production on a steady downward trend since the late 1990s, with an increased dependence on helium from the federal reserve and strong growth in the rest of the world supplies since 2004 (an average of 9% per year). Should the rest of the world's growth in production slow, then there could be short-term issues with helium supplies in this transition phase. Further, although helium resources are adequate, it may be the case that not all resources of helium are exploited for whatever reason (e.g., remote location, difficult geology, *etc.*). Finally, as helium is predominately a waste product of the natural gas industry, some of the helium resources are likely to be vented into the atmosphere, and hence, the projections presented here are likely to represent an overestimate of actual future production.

Historically, the USA in particular has viewed helium as a strategic resource, particularly in terms of defence (as helium can be used for blimps, weather balloons and welding). As a result of this, the USA has stockpiled helium. It is important now that governments both in the USA and in other countries understand the importance of helium and ensure that helium rich gas deposits are appropriately managed by strategically storing excess helium production, so that this precious resource is not squandered. In addition, it is important for helium to be recycled in suitable applications, such as cryogenics, where this is possible, rather than venting, and for the potential to replace helium with other gases where appropriate, e.g., tungsten inert gas (TIG) welding.

Figure 4. Projection of helium production in the USA by region: (a) regular growth and (b) high growth.

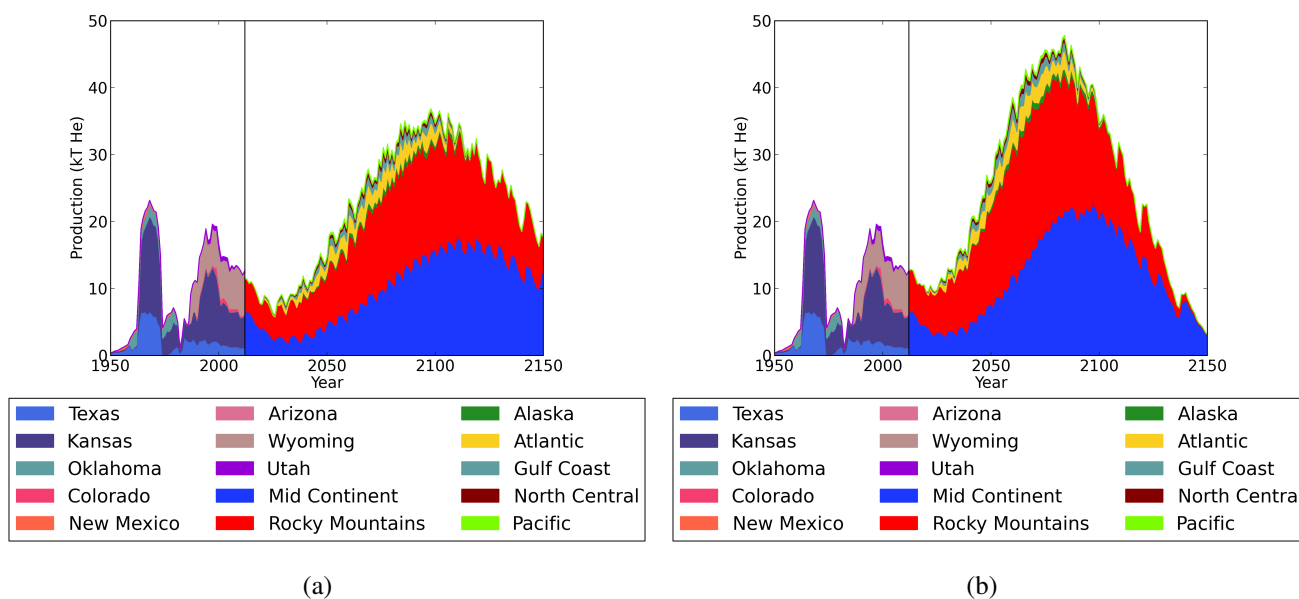
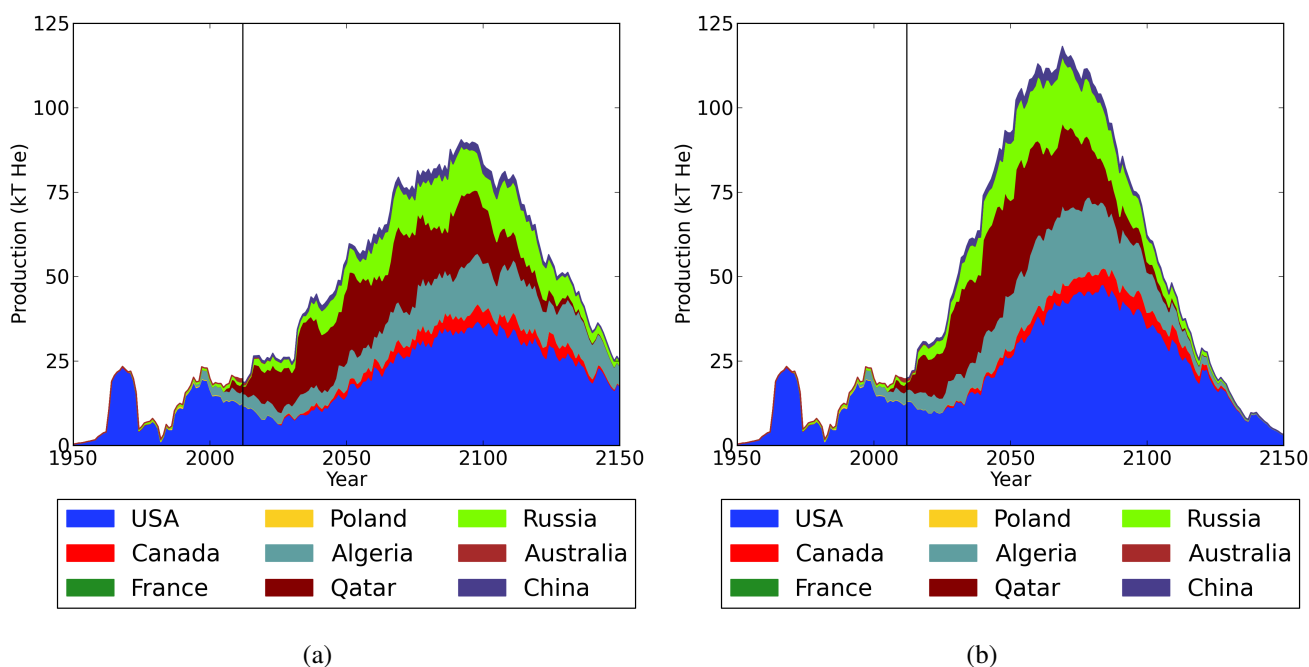


Figure 5. Projection of helium production for the world by country: (a) regular growth and (b) low weigh growth.



5. Conclusions

The issue of helium scarcity has been investigated using a disaggregated method. This has involved a detailed search of the literature with some estimation and resulted in the collation of historic helium production statistics by country and by U.S. state. This historic production has been combined with literature resources estimates to create a projection of helium production under both regular growth

and high growth scenarios. By creating disaggregated helium projections, it is determined that helium production will reach a plateau around 2090–2100 and 2060–2075 for the regular and high growth scenarios, respectively. Care is required to ensure that helium bearing natural gas deposits are appropriately managed so that the helium is not vented to the atmosphere, but instead, viewing helium as a critical mineral and having excess helium stored for future use, as previously happened in the USA. It is also important that helium be recycled and replaced with other minerals, wherever possible.

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Electronic Supplementary Information

The electronic supplement contains the collated/estimated disaggregated helium production statistics and the model and inputs used to generate the helium projections.

Conflicts of Interest

The authors declare no conflict of interest.

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