Evaluating Earth's Helium-3 Supply

Sarah Newbury- Harvard University,
Samuel Cohen, Charles Gentile- Princeton Plasma Physics Laboratory

ABSTRACT

D-3He is desirable as a fuel for fusion power because it is an advanced fuel, meaning that it produces few high energy neutrons, and yet with it one still can achieve a sufficient reaction rate in the plasma at reasonably lower temperatures. Major obstacles that could prevent the future application of this fuel in powering reactors are the scarcity of helium-3 on earth and the difficulty in confining the plasma long enough to attain an acceptable plasma temperature. In order to address these obstacles, a plan has been proposed to run a number of small field-reversed configuration (FRC) reactors for around 30 years using D-3He. This would demonstrate the feasibility of D-3He fusion power and encourage pursuit of lunar helium-3 sources. An investigation was conducted to determine whether the terrestrial helium-3 supply is large enough to power a number of small reactors. Current sources of helium-3, as well as potential future sources, were discovered and analyzed. The maximum potential fusion power that could be drawn from earth's helium-3 supply is predicted under various conditions.

Examples of Fusion Reactions

D+D → 3He(.82MeV) + n(2.45MeV)

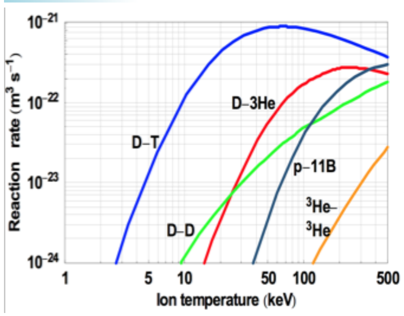
D+T → 4He(3.5MeV) + n(14.1MeV)

Most energy produced in the form of high energy neutrons, ~ 30% efficiency in energy conversion

D+3He → 4He(3.6MeV) + p(14.7MeV)

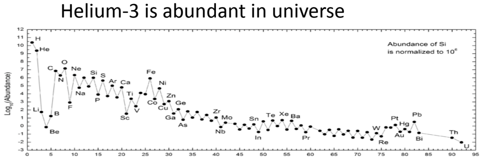
p + 11B → 3x4He + 8.7MeV

"Advanced Fuels"- few high energy neutrons resulting, products are charged particles, possibility of > 90% efficiency in energy conversion



D-3He does not require as much heat as p-11B to achieve a given reaction rate

Helium-3 is abundant in universe



He-3 accounts for .03% of He

Nearby quantities of He-3 large, but inaccessible

--10^9 kg = 7.54x10^12 L on the surface of the moon
--4 million kg of He-3 in atmosphere
--At least 13,260 kg in oceans and natural gas wells

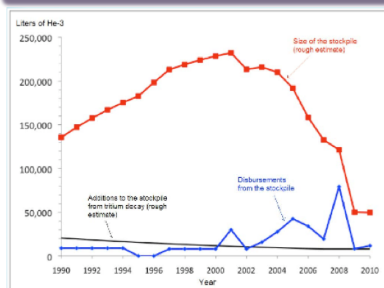
Current Sources of He-3:
He-3 Production in U.S.

1955: Tritium production starts at Savannah River Site for use in nuclear weapons stockpile
Tritium in stockpile decays over time into He-3:

T → 3He + e

He-3 extracted from stockpile and replaced with new tritium by National Nuclear Security Administration (NNSA)
1988: reactor shut down, reduced He-3 production
~1990: NNSA engages Isotope Program to begin sales of He-3
2003: tritium production through the irradiation of lithium authorized by DOE at TVA
2009: policy committee formed to allocate He-3

Present: NNSA extracts 8,000-10,000L/year He-3, which is then stored at Savannah River Site. Quantities are sold annually by the Isotope Program, with the customers chosen through an allocation process.

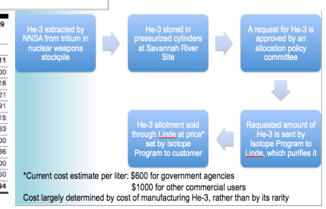


He-3 stockpile began continuously decreasing in 2001, when there was a sudden increase in demand for neutron detection applications.

Table 2: Quantities of Helium-3 Allocated and Used, in Liters, from Fiscal Year 2009 to Fiscal Year 2011

Customer	Quantities FY 2009	FY 2010	FY 2011
Low temperature research	N/A	452	700
DHS	N/A	438	1,218
DOD	N/A	1,530	3,521
NNSA	6,367	5,098	5,791
DOE's Office of Science	2,400	341	315
Intelligence Community	N/A	N/A	763
NIH	N/A	260	1,400
NIST	N/A	607	236
Oil and gas industry	N/A	695	1,000
Road construction industry	N/A	N/A	350
Total	**8,767**	**9,421**	**15,294**

Source: GAO analysis of information from the interagency policy committee and Linde.



He-3 Production in Russia

During the Cold War, Russia also produced large quantities of tritium to use in their weapons stockpile. As this tritium has decayed into He-3, they too have built up a supply.:
--Main supplier of He-3 to U.S. from 1995-2001
--From 2004-2008, about 25,000L/year He-3 were imported from Russia
--In 2008, Russia announced that they were reserving their supply for domestic use only, implying that they too are experiencing a shortage

Potential Future Sources of He-3:
CANDU Reactors

-power plants that use heavy water as a moderator
-when heavy water molecule absorbs a neutron, tritium is created
-extracted tritium decays into He-3
-reactors currently located in various countries:
-Canada, India, South Korea, China, Pakistan, Argentina, Romania
-biggest potential supply in Canada at Ontario Power Generation (OPG)

OPG owns 16 CANDU reactors, some of which are pictured right. They extract 15Mci tritium annually to reduce radioactivity of their reactors.. Right now, they do not extract any He-3 from their tritium stores.

If OPG began to extract he-3 from their stores, they could obtain an initial yield of 100,000L and then produce 10,000L/year.

Naturally-Occurring He-3

The DOE is looking into separating He-3 from natural helium stored at two reserves: the National Helium Reserve in Texas and another reserve owned by Cimarex in Wyoming.

DOE estimates that they could extract 125,000L He-3 from the National Helium Reserve, and 200,000L He-3 from the reserve in Wyoming.

Summary of Earth's Potential Helium-3 Supply

Approximate Current Inventory(L)	Annual Production Rate (L/year)	Current Form (S-separated, NS-mixed)	Location	Source
31,000	8,000-10,000	S	Savannah River Site	Decayed tritium of nuclear weapons stockpile
100,000	10,000	NS, w/ tritium	Ontario Power Generation	Decayed tritium from heavy water reactors
125,000		NS, w/ 4He	Amarillo, Texas	Natural helium gas in earth
200,000		NS, w/ 4He or natural gas	Wyoming	Natural helium gas in earth
1500	8,000-10,000 every 8-10 years	NS	National labs; Savannah River's TEF	Unused equipment and supplies; retired tritium beds
undisclosed	undisclosed	NS, w/ tritium	Russia, India, South Korea	Decayed tritium

CONCLUSION AND FUTURE WORK

At this point, the only helium-3 source on earth is the decay of tritium, created both by the U.S. and Russia to maintain each of their nuclear weapons stockpiles. However, due to the limited quantity of tritium and an increasing demand for helium-3, this supply is diminishing. There are several other potential helium-3 sources on earth that could help to assuage the shortage; these include the decay of tritium extracted from CANDU reactors, naturally occurring helium-3, as well as other miscellaneous sources. If access to a majority of these sources was maximized, the proposed plan of powering a number of small FRC reactors for around 30 years with D-3He fuel would be feasible. Efforts to increase access to potential He-3 sources- particularly naturally occurring He-3 and that produced at OPG- are currently underway at the DOE. Also, steps toward increasing the existing stockpile are in progress, as the DOE seeks out alternatives to He-3 in certain applications and is planning to start up additional reactors to produce tritium.