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ASSESSMENT OF LUNAR SOURCES OF He-3 FOR USE ON EARTH

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SUMMARY

As a gross measure of the economics of mining lunar sources of He-3, the energy densities (GJ/ton) of lunar soils were compared with the energy densities of various existing and future terrestrial sources of energy. On this basis, only the very richest lunar ores appear competitive with coal. Future lunar exploration might emphasize identification of lunar soils having higher concentrations of He-3.

INTRODUCTION

Because of the currently rising interest in possible use of ^3He from the Moon as a source of energy on Earth (ref. 1), assessment of the economics of this potential energy source is also of growing interest. A small effort has already begun to assess the cost of energy supplied in this way (refs. 2 - 3). In general, the existing studies have concentrated on the various unit operations for such an enterprise and estimated the cost of each unit of activity.

I suggest another approach to assessing the overall cost of this fusion energy, namely, to compare the energy densities (GJ/ton) of various terrestrial energy sources with the energy density of lunar soil containing ^3He. Because the processes of extracting and delivering energy from terrestrial and lunar sources differ so markedly, only in the crudest sense could one equate their economics. On the other hand, simply a gross comparison of the comparative magnitudes can aid us in forming a perspective on this issue, key attractions being its directness and simplicity.

My purpose is to supply just such a comparison.

LUNAR SOURCES OF ^3He

Table IV in reference 2 lists the helium content actually measured in several samples of lunar soil returned by the Apollo missions and reported in reference 4. The concentrations cited there range from 17 to 360 grams of helium per (metric) ton of soil; the bulk of this helium is, of course, conventional ^4He and not suitable for use in fusion reactors (as they are currently envisioned).

The concentration of ^3He in He on the Moon was measured to be as high as 423 atoms of ^3He per million atoms of He (ref. 2, Table IV), roughly equalling the ^3He fraction in the solar wind (ref. 2, Table III). Here on Earth, the concentration of ^3He is 1.3 atoms of ^3He per million atoms of He. I will bracket this entire range by assuming that the concentrations range from 1.3 to 423 atoms of 3He per million atoms of He.

In no mining operation is <u>all</u> of the desired material extracted, some losses inevitably occurring during the mining, during the beneficiation, and during the extraction processes. Those potential losses are ignored herein, 100-percent recovery of the ^3He being assumed. Fusion of this ^3He with D would produce 18.35 MeV of energy per ^3He atom fused. Fusion of every atom of ^3He is assumed herein, any losses being ignored. Because of these assumptions, the estimates herein of energy content of the lunar soil are optimistic.

Based on those assumptions, the energy contents of lunar soil are those shown in figure 1, ranging from 0.01 to 67 GJ/ton of soil.

TERRESTRIAL ENERGY SOURCES

The following terrestrial energy sources are considered:

Coal: Its energy content is taken to be 12,000 Btu per pound, or 28 GJ/ton.

Uranium: The concentration of uranium in its ore is taken as 100 grams of U_3O_8 (yellow cake) per ton of ore, and each fission releases 200 MeV of energy. Burner nuclear reactors are herein assumed to fission 1 percent of the U atoms present in the ore; in turn, the energy content of the ore is 69 GJ/ton. Breeder reactors are assumed to fission 50 percent of the U atoms present in the ore; in turn, their energy release is 3400 GJ/ton of ore.

D - T fusion: Each fusion of D and T produces 17.59 MeV of energy. The D content of water is taken as 150 D-atoms per million H-atoms. Complete fusion of this deuterium would produce 28,000 GJ/ton of water.

These energy contents for terrestrial sources are plotted in figure 2 along with the parallelogram for lunar ^3He from figure 1.

DISCUSSION

Only the very richest lunar ores cited in reference 2 exceed coal in their energy density, and the principal range of lunar energy sources has energy densities far below that of coal. The leanest lunar ores are thus surely not economic as energy sources here on Earth.

On the other hand, lunar ores may well vary widely in their content of ^3He, even as the terrestrial soils and rocks vary enormously in their composition. If so, lunar sources of ^3He still undiscovered might have concentrations of ^3He higher than shown in figure 1 and, in turn, have energy densities substantially exceeding that of coal. So we should still keep our minds open on this topic. But, it appears to me, considerable lunar exploration is required to locate richer deposits of ^3He before we infer that the lunar sources of ^3He will be economic to mine and to transport back to Earth as terrestrial energy sources.

Even though this comparison of terrestrial and lunar energy sources has, admittedly, a crude basis, its directness and simplicity aid in forming a view of the lunar sources. In future studies of the concepts for mining ^3He on the Moon, special attention should be given to estimating the costs of this mining and transportation so that we might improve on the assessment herein.

CONCLUDING REMARKS

Comparison of the energy densities (GJ/ton) of terrestrial sources of energy with those for ^3He on the Moon show that only the richest currently-known lunar sources are even marginally competitive with the terrestrial energy sources. If such lunar sources are in the future to compete economically with the terrestrial energy sources, lunar exploration is required in order to locate richer deposits of ^3He.

On the other hand, utilization of lunar sources of ^3He may prove advantageous for space propulsion even if these sources are uneconomic for terrestrial application.

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ENERGY CONTENT OF LUNAR SOIL

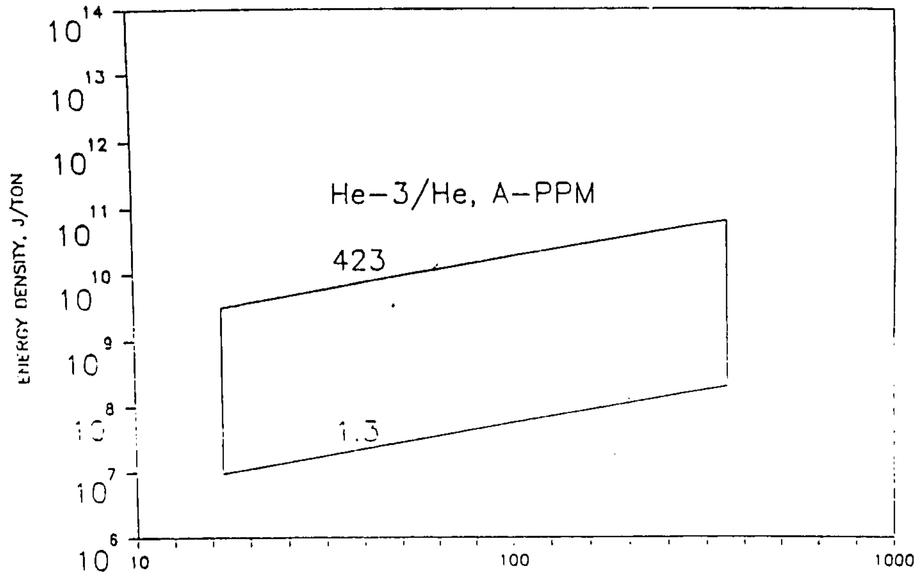

Figure 1

TERRESTRIAL ENERGY SOURCES

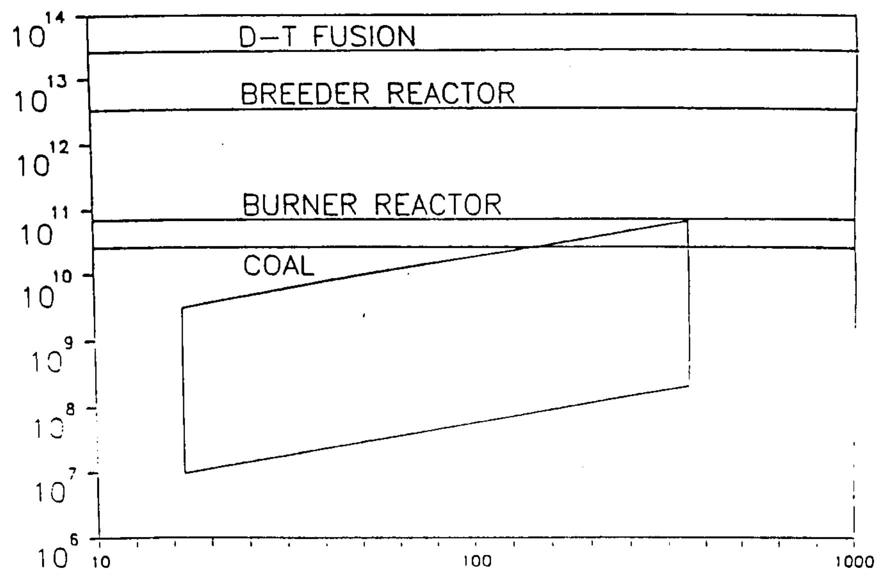

Figure 2