Nuclear Materials: Reconsidering Wastes and Assets – 13193

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ABSTRACT

The nuclear industry, both in the commercial and the government sectors, has generated large quantities of material that span the spectrum of usefulness, from highly valuable ("assets") to worthless ("wastes"). In many cases, the decision parameters are clear. Transuranic waste and high level waste, for example, have no value, and is either in a final disposition path today, or – in the case of high level waste – awaiting a policy decision about final disposition. Other materials, though discardable, have intrinsic scientific or market value that may be hidden by the complexity, hazard, or cost of recovery. An informed decision process should acknowledge the asset value, or lack of value, of the complete inventory of materials, and the structure necessary to implement the range of possible options.

It is important that informed decisions are made about the asset value for the variety of nuclear materials available. For example, there is a significant quantity of spent fuel available for recycle (an estimated $4 billion value in the Savannah River Site's (SRS) L area alone); in fact, SRS has already blended down more than 300 metric tons of uranium for commercial reactor use. Over 34 metric tons of surplus plutonium is also on a path to be used as commercial fuel. There are other radiological materials that are routinely handled at the site in large quantities that should be viewed as strategically important and / or commercially viable. In some cases, these materials are irreplaceable domestically, and failure to consider their recovery could jeopardize our technological leadership or national defense.

The inventories of nuclear materials at SRS that have been characterized as "waste" include isotopes of plutonium, uranium, americium, and helium. Although planning has been performed to establish the technical and regulatory bases for their discard and disposal, recovery of these materials is both economically attractive and in the national interest.

INTRODUCTION

The historical missions performed at the SRS have required vast flows of nuclear materials to support scientific and national defense objectives. With the end of the Cold War, the site's inventory of legacy nuclear materials, now excess to the nation's needs, require disposition.

Much of the radioactive material in storage at the site was intentionally separated from "valuable" materials (plutonium and uranium), and can rightly be called "waste". These materials are in a variety of solidified forms, including bulk boxed solids, drummed solids, and containerized glass. Disposition paths have been defined for these materials, and programs are in place to send these materials off site.

SRS will continue to receive nuclear materials for storage and eventual disposition. Much of the material is excess to national need, and could be discarded when suitable repositories become available. However, many of the materials (and related by-products) have intrinsic scientific or commercial value that makes recovery attractive.

Plutonium and Uranium

Legacy plutonium and uranium, in the form of spent fuel and unirradiated materials, are accumulating at the site as the Department of Energy continues receipts of research reactor fuel and consolidates its nuclear materials inventory. Although these materials are no longer required to complete DOE's mission, dispositioning them as "wastes" ignores their value as an energy resource for the nation.

While much of the plutonium is awaiting conversion to mixed oxide fuel, a quantity of impure plutonium could be purified to be suitable for mixed oxide (MOX) fuel. This can provide an additional 200 fuel assemblies capable of producing nearly $2 billion of electricity that can supply two million homes for a year. Similarly, the spent fuel at SRS could also be processed to provide fuel suitable for use in a commercial reactor, such as those operated by the Tennessee Valley Authority, or across the Savannah River at Georgia Power's Plant Vogtle. The electricity generated from the recovered uranium can provide enough electricity, valued at more than $6 billion, to power about six million homes for one year.

The cost of providing this fuel would be a small fraction of the nearly $900 million required for fuel produced from mining and enriching an equivalent amount of uranium from ore. Fuel processing could also provide recovery of other valuable isotopes for scientific and commercial use.

The total energy produced by the fissioning of SRS plutonium and uranium materials in the reactor is equal to

- 60 billion kgs (70 million tons) of coal ($3.5 billion)
- 40 million m^3 (250 million barrels) of oil ($22.5 billion)
- 4 trillion m^3 (140 trillion cubic feet) of natural gas ($4.0 billion)

All of this energy is produced without the generation of any greenhouse gases to harm the environment. As shown in Figure 1, coal will remain the dominant source for electricity supply in the United States. However, as EPA regulation escalates, and international pressure for greenhouse gas reductions increases, a shift away from coal could present an opportunity for large gains in nuclear power for base load electricity generation.

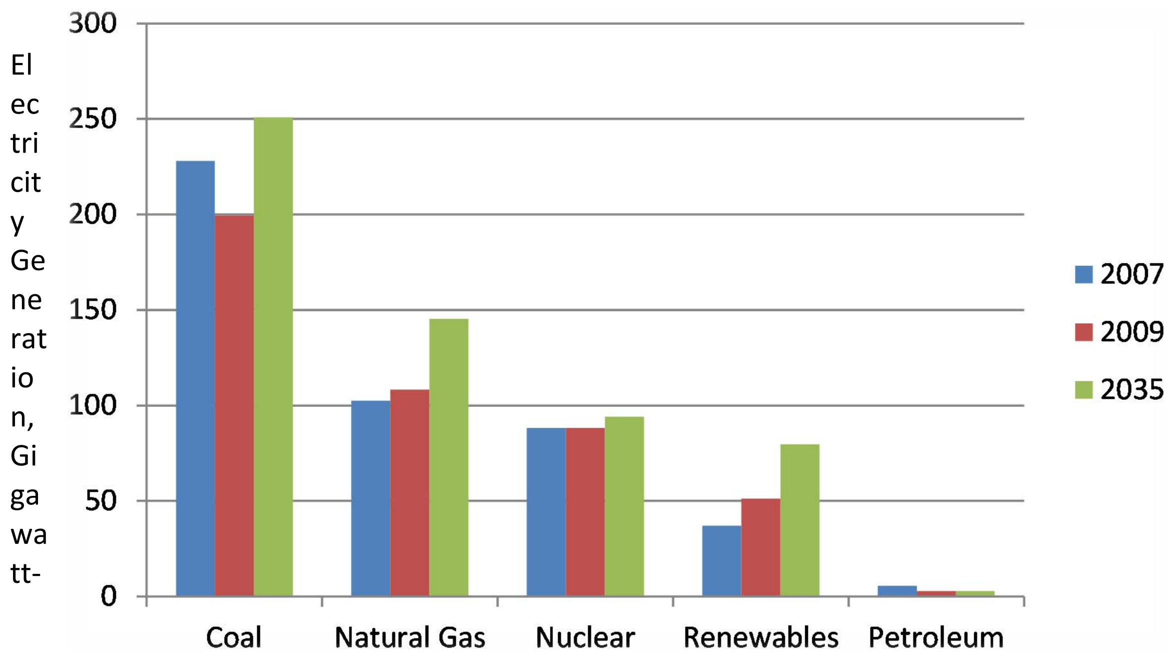

Figure 1. Electricity Generation by Fuel Type - 2007, 2009, and 2035 (projected)[1]

[1] U.S. Energy Information Administration/Annual Energy Outlook – 2011

The spent fuel and impure plutonium at SRS could also be turned into starter feed material for an advanced reactor that could provide substantially more electrical value than conventional reactors. These reactors can more efficiently consume the uranium and plutonium in the fuel, and can eventually be operated using fuel fabricated from spent commercial fuel. While reprocessing and fabrication costs are higher for these advanced technologies, energy production from fully utilized nuclear fuel can be as much as ten times higher for each pound of uranium in the fuel. In fact, the existing U.S. inventory of available uranium from spent fuel and fuel fabrication operations can supply enough energy to meet the total electricity demand (Figure 2) of the United States for about 300 years.

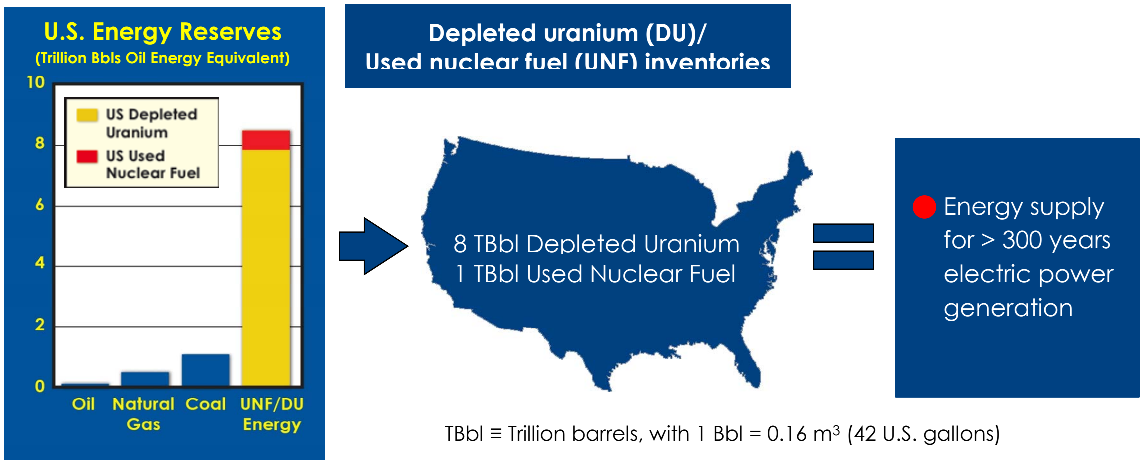

Figure 2. United States Energy Reserves

While the economics of fuel recycling can be debated, the energy value of these materials (and in particular, for the SRS fuel) is indisputable. If the SRS materials will not be reprocessed, then they must be disposed as waste. Packaging, transportation, and disposal of this fuel in a waste repository will likely cost hundreds of millions of dollars. This will be in addition to the hundreds of millions of dollars required for storage, monitoring, and safeguarding of the materials awaiting the selection, construction, and operation of the repository site.

Since rising living standards correlate well with rising energy consumption, the next generation of Americans will rightly question our short-sightedness and disregard for our economic future in ignoring this huge energy resource. We have the technical skill – we must find the political will.

Americium

The principle isotope of interest is Am-241, which historically has been present throughout the history of the Weapons' Complex as a "waste" that is produced from radioactive decay of the Pu-241 present in nuclear weapons. Americium removal (and subsequent disposal) has been a high priority, mainly because of the radiation exposure it causes to workers in processing facilities.

However, commercial applications have been developed that benefit from the unique properties of Am-241. Americium can be handled commercially and fabricated into sources (Figure 3) for industrial use, including:

- Thickness gauging of light alloys, plastics, rubber, and flowing fluids
- Non-destructive material analysis based on spectrometry
- Ionization smoke detectors
- Target material for higher transplutonium actinide production

Figure 3. Americium Sources for Commercial Industrial Applications

When combined with beryllium, the americium can provide a generous source of neutrons for use in material analysis, thickness gauging, and well logging.

Although much of the legacy Am-241 at SRS has been transferred to the waste tanks for vitrification and disposal as high level waste, the Mixed Oxide Fuel Fabrication Facility (MFFF) offers a unique opportunity for recovery of this valuable isotope. The front end aqueous polishing processing of 34 metric tons of weapons-grade plutonium will separate over 200 kilograms of Am-241 over the facility life. An evaluation could be performed to determine the scientific, commercial, and environmental benefits of recovering this material for reuse.

Helium-3

SRS has a long history of tritium operations in support of the country's nuclear weapons stockpile, and is recognized as the "Tritium Center of Excellence" for the Department of Energy (DOE). An important function of the Tritium Facilities at SRS is the processing and purification of reservoirs in nuclear weapons to purify and replenish the stored tritium, which has a radioactive half-life of about twelve years.

Helium-3 (He-3) is a stable isotope that is formed by radioactive decay of tritium. Although technically a "waste" product, it is an extremely valuable material, used in neutron detectors, well logging, medical imaging, and ultra-low temperature physics research related to superconducting and superfluidic materials properties. It is an essential component for the operation of neutron scattering facilities (Spallation Neutron Source) and cryogenic applications related to development of supercomputing and nanomaterials fabrication.

To date, the principle source of He-3 has been material recovered from recycled weapons material at SRS, and marketed commercially by DOE. Since the terrorist attacks of September, 2001, the increased demand for container monitoring and other security systems, coupled with declining tritium processing at SRS, are creating a global shortage of this material, as shown in Figure 4.

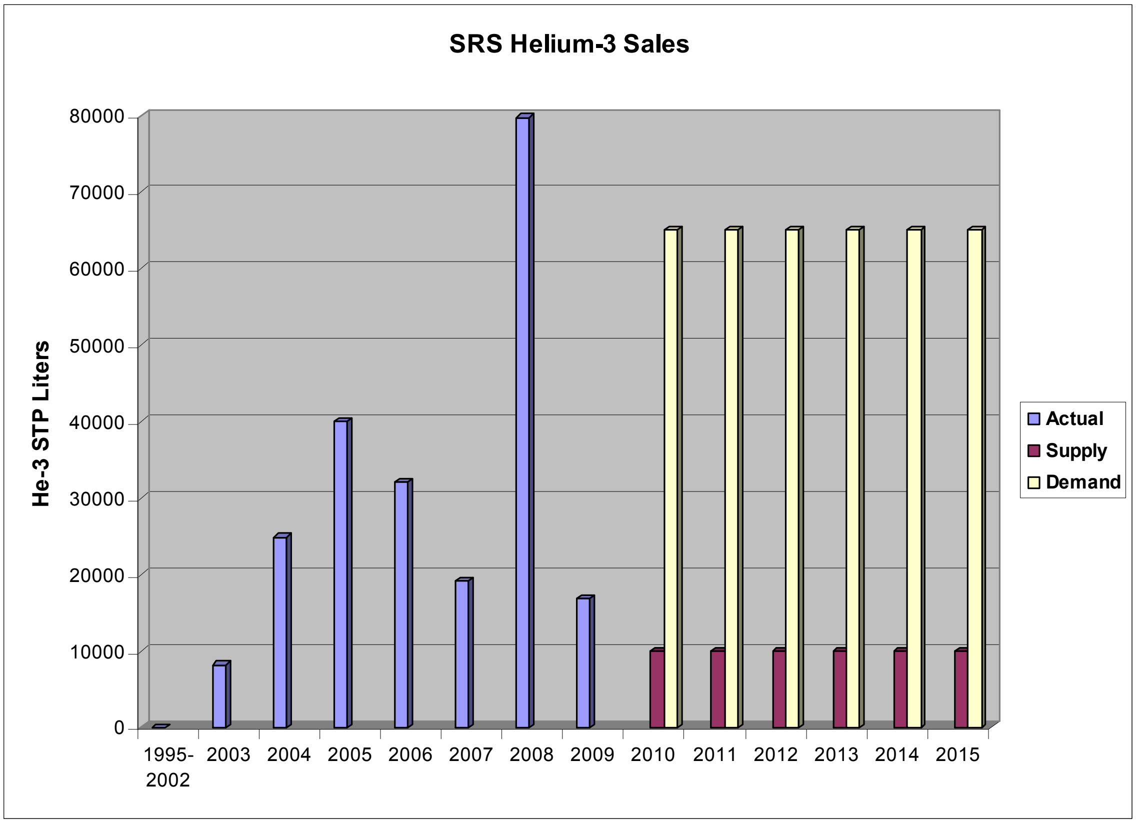

Figure 4. Past and Projected Sales of Helium-3

In addition tritium operations, additional sources of helium-3 must be sought out to meet expected global demand of more than 60,000 liters per year. The reality of the supply/demand situation has resulted in a 20-fold price increase of this "waste" to $2,000 per liter.

CONCLUSION

Historically, the nuclear industry (both commercial and military) has been able to distinctly identify "assets" and "wastes" in accordance with programmatic needs and defined disposition paths. Due to changing economic, regulatory, environmental, and technological factors, materials once categorized as "waste" are being re-evaluated to determine if they have intrinsic value as "assets". The Savannah River Site has the facilities and the technological expertise to identify and capture the value from these materials for scientific research and energy security.