TABLE 2
Comparative costs of uranium enrichment alternatives

Process	Capital	Energy	Labor and material
Gaseous diffusion	High ($300–400 per SWU/year)	High (~2,400 kWh/SWU)	Low
Gas centrifuge (Set V)	High ($400–500 per SWU/year)	Low (~100 kWh/SWU)	Low
Laser isotope separation	Low ($100–150 per SWU/year)	Low (~100 kWh/SWU)	Low

Source: Lawrence Livermore National Laboratory, "Business Development Opportunities in Laser Applications: Isotope Separation," p. 4.

The basic advantages—low capital costs and low energy costs—of the AVLIS system are shown here. As can be seen, the gas centrifuge system is more energy-efficient than gaseous diffusion, but the capital cost is about the same.

The isotope market

The existence of isotopes has been known since the early 1900s, but it was only after the Manhattan Project work during World War II that artificially produced isotopes came into commercial use because they could be cheaply produced in nuclear reactors or by accelerators. The isotopes of an element are basically the same chemically but differ in the number of neutrons present in the nucleus of the atom. Uranium-238 is so designated because it has 92 protons and 146 neutrons in its nucleus, which add up to 238. Uranium-235 has the same number of protons but only 143 neutrons. The similarity of the chemical properties of isotopes is what makes it so difficult to alter the naturally occurring proportions of isotopes.

The Atoms for Peace program spurred the growth of hundreds of applications for isotope research worldwide. In the late 1950s, the International Atomic Energy Agency awarded millions of dollars in research funds to laboratories and institutes, especially in the developing countries, to encourage research on using isotopes in biology, medicine, water resources, agriculture, plant breeding, insect and pest control, livestock production, pollution, and food preservation.

How radioactive isotopes came to be used as biological tracers is quite an unappetizing story. In 1911, George de Hevesy, a pioneer in work with radioactive elements who won the Nobel Prize in 1943, reportedly suspected his boarding-house landlady in Manchester, England, of serving recycled food scraps. One day he took a trace of radioactive material from his laboratory and put it in the leftovers on his plate. Sure enough, several days later when he was served the same dish, he tested it with a gold leaf electroscope and discovered that he was right: The food was radioactive, proving that the landlady recycled table scraps.

Today radioisotopes are an essential part of medical diagnosis and treatment, and new applications continuously being developed. Radiochemicals is a $65 million-a-year business; and radiopharmaceuticals a $200 million-a-year business and growing at a yearly rate of 15%.*

Almost every industry today makes use of isotopes, particularly radioisotopes, in some form—as a tracer, as an instrument gauge, or as a chemical catalyst. Radioisotope instruments can make measurements down to a thousandth of an inch without coming into direct contact with the material or substance being measured, need little maintenance, and are economical. For example, a radioisotope gauge in a galvanizing machine can save 10% of the tin used. Thus the cost of the gauge, approximately $200,000 in the late 1970s, could be recovered within a year.

Similar savings can be realized in other production processes. Gamma radiography, using a source like iridium-192, is used to check the structural integrity of pipes and metal castings without damaging them. Radioisotopes are also used routinely in the making of plastics to graft them to other materials and in geophysical exploration for uranium, oil, and other minerals. Nonradioactive isotopes are used in weapons diagnostics to measure radiation flux density and energy distribution from weapons tests.

* "PSP: The Plasma Separation Process for Isotope Separation," by Steve L. Korn, Laurence N. Harnett, Thomas E. Romesser, and Sol R. Rocklin, *TRW Electronics & Defense/Quest*, Winter 1982-1983, p. 21.