The Nuclear Fuel Cycle vs. The Carbon Cycle: Pu vs. C

RODNEY C. EWING[1]

[1]Geological and Environmental Sciences, Stanford University, Stanford, CA 94305 (rewing1@stanford.edu)

One hundred commercial nuclear reactors in the United States generate ~ 800 billion kWh of energy each year. This accounts for 19% of the electricity generated in the U.S. The nuclear power plants (NPP) themselves produce no carbon dioxide, but the construction of the NPPs does require energy that leads to limited CO_2 emissions. The essential issue is: What is required of the nuclear fuel cycle in order to have a significant impact on the carbon cycle.

Globally, nuclear power plants account for a reduction of carbon emmissions of ~ 0.5 gigatonnes (Gt) of C/yr This is a modest reduction, as compared with global eissions of carbon, just over 8 GtC/yr. Most analyses suggest that in order to have a timely impact on carbon emissions, carbon-free sources, such as nuclear power, would have to expand total production of energy by factors of three to ten by 2050.

A three-fold increase in nuclear power capactiy would result in a projected reduction in carbon emissions of 1 to 2 Gt C/yr, depending on the type of carbon-based energy source that is displaced. This three-fold increase utilizing present nuclear technologies would create 25,000 metric tonnes (t) of spent nuclear fuel (SNF) per year, containing over 200 t of plutonium. This is compared to a present global inventory of approixately ~300,000 metric tons of heavy metal (tHM) of SNF, which contains over 2,000 t of Pu. At present, the amount of separated Pu from weapons and commercial power production is ~ 500 t. A nuclear weapon can be fashioned from less that 5 kg of ^{239}Pu. However, there is considerable technological flexibility in the nuclear fuel cycle. There are three types of nuclear fuel cycles that might be utilized for the increased production of energy: open, closed, or a symbiotic combination of different types of reactors. The neutron energy spectrum has a significant effect on the fission product yield; and the consumption of long-live actinides, by fission, is best achieved by fast neutrons. Within each cycle, the volume and composition of the high-level nuclear waste and fissile material depend on the type of nuclear fuel, the amount of burn-up, the extent of radionuclide separation during reprocessing, and the types of materials used to immobilize different radionuclides. Further, the nuclear fuel cycle can be augmented by the different strategies provided by immobilization of nuclear waste and geologic disposal, which can, properly designed, substantially reduce the risk associated with the production of fissile material.