22.251 Systems Analysis of the Nuclear Fuel Cycle
Fall 2009
PROBLEM SET #1

State the assumptions that you made in order to reach answers to the questions below.

(1)   The USEC is currently in the process of gradually integrating some 500 MT of highly enriched uranium (HEU) from Russia as part of the nuclear weapons "Megatons to Megawatts" program. The HEU (at 90% U-235)* is blended down to 5 w/o U-235* in Russia before export by mixing it with natural U*(at 0.711 w/o U-235).

   (1.a)   How much net newly-mined U_{NAT} will this displace, assuming an enrichment plant tails of 0.3 w/o U-235*?

   (1.b)   How much SWU will this displace?

   (1.c)   How many reactor full-power years of energy is represented by the 5 w/o product, assuming:
                discharge burnup = 60 MWd/kg
                Reactor rating = 1150 MWe; 3411 MWth

   (1.d)   Assume that natural uranium costs 100 $/kg and SWU 130 $/kg on today's market. How much is the Russian blended-down product worth? Is it a bargain at the (originally) agreed to price of 12 billion dollars?

(2)   Consider the spent fuel from the Russian origin fuel:

   (2.a)   What is the volume of the spent fuel assemblies represented by this deal if the fuel density is 10 g/cc and the fuel is 25% of the fuel volume?

   (2.b)   What is the total activity in curies that is associated with the spent fuel at discharge? [see Table 9.1 of the Textbook, attached]

   (2.c)   What is the ore volume that is "saved" by this deal?
           (See Table 9.1 for info)

   (2.d)   What is the total waste saved from conversion and enrichment?

*assume for simplicity

(3)   The following was reported by the Reuters news agency on Sept. 1 2004:
"The International Atomic Energy Agency (IAEA) said in the confidential report
circulated to diplomats and obtained by Reuters that Iran planned a "larger test" of
a uranium conversion facility "involving 37 tons of yellowcake."

David Albright, a former U.N. weapons inspector and currently president of the
Institute for Science and International Security (ISIS) said this could theoretically
result in 100 kg of weapons-grade highly-enriched uranium."

(3.a)   Do you agree with this (implied) calculation? What tails enrichment is
required to make the calculation correct?
(Assume "weapons-grade" is 93 w/o)

(3.b)   How many SWU are required to produce the 100kg weapon grade HEU?

(3.c)   Twenty percent is the U235 enrichment considered as the boundary
between "proliferative" and "non-proliferative". (More on this in a later
lecture.) How many kilograms of 20 w/o enriched uranium are require to
produce 100 kg of weapons-grade uranium, (that is, you use the 20 w/o
material as feed to the enrichment process)? How many SWU are
required?

Lifetime Radioactive Waste Generation from a PWR and a BWR[†]

Waste type	Reference PWR, 1 GW(e)		Reference BWR, 1 GW(e)	
	Volume (m^3)	Radioactivity (Undecayed Curies)	Volume (m^3)	Radioactivity (Undecayed Curies)
Once-through fuel cycle wastes				
Mill tailings	4.353×10^6	3.710×10^4	4.867×10^6	4.149×10^4
LLW from uranium conversion[*]	3.411×10^2	9.813×10^3	3.814×10^2	1.097×10^4
LLW from uranium enrichment[**]	1.328×10^2	9.716×10^3	1.356×10^2	1.080×10^4
LLW from fuel fabrication	3.063×10^3	7.288×10^0	4.110×10^3	9.781×10^0
LLW from reactor power generation	3.032×10^4	2.866×10^4	5.217×10^4	7.956×10^4
Reactor spent fuel	5.213×10^2	$3.270 \times 10^{9***}$	6.996×10^2	$3.342 \times 10^{9***}$
Decommissioning waste				
LLW	1.510×10^4	1.057×10^5	1.640×10^4	2.532×10^5
Greater than class C	1.130×10^2	4.070×10^6	4.070×10^1	3.300×10^6
Totals	4.403×10^6	3.274×10^9	4.941×10^6	3.348×10^9

†Waste generated from 40yr of reactor operation and 26 GW(e)-yr of electric production.

*Applies to the fluorination/fractionation process.

**Applies to the gaseous diffusion process.

***Based on activity level measured 1 yr after reactor discharge. For the PWR, these levels are based on a burnup of 33,000 MWD/MTIHM.
    Activity levels reported for the BWR based on a burnup of 27,500 MWD/MTIHM

22.251 Systems Analysis of the Nuclear Fuel Cycle
Fall 2009