SE Take Home Exam 2 Solution

December 6, 2010

1. a. The fissile material in the discharged fuel consists of 235U, 239Pu, and to a lesser extent, 241Pu, 237Np, and 241Am. Recall that fissile means that the isotope can be fissioned with a neutron of any energy, where other isotopes require a high energy neutron in order to surpass the fission activation barrier.

b. We assume that all of the fission products originate with the fission of 235U. We know that by discharge, we have destroyed 4 wt% of the fuel's weight uranium. Not all of the mass of the fuel consists of uranium, however, so we need to adjust to account for the presence of oxygen. Also, not all of this mass appears as fission products. During the fission process, a number of free neutrons are released, continuing on to react with other isotopes in the material. The result is that we end up with

$$\frac{235 - \nu}{235} \frac{0.05*235 + 0.95*238}{0.05*235 + 0.95*238 + 2*16}(4\%) = \frac{235 - 2.5}{235}(0.881)(4\%) = 3.488\%$$

fission products in the fuel. This is not exact, as many of the neutrons go on to be captured by fission products and increase their masses, but it is a good first approximation.

c. By the end of an operating cycle, we have fissioned 4%*0.881=3.524% of the weight of the original fuel. This means that we've fissioned 35.24 grams of 235U. Approximately 200 MeV per fission event is recoverable (published values of this number vary, so it's okay if you use a different one).

$$\frac{35.24g}{235g/mol} \frac{6.022x1023a}{mol} \frac{200MeV}{a} \frac{1.6x10-13J}{MeV} = 2.89x1012J$$

d. This assumption is not accurate because as fuel is depleted, 239Pu is being produced, and this 239Pu is being simultaneously depleted. By the end of the fuel's residence time in the core, much of its power is being produced by fission of 239Pu.

e. The increase in conversion ratio means that the probability of producing a new fissile nucleus with each fission event is increased fivefold. This increase also means that 239Pu will produce an increased fraction of the power generated by the reactor. Additionally, since fuel is being depleted at an overall slower rate, the residence time of the fuel in the core can be extended.

2.

Interest Group	Costs	Benefits
Homeowners	Future maintenance costs not covered	Free electricity, plus money from sale of excess
Taxpayers	Not all taxpayers are homeowners, but all burdened with costs of program	Subsidy of renewables benefits environment
Solar PV manufacturers	Potential scarcity of materials if demand is high enough	Huge demand
Solar PV installers	Decline in demand after initial boom	Huge demand for services initially
Solar PV maintenance		Increasing, then plateauing demand
Electricity consumers	High cost of renewables passed on to consumer	Greater fraction of purchased power comes from renewables
ons suffering health impacts from coal		Improved air quality
future residents of CA, OR, NV	Economic consequences to regional utilities	Improved air quality
persons benefitted by other uses	Money spent could be used for education, health care, police, etc.	Subsidy of renewables benefits environment

Extra credit: This is a difficult task in that the costs and benefits of each follow different units of measurement. It's difficult to compare dollar amounts with quality of life improvements, or with health improvements. So one of two approaches is possible: one could either put all of the costs and benefits in the same unit of measurement and sum them up (assigning a dollar value to improvements in health/reduced costs of healthcare, for example), or one could divide up the costs and benefits into groups which can be defined by the same units of measurement and sum each group. Then the analyst would, for example, be free to compare the total economic impact of the project with the total quality of life improvement, or amount of greenhouse gas saved, and draw conclusions from that.

22.081J / 2.650J / 10.291J / 1.818J / 2.65J / 10.391J / 11.371J / 22.811J / ESD.166J
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