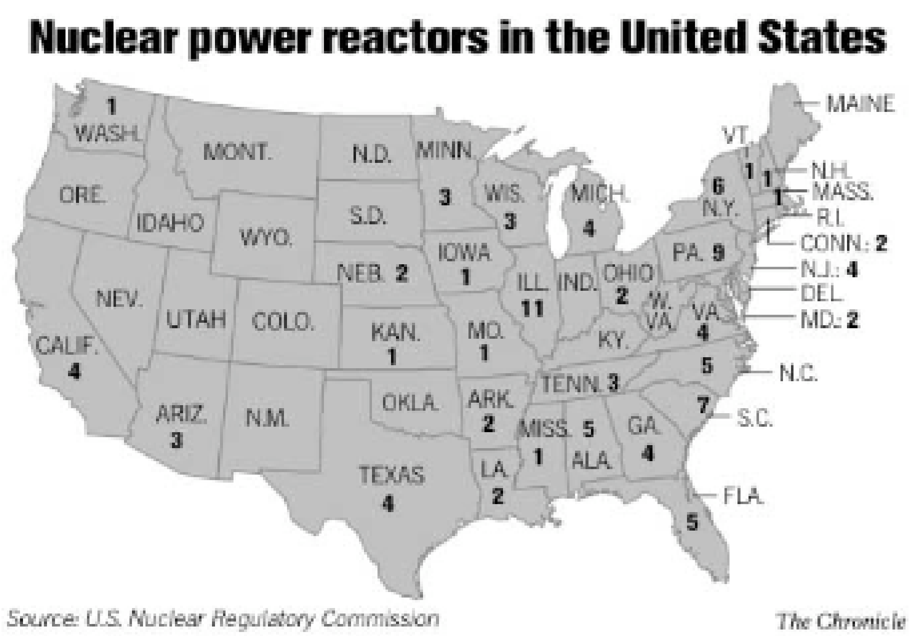
Essay 2 - Nuclear Waste

Introduction:

In the summer of 1939, Albert Einstein sent a letter to President Franklin Delano Roosevelt in which he alerted the President to recent scientific work in physics involving nuclear chain reaction in a mass of uranium, which could, he thought, lead to the construction of extremely powerful bombs. Einstein expressed concern that Germany had stopped the sale of uranium from mines in Czechoslovakia, and stated that American work on uranium was being repeated at the Kaiser-Wilhelm Institute in Berlin. He recommended that the Administration should establish contact with American physicists working on chain reaction and should provide financial support for that work.

Einstein's letter was the initial impetus for the Manhattan Project, a secret World War II effort on a remote mesa at Los Alamos, New Mexico. Robert Oppenheimer was selected as director of the new laboratory, and he recruited many of the top physicists in the nation to work on the project. Hans Bethe, a physicist from Cornell University who later won a Nobel Prize for his work on chain reactions that supply the energy in the stars, headed the Theoretical Division at the lab. In a little over two years, the physicists at the lab at Los Alamos succeeded in designing, building, and testing an atomic bomb. Two atomic bombs were used at the end of World War II against the cities of Hiroshima and Nagasaki, Japan. The destructive power of the bombs was so horrifying that none have been used since.

After the war, the government began promoting peaceful uses of atomic energy to a skeptical American public. President Dwight Eisenhower, in a 1953 speech to the United Nations titled "Atoms for Peace", promoted the use of atomic energy for the generation of electrical energy. In 1955, Lewis Strauss, the chairman of the Atomic Energy Commission, suggested that in the future, Americans would "enjoy in their homes electrical energy too cheap to meter." Because of uncertainties about the risks posed by nuclear power, however, the insurance industry refused to insure nuclear power plants. As a result, Congress passed the Price-Anderson Act in 1957. The goal was to encourage the development of the nuclear power industry by shielding the power companies from responsibility in the event of a nuclear accident. No other industry enjoys this kind of Federal protection. The Price-Anderson Act has been renewed periodically since 1957, most recently in 2005. With the protection offered by the Price-Anderson Act, the public utility companies in America constructed dozens of nuclear power plants in the 1960's and 1970's, plants which today supply about 20% of the nation's electrical energy.



In a paper titled "The Necessity of Fission Power" published in the January, 1976 issue of *Scientific American*, Hans Bethe argued that "if the U. S. must have sources of energy other than fossil fuels, the only source that can make a major contribution between now and the end of the century is nuclear fission." The price of oil had quadrupled in the fall of 1973, which sent a shock through our economic system. One political response to this was the call for America to become "energy independent," and Bethe's article addressed the feasibility of that question. The article examined alternatives to oil and coal (the fossil fuels), and concluded that, although energy sources such as solar power and wind power had some long term promise, only atomic energy had the potential to supply a significant portion of the energy America would need before the end of the century. Bethe then offered a detailed discussion of both the promise and the problems of nuclear power, including a careful look at the challenges posed by nuclear waste. He suggested, in the article, that the United States should construct as many as 600 reactors by the year 2000.

The move to nuclear energy envisioned by Hans Bethe never happened. In fact, power companies in the United States have ordered no new reactors since the 1970's. In California, for example, only two nuclear power plants are in operation: San Onofre, south of Los Angeles on the coast, and Diablo Canyon, on the coast near San Luis Obispo. Pacific Gas and Electric (PG&E) had plans for plants at Davenport (just north of Santa Cruz), and at Bodega Bay and Point Arena, areas of great scenic beauty on the north coast. The Los Angeles Department of Water and Power (LADWP) tried to build plants in Malibu and in Kern county near Bakersfield. And San Diego Gas and Electric (SDG&E) proposed construction of the Sundesert plant, near Blythe on the Colorado River, to be followed by four additional plants. But the public, already concerned about radioactive fallout from atmospheric testing of atomic weapons by the United States and Russia, had serious doubts about the wisdom of using nuclear power. Eventually, public opposition, safety concerns (several of the proposed sites were on or near earthquake faults), rising costs, and, finally, state legislation forced cancellation of all of these plants. Two subsequent events solidified American public opinion against the construction of new nuclear plants: the partial meltdown at Three Mile Island in Pennsylvania (1979) and the far more serious explosion at Chernobyl in the Ukraine (1986). Nuclear power was effectively dead as an energy source for the United States.

In retrospect, along with issues of plant safety brought to the fore by the Three Mile Island and Chernobyl events, perhaps the most serious problem with nuclear power was the difficulty of disposing of nuclear waste. The fuel used to power the plants is radioactive, and therefore extremely dangerous. When the fuel rods are spent, they are removed from the reactor for storage elsewhere; and they are still radioactive at this point. The spent fuel rods are currently stored in cooling ponds and concrete containers at the plant sites, but there is general agreement that this is not a satisfactory long term solution. One of the bills passed by the California Legislature (1976) forbids construction of new nuclear plants in California until the State Energy Commission certifies that the federal government has found a solution to the problem of radioactive waste disposal. Today, 30 years later, there is still no solution to this problem.

In 1987 Congress identified Yucca Mountain in Nevada as the site of a permanent storage facility for radioactive nuclear waste, and directed the Secretary of Energy to conduct a feasibility study of the site. The plan is to bury the waste underground in Yucca Mountain, and the site does have much to recommend it. After years of study, President Bush, in 2002, authorized construction of a nuclear waste repository at Yucca Mountain. The State of Nevada, on the other hand, strongly opposes the Yucca Mountain site. It is only 100 miles from Las Vegas, and there are concerns about transportation of radioactive materials to the site and about seepage of radioactive waste into the aquifer that underlies Yucca Mountain. The State of Nevada is suing the federal government about the matter. It remains to be seen whether Yucca Mountain will actually be developed as a nuclear waste storage facility.

But now, in spite of the fact that major problems with nuclear power remain unresolved, nuclear power is making a comeback. After thirty years of no activity on the nuclear front, there are now a number of pending applications for the construction of new nuclear plants. President Bush is pushing nuclear energy, and even environmentalists are taking a second look. Is this wise?

In this paper, we want to carefully consider one aspect of the storage problem for nuclear waste: for how long must the radioactive material be safely stored? We return to the 1976 *Scientific American* article for a statement of the problem. Hans Bethe writes that plutonium 239, one of the products of fission reactors, has a half-life of 25,000 years, and suggests that the material will not be safe until the level of radioactivity is cut by a factor of 1000. For how long must a storage facility (in Yucca Mountain or elsewhere) keep the radioactive waste out of the biosphere?

Initial Mathematical Work:

Before you write your essay, begin with a mathematical analysis. Some initial mathematical work will get you started.

- Suppose that we begin to store waste in Yucca Mountain in the year 2010. Let t represent the number of years (into the future) and P(t) represent the level of radioactivity at time t. And suppose that the initial level of radioactivity is P_0.

- Use the fact that the half-life of plutonium 239 is 25,000 years to construct an exponential decay model for the level of radioactivity of the nuclear waste inside Yucca Mountain at time t years in the future. The mathematical details of this work should be presented in an appendix.

- Build a spreadsheet to implement your model. You may want to use increments of 10,000 years, and you will need to extend the spreadsheet far into the future to find how long it will be until the level of radioactivity will be cut by a factor of 1,000.

- Use the spreadsheet to construct a graph of the model. Again, the graph will need to extend far into the future.

- Use your model to predict the level of radioactivity after 10,000 years, as a percentage of the original level of radioactivity.

- Use your model to predict how long it will take for the level of radioactivity to be reduced by a factor of 5 (to 20% of the initial level or 0.20), by a factor of 10 (to 10% or 0.10), and by a factor of 1,000 (to 0.1% or 0.001). Mathematical details of these calculations should be shown in the appendix.

- Verify that your calculations are correct by using both the table and the graph to make the same predictions.

Be sure to incorporate the answers to the above questions in your discussion of the model in your paper. The mathematical details involved in deriving your model and in answering the final questions should be presented in an appendix to your paper.

Writing Your Paper:

Your paper should begin with an introduction that will appeal to the reader. It should introduce the information about half-life from Hans Bethe and continue with the development and presentation of a mathematical model (an exponential decay model) for the level of radioactivity of plutonium 239 in the future. Of course, the model must be presented with both a table and a graph. You should then interpret your model by specifically answering the four questions posed above. This should be followed by a rather extensive discussion of the implications of your model on the question of the feasibility of nuclear power. Feel free to draw on material from background reading for context, but do not adopt someone else's conclusions as your own. Your conclusion should be based on your own work and thoughts -- on the facts, as expressed by your mathematical model, and on your assessment of the implications of the model. Finish with a conclusion that draws your paper together, and addresses the central question here: would it be wise to construct additional nuclear power plants at this time?

Due Dates: Completed rough draft due Monday, March 20
Paper due on Thursday, March 23

Sources:
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