REPLY TO "COMMENTS ON 'TOTAL ENERGY INVESTMENT IN NUCLEAR POWER PLANTS' "

We thank Emmett and Winstanley for their comments and interest in energy analysis, and we address their objections below:

1. An energy analysis is superior to an economic analysis for the following reasons:

a. Energy is a physical quantity and barring any major technological change in doing things, the amount of energy required to perform a specific task today will be the same as the amount of energy required to perform the same task 20 years from now. This is not true of the dollar, which can change its value almost instantly depending on a variety of economic, social, and political conditions. Note that we said the results were generally independent of time because there are (and will be) technological changes. The point is that the variability of energy values with time is far less than the variability of the value of the dollar.

b. For the same reason, the amount of energy required to perform a specific task is completely independent of the cost of that energy. That is, if the supply of energy (not uranium ore) decreases, then by the law of supply and demand the cost of energy will rise. Nevertheless, the amount of energy (Btu's) required to perform the task still remains the same. We, therefore, stand by the assertion that "the results are generally independent of time, economic instability, and even the supply of energy." We made no statement claiming that the results were independent of the supply of uranium ore.

c. The fact that some forms of energy cost more than others is precisely one of the reasons that energy analysis is superior. If an energy analysis determines how much oil is required to do something, it doesn't matter where that oil comes from (other than the energy needed in transportation). On the other hand, an economic analysis is entirely dependent on whether the oil is domestic or foreign. It seems obvious to us that the goal should be to reduce the amount of energy used, and this is precisely what an energy analysis yields.

d. Without exception, all of the conditions proposed by Emmett and Winstanley, which alter the results of an energy analysis, would also alter the results of an economic analysis and, therefore, nothing could be gained by preferring the latter. In fact, it seems that it would be much more important to consider how different conditions would affect the amount of energy used rather than the dollar costs.

2. The assumptions used in the foregoing energy analysis were the following:

a. 30-yr life for both coal and nuclear

b. 80% capacity factor for both coal and nuclear

c. 0.2% ore grade for U_3O_8

d. 50% ore grade for coal.

It is apparent that Emmett and Winstanley disagree with some of these assumptions and so naturally the results will change depending on what assumptions are used. What may seem reasonable to us may not seem reasonable to others, but to generate the results, certain assumptions have to be made. We regret that some of these assumptions were not explicitly stated in the paper. Note that changing any or all of these assumptions will not only change the energy costs but will change the dollar costs as well. The results of an economic analysis are just as vulnerable to the assumptions used as the results of an energy or any other analysis.

3. We agree that it is important to consider the indirect energy costs associated with the nuclear system. A more complete accounting of the energy investment can be found in Ref. 1. This work evaluates the indirect energy costs associated with the fuel cycle facilities, transportation, waste disposal, operation and maintenance, government subsidy, nuclear accidents, and environmental aspects (all of these secondary costs comprise ~20% of the total). Since such an exhaustive analysis of a coal plant has not been performed, these secondary costs were not included so that the comparison could be made on the same basis.

4. Finally, there is a dispute on how different forms of energy should be handled in an energy analysis (especially electrical energy). Consider the following inputs—50 Btu's of electricity and 50 Btu's of thermal energy for an output of 1000 Btu's of electricity. Basically, there are four ways to analyze these data:

a. Convert all energy to electricity. This assumes that the 50 Btu's of thermal energy could have been used to generate 50/3 = 17 Btu's of electricity. The energy ratio, energy in/energy out is then (50 + 17)/1000 = 6.7%.

b. Convert all input energy to thermal energy. This assumes that the output energy is "primary." The ratio is then $(50 \times 3 + 50)/1000 = 20\%$.

c. Assume that the output electricity can be substituted directly for all input energy. This is straightforward for the input electricity but may be conservative for the thermal energy because electricity is generally used more efficiently than thermal energy. In this case, the ratio is (50 + 50)/1000 = 10%.

d. Convert all energy forms to some other unit representing the amount of equivalent useful work available from the energy. This last case would account for the differences in efficiencies between electricity and thermal energy. For example, a natural gas water heater may be 62% efficient compared to a 95% efficient electric water heater. For this case, let the unit be the equivalent number of pounds of water that can be heated 1°F for each energy form:

50 Btu's electricity = $50 \times 0.95 = 47.5$ lb

50 Btu's thermal = $50 \times 0.62 = 31.0$ lb

1000 Btu's electricity = 950 lb .

The ratio for this case is then 78.5/950 = 8.3%.

Note that there are four different results depending on which method is chosen. As previously noted, we chose method 3, although method 4 is probably the most realistic, while method 2 is probably the most unrealistic. Hopefully, the scientific community can agree as to which method is best so that all future analyses will be made on the same basis.

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REFERENCE

1. C. T. ROMBOUGH and B. V. KOEN, "Total Energy Investment in Nuclear Power Plants," ESL-31, Energy Systems Laboratories, College of Engineering, The University of Texas, Austin, Texas; see also, *Nucl. Technol.*, **26**, 5 (1975).