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# An Analysis of the Economic Feasibility, Technical Significance, and Time Scale for Application of Peaceful Nuclear Explosions in the U.S., with Special Reference to the GURC Report Thereon

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Although we have benefited from the comments and advice of many people, the analyses and conclusions of this report are the responsibility of the panel members only. In particular, they should not be construed as representing official positions of the ACDA or any other department or agency of the U.S. government.

## Appendix C: COMPARATIVE COST ANALYSES FOR ELECTRIC POWER FROM PROJECT PACER

The panel is aware of the necessarily uncertain character of these cost comparisons, in that economic analysis of PACER, like the technical analysis, is in a very preliminary state. It follows that our comments are not to be regarded as a criticism of the available analyses of PACER, but only as our attempt to present as firm a basis for evaluation as we can with the concepts and ideas at hand. The comparison which we give is for electric power generation by a conventional Pressurized Water Reactor (PWR) and an assumed successful PACER generation system.

A PWR of 1000 Mw(e) in 1974 cost about $600 million, of which less than $75 million was for the nuclear steam system (NSS). Thus, the non-nuclear portion of the plant cost some $535 million. By contrast, a recent report[5] estimates the cost of a 2000 Mw(e) PACER plant at some $385 per kw, of which only some $142 per kw can be associated with the PACER NSS, namely the site selection and testing, cavity and shaft formation, pipes, and insertion system. Thus, that analysis ascribes to the non-nuclear portion of the plant about $243 per kw in contrast with the $525 per kw for actual PWR non-nuclear systems being purchased today. A more reasonable base for economic analysis would seem to be to assume equal cost per kw for the non-NSS aspects of a PWR plant and the non-NSS aspects of PACER, and we shall do that, so that capital costs for PACER are assumed to be $67 larger than for PWR ($142 minus $75). Assuming equal maintenance costs for PWR and PACER, and converting capital costs to energy costs with a factor of 15% per year and 80% capacity (7000 full-power hours per year), we find a non-fuel cost for PWR energy of B mills/kwh and a non-fuel cost for PACER energy of B + 1.4 mills/kwh, (where B is a "base" cost including maintenance and the charges on $525 per kw of capital.)

Both PACER and the PWR are assumed to have about 30% efficiency of conversion of thermal energy into electrical output. Thus, 1 kwh requires an input of 11,400 BTU. One gram of U-235 contributes about 77 million BTU. Thus, one kwh of electrical energy requires the supply of 0.15 milligrams of U-235. The PWR fuel cost is composed of contributions from the cost of fuel-element fabrication, U-235 isotope separation from natural uranium (at present by gaseous-diffusion process), and natural-uranium material cost. The total PWR fuel cost at present is given in the reference as 2 mill/kwh. The reference considers the cost of a PACER fuel charge as $42,000 or, alternatively, $100,000, but such estimates are very low compared with either the 1964 AEC statement of $460,000 for the explosive for a 100 kt PNE or the 1974 update of such estimates -- from $400,000 to $1,000,000 each, the mean of which was $700,000.

Since PACER has no capital advantage over the PWR and suffers substantially more restrictions as to siting (not to mention the uncertainty of costs and feasibility) and uses very similar technology and resources to the PWR (with the sole exception of the nuclear steam supply system and the nature of the fuel), it is of interest to compare the power costs from an assumed-successful PACER with those from the PWR as a function of PACER explosive costs and of natural uranium feed costs. We shall take for our comparison PACER explosive costs of $42,000, $100,000, $400,000, and $700,000 per 50 kt charge.

We shall ask the natural uranium supply price at which current fuel fabrication and isotope separation costs will provide PWR power at the same price as PACER power. Both plants are assumed to operate at 80% capacity. Natural uranium contains about 0.7% U-235, and the present separation plants run about 0.3% tails (thus requiring a feed of 219 grams of natural uranium per gram of pure U-235 in the output). If natural uranium prices become very high, the present plants can be rebalanced to run at 0.1% tails (and future separation technologies can naturally run at low tails fractions) to require only 158 grams of uranium feed per gram of U-235 output. With 0.3% tails, natural uranium feed at $140 per lb. will increase the cost of PWR power by

10 mill/kwh above the cost at zero uranium cost. At 0.1% tails, natural uranium would have to rise to $196 per lb. to increase the cost of power by 10 mill/kwh above the zero-uranium-charge cost.

As a function of uranium cost, U $/lb., the cost of power from the PWR is assumed to be

P (PWR) = B + 2 + U/$14.0 mill/kwh for 0.3% tails,

P (PWR) = B + 2 + U/$19.6 mill/kwh for 0.1% tails.

The cost of PACER power is assumed to be

P (PACER) = B + 1.4 + 6 FC/$100,000 mill/kwh,

where FC is the cost in dollars of the 50 kt thermonuclear charge. The 6 mill/kwh fuel cost for FC = $100,000 is consistent with the result shown in the reference. Thus, for equal electrical power costs, we have

B + 2 + U/$14.0 = B + 1.4 + 6 FC/$100,000 for 0.3% tails,

B + 2 + U/$19.6 = B + 1.4 + 6 FC/$100,000 for 0.1% tails.

For PACER to be economically preferred to the PWR, natural uranium supply prices must exceed the $/lb. figures given in the following table:

| | $42,000 | $100,000 | $400,000 | $700,000 | (cost of explosive) |
|---|---|---|---|---|---|
| 0.3% tails | $27/lb. | $76/lb. | $328/lb. | $580/lb. | |
| 0.1% tails | $38/lb. | $106/lb. | $459/lb. | $811/lb. | |

Since the present supply price of natural uranium is around $10/lb., PACER is unlikely to contribute in competition with the PWR (and even less in competition with advanced reactors) until the uranium supply is largely dependent on ores of very low uranium content.

Even for uranium prices of $1000 per pound or more, PACER would have to win out in competition with the breeder reactor, whose power cost is quite independent of natural uranium price, since it uses most of the U-238, rather than just the U-235.

The technical groups who are investigating PACER emphasize that production of fissile materials, i.e., Pu-239 from U-238 and U-233 from thorium, may be a much more significant use of PACER than just generation of electricity from the heated steam. Since studies of the technical aspects of this application (breeder yields, fissile material recovery, etc.) are in the earliest stages, we do not believe that a meaningful economic analysis is currently possible. When technical feasibility for this application is established and procedures are roughly delineated, the comparisons of importance will become those between this use of PACER and the various breeder reactor approaches, e.g., the LMFBR, since, when used in this mode, the power production from PACER itself will be secondary.