The Fusion Hybrid as a Response to William Parkins' Letter to *Science* Magazine

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William Parkins' letter (1) about fusion in the March 10, 2006 issue of *Science (and also included in the Fire web site, March 2006)* has recently been brought to my attention. In that letter, he gave estimates of the cost of a fusion reactor based on very simple considerations. These considerations included the size and cost of the neutron absorbing blanket, and the difficulty of maintaining an extremely large vacuum system with many ports and connections, and which produces and extracts gigawatts of average power. His conclusion was that fusion could not be economical. For instance he cited a Bechtel estimate that a 3GWth (1GWe) fusion plant would cost $15 billion. He then estimated a power cost, from capital cost alone, of 36 cents per kilowatt hour, far outside the competitive range. Several other letters concerning this were posted on the Fire web site, three of which were published in Science. One letter, by power company executives, said that of course fusion cannot be economical and they knew it all along. Another by Robert Bourque of LANL said that tokamak fusion cannot be economical and proposed large increases in the budget to find other more optimal confinement configurations. Three others, one by a group of Europeans, one by Farrokh Najmabadi and Charles Baker, and one by Steven Dean disputed Parkins, and asserted that he used outdated data, and that designs for economical fusion reactors are well known. I have neither the confidence nor competence to sort out the conflicting claims, but it seems to me that Parkins makes a reasonable case, certainly one that cannot be dismissed out of hand. After all, he had had a great deal of experience in the nuclear industry, and was chief scientist at Rockwell.

The purpose of this letter is to show, using the most pessimistic assumptions of Parkins, that if the fusion plant is run as a hybrid fuel factory, Parkins' estimate of the cost becomes much more reasonable. In conventional fusion, the reactor produces a 14 MeV neutron, which is absorbed in the blanket and with various heat exchangers, is used to run an electric power plant. The fusion hybrid, instead uses the neutron to transmute a fertile material such as ^{232}Th to ^{233}U, or ^{238}U to ^{239}Pu. However when say the ^{233}U is burned, it gives off about 200 MeV. Thus instead of using the kinetic energy of the neutron to boil water, it uses the neutron's potential energy to create about ten times more fuel.

The fusion hybrid is hardly a new idea. The earliest reference to it I have found dates to 1950 where Andrei Sakharov (2) made exactly this case. In the 1970's Hans Bethe (3) also advocated it, and many studies of it, with designs for plants, have been published in the scientific literature, mostly in the 1970's and early 1980's.

Taking Parkins' estimate, and assuming that the power plant is 1/3 efficient, his estimate of 36 cents per kilowatt hour of electricity becomes 12 cents for a kilowatt hour of raw neutron power. But if these neutrons are used to produce ten times more nuclear fuel, this becomes a fuel cost of only 1.2 cents per kwhr, now well within the competitive range (gasoline at a dollar a gallon is roughly 3 cents per kilowatt hour). This author, over the last decade or so has advocated that the fusion project shift its focus from pure fusion to the fusion hybrid (4-7). These paper cite much of the 1970's and 1980's work on various hybrid designs. They also make a case that over the next 50 years, world development does indeed require far more energy than can be supplied by mined uranium with a once through fuel cycle (and of course more than can be supplied by oil or natural gas). Furthermore, these papers made several other cases, first, that the adverse environmental effects of coal may hinder its widespread use, second that the environmental effects of the nuclear power can be made relatively benign, third, that renewable energy cannot support world development on the scale required, and fourth, that by embracing the hybrid, fusion may be able to produce power in large amounts by mid century when it will be desperately needed (8). Indeed, it seems to this author that breeding nuclear fuel, via either fission or fusion are about the only sources of mid century power in the quantity required. As such, they deserve strong government support.

1. W. E. Parkins, Science, 311, 1380, 2006
2. Andrei Sakharov, Memiors, Vintage Books, New York, 1990, page 142
3. H. Bethe, *The Fusion Hybrid,* Physics Today, May, 1979;
4. W. Manheimer, Fusion Tech. 36, 1, (1999);
5. W. Manheimer, J. Fusion Energy, 20, #4, 131, (2001, cc2003);
6. W. Manheimer, J. Fusion Energy, 23, #4, Dec 2004 (cc2005)
7. W. Manheimer, J. Fusion Energy, to be published 2006, available on line
8. M. Hoffert et al, Science, 298, 981, (2002)