THE FOREST AND THE TREES

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The development of fusion energy only occupies a very small part of the world's energy picture and the fusion community often has difficulty seeing the forest from the trees.

In the last few years, several big, game changing developments have occurred in energy. The biggest is the capturing of natural gas previously thought unrecoverable. With this development the U.S. has the potential to adequately meet energy needs for the foreseeable future, free ourselves from mideast politics, and reduce greenhouse emissions (in a longer term carbon sequestration will be required to eliminate emissions from natural gas). Solar power stations are also under construction that will demonstrate several hundred MW reliably delivered at affordable capital costs. In the the U.S., four new Gen-III nuclear reactors are under construction, and the first two AP-1000's will be on-line in 2016-17. Twelve new AP-1000's will be operational in China by the same time. These developments have eliminated the urgency of fusion energy development and show that safe nuclear and solar are fusion's economic competitors.

During these years of changing energy developments, fusion has been dominated by ITER. **ITER is the elephant in the room.** At its inception ITER was estimated to cost $4B (and our share was about $0.4B). First plasma was scheduled for 2014. At this level and with the provision that it be built on new money, it made sense for our community to rejoin ITER. ITER addresses key burning plasma research, but it's not a sure thing. Technically ITER could fail due to magnet issues, disruptions, diverter power load, etc. Scientifically ITER could show low stability limits and/or poor energy and particle confinement. Most importantly the huge $26B cost and complexity of ITER may provide the proof that fusion is unlikely to lead to a cost competitive power source. If you bought a car for $25k and were later notified that it will cost $150k, it

may not work and you are expected to sell-off your house and other assets to pay for it, would you protest?

Although the DoE charge attempts to avoid discussion of ITER, I don't think budgetary priorities can be discussed without discussing ITER and the role of the tokamak in the long-term development of cost-competitive fusion power. How best to spend the relatively small U.S. fusion base program budget (i.e. $250M or $300M) depends both on our judgement as to whether ITER will succeed technically and scientifically and also whether it will provide a path to commercial energy.

Looking at the "forest", big-picture of energy developments in the long term we must consider the competitive cost of a fusion power plant in the context of a long term (50 year) research and development effort. It seems clear to me that the fusion program needs to enlarge its research scope with a stronger focus on simpler confinement approaches that have the potential to provide a more cost effective energy source. It was folly, or worse, for DOE to close down promising and inexpensive research related to rotating mirrors (MCX at U Md), dipoles (LDX at MIT), FRCs (TSC at U Wash). Each of these intermediate scale experiments were successfully demonstrating that high-beta, steady state, disruption-free plasma confinement can be obtained without the large toroidal field coils that contribute to the high-cost of tokamak fusion.

Recommendations for a $300M+ base program budget:

1) Increased investment in small scale unorthodox confinement approaches at a level of at least 20% of the fusion budget. Additionally, advanced fuel research should be funded as it offers a possible solution of the the materials problem that is associated with the DT cycle.

2) An enlarged effort in stellarator research, including a quasi symmetric experiment that replaces one of the 3 large tokamaks (NSTX, C-mod, DIII-D). Such an effort would fit naturally at PPPL. Given budgetary constraints, this suggests having the NCSX stellarator replace NSTX.

Unfortunately, a transition at PPPL may be delayed by a period of operation of the upgraded NSTX facility.

3) Continued operation of C-mod and DIII-D. Closing down either C-mod or DIII-D would represent a significant loss of capability, scientific personnel and student training and therefore it is a very bad idea. Although I question whether the tokamak path will lead to a competitive power source, both C-mod and DIII-D are superlative facilities for the study of plasma physics in fusion grade plasmas.

Recommendation for a $250M base program budget:

While one could argue that budgetary concerns can be met if the US operates only one tokamak facility (in combination with a stellarator) I do not support the closing of productive facilities. Therefore, I would not consider a $250M base program budget and I would recommend leaving ITER rather than accepting the catastrophic reduction of the base program that would result from the budget cut required by a $250M budget.