FUSION DEMO CHARACTERISTICS & PATHS TO DEMO

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There are at least two ways to go about defining the characteristics of a DEMO, let's call them the roll-back and the roll-forward approaches.

The roll-back approach would start by defining the characteristics of a DEMO-rb which, if it was successful, would give electric utilities the confidence and motivation to start ordering fusion reactors. Today electric utilities can buy nuclear reactors that typically produce 600-1000 MWe for 1.7 cents per kilowatt hour with plant capacity factors of about 90% (i.e. the plant produces 90% of the electricity that it theoretically could if it ran at full power every second in the year). A fusion DEMO-rb would not have to meet these performance characteristics, but it would have to come close enough to make a convincing case that the fusion plant which followed would meet them. How close is close enough? My guess is that a DEMO-rb producing 300-600 MWe with a plant capacity factor which rose to 70-75% by the end of operation would be close enough. The 1.7 cents per kilowatt hour is going to be tough to come close enough to that arguments about higher first-of-a-kind costs and economy of scale are convincing, but surely the DEMO-rb must produce electricity for no more than 10-20 cents per kilowatt hour (gas and oil plants are at about 8, coal is at about 2) to be a successful demonstration of economic feasibility.

The roll-forward approach, which is the one that has always been taken in fusion and that was taken for ITER, would start by defining the characteristics of a DEMO-rf that we would have the confidence to build on the basis of the data-base provided by ITER and ITER-complementary facilities and activities, with a few modest but agonizing extrapolations.

Since DEMO-rb will have to be built some day on the path to fusion electricity, the charge to FESAC might be rephrased as a request to define those ITER-complementary facilities and activities that would make the resulting DEMO-rf have characteristics close enough to those of DEMO-rb to serve its purpose.

So, what are the likely characteristics of DEMO-rf extrapolated from ITER? ITER will produce 400 MWth and probably operate with an equivalent plant capacity factor < 10%. Extrapolating to 800-900 MWth (to get 300 MWe) or more in DEMO-rf is plausible. On the other hand, extrapolating from a plant capacity factor < 10% to 75% would not only require a focus of the ITER-complementary physics program on quasi-steady-state operation but also would require focusing a significantly expanded ITER-complementary fusion program on component reliability and the construction and operation of component test facilities to that end. The required extrapolation (reduction) relative to ITER in cents/kW-hr is several orders of magnitude. Thus, it seems unlikely that we could build a single DEMO-rf based on extrapolation of the data-base from ITER and ITER-complementary facilities and activities that would serve the purpose of a DEMO-rb which would give electric utilities the confidence and motivation to start ordering fusion reactors.

As far as I know, the most recent examination of the likely physical parameters of DEMO-rf was done more than a dozen years ago (Nuclear Fusion,35,1369,1995), with the general conclusion that anticipated advances in physics and hoped for advances in structural materials could lead to a DEMO-rf extrapolated from ITER with $R \approx 6-7m, I \approx 12-14MA$. This surely needs to be revisited.

The old "2 steps from TFTR to commercial" scenario that we proposed 30 years ago was based on an Engineering Test Reactor first step that was significantly more robust technologically than ITER. Perhaps the FESAC DEMO committee should re-examine whether this old scenario is still a valid basis for planning, or whether there need to be two demos after ITER, DEMO-rf and then DEMO-rb, in the direct path to fusion electric power.

We might also examine indirect paths to fusion electric power. I have in mind using fusion neutron sources with somewhat less demanding characteristics than DEMO-rf to drive sub-critical fast reactors designed to close the nuclear fuel cycle (Nuclear Fusion, 47, 217, 2007; Fusion Engr. Design, 82, 11, 2007). Such a path would enable fusion to contribute to meeting the nation's energy needs after ITER, while also developing the physics and technology needed to later build DEMO-rb and develop fusion electric power.