Comments on TerraPower's Travelling Wave Reactor

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We hear from time to time about the Traveling Wave Reactor that is being developed by TerraPower, an organization sponsored by Bill Gates. The developers are keeping many of the technical details to themselves. However, from the available info about the TWR, one can make some ball-park calculations. Some assumptions are necessary, because better numbers have not, to my knowledge, been revealed. If anyone has better info, please come forward.

Fact 1: In generating 1 GWe-yr of energy, any nuclear reactor necessarily fissions about 1 tonne of heavy metal, creating 1 tonne of fission products.

Fact 2: The TWR is based on the technology of the IFR (Integral Fast Reactor), developed at Argonne National Laboratory in the '80s and '90s—it uses metallic fuel and is cooled by liquid sodium. In effect, the TWR is a very large IFR (in size, not in GWe) that forgoes reprocessing, storing its fission products in the used part of the core (behind the traveling wave). This pushes the disposal problem perhaps 60 or more years into the future. Unlike the IFR, the TWR does not completely burn its fuel, and leaves behind a mixture of transuranic actinides -- which perhaps eventually could be recycled (not clear).

Fact 3. In commercial readiness, the TWR is at least a decade or two behind the IFR.

Assumption 1: A TWR will operate for the predicted 60 years without refueling.

At the end of its life, therefore, it will contain 60 tonnes of fission products mixed in with 240 tonnes of heavy metal (uranium and transuranics) (see below).

Assumption 2: No net breeding.

Once started, a TWR will presumably create enough fissile material (Pu-239) to sustain itself throughout its useful life, but no net breeding potential is claimed.

Assumption 3: The TWR will achieve a burnup of 25%.

This is a guess, approximately what might be achieved in an IFR in a single pass. (LWRs achieve 4-5%.)

Assumption 4: The enrichment of the initial critical zone is 20% (i.e., it's 20% fissile).

This too is a guess, based on the 20% enrichment that a normal IFR needs.

Assumption 5: The initial fissile loading is 4 tonnes per GWe.

This is still another guess, based on the approximate fissile loading of an IFR core. (An IFR plant also has another 4 tonnes of fissile in the ex-core inventory, which a TWR does not have.)

The above facts and assumptions lead to the following conclusions:

1. The initial core loading will consist of 300 tonnes of heavy metal (mainly U-238—or could be Th-232): 60 tonnes destined to be burned, plus 240 tonnes that will be left over, unused, after 60 years (Assumption 3).

   Note: An IFR core has about 20 tonnes of heavy metal per GWe, and another 20 tonnes or so in ex-core inventory.

2. The initial 4 tonnes of fissile could come from three sources:
   (a) It can consist of excess weapons Pu.
   (b) It can be Pu recovered from LWR spent fuel. Or
   (c) It can be the fissile content of 20 tonnes of uranium that has been enriched to 20% U-235.

(a) Weapons Pu

The United States has about 85 tonnes of weapons Pu, only part of which is declared to be "excess" (<http://fas.org/sgp/othergov/doe/pu50yb.html>). That would be enough to prime about 10 IFRs or 20 TWRs—a worthwhile contribution to the longer-term energy supply, but not a major one.

(b) LWR Spent Fuel

The United States is projected to have about 85,000 tonnes of heavy metal (HM) in commercial spent fuel (<http://snipurl.com/v40kv>) by 2020, containing perhaps 680 tonnes of fissile Pu. That would be enough fissile to start up 170 TWRs or 85 IFRs. For talking purposes, suppose either 170 TWRs or 85 IFRs magically spring into existence in 2020, and no more fissile Pu comes from LWRs, and also assume for a moment that enriched uranium is not available.

Now IFRs can breed, with a doubling time of less than 15 years, whereas TWRs do not breed. In the TWR case, therefore, the nuclear capacity would remain at 170 GWe from 2020 on, The IFRs, however, would catch up in 15 years, reaching 170 GWe by 1035, 340 GWe by 2050, and so on.

Fact: Every tonne of fissile invested in a non-breeding reactor is a tonne of fissile unavailable for use in a reactor type that has growth potential.

Comment: Investing fissile material in a non-breeding (break-even) reactor is like putting money under a mattress. Deliberate net burning of fissile material is analogous to throwing banknotes into a fire.

(c) Enriched uranium

When the supply of fissile from LWRs is exhausted, the growth of a non-breeding TWR fleet is over unless there is some other source of fissile material—and there would be no fissile to get a fleet of breeders going either. As of now, the only other carrier of usable fissile material is enriched uranium.

To get the twenty tonnes of 20%-enriched uranium needed to prime a TWR, one must mine 800 tonnes of natural uranium. The global uranium reserves could support a growing TWR fleet for perhaps a century or more, but that would mean intensified worldwide mining activity and an expanding enrichment capacity, to the distress of arms-control advocates. IFRs, on the other hand, would eliminate for centuries the need to mine uranium, and eliminate forever the need to enrich uranium.

Comment: Thorium could probably substitute for the U-238 part of the TWR fuel. However that would be pointless, since it would do nothing to reduce the need for the initial fissile loading, and anyway enough U-238 to last a long time has already been mined.

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Postponement of reprocessing or waste disposal is not an obvious advantage, and brings with it eventually a significant extra waste-management effort. The TWR seems to have no significant capability that is not shared by the IFR, and it has a number of inherent disadvantages. Moreover the IFR is almost ready for prime time now, whereas the TWR development is about where the IFR was in 1980. Yes, there are non-trivial technical issues.

Will TerraPower sell enough TWRs to recoup Mr. Gates' investment? I don't know, of course. But the TWR's lack of breeding alone makes it look like a second-best product, even if it can be made to work as hoped. It will have no market at all unless there is official failure to permit the IFR to come to fruition—in which case the LFTR (liquid fluoride thorium reactor) would probably be a more satisfactory non-breeding technology—but that's another story.

And that's how I see it..