THE FUSION HYBRID, A NEW (OLD) IDEA FOR FUSION DEVELOPMENT

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Retired from NRL

With lots of help from:

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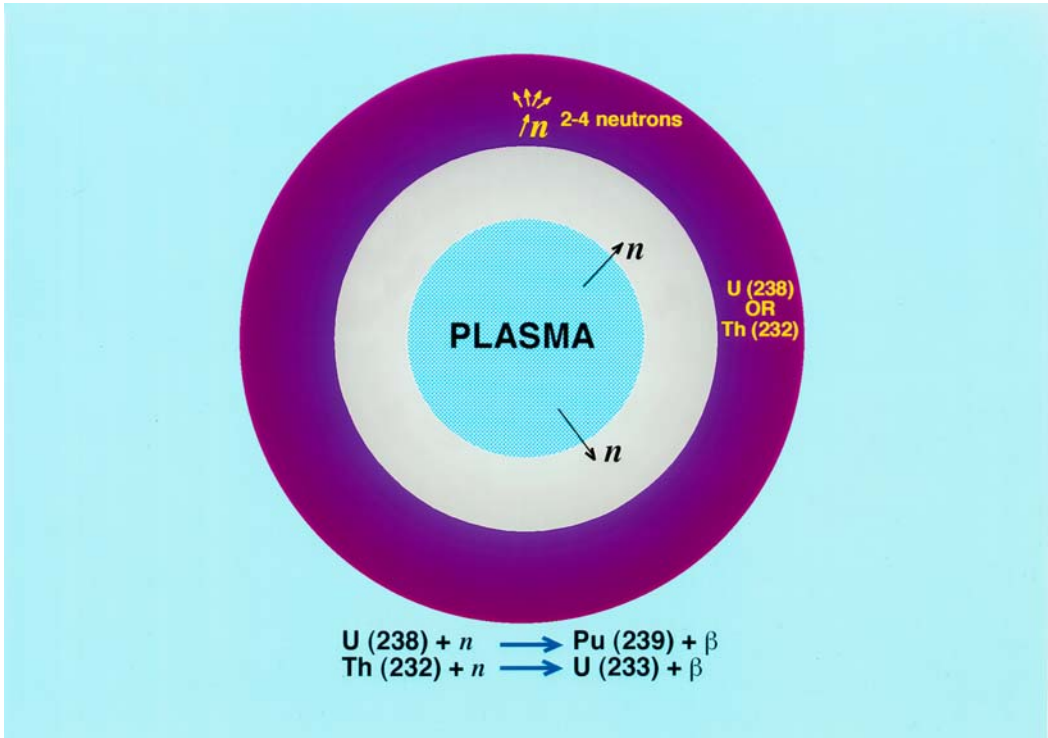
And Special thanks to Ralph Moir

The hybrid

- What is it?
- Does the fusion program need it?
- Does the world need it?
- Can we deliver?

From Hans Bethe, Phys. Today, May 1979



But each 233U releases ~200 MeV when burned. Q is effectively raised by at least an order of magnitude

Fission is energy rich and neutron poor, while fusion is energy poor and neutron rich. A perfect match!

This is a very old idea

- Andrei Sakharov, Memoirs, p142: “An important proposal of mine (in 1951 or late 1950) was that neutrons from thermonuclear reactions be used for breeding purposes”.

- Hans Bethe,Physics Today, May, 1979: “It seems important to me to have an achievable goal in the not too distant future in order to encourage continued work, and continued progress toward the larger goal, in this case pure fusion”

- Others: R. Moir, J. Kelly, D. Jassby, J. Maniscalco, etc

How does it look today?

- You are combining the worst of fusion with the worst of fission!
- You are solving the only problem nuclear power does not have (fuel supply) and sweeping all the problems it does have under the rug!
- Maybe there is something to your idea (MY IDEA!), but it’s too late. ITER is the only game in town and that is pure fusion.

- **Fission is BAD!!!**

- Fusion is **GOOD!!!**

Does the fusion program need it?

FUSION HAS A DIFFICULT CREDIBILITY PROBLEM:

- T~1955 FUSION POWERED ROCKETS 30 YEARS IN THE FUTURE (LIFE MAGAZINE)
- T~ 1990 COMMERICAL POWER PLANT 50 YEARS IN THE FUTURE IF THE WHOLE WORLD BUILDS LARGE ITER (ADMIRAL WATKINS PLAN)
- T~ 1996 FUSION BUDGET SLASHED, FUSION RECAST AS AN RESEARCH PROGRAM, NO RUSH FOR IMPLEMENTATION
- T ~ 1998 USA PULLS OUT OF ITER, MAYBE TO REJOIN
- ITER REDUCED TO HALF SIZE, TO PROCEED WITH OR WITHOUT USA

•T ~ 2003: DOE NOW ASKS IF WE CAN GET A COMMERCIAL REACTOR ON LINE IN 35 YEARS, 3 YEARS EARLIER, (AFTER LOSING 13 YEARS) AND WITH A SMALLER PROGRAM THAN ADMIRAL WATKINS ORIGINAL PLAN

HALF SIZED ITER APPORVED ~ $11B TOTAL COST

WHAT DO WE GET FOR THIS $11B? ASSUMPTIONS:

COMES ON LINE T~2025-2030

OPERATES AS A POWER PLANT (400 MW) AT ITS OPERATING COST FOR 30 YEARS.

CONSTRUCTION AND DISMANTLING COSTS THEN ADDED IN.

POWER AT ~0.7/KWHR

NEED AT LEAST AN ORDER OF MAGNITUDE HIGHER Q.

NO CLEAR IDEA ON WHAT COMES NEXT.

IS ITER A ‘BRIDGE TO NOWHERE?’

BY THEN FUSION WILL HAVE BEEN SUPPORTED FOR 80 YEARS WITH NO ECONOMIC PAYOFF IN SIGHT.

HOW MUCH PATIENCE CAN SPONSORS HAVE?

FUSION NEEDS A NEW AND MORE RELEVANT DEVELOPMENT PATH. THE FUSION HYBRID IS ONE POSSIBLITY.

Does the world need the hybrid?

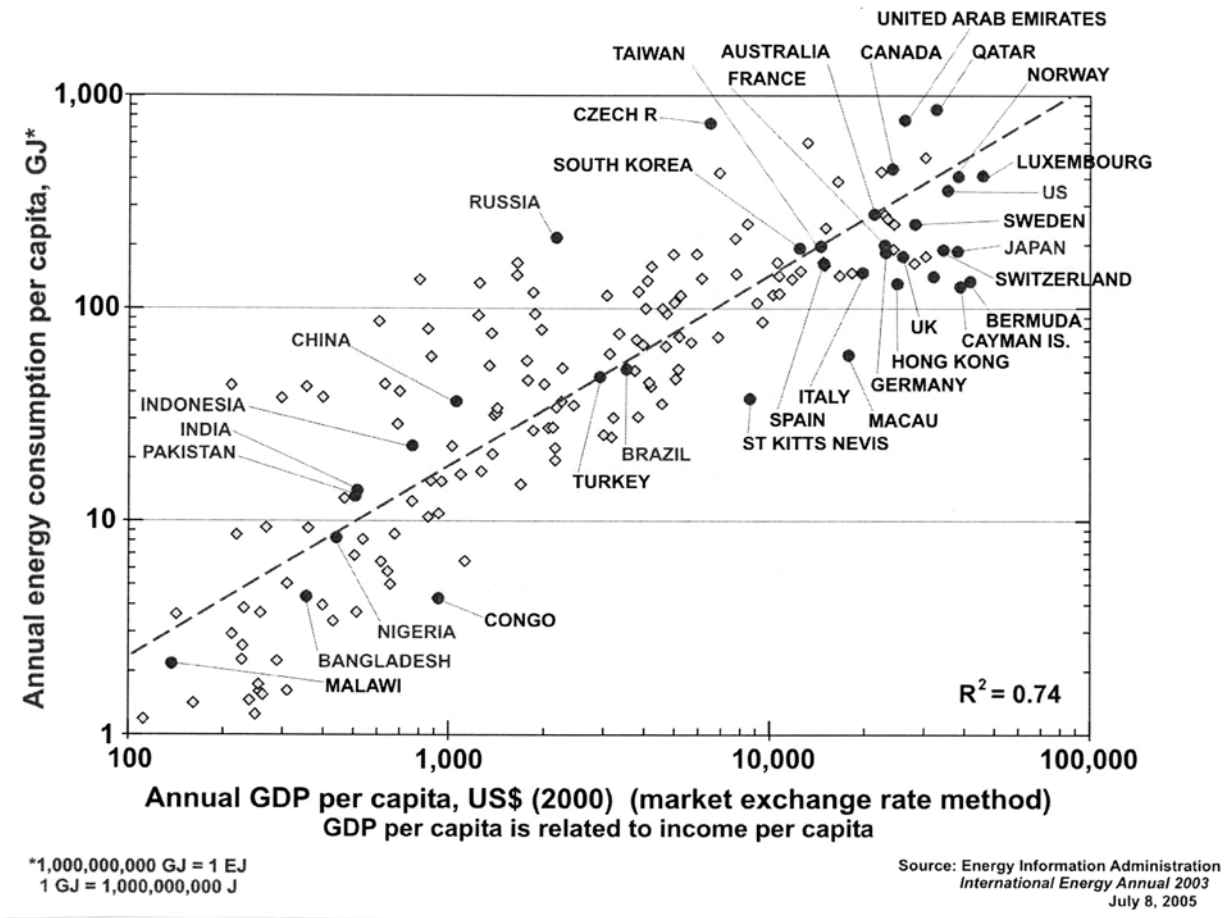
I claim the threat to civilization is not global warming, but lack of cheap energy.

Today the world uses 13 TW, but population growth to 10B means 20 TW by 2050.

But it is much worse, 15-20% of people in developed world use lion's share. World development means 50-100 TW.

Fortunately, efficiency improvements and decarbonization brings added power to 10-30 TW, but it should be carbon free (Hoffert et al, Nature, 1998)

What does the world energy and dollar use look like?



What are the world's energy resources (with lots of qualifications)

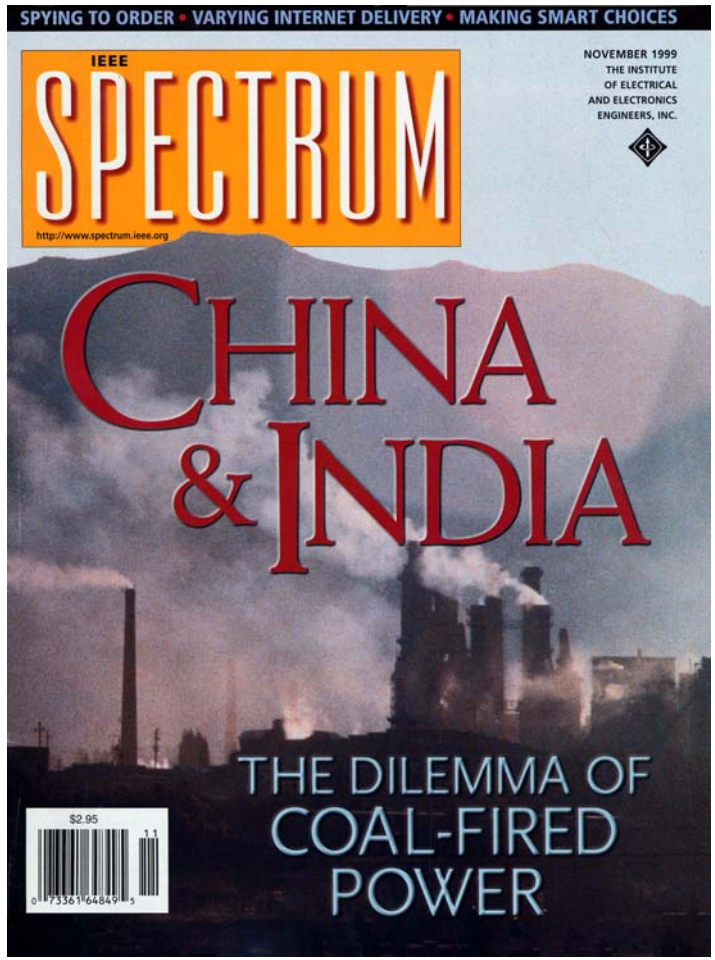
Source	Energy (TW-yrs)	Relative Carbon
Coal	5000	1.6
Oil	1200	1.3
Natural Gas	1200	1.0
Mined Uranium Burner	300	0
Mined Uranium Breeder	45,000	0
Thorium Breeder	135,000	0
DT fusion*	16,000	0
DD fusion**	infinity	0

- *Limited by lithium supply
- **Not much of a reactor, but what a breeder! It breeds T, He3 and a neutron for breeding nuclear fuel.

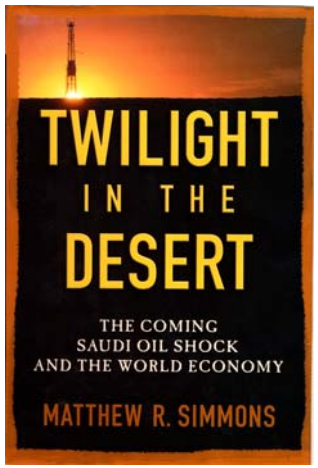
- Hoffert, 2002 Science and lots of references quoted there

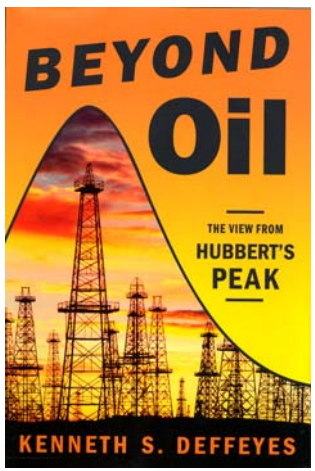
What about coal

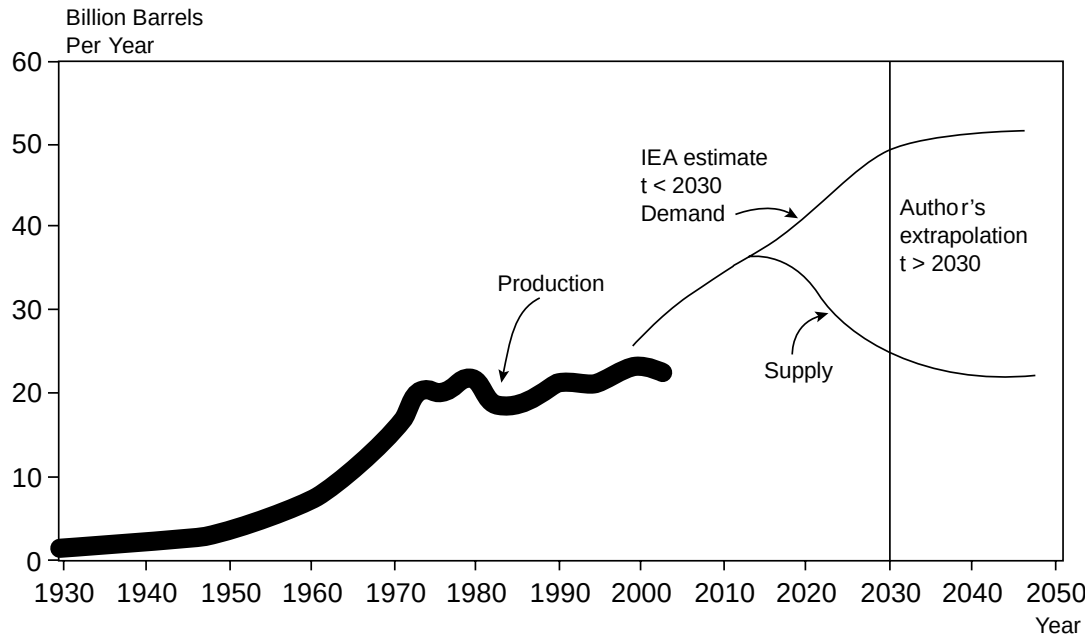
- In the absence of carbon free sources, India and China are mining and burning coal as fast as they can. They are building 750 coal fired power plants (and USA is building 100)



Oil. When will be (or was) the Hubbert's peak. In USA ~ 1970

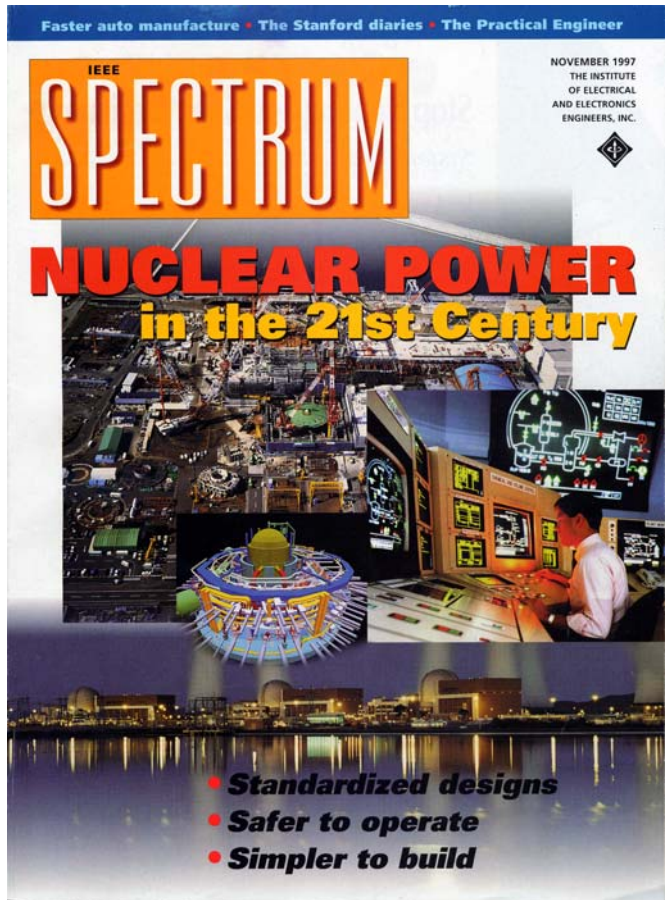






Nuclear Power

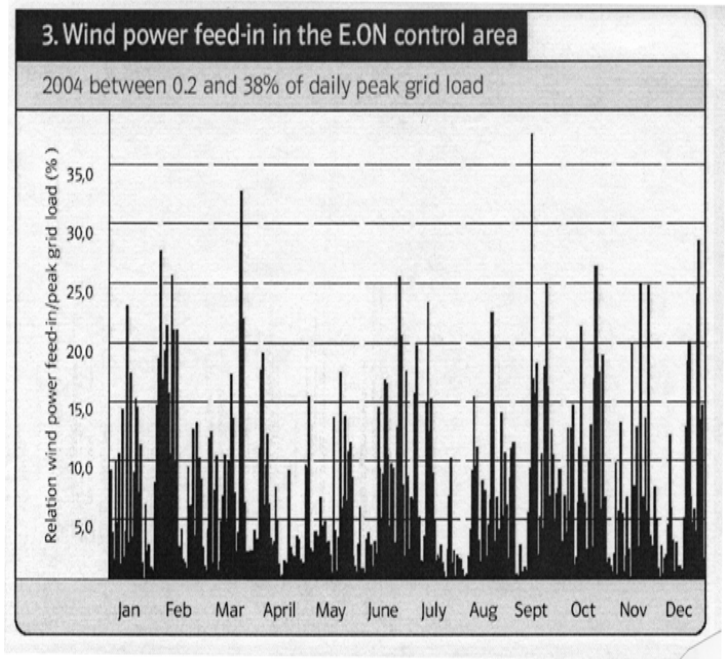
- The world will build nuclear power plants with or without us. The 400 power plants today (1.2TWth) have plenty of cheap fuel. A scale up of a factor of 10, fuel becomes a big problem.



Renewables, example of wind

- Grid cannot accept more than 10% of capacity from such a sporadic source. More windmills, less fractional utilization.
- Denmark has made largest commitment to wind power (24% of its power, 8% of Nordel grid) but was unable to decommission any thermal power plants and will be unable to meet its Kyoto treaty requirements.
- No simple extrapolation of renewables from where they are now to providing power on scale required for mid century.

From Eon-Netz, largest wind provider in Germany



What about fission breeder reactors?

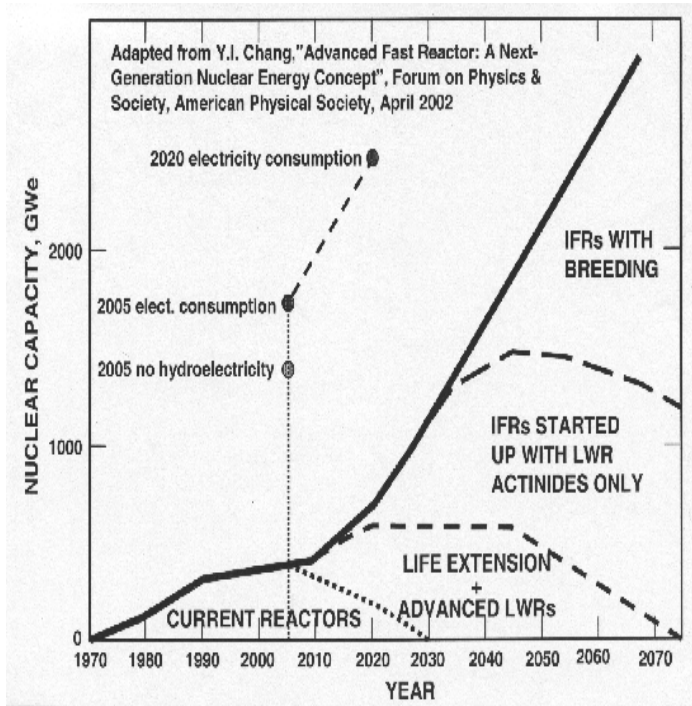
- They use all the energy in the uranium and thorium, not just the 0.7% in U(235).
- Effectively an infinite supply, more so than DT fusion which is limited by lithium.
- Breeder can be configured as net burner, net producer or neutral producer of nuclear fuel.
- A breeder fueling only itself can be engineered so it has virtually no proliferation problem.
- **Breeder advocates understand mid century power requirements and are beginning to make a strong pitch that they can meet them.**
- They claim breeders are clean.

What do they mean clean breeders?

- What we call nuclear waste comes in 2 flavors, actinides (mostly Pu with 24,000 year half life) and radio nuclides, which have half life of typically 30 years or less.
- Breeders do not consider the actinides to be waste, they inherently burn these to produce power.
- Radio nuclides are just left to decay, perhaps 10-20 half lives or 300-600 years. This is a time scale human society can plan for, not like the multi hundred thousand year time for an actinide repository.
- **I think they make a valid an very strong case.**

Do breeder advocates see any problems?

- Breeders breed slowly, ‘speed limit’ of ~5%/yr.
- Will be a large legacy of burners that cannot be fueled at this rate.
- If they produce plutonium, transportation of it to nuclear burners is an obvious risk.



Do we see problems they will not admit?

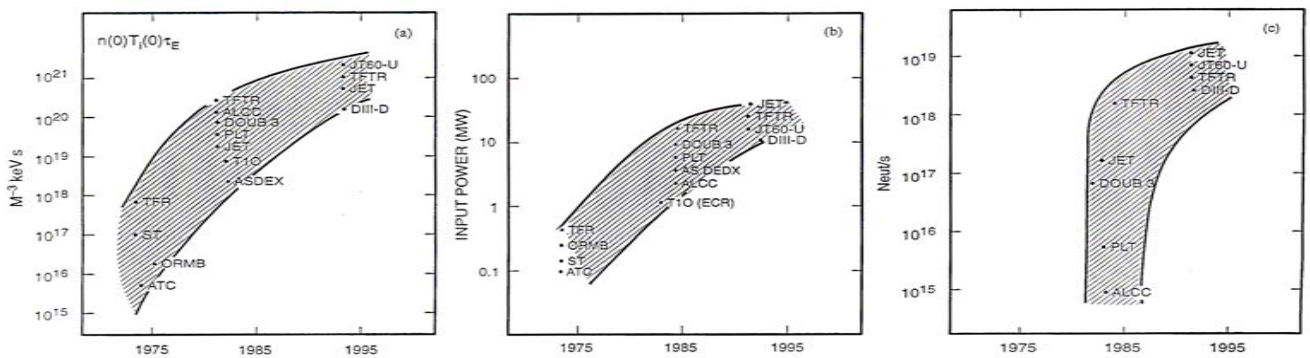
- Many fast neutron reactors have worked well, but others (i.e. the largest, Superphenix) have been plagued with problems and have been very costly. Bernard Magnum (head of Superphenix): “Running Superphenix has been a good lesson modesty”. The French and many others have abandoned breeders for now.
- The world has much more experience with thermal neutron reactors.
- There are also long lived radio nuclides (i.e. Tc(99)) with 200,000 half life). Breeder advocates dismiss these because of low activity, but they could be a problem. Could be treated by fusion neutrons.

My conclusion

- By mid century, even if breeders work as their advocates hope, the world by will need a large additional supply of nuclear fuel. If breeders fall short, the need will be even more acute.
- THE WORLD NEEDS THE FUSION HYBRID!

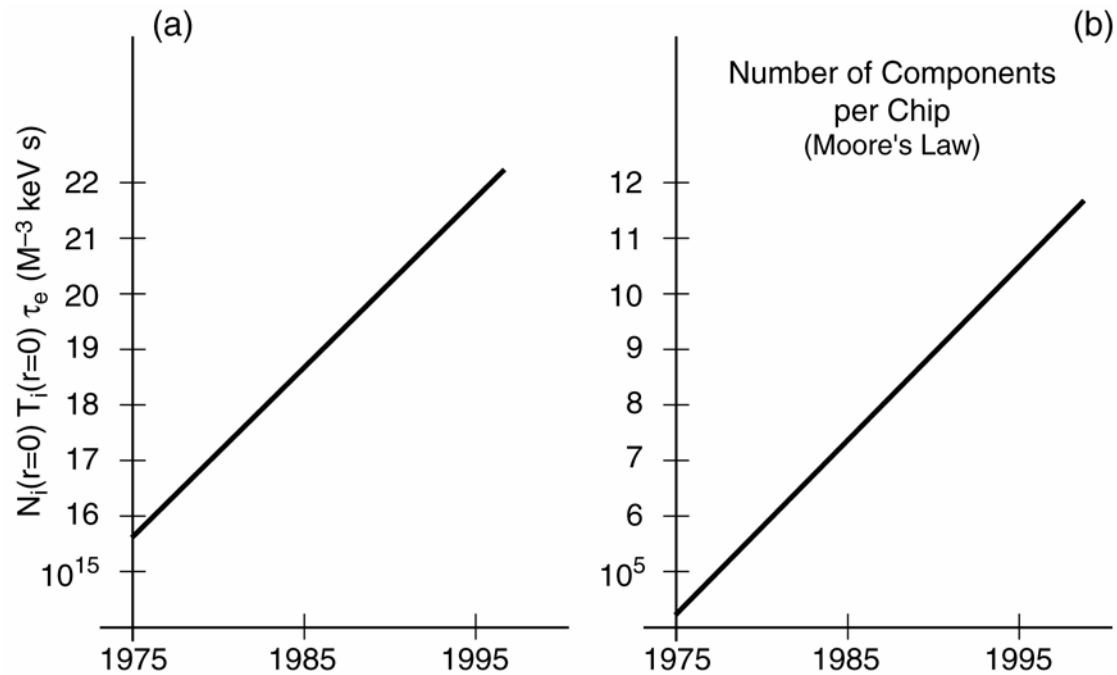
Can fusion deliver by mid century?

- Tokamaks have delivered 20 MW (10exp19) neutrons in a 1 second pulse with ~30% efficient driver.



Figures of merit for recent tokamaks: (a) triple fusion product, (b) input power, and (c) D-T neutron production rate.

The graph of tokamak advance is comparable to Moore's law.

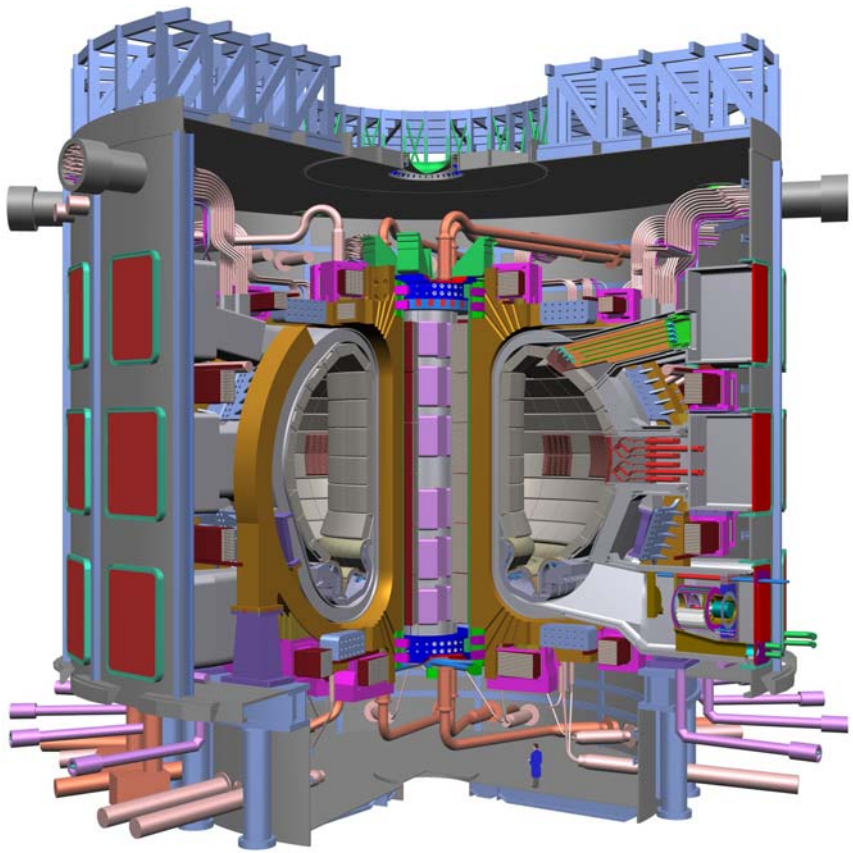


My own efforts concentrated on U(233) cycle

- Could be mixed with U(238) in a slightly enriched fuel with no greater a proliferation risk than today's fuels.
- In case of an accident, uranium is much less toxic (chemically) than plutonium.
- In case of an accident, U(233), because of mix with U(232), which has a high energy gamma in its decay chain, is much easier to find, and much more dangerous for a terrorist user.

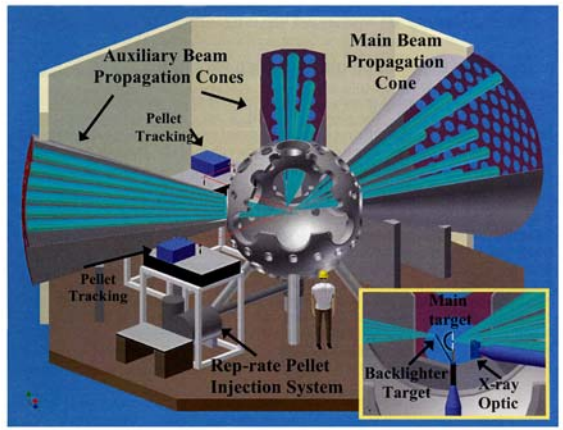
The ITER PROJECT

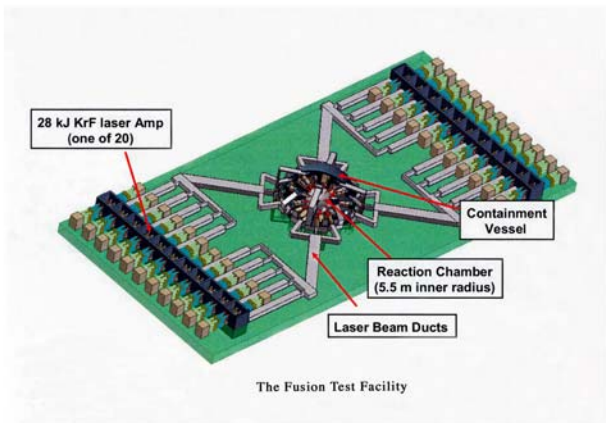
- WORLD WIDE EFFORT TO BUILD A TOKAMAK TO GENERATE ABOUT 400 MW OF NEUTRON POWER



Now there is a new concept to consider

- NRL's concept of a fusion test facility based on direct drive and KrF laser technology.





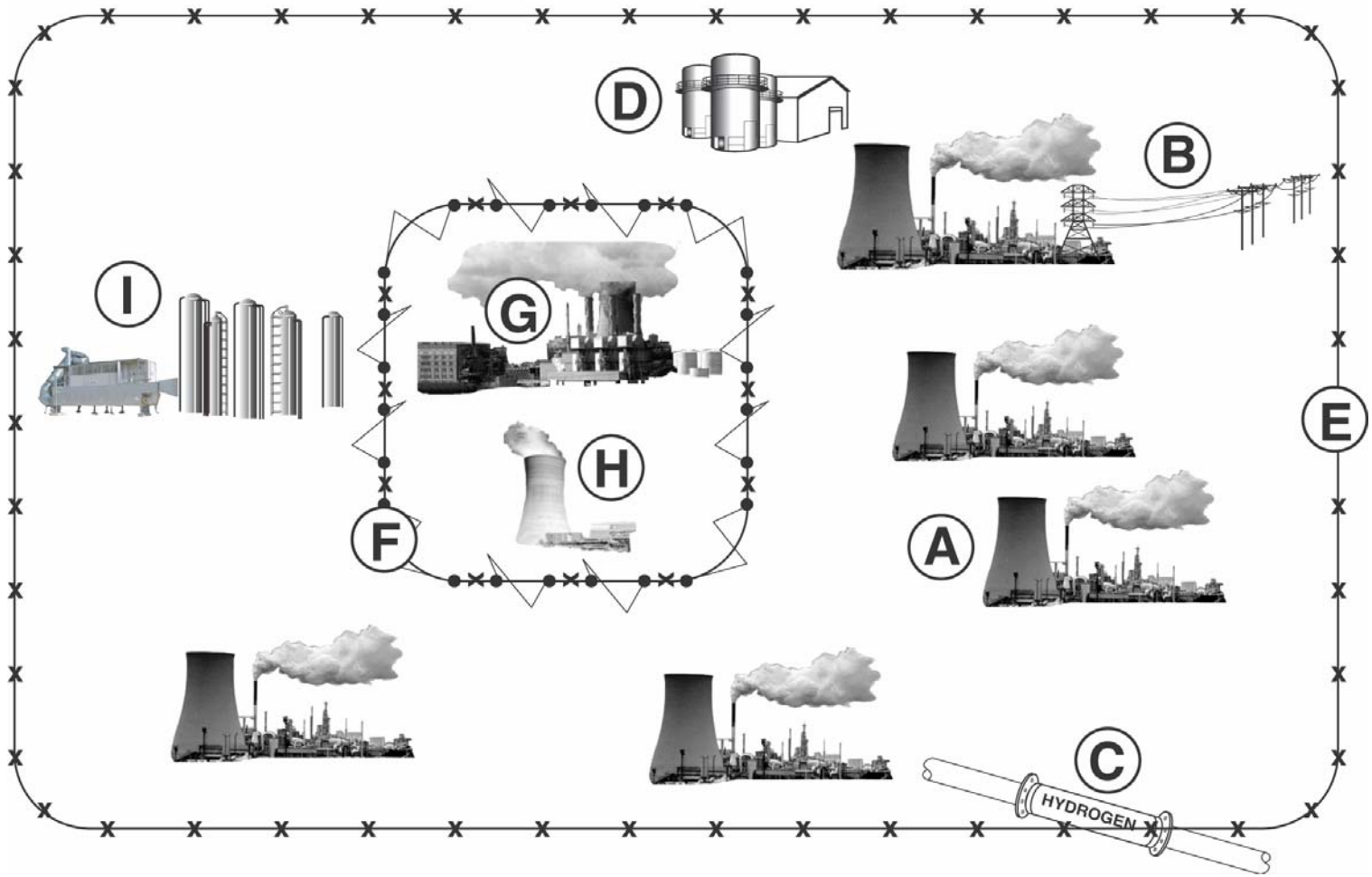
Comparison of magnetic and inertial fusion results

- Magnetic: 10exp19 DT neutrons with ~ 30% efficient driver. Few real studies of running at high average power.
- Inertial: 10exp13 equivalent DT neutrons (cryogenic target implosions at UR LLE) with ~1% efficient driver. But real progress on achieving average power capability with HAPL program which has persisted and advanced for about a decade already.

An ITER based scheme for mid century

- Simple estimate gave power cost from ITER at $0.7/kwhr.
- Large ITER, twice the cost, more than 4 times the power, $0.3/KWhr.
- But as hybrid this translates to $0.03/KWhr as a fuel cost.
- Gasoline at $1/gallon is $0.03/KWhr.
- ITER is no longer a bridge to nowhere, but becomes a bridge to somewhere.

This led to the fusion-fission energy park



Symbiotic relation between fission and fusion breeding

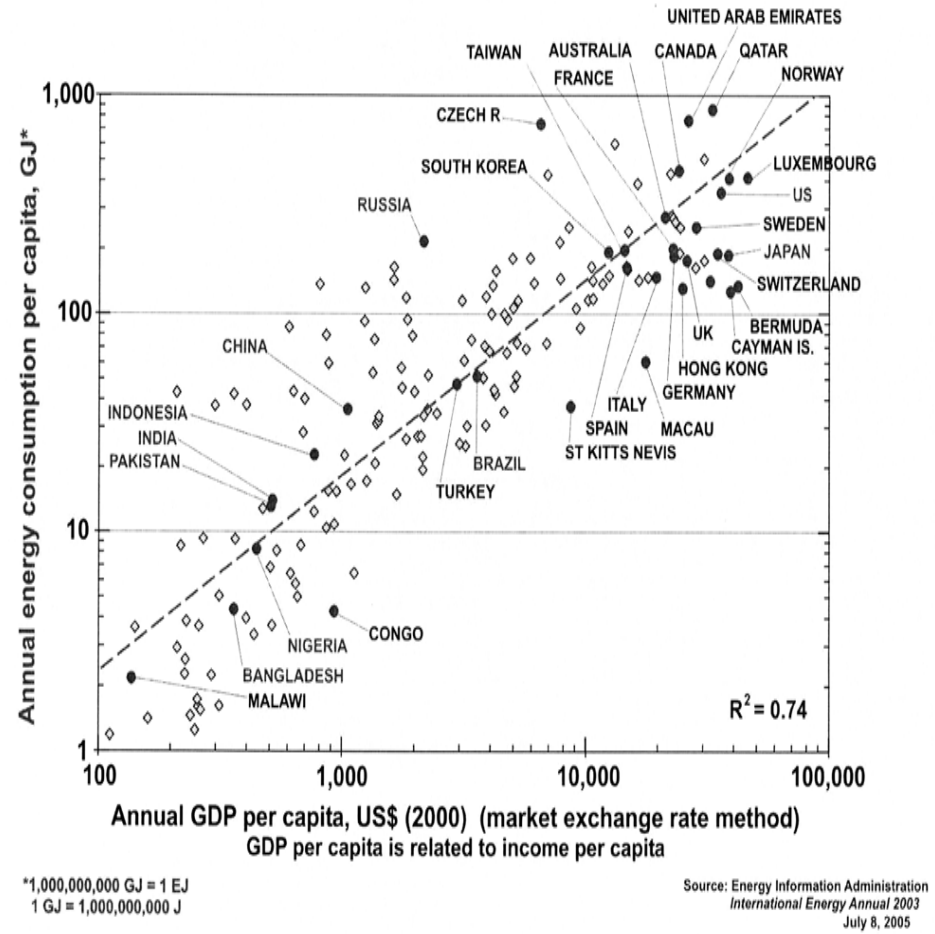
- In steady state, with 5%/yr ‘speed limit’, 20 fission breeders are needed to fuel one of today’s reactors.
- Transporting the plutonium fuel may be the most dangerous aspect of fission breeders.
- Possibility is to have fission breeders fuel only themselves.
- Fusion breeders could then fuel existing stock of burners with a uranium fuel enriched to 4% U233.

Conclusions

- Fusion (MFE, IFE or both) can contribute in an important way to mid century power requirements, but only if reoriented toward a focused program emphasizing the fusion fission hybrid.
- Barring miracles (ie world wide superconducting grid, or large scale electric power storage, probably both more distant than fusion), without fission and/or fusion breeding, difficult to see how mid century world can be powered in an environmentally acceptable way.

The upshot:

- Without fission or fusion breeding, not only will we be unable to lift low countries up the curve, the high countries will begin to slide down.
- **This is the real threat to civilization.**



Published papers, APS talk in electronic form available from author, contact wallymanheimer@yahoo.com, or wallace.manheimer@nrl.navy.mil

- 1. W. Manheimer, *Back to the Future, the Historical, Scientific, Naval and Environmental Case for Fission Fusion,* Fusion Tech. 36, 1, (1999);
- 2. W. Manheimer, *Can a Return to the Fusion Hybrid Help both the Fission and Fusion Programs?* Physics and Society, v29, #3, July 2000
- 3. W. Manheimer, *An Alternate Development Path for Magnetic Fusion,* J. Fusion Energy, 20, #4, 131, (2001, cc2003);
- 4. W. Manheimer, *The Fusion Hybrid as a Key to Sustainable Development,* J. Fusion Energy, 23, #4, Dec 2004 (cc2005)
- 5. W. Manheimer, *Hybrid Fusion*, Physics and Society, vol25, #2, April 2006
- 6 W. Manheimer, Can Fusion and Fission Breeding Help Civilization Survive? J. Fusion Energy, Published on line, Aug 25, 2006

- Dear Wally: I am now visiting granddaughters, so have a full schedule till Sunday evening. I'll send comments as soon as possible after I return home.
- I've nearly finished prepping my talk for the CNS on June 13th -- from what I can see now, we will need A LOT of fissile isotopes if we want to fill in the petroleum-energy deficit that is coming upon us. Breeders cannot do it -- your competition will be enrichment of expensive uranium, electro-breeding,. Good luck.
- Very best regards,
- Dan