How to make fusion relevant

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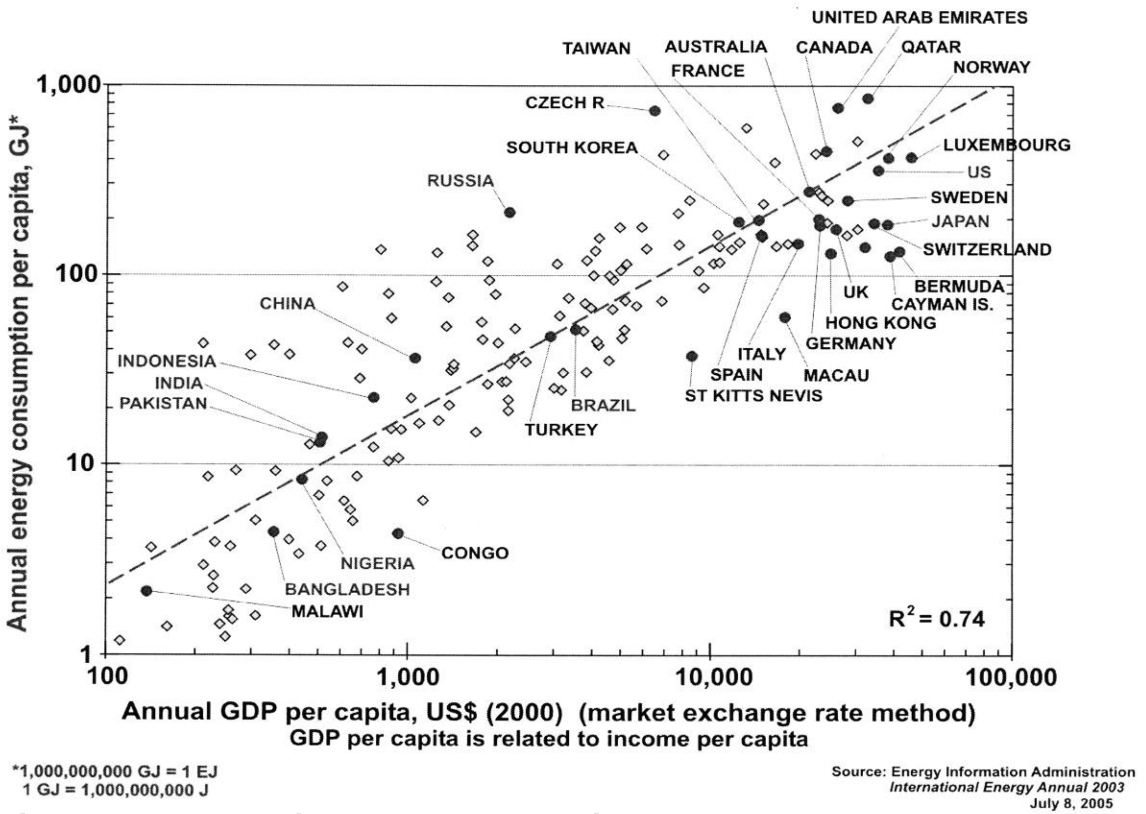
May 22, 2013

The combination of fuel production by fusion, power production by light water reactors, and actinide waste treatment by integrated fast reactors have the potential of providing 20-30 terawatts of carbon free power economically, environmentally soundly, and with no proliferation risk, at least as far into the future as the dawn of civilization was in the past.

- The status of ‘ solar sustainable’ energy
- Why is fusion needed?
- Conventional fusion: The long road ahead, MFE and ICF.
- Fission suppressed hybrid fusion, a possible short cut, MFE and ICF.
- The energy park, a possible sustainable, economically, and environmentally viable approach to energy

Country's energy use vs per capita GNP, 2000 data



Even with conservation, a great deal more energy will be needed to satisfy worldwide demand. Since 2000, China's per capita energy use has roughly doubled and it is now the world's largest carbon emitter.

What are these daunting energy requirements? (World wide perspective)

- World now uses ~ 14 TW energy, but this is countries on top of chart.
- At Gaithersburg Hybrid conference 2009, Dr. Wu of Hefei: even now, the average Chinese uses only 20% of the energy as the average American, and said they are determined to change this.
- Even if USA reduces its energy use, much more energy is needed.
- Hoffert et al claim the world needs an additional 10-30 TW of carbon free energy by midcentury. No known way to accomplish this now.

What about Kyoto and CO_2

	1990	2005	%increase
Non Warsaw Eur.	2166	2516	16
Warsaw Eur.	2621	2129	-19
USA	4747	5289	11
Japan	935	1075	15
China	1454	2844	96
India	288	862	199
Egypt	42	98	133
Malawi	0.53	0.85	62

Solar Sources

- Solar thermal
- Solar Photo voltaic
- Wind
- Biofuel
- All are limited by the solar power/area and the efficiency with which it is transformed to usable power.

Peak and average power

- Often proponents will quote peak power when average power is the relevant quantity.
- Examples:
- Solar voltaic at noon on a hot summer day gives x Watts and y% efficiency. But averaging over solar angle, night and day, winter and summer, sun and rain turns these into roughly x/5 and y/5.
- Windmills give z Watts when the wind speed is optimal, but average power is more like z/6.

Subsidies and Subsidies

- Subsidies for power sources are often (deliberately) confusing.
- Sierra Club: Coal has been given \$20B/yr subsidies in depletion allowances!
- Exxon: Wind has been given \$10/yr for 20 years.
- Question: Who gets the larger subsidy?

Level the playing field!

- Only reasonable measure is subsidy per kwhr. In my example, wind gives 10GW, so gets 10 cents/kwhr. Coal give 300 GW, so gets 2/3 cent/kwhr.
- Subsidies are difficult to discern. One easily citable source is in IEEE Spectrum August 2011 pointed out that the Japanese are subsiding wind power at 25 cents/kwhr and solar voltaic at 60 cents/kwhr. (I cannot afford it!)

Renewable energy: solar thermal

- Sun heats a liquid which can be stored overnight. Sun to liquid heat ~ 70% efficient.
- Hot liquid powers generator 30% efficient so total efficiency is ~20%.
- So far most efficient, but little room for efficiency enhancement.
- 1 GW power plant 5 km on a side

Renewable energy: solar photo voltaic

- Mid latitude ~1KW/M^2 PEAK, 200W/m^2 average solar power (200MW/km^2)
- Eff ~10% 20MW/km^2, 1 GW plant ~ 25 square miles (Manhattan is ~50 sq miles)
- Servicing means driving many miles
- 1998-2007 Total photovoltaic shipments, ~10km^2 <200 MW average.
- Entail huge scale up in production for meaningful power
- Research could yield improvement in cell efficiency.

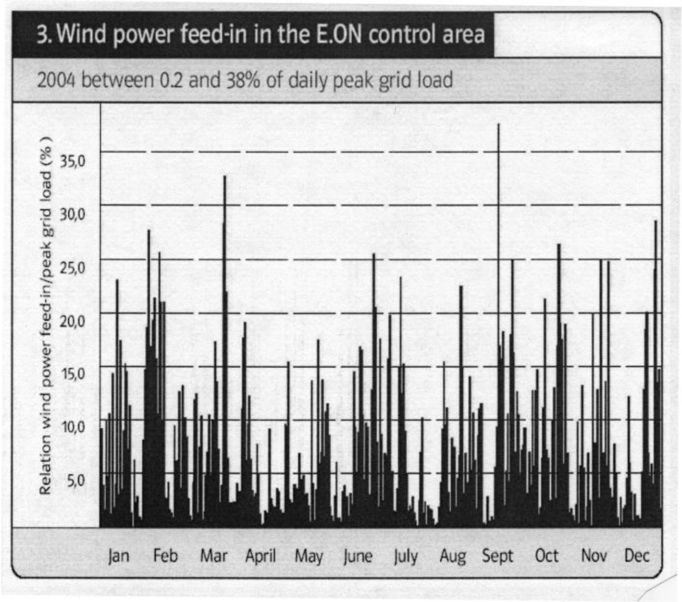
Renewable solar energy: wind

- Not easy to figure efficiency, but can do so from sizes.
- Elk River Wind Farm in Beaumont KS delivers < 40 MW (Name plate value 150 MW) in 40 square km.
- Translates to an efficiency or 0.5-1%
- No way to enhance efficiency

Renewable Solar Energy :Wind

- Grid cannot stably accept more than 10% of capacity from such a sporadic source. More windmills, less fractional utilization.
- Requires a spinning reserve (like a car at a stoplight) to make up for time of little wind.
- Wind power varies as v^3 so only a narrow range of optimal wind velocities.
- Canada subsidizes wind power at Hydro Quebec at ~ 10¢/kwhr

From Eon-Netz, largest wind provider in Germany



Renewable solar energy: ethanol

- Photosynthesis is inefficient (~1%), and land can be used for other purposes, food, lumber, cotton, conservation, etc.
- In 1850, USA with a population of 30 million used biofuel and deforested half a continent.
- USA produces ~5B gallons of ethanol (energy of ~3.5B gallons oil)/year using 25% of our corn crop. This is ~1% of our petroleum use.
- Price of corn is already skyrocketing due to American ethanol production, greatly harming poor people in Mexico and Africa.
- Bogdan Kippling (IBD) describes it as taking food from the stomachs of the world's poorest to put a speck more gasoline in our cars. He calls this a crime against humanity.

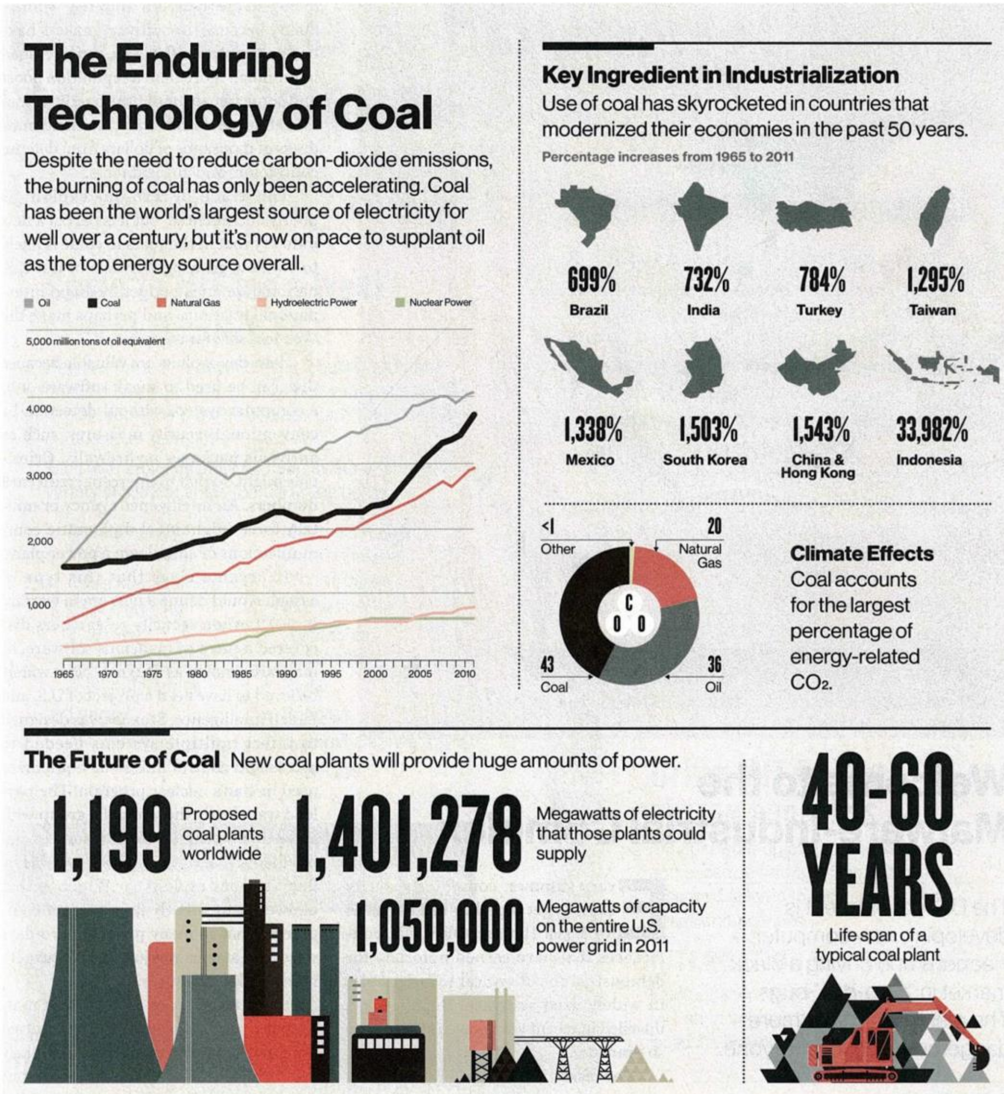
- **And GW is called a moral issue!**

- Research into chemistry might produce a more efficient conversion, and energy storage is no problem.

Solar energy Summary

- All solar sources use a lot of land. USA uses ~500 GW of electricity. All solar voltaic (10%) uses 2.5×10^4 km^2 (About the area of Connecticut); wind (1%), ~ North Dakota
- Solar thermal: 20%, 1 GW in 25 km^2 as efficient as it can be.
- Solar photo voltaic: 10%, 1 GW in 25 $miles^2$, improvement possible via better cells
- Wind 1%, 1 GW in1000 km^2, as efficient as it can be
- Maintenance on these will be expensive, long distances, large facilities, hostile environment.
- Large scale energy storage likely a show stopper.
- Photosynthesis: ~1%, chemistry research might improve this
- Solar sustainable energy is nowhere near ready to provide needed energy and will not be for a very long time (if ever)

Now let’s get real Tech. Rev May 2013

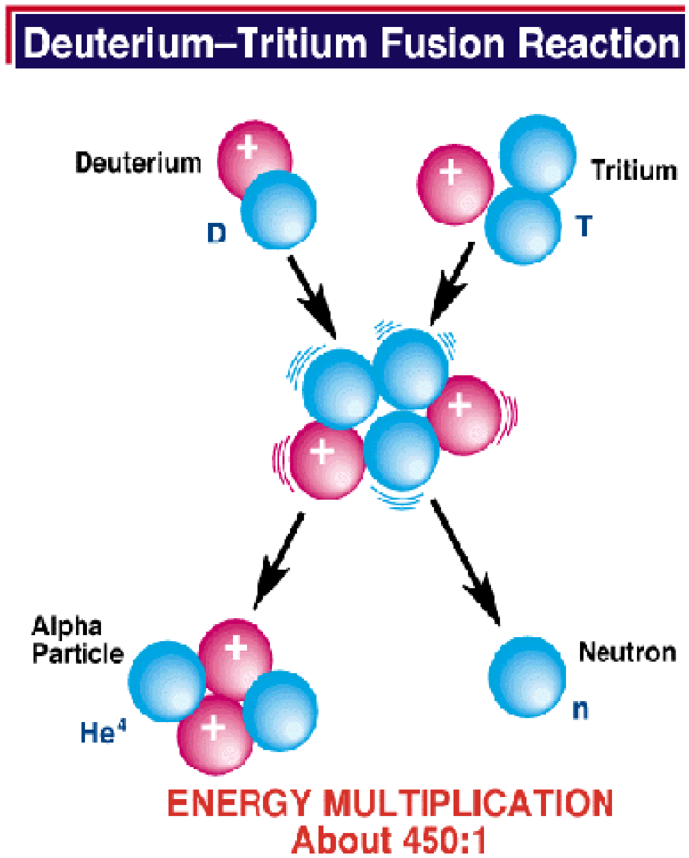


Question: Can fusion make an impact?

- My answer:
- Pure fusion? NO! Its most optimistic proponents admit this.
- Fission suppressed hybrid fusion, or fusion breeding, YES!, if the program is willing to change its focus and pursue it with laser like focus and if the time scale for impact is mid century.

Conventional fusion: The long road ahead

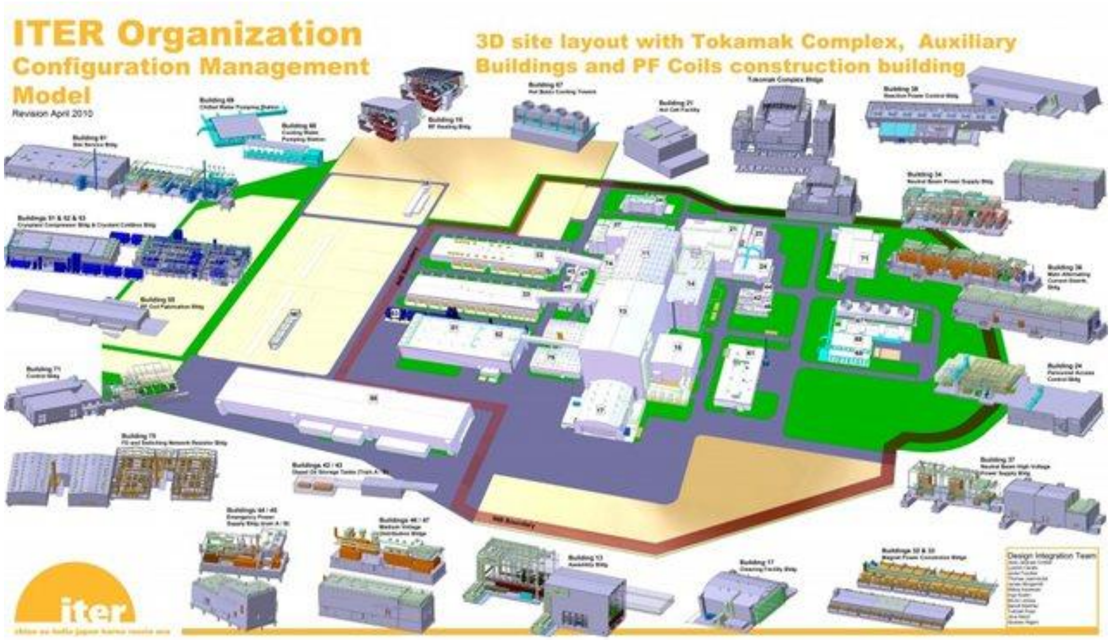
What is fusion

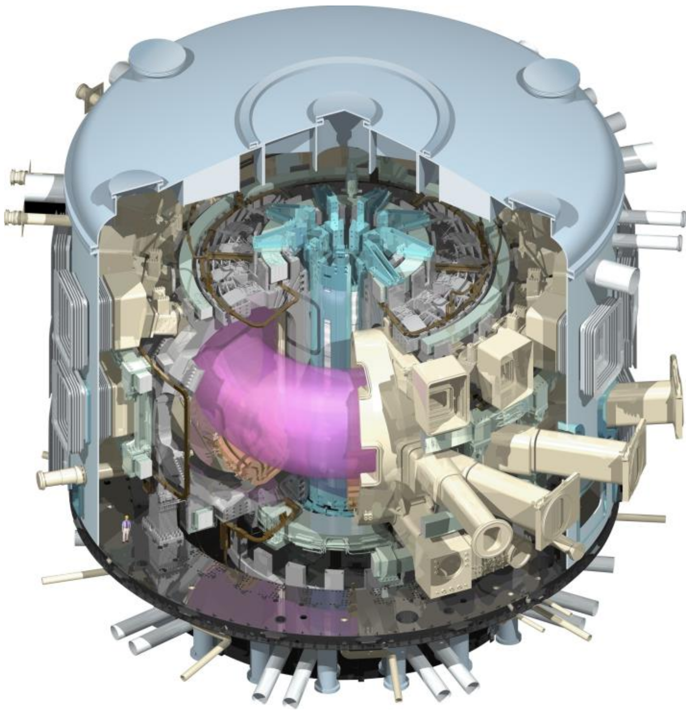


Tritium must be bred from lithium and this is an ultimate limit to the resource.

- Two approaches:
- Magnetic: Long series of tokomak experiments ultimately producing ~10^{19} neutrons in a 1 second pulse for Q~0.5 with a 30% efficient driver (neutral beams) {TFTR, JET, JT60}
- Inertial: Not nearly as mature. ~10^{13} neutrons for Q~10^{-3}, but with a 1% efficient driver {UR: LLE}.
- Fusion has made great progress over the last 60 years but has a very long way to go, greatly testing the patience of sponsors.

ITER: THE SITE AND TOKAMAK



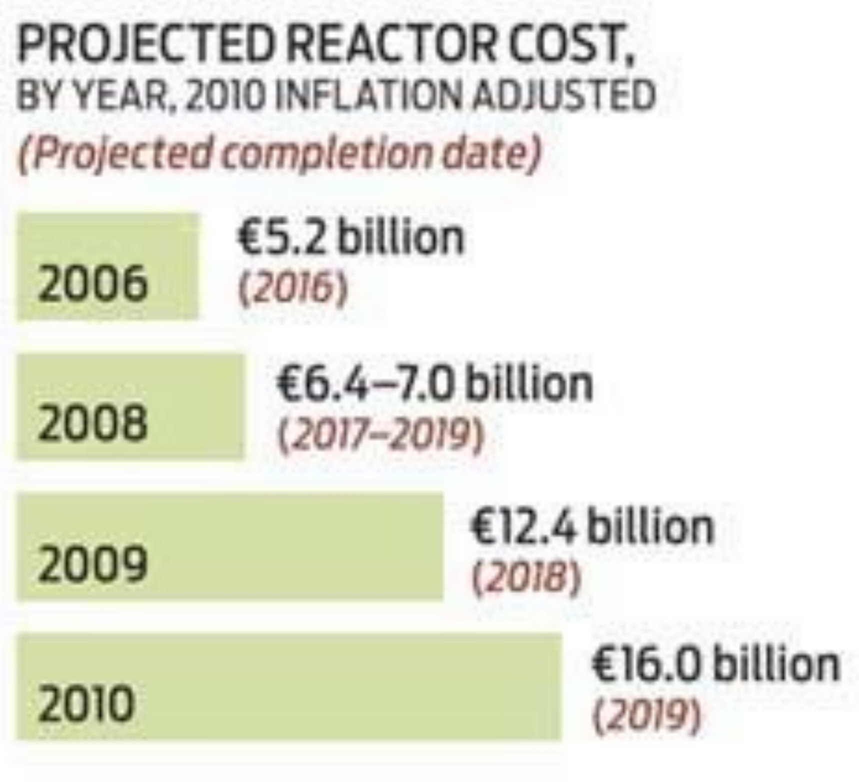


MFE: ITER (Pulsed device)

- Original (Large ITER): $20B, half for construction, half for operation for 10 years
- 1.5 GW neutron power, 150 MW driver power (Q=10)
- Too expensive, USA pulls out
- Redone as $10B, half for construction, half for operation
- 400MW neutron power
- USA rejoins
- Any magnetic fusion, especially a current carrying one like at tokamak concentrates tremendous energy into a small space and is at risk of a disruption. ITER contains at least 800 MJ, about the energy of a 400 pound bomb (and maybe 10 times that amount if you count the energy in the toroidal field).

But what is ITER cost and completion date?

- From IEEE Spectrum, Sept. 2010



Large ITER size based pure fusion power plant

- Consider the original Large ITER for pure fusion
- (Q~10, P~1.5GW)
- But this is 500 MWe
- The driver (microwaves or beams have efficiency of 1/3 as well) so we need 450 MWe for the driver
- This leaves all of 50 MW for the grid!

Clearly ITER does not cut it as a reactor!

After ITER- An Economical Demo Tokamak?

- But does this make any sense? It must generate at least 10 times the neutron power at much reduced cost.
- I have argued that there are constraints to the pressure, current and density in a tokamak that prevent this. Individually they are well established; taken together they seem to prevent tokamak evolving into a pure fusion device. I’ve called these ‘Conservative Design Rules’ (CDR). I’ll skip the plasma nitty gritty.
- MFE’s failure to confront, discuss, or disprove CDR is not encouraging.
- But whether CDR’s are right or not, getting 10 times the performance of ITER a major undertaking.

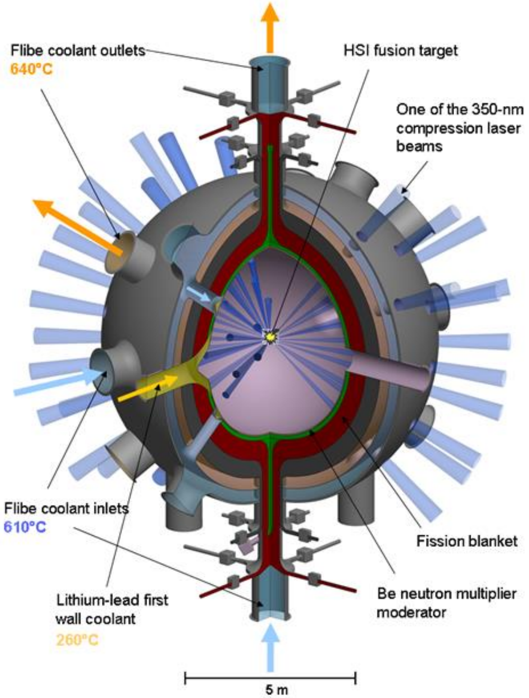
ICF has several major advantages

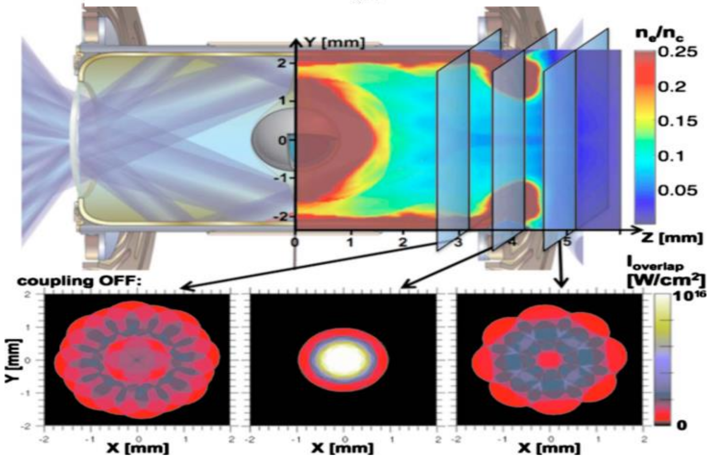
- Does not have to worry about confining a burning plasma.
- Does not concentrate energy in small space, no possibility of major disruption.
- Seem to be no limits like CDR for tokamaks.
- Compared to MFE, plasma physics of IFE is relatively simple.
- Again I'll skip the plasma nitty gritty.
- Scuttlebutt that classified experiments confirm the concept?????

National Ignition Facility

- NIF is supported for stockpile stewardship, not energy. Sponsor is interested only in X-ray driven implosions and is not concerned with laser efficiency or average power.
- Now NIF is routinely getting megajoule shots at third harmonic ($\lambda=(1/3)\mu$m
- To get X-ray drive, the laser illuminates a gold lined hohlraum and heats the walls to 250-300eV producing the X-rays to drive the implosion of a target centered in the hohlraum

NIF The large and small





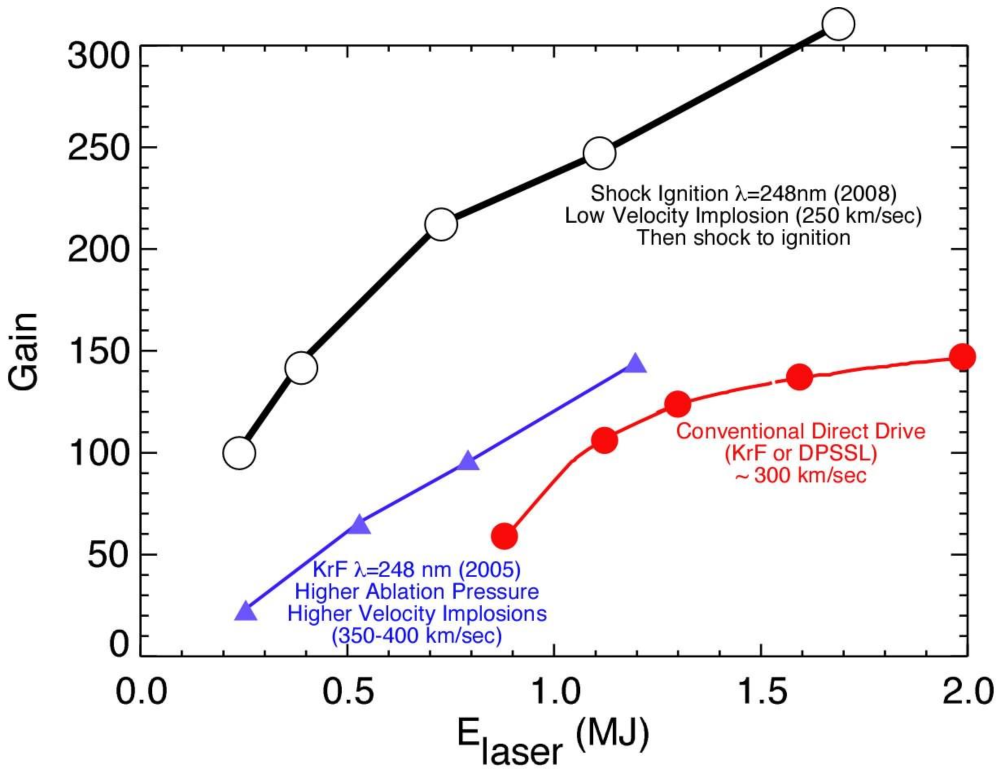
NIF: Time and Budget and milestones

- Began in 1995 to finish in 2002 for $1.1B, actually finished in 2009 for $3.5B (SF Chronicle, 8/17/12)
- Gain milestone has decreased : G=35: E. Moses et al, Fus. Sci and Tech, 56, 548, 2009; G=8, R. Boyd, L. Bernstein and C. Bruce, Physics Today, Aug 2009; G=1, D. Clery, Science, 327, 514, 2010
- Efficiency of NIF ~ 1%, so need much higher gain, and much more efficient laser if energy is the goal.

NIF could be in big trouble

- NIC ended Sept 30, 2012.
- Best gains were ~10^{-3} and even these were not reproducible.
- Major newspapers (NY Times, SF Chronicle) called it a disaster: "I thing they're in real trouble and that continuing the funding at the current level makes no sense." Stephen Bodner quoted in, NY Times 9/30/12
- Congress wants answers: "As the first ignition campaign comes to a close in fiscal year 2012, it is a distinct possibility that NNSA will not have achieved ignition during these initial experiments. While achieving ignition was never scientifically assured, the considerable costs will not have been warranted if the only role of …(NIF) serves is that of an expensive platform for routing high energy density experiments". House Appropriations Committee
- "These are exciting times in laser fusion!". Bob McCrory, APS-DPP 2008 (correct, but not for the reason he thought)

NRL's long held corporate position: indirect drive is the wrong target configuration



- URLLE has done direct drive experiments at 30kJ, far below ignition. They see spherical implosions and compression, but neutron yield so far is ~ one order of magnitude below 1d code predictions.

NRL's long held corporate position: Nd is the wrong laser

- KrF has shorter wavelength, more uniform beam, more bandwidth, and zooming capability.
- But can we convince anyone to build a new laser, or can NIF still be productive?
- Way forward is unclear for ICF.
- FY2013 budgets for NIF (LLNL), OMEGA (URLLE) and NRL were all cut, biggest % cut went to NIF.

Are alternate concepts the answer?

No for MFE

- Conventional is only answer. Tokamaks took 50 years to get to where they are today. Huge international consortium, TFTR, JET, JT-60, ITER, EAST, K-Star…. They are way ahead of their competitors. Unlikely a genius will produce a reactor in his garage.

Look at $nT\tau$ (proportional to Q at fusion temperatures, i.e. $<\sigma v> \sim T^2$) in m^3keVs for various machines, and confined energy in MJ

Tokamak: JT-60:	$1.6\text{x}10^{21}$,	8.6
Stellarator: LHD:	$4\text{x}10^{19}$	1.4
Spherical Tok: NSTX	$5\text{x}10^{18}$	0.2 (and center post likely a show stopper)
Mirror: GDT	10^{18}	0.03 (non Maxwellian distribution likely a show stopper)

No for ICF

- Conventional is only answer: Lasers took 40 years to get to where they are today, and also have a huge international constituency, NIF, LMJ, Osaka, NRL (NIKE, ELECTRA), URLLE (OMEGA)…
- NIF has routinely generated Megajoule shots at 1/3 micron.
- NRL in its HAPL and ELECTRA program has investigated many questions related to energy, laser efficiency, aiming, clearing chamber, final optics, wall material… Seem to be no show stoppers
- What else is there? Heavy Ions? No accelerator capable of doing fusion experiments has ever been built. Symmetric illumination seems difficult, likely hard wired into indirect drive. Z pinches? Standoff?? Clearing target area??

- Can we really go to our sponsors and say, sorry, we made a big mistake, give us a few billion more and we will try the next thing??????
- For better or worse, we placed enormous bets on tokamaks and lasers. We have little choice now but to dance with the ladies we came in with.
- Realistically, these are still the best options.

Fission suppressed hybrid fusion (FSHF), or fusion breeding, a possible short cut.

The idea is to fuel existing nuclear reactors (e.g. light water reactors, (LWR's))

- 400 LWR's in world today, ~75 in various stages of construction or planning.
- Many countries, France, Belgium, China, Finland, India, Canada Japan(?), USA (?) find them safe and affordable.
- High cost in USA largely legal delays, NIMBY and BANANA.
- Nuclear fuel is 4% ^{235}U in 96% ^{238}U. Not a proliferation risk.
- 4% ^{233}U or ^{239}Pu can also be used. To have raw fuel proliferation resistant, consider only ^{233}U.

But what about Fukushima?

- Many more killed by oil and coal than by nuclear .
- Main danger is to land, not people, they have time to get away.
- Google “Cost of Fukushima cleanup” $15B < $$ < $300B
- But how much is this really? 400 GW for 30 years and one such accident. This means a cost per kwhr of the clean up is 1/80 ¢ < ¢ < 1/4 ¢ per kwhr. Worldwide nuclear industry can easily self insure.

Still safety in the event of extreme events must obviously be reexamined

A 1 GWe LWR, fuel and discharge

- Each year an LWR takes in 1 metric ton of ^{235}U in 24 tons of ^{238}U.

- Each year it spits out about 24 metric tons of uranium (various isotopes) and ~ 200 kG of plutonium (24,000 year half life) and higher actinides, and 700 kg of fission products (typically 30 year half life).

- Note that the plutonium from 5 LWR's can fuel one reactor of equal power.

But LWR's have other (solvable) problems than safety.

- **Fuel supply**: LWR's use only the 0.7% of U that is ^{235}U. But all uranium and thorium (3x as much) can potentially breed fuel. 40 years of 400GWe power by LWR's means in depleted uranium alone, there is potential fuel for 4 TWe for 400 years! Here is where fusion can play a crucial role.

- **Proliferation**: Burn the actinide discharges of LWR's in fast neutron reactors. (Fusion has been proposed, but I don't see it).

- **Waste**: Burn actinide wastes. Some fission products have commercial use, separate these out, let the rest decay over several centuries.

What is Fusion Breeding?

- One 14 MeV n + Be, U, Pb ⟹ 2-3 slow neutrons

2-3 slow neutrons + Li, ^{232}Th ⟹ 1.1 T + ~0.6 ^{233}Th

^{233}Th decays to ^{233}Pa (22 min), ^{233}Pa decays to ^{233}U (25 days) .

Breeding reactions (T and 233U) are exothermic, they roughly double the neutron energy.

But burning 0.6 ^{233}U in an LWR gives 120 MeV, the neutron energy is multiplied by a factor of about 10 and the fusion reactor power by about 5 (since the breeding reactions are exothermic).

Fission suppression

- Must separate the nuclear fuel from the fusion reactor
- Needs liquid liner to do this, so Pa can be removed elsewhere
- Many possible liners, but molten salt FLIBE keeps appearing
- Li produces T, Be multiplies neutrons, Th and U are soluble in molten FLIBE

For energy is there an advantage to fusion over fission breeding?

Most definitely!

Device	Additional fissile atoms per reaction	Satellite LWR’s of equal power	Tons of fissile material needed for startup
IFR*	0.5	0.5	10
Fusion	0.6	5	0

•An IFR in its normal breeding mode of operation

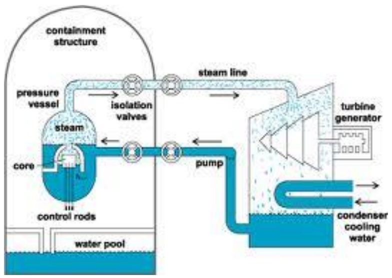
•Fusion is neutron rich and energy poor, fission is energy rich and neutron poor, a perfect match if exploited optimally!

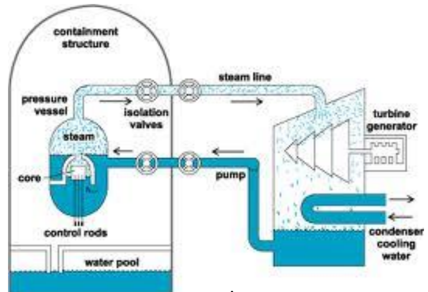
Its Pedigree

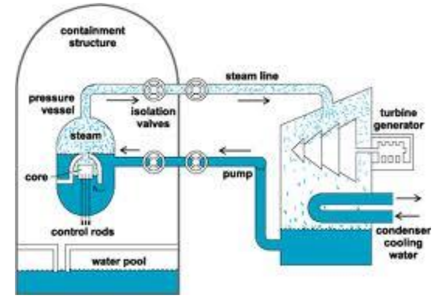
- Andrei Sakharov proposed fusion breeding in 1950 (Memoirs, p 142)
- Hans Bethe advocated it in 1979 (Physics Today, May 1979)
- I believe Sakharov and Bethe had it right and today’s conventional fusion approach has it wrong.

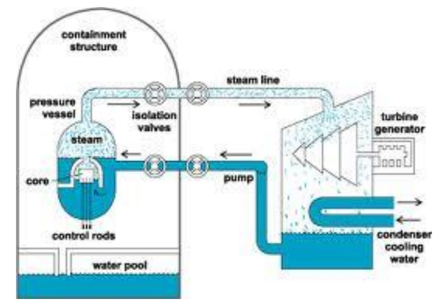
Google image view of fusion breeding

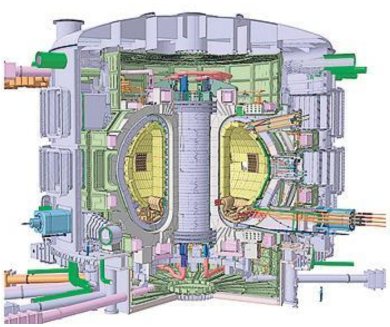
3GWth (1GWe)
LWR

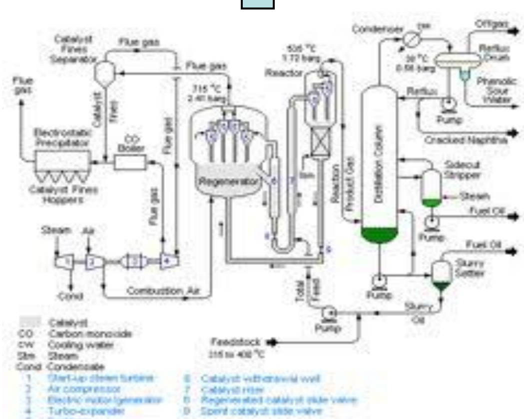


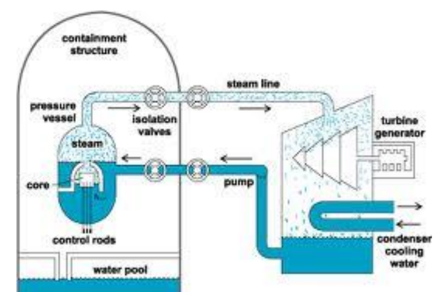












3 GW fusion plant (ITER image)

Liquid liner pipes to a chemical plant where Pa is separated and mixed with uranium

Digression: Fast Fusion is a fusion reactor surrounded by subcritical fission reactor

- Many reasons for skepticism, but principally:
- Beams, rf, lots of wires, etc, must pass through a 3GW nuclear reactor to reach the plasma deep inside. Extremely complicated! Can this really be done? Has anything like this ever been done?
- Would anyone ever put a fusion reactor in the middle of a 3 GWth coal fired power plant? What's the difference?
- **AND ESPECIALLY:**
- **Plasma which we do not understand very well, stores energy ~ 4000lbs of TNT, and which might disrupt, is just a thin wall away from a ton or so of plutonium. Significant safety issue.**

To continue, use fast neutron reactors to treat waste.

- A solution to the waste actinide problem likely already exists, fast neutron reactors like the IFR and AFR. These have been built, tested and they work.
- One could argue that a fast fusion IFE or MFE reactor is an expensive, technically risky, and indeed dangerous solution to a problem which likely has already been solved.

The IFR (a fast neutron reactor developed in Idaho by ANL)

- Was built and worked well for several years.
- Claimed it burns all transuranic elements, and does so in reactor mode which is passively safe.
- Can run as a breeder, burner, or in a breakeven mode.
- Also there are years of experience with superphenix.
- Still development issues, but much closer than fusion

My 10 year pipe dream may become a reality. The British are planning a large IFR (now called the GE-Hitachi Prism reactor) to burn plutonium

Plans to build massive new reactor at Sellafield

(IRISH INDEPENDENT, APR 3, 2012)

Steve Connor
in London

A RADICAL plan to deal with Britain's plutonium waste – the biggest civil deposit in the world – has come a step closer with a legal contract to test the feasibility of building a US nuclear fast reactor on the Sellafield site in Cumbria.

Britain's own fast-reactor programme was abandoned two decades ago and yesterday it was announced that the fast-reactor site at Dounreay in Scotland will be dismantled by 2025 at a cost of £2.7bn. (€2.4bn)

However, nuclear officials have signed a feasibility study to investigate the possibility of building an American-designed fast reactor to "burn" the plutonium waste on-site at Sellafield.

The Nuclear Decommissioning Authority (NDA) has signed the deal with GE Hitachi to see whether its Prism fast reactor can directly eliminate the plutonium waste rather than using the alternative method of converting it into mixed oxide (Mox) fuel for conventional nuclear reactors.

The deal represents a remarkable U-turn on the part of the NDA which has consistently said that its preferred option to deal with the plutonium waste at Sellafield is to build a second Mox fuel plant at Sellafield - the first Mox fuel plant was closed last year after a catalogue of failures costing £1.34bn. (€1.5bn)

It is also ironic given that the reason why Britain has such a large amount of civil plutonium waste is because the UK nuclear industry wanted to burn it in fast reactors at Dounreay in Scotland, which had to be abandoned two decades ago, again because of technical failures.

Yesterday, the NDA announced that it would now cost nearly £3bn to decommission the heavily-contaminated site at Dounreay, although it attempted to sweeten the pill by claiming that this was £1bn less than originally planned.

Technology

In a statement the NDA said that it had originally ruled out fast reactors as a "credible option" because the technology was immature and such reactors would not be commercially available for several decades.

"GE Hitachi subsequently approached NDA to suggest their technology was at a more advanced stage of development. Discussions are now ongoing and a contract has been signed between NDA and GE Hitachi for a study and, after review of the outputs, the NDA will consider the credibility, or otherwise, of the proposal," the NDA said. "At this stage, evidence has not been provided which changes the NDA position that fast reactors are not credible."

The GE Hitachi Prism reactor has come out of the US Department of Energy's integral fast-reactor programme, itself abandoned by President Bill Clinton in 1994, just before Britain abandoned its own fast-reactor programme. (© Independent News Service)

Very rough estimate the cost of FSHF based on the cost of ITER

There is no better basis, it is not a paper study, contracts are being written.

But we have seen the cost of ITER is increasing rapidly and this makes estimates difficult.

Assume a large ITER cost of $20B and a $1B/yr for a 30 year lifetime operating cost. Construction + operating cost is then ~$2B/yr

Large ITER based FSHF power plant

- Now breeding increases power to 3GW, or 1 GWe.
- Also produces 13 GW of nuclear fuel.
- Enough for five 900 MWe LWR's
- Driver power is now a perturbation.
- ITER size device can operate as a breeder but most likely not as a stand alone power producer!

Zero order estimate of cost

- ITER costs $2B/yr
- Produces 1 GW of electric power it sells for 10 cents/kwhr. Earns ~ $0.9B/yr
- Produces 4.3 TWe of nuclear fuel at a cost of ~$1.1B/yr ~ 2 cents/kwhr
- Uranium fuel today costs ~1 cent/kwhr
- Gasoline at $1/gallon, running a generator costs ~7 cents/kwhr
- Fuel costs from Large ITER based FSHF seem affordable!

Two enormous advantages

- An ITER sized device now becomes an end in itself instead of a stepping stone to who knows what DEMO decades and decades later. While there is still disruption danger, there is little fissile material near the reactor at any time.

- With breeding, only ~10% of the total power is neutrons and fast ions, 90% burned elsewhere, so in a pure fusion system, blankets must absorb 10 times the power as in a breeding system.

Laser fusion: Pure fusion

- Case 1: Assume 1 MJ laser, gain of 100, 10% efficient laser pulsed 15 times/sec
  - 1.5 GW of fusion power, but 350MWe to grid. Possibly economical but more likely marginal

- Case 2: Assume technological development stops short; G=75, $\eta=5\%$
  - 1.125GW of fusion power, but only 75 MW to grid, almost certainly not economical

Laser fusion: FSHF

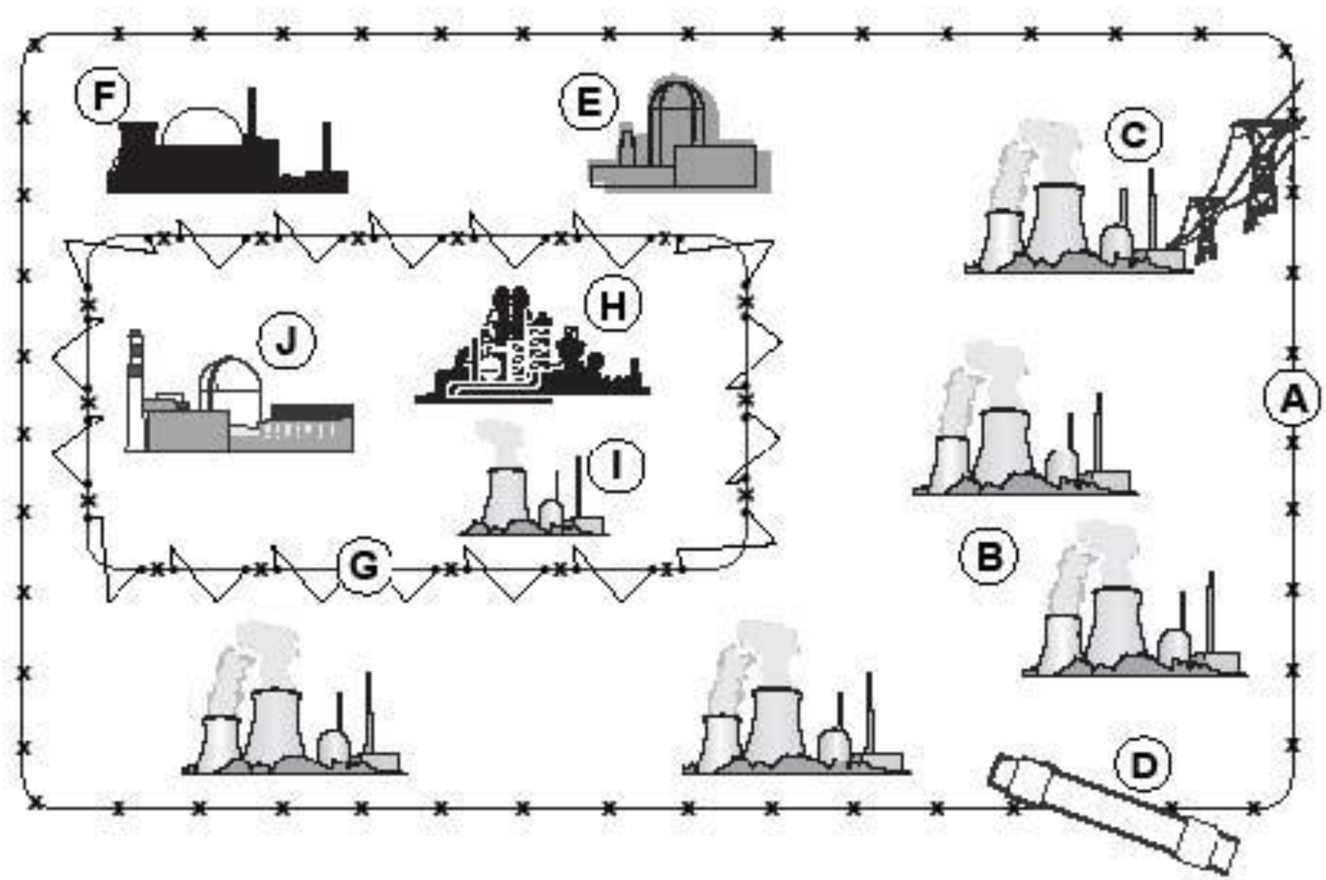
- Case 1: Now power = 3GW (1GWe) plus 4.3 GWe of nuclear fuel produced. Driver power now a perturbation, probably economical
- Case 2: Now power to grid is 750MW plus 3.2GWe of nuclear fuel. Driver power is still a perturbation, still probably economical

- The energy park, a possible scheme for mid century power with is economically, environmentally viable and has no proliferation risk.

A model for sustainable midcentury power

- One fusion reactor fuels 5 LWR's and produces one unit of power.
- 5 LWR's produce 5 units of power.
- 1 IFR cleans up after the 5 LWR's and produces 1 unit of power.
- 5/7 of power we can produce economically today.
- Fission fragments left to decay over 3-6 centuries.
- Geological disposal not necessary, or need for it greatly reduced.

This led to the fusion-fission energy park; more than a dream, much less than a careful plan.



Everything shown in same location, but of course it does not have to be

The Energy Park Con’t

A. Low Security fence
B. A Nuclear reactor, perhaps of today’s design.
C. Output electricity
D. Hydrogen or other manufactured liquid or gaseous fuel.
E. Cooling pool where waste is taken and highly radioactive fission fragments cool for perhaps 300-500 years. High security fence
F. Liquid or gaseous fuel factory

The energy Park, con't

G. High security fence. All material with proliferation risk in are here until they are burned or diluted. No long time storage or long distance travel of material with proliferation risk.

H. Separation and reprocessing plant. Fission products go to storage pools, actinides to IFR.

I. IFR actinide burner

J. The fusion reactor

The Energy Park, conclusion

- Produces 6 GWe from ~2060 to t=∞.
- No long time storage or long distance travel of material with proliferation potential.
- Treats all of its own wastes.
- Waste treated with a combination of fission and patience.
- Only ^{232}Th comes in, only electricity and perhaps liquid fuel go out!

An Appeal

Anyone interested on working on this with me?

I’ve about run out of ideas.

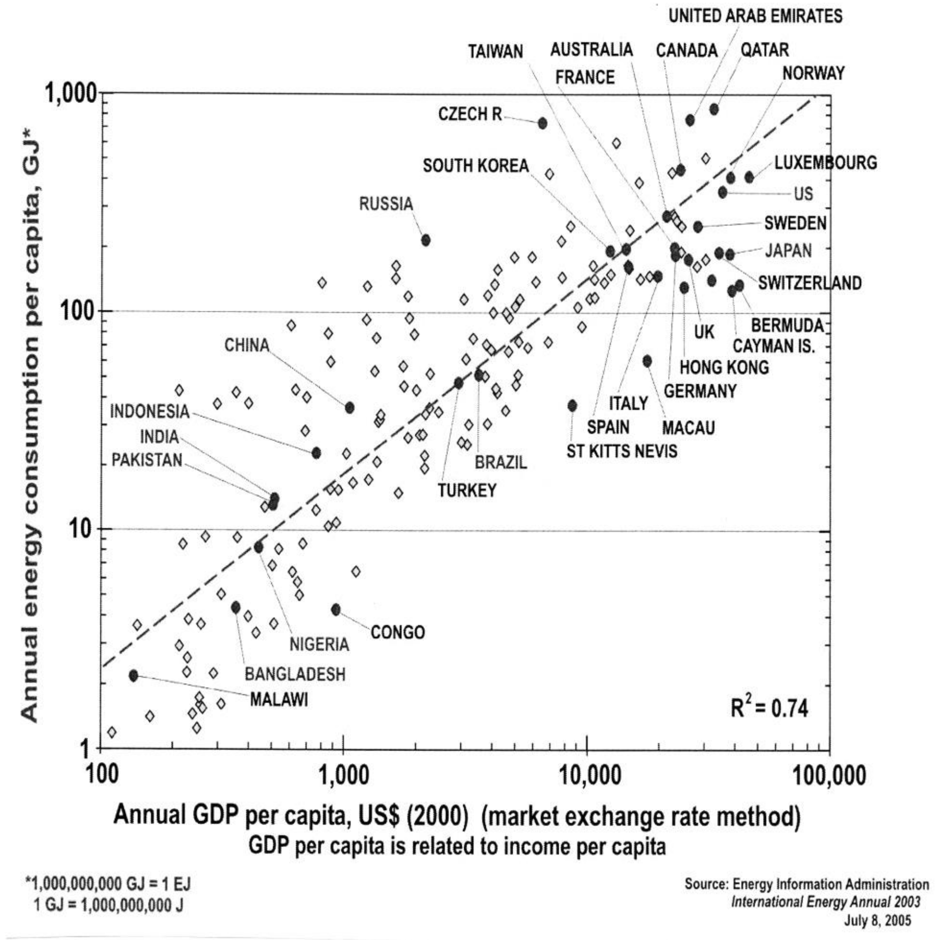
Terrible project for young scientist; in current environment; you will never get $$$ or tenure.

Wonderful project for scientist retired or approaching retirement: Interesting problem; May help save civilization, You will definitely have lots of fun.

HELP!!

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 back down.
- **This is the real threat to civilization.**



Published papers, available from author, contact wallymanheimer@yahoo.com,

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