The Integral Fast Reactor

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> "In the decade from 1984 to 1994, scientists at Argonne National Laboratory developed an advanced technology that promised safe nuclear power unlimited by fuel supplies, with a waste product sharply reduced both in radioactive lifetime and amount. The program, called the IFR, was cancelled suddenly in 1994, before the technology could be perfected in every detail. Its story is not widely known, nor are its implications widely appreciated. It is a story well worth telling, and this series of articles does precisely that."
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> --- excerpt from Plentiful Energy and the IFR story by Charles Till, former Associate Director, Argonne National Laboratory

> "Dr. Till soon became responsible for all fast reactor work at Argonne, and continued to emerge as a leader in his field. ...But his greatest contribution, to both his discipline and to the world, lies in the development of the Integral Fast Reactor, the IFR. This inspired source of electrical power has the capability to achieve incredible efficiency in fuel use, while significantly lessening problems associated with reactor safety and nuclear waste. In 1986, the IFR showed that it can protect itself from overheating and meltdown. It does so through the natural physical properties of the materials used rather than by relying on operator intervention or an engineered safety system. The IFR was also designed to burn most of its own waste, as well as that of other reactors and the material from dismantled weapons. Unfortunately, this program was canceled just 2 short years before the proof of concept. I assure my colleagues someday our Nation will regret and reverse this shortsighted decision. But complete or not, the concept and the work done to prove it remain genius and a great contribution to the world."
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> --Senator Kempthorne,
> excerpt from Congressional Record: Nov. 6, 1997 (Senate)
> Page S11890-S11891

Executive summary

Congress should add a provision to the climate bills to authorize $3B to have DOE work with industry to build a demonstration Integral Fast Reactor (IFR) plant in order to restart fast reactor clean energy technology.

A successful IFR demonstration has the following important benefits:

1. **The only technology we have with a realistic potential to save the planet.** Eliminating carbon emissions from coal plants worldwide is required to prevent a climate catastrophe. But using carbon capture adds cost and may not be practical or viable. The IFR, on the other hand, can replace the burner in an existing coal plant while reducing operating costs. So countries will actually want to eliminate

their carbon emissions because they'll save money. This is why the IFR is one of Jim Hansen's top five priorities for saving the planet: because the IFR is the only viable solution we know of today can eliminate CO_2 emissions from coal plants without increasing energy costs.

2. **Addresses the climate change problem while helping our ecomomy with lower energy costs and increased jobs.** Unlike many renewable sources, nuclear power has the potential to decrease energy costs and create new high paying jobs. You don't have to believe in climate change to support nuclear power.
3. **Allows power companies to meet national carbon caps without raising prices.** It's critical we have the technology we need in order for power companies to meet the carbon caps that we establish for our country. IFRs can replace the coal burners of a coal plant allowing power plant operators an economical way to meet their carbon reduction goals. IFRs provide a compelling solution on pure economics alone. The National Academies study showed clearly that nuclear is cheaper than coal with carbon capture (see Figure 2.10 on p. 58).
4. **Solves the nuclear waste problem without creating a proliferation risk and opens the door for the expansion of nuclear power in the US.** Fast reactors use nuclear waste as fuel. The waste product from the IFR is minimal and short-lived. Solving the waste problem is required if we are to expand nuclear power in the US. The IFR does this. The unique reprocessing technology used in the IFR does not create a proliferation risk because it cannot be used to separate out plutonium. However, even if you still believe there is a proliferation risk and restricted the IFR to only those countries which already have nuclear power, you be hitting 93% of global carbon emissions which is more than sufficient.
5. **Creates an opportunity to become the world leader in clean energy.** Obama said at MIT that he wants the US to be a world leader in clean power. Nuclear is the largest clean energy source and the IFR was determined to be the best nuclear power technology in the most extensive comparative nuclear study ever done. That means the IFR is, in the objective opinion of international energy experts, our single best clean power source. But we aren't exploiting it. We are investing nothing in it today. One of the IFR scientists, an Argonne Distinguished Fellow, went to DOE recently and to ask for funds to at least start the IFR planning. He got nothing. Not even a dime. How do we expect to be a leader in clean energy by leaving our best technology sitting on the shelf? Nobody has been able to answer that.
6. **Creates enormous economic value.** Because they use our existing nuclear waste as fuel, fast reactors turn our existing nuclear waste stockpile into an asset worth over $30 trillion dollars. That is an amazing return on investment for a one-time $3B investment to jump-start the technology. Nothing else provides such an enormous return on investment (ROI). Plus, the ROI is guaranteed: we know the technology works since we ran it for 30 years and we also know it is practical since the Russians are exporting commercial fast reactors to China.

7. **Unlimited clean power.** The IFR allows us to power the entire US electricity needs for the next 1,500 years without doing any additional mining of uranium; using just the "waste" we have on-hand that nobody wants. The power is carbon free. If we mine, we can power the power needs of the entire planet forever.
8. **Required for the future of nuclear power worldwide.** Nuclear is required to be part of the energy mix going forward. But we will run out of affordable fuel for existing nuclear reactors if we don't deploy fast reactors on or before 2030.[1] We haven't had a fast reactor in the US since 1994. Unless we re-start our fast reactor program now, we will have no chance of meeting this deadline, setting ourselves up for yet another energy disaster.
9. **Nuclear is of the two key technologies absolutely required for CO2 mitigation and fast reactors must be phased in by 2030 at the latest to ensure nuclear fuel availability**. The National Academies' report on America's Energy Future said this about CCS and evolutionary nuclear:[2]

> A failure to demonstrate the viability of these technologies [CCS and evolutionay nuclear] during the next decade would greatly restrict options to reduce the electricity sector's CO_2 emissions over succeeding decades. The urgency of getting started on these demonstrations to clarify future deployment options cannot be overstated.

Although the National Academies report is referring to Gen III+ when they use the term "evolutionary nuclear technologies," by implication, Gen IV (fast nuclear) must also be restarted immediately since without fast reactors deployed starting in 2030, we'll run out of nuclear fuel as described in the Gen IV International Forum (GIF) Technology Roadmap, p. 13. Although you can find some studies which claim we have more fuel than that, it would be a mistake to bank the future of our planet on a "best case" scenario. A recent International Nuclear Energy Academy (INEA) position paper says essentially the same thing as the GIF roadmap:

> Having already a *sizeable* fleet of Generation IV breeders in operation by 2050 is therefore recommended to ensure a significant contribution from fission to the limitation of global warming for the rest of the century.

Environmental groups, including the Sierra Club and Environmental Defense Fund, believe that no clean energy technology should be off the table.

The Sierra Club, which historically has been opposed to nuclear power, has looked at the IFR specifically and will support the building of an IFR demo reactor.

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[1] See Gen IV Technology Roadmap, http://www.gen-4.org/Technology/roadmap.htm, p. 13

Background

The IFR is an advanced fourth generation sodium-cooled fast nuclear reactor (SFR) combined with a reprocessing facility using pyroprocessing, typically in the same power plant. The combination of a fast reactor plus waste processing is known as the Integral Fast Reactor.

Unlike today's nuclear power plants (all of which are second generation designs built 30 years ago), the IFR uses fast neutrons (instead of slow neutrons) and thus is known as a "fast reactor." Fast neutrons have the advantage of "burning" the nuclear material completely so that the only waste products are fission products (elements near the middle of the periodic table). This waste is only dangerous for a few hundred years which is much less than the 100,000-year sequestration time that many think is needed for conventional nuclear waste.

Sodium-cooled fast nuclear reactor technology was developed beginning in 1964 by a team of scientists at Argonne National Laboratories. Their test-bed reactor, known as the EBR-II, ran flawlessly for 30 years until being permanently shut down by Congress in 1994.

Today, while other countries such as Russia, India, China, France and Japan are successfully and aggressively pursuing fast reactors,[3] the US hasn't had an operating fast reactor since the EBR-II was shut down 15 years ago.

The need

To prevent a climate disaster, we must eliminate virtually all coal plant emissions *worldwide* in 25 years. The best way and, for all practical purposes, the only way to get all countries off of coal is not with coercion; it is to make them want to replace their coal burners by giving them a plug-compatible technology that is less expensive. The IFR can do this. It is plug-compatible with the burners in a coal plant (see Nuclear Power: Going Fast). No other technology can upgrade a coal plant so it is greenhouse gas free while reducing operating costs at the same time. In fact, no other technology can achieve either of these goals. The IFR can achieve both.

The bottom line is that without the IFR (or a yet-to-be-invented technology with similar ability to replace the coal burner with a cheaper alternative), it is unlikely that we'll be able to keep CO2 under 450 ppm.

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[3]For example, China, in addition to completing the work on its own 65 MW experimental fast reactor at the China Institute of Atomic Energy (CIAE), just ordered two of the Russian BN-800 fast reactors.

Today, the IFR is the only technology with the potential to displace the coal burner. That is why restarting the IFR is so critical and why Jim Hansen has listed it as one of the top five things we must do to avert a climate disaster.[4]

Without eliminating virtually all coal emissions by 2030, the sum total of all of our other climate mitigation efforts will be inconsequential. Hansen often refers to the near complete phase-out of carbon emissions from coal plants worldwide by 2030 as the *sine qua non* for climate stabilization (see for example, the top of page 6 in his August 4, 2008 trip report).

To stay under 450ppm, we would have to install about 13,000 GWe of new carbon-free power over the next 25 years. That number was calculated by Nathan Lewis of Caltech for *the Atlantic*, but others such as Saul Griffith have independently derived a very similar number and White House Science Advisor John Holdren used 5,600 GWe to 7,200 GWe in his presentation to the Energy Bar Association Annual Meeting on April 23, 2009. That means that if we want to save the planet, we must install more than **1 GWe per day of clean power *every single day* for the next 25 years**. That is a very, very tough goal. It is equivalent to building one large nuclear reactor per day, or 1,500 huge wind turbines per day, or 80,000 37 foot diameter solar dishes covering 100 square miles every day, or some linear combination of these or other carbon free power generation technologies. Note that the required rate is actually higher than this because Hansen and Rajendra Pachauri, the chair of the IPCC, now both agree that 350ppm is a more realistic "not to exceed" number (and we've already exceeded it).

Today, we are nowhere close to that installation rate with renewables alone. For example, in 2008, the *average* power delivered by solar worldwide was only 2 GWe (which is to be distinguished from the *peak* solar capacity of 13.4GWe). That is why every renewable expert at the 2009 Aspen Institute Environment Forum agreed that nuclear must be part of the solution. Al Gore also acknowledges that nuclear must play an important role.

Nuclear has always been the world's largest source of carbon free power. In the US, for example, even though we haven't built a new nuclear plant in the US for 30 years, nuclear still supplies 70% of our clean power!

Nuclear can be installed very rapidly; much more rapidly than renewables. For example, about two thirds of the currently operating 440 reactors around the world came online during a 10 year period between 1980 and 1990. So our best chance of meeting the required installation of new power goal and saving the planet is with an aggressive nuclear program.

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[4] See the bottom of page 7 in Hansen's Tell Barack Obama the Truth -- The Whole Truth.

Unlike renewables, nuclear generates base load power, reliably, regardless of weather. Nuclear also uses very little land area. It does not require the installation of new power lines since it can be installed where the power is needed. However, even with a very aggressive plan involving nuclear, it will still be extremely difficult to install clean power fast enough.

Unfortunately, even in the US, we have no plan to install the clean power we need fast enough to save the planet. Even if every country were to agree tomorrow to completely eliminate their coal plant emissions by 2030, how do we think they are actually going to achieve that? There is no White House plan that explains this. There is no DOE plan. There is no plan or strategy. The deadlines will come and go and most countries will profusely apologize for not meeting their goals, just like we have with most of the signers of the Kyoto Protocol today. Apologies are nice, but they will not restore the environment.

We need a strategy that is believable, practical, and affordable for countries to adopt. The IFR offers our best hope of being a centerpiece in such a strategy because it the only technology we know of that can provide an economically compelling reason to change.

At a speech at MIT on October 23, 2009, President Obama said "And that's why the world is now engaged in a peaceful competition to determine the technologies that will power the 21st century. … The nation that wins this competition will be the nation that leads the global economy. I am convinced of that. And I want America to be that nation, it's that simple."

Nuclear is our best clean power technology and the IFR is our best nuclear technology. The Gen IV International Forum (GIF) did a study in 2001-2002 of 19 different reactor designs on 15 different criteria and 24 metrics. The IFR ranked #1 overall. Over 242 experts from around the world participated in the study. It was the most comprehensive evaluation of competitive nuclear designs ever done. Top DOE nuclear management ignored the study because it didn't endorse the design the Bush administration wanted.

The IFR has been sitting on the shelf for 15 years and the DOE currently has no plans to change that.

How does the US expect to be a leader in clean energy by ignoring our best nuclear technology? Nobody I've talked to has been able to answer that question.

We have the technology (it was running for 30 years before we were ordered to tear it down). And we have the money: The Recovery Act has $80 billion dollars. Why aren't we building a demo plant?

IFRs are better than conventional nuclear in every dimension. Here are a few:

1. **Efficiency**: IFRs are over 100 times more efficient than conventional nuclear. It extracts nearly 100% of the energy from nuclear material. Today's nuclear reactors extract less than 1%. So you need only 1 ton of actinides each year to feed an IFR (we can use existing nuclear waste for this), whereas you need 100 tons of freshly mined uranium each year to extract enough material to feed a conventional nuclear plant.
2. **Unlimited power forever:** IFRs can use virtually any actinide for fuel. Fast reactors with reprocessing are so efficient that even if we restrict ourselves to just our existing uranium resources, we can power the entire planet forever (the Sun will consume the Earth before we run out of material to fuel fast reactors). If we limited ourselves to using just our DU "waste" currently in storage, then using the IFR we can power the US for over 1,500 years without doing any new mining of uranium.[5]
3. **Exploits our largest energy resource:** In the US, there is 10 times as much energy in the depleted uranium (DU) that is just sitting there as there is coal in the ground. This DU waste is our largest natural energy resource…but only if we have fast reactors. Otherwise, it is just waste. With fast reactors, virtually all our nuclear waste (from nuclear power plants, leftover from enrichment, and from decommissioned nuclear weapons)[6] becomes an energy asset worth about $30 trillion dollars…that's not a typo…$30 *t*rillion, not *b*illion.[7] An 11 year old child was able to determine this from publicly available information in 2004.
4. **Safety**: The IFR is safer than conventional nuclear because the reactors safely shut down based on the laws of physics if something goes wrong. Today's third generation nuclear designs are very safe: 1 accident predicted every 29 million reactor years. The IFR should be even safer due to the passive safety inherent in the design. Also, IFRs are much safer than the coal plants they replace. Coal power plants are estimated to kill 24,000 Americans per year, due to lung disease as well as causing 40,000 heart attacks per year. Outside of the Soviet Union,[8] commercial nuclear has never killed even a single member of the public in its entire 50 year operating history.

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[5]The U.S. stockpile of DU amounts to about 700,000 tonnes, which is 7E5 reactor-years of power, or 7E5 x 8760 hours/yr x 1E6 kW/reactor = 6.1E15 kWhr of energy. The annual U.S electricity consumption these days is ~4E12 kWh. This works out to be 1,525 years of fuel.

[6] More than 99% of the current nuclear waste from nuclear power plants, uranium enrichment, and decommissioned nuclear weapons can be re-used to fuel fast reactors. The fission products, which comprise less than 1% by weight of our current nuclear waste, cannot be used for electric power generation, but everything else can. The DU comprises about 90% of the nuclear waste in the US today.

[7] The U.S. stockpile of DU amounts to about 700,000 tonnes, which is 7E5 reactor-years of power, or 7E5 x 8760 hours/yr x 1E6 kW/reactor = 6.1E15 kWhr of energy. At 0.5 cents per kWh, which is the current value of uranium for second generation reactors, this is $30 trillion dollars.

[8] The reactor design at Chernobyl would never have been approved in the US. If Chernobyl was a US-approved reactor design run in accordance with US standards that accident would not have happened.

5. **Proliferation resistant**: The IFR is proliferation resistant on two counts. First, the pyroprocess used to recycle the fuel does not and cannot produce plutonium with the chemical purity needed for nuclear weapon. One of the world's top nuclear proliferation experts is strongly in favor of the IFR for this reason. Second, if all reactors were IFRs, there would never again be need for enriched uranium. Facilities for both reprocessing and uranium enrichment should be operated under strict international supervision. The need for international control is arguably the most compelling reason for the U.S. to proceed rapidly with the IFR.
6. **Consumes existing nuclear waste from nuclear reactors and weapons**: Fast reactors consume our existing nuclear waste (from reactors and decommissioned weapons) and transforms it into elements that are safe after 300 years.
7. **Minimal waste**: A 1 GWe IFR plant generates 1 ton of fission products each year that needs to be sequestered for 300 years until it is safe. A conventional nuclear plant of the same capacity creates about 100 tons of "waste" each year, containing isotopes that need to be sequestered for 1 million years according to the current US depository requirements. If you powered your entire life from IFRs, the amount of waste you'd generate would be smaller than 1 soda can and it would need to be stored for only 300 years.
8. **Nuclear material security**: The nuclear material in the reactor or reprocessing facility would be too hot for a terrorist to handle. The nuclear material that leaves the site are the fission products which are completely useless for making a nuclear bomb.
9. **The IFR creates a huge economic opportunity for the US to be the leading clean energy supplier to the world.** Nuclear is the lowest cost scalable energy technology we have and the IFR is our best nuclear technology. If we focus on the IFR and invest in ramping up the volumes and reducing the cost, the IFR will be cheapest power source that every country will want everywhere instead of coal. Our economy will benefit and our planet will too.

A brief history of the IFR

Developed in the last decades of the 20th century by a team of scientists at Argonne National Laboratory led by Charles Till. It used as a test bed a small fast reactor that first produced power in 1965 and ran for 30 years without incident.

In the 1970's, the fast reactor was the top energy priority of the President, Congress, and the Atomic Energy Commission. In 1971 Nixon said, "Our best hope today for meeting the Nation's growing demand for economical clean energy lies with the fast breeder reactor."

In his 1994 State of the Union address, President Clinton declared that the IFR was unnecessary and later that year Congress terminated the project. The scientists were

ordered to dismantle the test reactor so it could never be restarted, and they came to understand that it would not be wise to criticize official policy so they stopped talking about it.

The IFR demonstrated that fast reactors can be operated for decades without incident or mishap and that the on-site reprocessing technique for removing the fission products and putting the material back into the reactor works.

Support

1. Secretary of Energy Steven Chu[9]
2. White House Science Advisor John Holdren[10]
3. James Hansen, Director, NASA Goddard Institute for Space Studies
4. Bill Gates
5. Hans Bethe, Nobel laureate, Physics[11]
6. Charles Till, Former Associate Director Argonne National Laboratory
7. Yoon Chang, former Associate Laboratory Director, Argonne National Laboratory
8. John Sackett, former Associate Director, Argonne National Laboratory
9. Ray Hunter, former Deputy Director of the Office of Nuclear Energy, Science and Technology in the U.S. Department of Energy (DOE)
10. Leonard Koch, 2004 winner of the Global Energy International Prize (equivalent to the Nobel prize for energy)
11. California Lt. Governor John Garamendi
12. Congressman Jerry McNerney
13. Congresswoman Anna Eshoo
14. Congresswoman Jackie Speier
15. Senator Lamar Alexander
16. Senator Jeff Bingaman[12]
17. General Electric (who already has a plant design for the IFR ready to build)
18. The American public, 59% of whom support nuclear power according to a March 2009 Gallup poll, despite zero PR by the nuclear industry.[13]

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[9] Chu has talked favorably about fast reactors and pyroprocessing which are the two key features of the IFR. Chu has not specifically mentioned the IFR by name, however.

[10] Holdren as not publicly announced his support of the IFR, but has spoken favorably about the IFR in private meetings.

[11] Bethe met with Till for a full day of briefings on the IFR before the project started. Bethe's support was important for getting Congress to fund the IFR.

[12] Senator Bingaman has incorporated language into his bill (Section 313 of S.1462) which would allow DOE to lay the ground work for doing some of the planning necessary to restart the IFR. Bingaman prefers that Secretary Chu to lead on this issue rather than have it dictated by Congress.

[13] The public is uninformed about the IFR. The 59% approval is for nuclear power in general.

Opposition

1. We do not know of any members of Congress who oppose restarting the IFR. Most have never heard of it.
2. Environmental groups, in general, do not like nuclear power. For example, environmental groups in Germany got Germany to ban nuclear power. The result is that Germany is forced to build more new coal plants...the worst possible outcome for the environment and exactly the opposite of what the green groups wanted. The green case against nuclear is based largely on dogma and myth. See Mark Lynas: the green heretic persecuted for his nuclear conversion which is an eye-opening account of a noted environmentalist who took an objective look at the facts. One of the top people at NRDC (speaking on his own behalf), says his only objection to the IFR is the cost competiveness of nuclear. GE says IFRs can be built in volume for $1,500 per kW which is cheaper than coal (and slightly less than the $2,000 per kW that the Chinese paid to construct Qinshan Phase 3 which was completed 52 days ahead of schedule and under budget in 2003). The NRDC spokesperson is skeptical of GE's cost numbers for the IFR ($1,500 per kW).
3. NRDC opposes the IFR because they say it will cost too much, even though they admit that they don't know how much it will cost. Their expert also doesn't like it due to nuclear proliferation reasons, but NRDC concedes that John Holdren outranks their expert and Holdren loves the IFR.
4. UCS opposes the IFR and refused to be briefed on it.

You won't have any trouble finding people who will throw darts at the IFR. They will argue it's too expensive, unreliable, unproven, increases the proliferation risk, etc. These arguments lack credibility; they all fail in the face of the facts, e.g., the EBR-II and the Russian BN-600 experiences (a commercial nuclear reactor that has operated for 30 years without incident and the precursor to Russia's next generation fast reactors that are now being built). These two reactors are are the "inconvenient truths" for the fast reactor skeptics.

Even if you believe all the arguments of the opposition and completely discount the arguments of the Argonne scientists who best know the technology, it doesn't matter because we do not have an option: we have to make this work now. Renewables alone can't kill coal in the time allotted. The point is:1) virtually every credible renewable expert agrees we cannot reduce our carbon emissions enough without nuclear, 2) the IFR is our best nuclear, 3) the IFR is the only technology we have with a realistic chance of replacing coal burners in a coal plant with a lower-cost carbon-free alternative.

So objections noted, but our planet is at stake and we have got to make this work. We should be joining together and doing things that our most credible scientists tell us we have to do to save our planet, rather than arguing amongst ourselves and debating what the optimum solution is. The time for debate is over. We are so late on deploying clean

energy technologies that any new technology that has a realistic potential to make a significant positive impact should be welcomed with open arms by every human being.

Urgency

"Within the next four decades, human civilisation must eliminate its use of fossil fuels and replace them with 10,000 gigawatts of reliable, sustainable power. The only realistic way that this extraordinary challenge can be met is with the rapid and large-scale deployment of nuclear power, on a worldwide basis, led by countries like the US, Russia, the EU, China and India. Generation III nuclear plants will be critical to this expansion over the short term, Generation IV technology is the astoundingly attractive long-term prospect, with the IFR being the flagship Gen IV design. The urgency in getting the IFR commercialised and deployment on an industrial scale cannot be overstated".

-- Professor Barry Brook
Sir Hubert Wilkins Chair of Climate Change
The University of Adelaide

1. **Our top scientists tell us that evolutionary nuclear technologies are one of the two key technologies that must be done immediately.** The report of the Committee on America's Energy Future of the National Research Council of the National Academies said this about evolutionary nuclear technologies and carbon capture: "A failure to demonstrate the viability of these technologies during the next decade would greatly restrict options to reduce the electricity sector's CO2 emissions over succeeding decades.The urgency of getting started on these demonstrations to clarify future deployment options cannot be overstated."
2. **The climate crisis won't wait.** The sooner the IFR is perfected and deployed to eliminate emissions from coal plants, the better.
3. **We are setting yourself up for a bigger disaster if we wait.** The Gen IV Internatioal Forum Technology Roadmap and a 2008 INEA position paper on uranium availability clearly show that we must deploy commercial fast reactors starting in 2030 or we'll run out of fuel for all reactors. We are nowhere close to that goal.
4. **You can't expand nuclear in the US without a solution to the waste problem.** For example, in California, you can't build a new nuclear power plant until there is a federal waste repository.
5. **We need to do the technology transfer while the people who know how to do it are still alive.** This technology is not trivial. No other country has been able to successfully replicate the IFR. If we wait 10 years, the people who built the IFR will all be dead. This could set the project back another decade or two.
6. **Ensures energy independence for the future.** If the world ramps up conventional nuclear, we will run out of cheap nuclear fuel faster than many people think. For example, the Russians published a paper showing that in Russia, if they doubled their nuclear capacity in 20 years, they would run out of cheap

nuclear fuel in as little as 25 years. (see the first paragraph of BN-800 as a New Stage in the Development of Fast Sodium-Cooled Reactors). With fast reactors in place, we never run out of fuel.

7. **Solves the waste problem now.** President Obama has said nuclear power will not be expanded in the US until we have a solution to the waste problem. The IFR provides that solution since today's "waste" now becomes valuable "fuel" for our future fast reactors. The only real waste, the fission products, are small and only need be stored for about 200 years. This is a trivial challenge compared to the problem we face today. Regarding storage today, the US government could make this offer any state willing to store nuclear waste: "if you store it, you can sell it." So if one state stores all the nuclear waste, that state would own an asset with an eventual market value of $30 trillion dollars. What state can resist that offer? Instead of rejecting nuclear waste, every state would be clamoring to get its piece of this national asset. If all the states are foolish enough to reject that offer, a number of American Indian tribes have said they are more than happy to store the nuclear waste on their land so long as they can sell that "waste" to power fast reactors, whether in the US or other parts of the world. Senator Bingaman's bill in fact contemplates such compensation to a State and/or Indian tribe which hosts a repository.[14] The DOE would have to supervise the storage.
8. **The genie is out of the bottle: refusing to play will not make fast reactors go away and will ultimately make us less safe.** If we don't re-start our fast reactor technology, then other countries will take the lead. France, Russia, India, Japan, and China all have fast reactor programs and all are either operating fast reactors now, or soon will be. The US shut down our last remaining fast reactor 15 years ago. Leadership is important for two reasons: 1) if we fail to lead, we will have missed taking advantage of our superior technology and missed a major economic opportunity as the premiere supplier of clean power technology and 2) the nuclear industry is in far safer hands if the US leads the way than if we abdicate. For example, if Chernobyl had been a US reactor design, that accident could never have happened.
9. **No advantage to waiting.** Fast reactors are the future of nuclear power. These reactors are better in every dimension than today's nuclear designs. The sooner we transition to them and standardize them, and focus on getting the volumes up and the costs down, the lower our energy costs, the greater our impact on climate change, and the greater our chances of capturing the economic opportunity. There is no advantage to waiting to deploy these reactors. But we cannot deploy them until we build one first. We are way behind other countries. The Russian BN-600 fast breeder reactor - Beloyarsk unit 3 - has been supplying electricity to the grid since 1980 and is said to have the best operating and production record of all Russia's nuclear power units. China recently ordered two of the Russian BN-800 fast reactors. So while the Russians are the first country to be exporting

[14] S.1462, Section 604(d)(2) which can be found on page 329, line 16.

commercial fast reactors and had no trouble getting $3.5B from the Russian government for their fast reactor program, the US hasn't spent a dime exploiting the world's best fast technology that we shelved in 1994 (which the Russians would love to get from us). That is not a winning strategy. It is a dumb strategy. We should either fish or cut bait on fast reactors. If we aren't going to pursue them, then we should sell the technology to the Russians so we get at least some economic benefit from our research instead of zero. If we are going to pursue fast reactors, we need to get off our butts and build one now like our top Argonne scientists have been telling us for the last 15 years. If our objective is for Russia to lead the world on commercial advanced nuclear reactors, then we should keep doing what we are doing now, i.e., nothing.

10. **Building high dollar value nuclear reactors will help re-start our economy.** Unlike with convention nuclear plants, the IFR reactors are built in a factory then shipped to the site on rail. We can re-tool idle factories, create jobs, and help reverse our trade deficit. Today, thanks to US government inaction, the Russians are the first to export commercial fast nuclear reactors. This is technology we invented and perfected.
11. **France and Japan aren't going to wait for us.** If we want to influence the fast reactor program in other countries, we need to have a program in the US. Today, we have nothing.

Here are the reasons for moving forward now from George Stanford:

1. Eighty years of waste from 1000 (1-GWe) reactors would leave enough used fuel for 10 or 20 Yucca Mountains.

2. The environmental effects of accelerated uranium mining will impinge increasingly on the public's consciousness. Resistance to uranium mining is already growing.

3. The accumulating plutonium inventory will, rightly or wrongly, be seen as an ever-increasing proliferation risk,

4. The multiplying need for uranium enrichment means the spread of centrifuge technology and loss of international control of that technology, with serious proliferation implications.

5. Since China, India, Russia, et al. are forging ahead with their fast-reactor programs, technological leadership will continue to move in that direction.

6. The concomitant spread of fuel-processing technology will mean loss of international control of that technology, with further serious proliferation implications.

7. No nation can make nuclear weapons without either enrichment or reprocessing facilities, regardless of how many reactors it has. The loss of U.S. technological leadership will mean the loss of ability to bring order to the global development and deployment of nuclear technology, with the consequent uninhibited spread of proliferation potential.

8. The institutional knowledge of the U.S.-developed IFR technology is rapidly dying off, accelerating the North American descent to second-class technological status.

Why Congress must order the DOE to build an IFR demo

A member of Congress inquired about the IFR with the DOE and was told the following:

> Although the IFR program per se is no longer active, research and development in sodium fast reactor and pyroprocessing technologies have continued. In its FY 2010 budget, the Office of Nuclear Energy is requesting $153.8 million for Fuel Cycle Research and Development, a portion of which will continue research in IFR related technologies like metal fuel development and pyroprocessing. Some additional funding is also requested in the Generation IV R&D activity to support sodium fast reactor work. The precise distribution in FY 2010 for these activities will depend on the final appropriation. Further research is needed to establish the scalability and economics of liquid metal and pyroprocessing technologies as well as their fuel cycle and proliferation-resistant benefits before they are ready for commercial consideration.

From this response (which doesn't really tell the full picture), you get the impression that DOE, if left alone, will just do more research. While the Russians are building commerical fast reactors for export, DOE wants to study it more.

Think back 44 years ago. The EBR-II sodium cooled fast reactor was designed and constructed in just a few years. That's without the aid of computers. After over 30 years of operating experience, the original scientists who worked on the IFR say we are ready to build a full-scale demo plant now. That is their expert opinion.

Today, the DOE wants to do more research and they haven't even committed to building a small test reactor. **So we were further along 44 years ago than we are today. At least back then, we actually had an operating fast reactor**. Forty four years ago, we had a "can do" attitude. **Today, we've completely lost it.** We have a "do more research" attitude. Today we have no operating fast reactor of any kind and DOE has no plans to change that.

How is it that we need more research today, yet 44 years ago, we had sufficient research to design, build and operate a sodium cooled fast reactor? Did we lose all that knowledge? Did we not learn anything of value over the 30 years of operation?

Compare what is not happening in the US to what is happening in Russia today. They have been operating their BN-600 sodium-cooled fast breeder reactor without incident for the past 30 years. This is a commercial reactor, not a test reactor. And now they are building commercial fast reactors for the Chinese. So we are currently 30 years behind the Russians and even today, the DOE would rather to fund more research rather than deciding to actually build something.

We are out of time.

If the government orders DOE to have a 300 MWe IFR plant built and operating in <8 years and they make it a priority, then DOE will get it done. Short of that, nothing will happen. It's like JFK and putting a man on the moon. Without setting high expectations, nothing gets done. **It's clear that Congress has got to request it and set high goals (just like the Chinese do) because left alone, DOE will simply research fast reactors until the cows come home and nothing will get built.** If Congress requests nothing, then that's what we will get: nothing.

The Gen IV International Forum Technology Roadmap

http://www.gen-4.org/Technology/roadmap.htm summarizes the results of extensive deliberations of the world's top nuclear experts on generation IV reactors.

Four key points:

1. The IFR comes in at lowest cost for viability/performance (p. 83)
2. The IFR has the best "best case deployment date" (p. 20)
3. The chart on p. 13 shows we will be in serious trouble if fast reactors aren't introduced starting in 2030. A September 2008 INEA position paper confirms that we will need to have a sizable fleet of Gen IV breeder reactors in operation by 2050.

Not shown in this report were the overall scores of each system where the IFR ranked #1. See the Gen IV Evaluation Summaries presentation which discloses this.

Also, p. 41 of the Technology Roadmap basically confirms the US is not giving the IFR the attention it deserves:

> **SFR Design and Evaluation R&D**
> While there are design studies in progress in Japan on SFRs, there is little design work in the United States, even at the preconceptual level. Design work is an

important performance issue, and it should accelerate given the importance of economics for the SFR. R&D activity is needed with a focus on the base technology for component development.

Next steps

"On the waste issue, GE has technology called PRISM reactors that we can employ …we can deal with nuclear waste through those reactors, but again, the decision to deploy that technology is really in the hands of the government. What China has done right though is they've set long-term policy with very very tall objectives. And the US has been very on and off, very short term."

- John Krenicki, president and CEO of GE Energy during interview on CNBC
  (Note: PRISM is GE's commercial implementation of the IFR)

The House bill already allocates $10B for Carbon Capture and Sequestration (CCS) and $0 for fast nuclear. Bingaman's bill allocates $6.6 billion for 10 "early mover" large-scale CCS projects and $0 for fast nuclear.

The Boxer-Kerry Climate bill should be modified to provide DOE at least $3B to construct a demonstration IFR plant.

This would be a better use of public funds than CCS, because 1) there is a greater likelihood of a successful outcome with the IFR than with CCS, and 2) the IFR solution is a superior solution to CCS because the IFR reduces the cost of operating a power plant, whereas CCS will dramatically increase it. So even if CCS worked as designed, everyone will find a reason not to adopt it. Every country would be much more likely to adopt an IFR solution (that lowers costs) than a CCS solution (that increases costs).

So why are we allocating billions to CCS and zero to the IFR? It makes no sense. You'd only do that if you were 100% confident CCS would work and would negligibly increases costs and were 100% confident the IFR would fail. But it is much more likely that the IFR will work and CCS will fail.

There is over $20 billion dollars in the Nuclear Waste Fund. Senator Lindsay Graham introduced legislation in April to have all of it rebated to consumers. That's a dumb idea; it would not move us closer to solving the waste problem. But taking some of that $20 billion dollars and investing it in building an IFR would be a brilliant move.

For further reading

http://dl.getdropbox.com/u/390139/ifr/IFRintro.doc
Is the electronic version of this document with all the hyperlinks (if you are reading a print version)

http://bravenewclimate.com/2009/10/16/ifr-spm/
This is a more readable on-line HTML version of this document with pretty graphics done by Barry Brook.

http://www.sustainablenuclear.org/PADs/pad0509till.html
Article about the history and significance of the IFR written by the IFR inventor himself, Charles Till.

http://www.anl.gov/Media_Center/Argonne_News/news97/crtill.html
Senator Kempthorne wrote into the Congressional Record on the retirement of Charles Till a nice summary of the IFR, and that " I assure my colleagues someday our Nation will regret and reverse this shortsighted decision."

http://www.huffingtonpost.com/steve-kirsch/climate-bill-ignores-our_b_221796.html
My Huffington piece provides a good overview and has links to various primary sources.

http://dl.getdropbox.com/u/390139/ifr/IFRKirschCongressBriefing.ppt
A PowerPoint that gives you the gist in the first 15 slides

http://dl.getdropbox.com/u/390139/ifr/Ray%20Hunter%20email%20to%20Senator%20Reid.doc
A letter written to Senator Reid by the former #2 nuclear guy at DOE. Ray Hunter was at DOE for 30 years.

http://www.columbia.edu/~jeh1/mailings/2008/20081121_Obama.pdf
Jim Hansen says IFR is priority #4 of the 5 things we must do (see bottom of page 7)

http://www.timesonline.co.uk/tol/news/environment/article4836556.ece
Mark Lynas, a well known UK environmentalist, read about the IFR and he realized that the green groups had been pulling the wool over his eyes all these years. It is a great read if you have time

http://blogs.reuters.com/felix-salmon/2009/06/23/nuclear-power-going-fast/
This article talks about using the IFR to replace the burner in a coal plant. The comments on this article are also interesting reading. Some of the comments are from people who are misinformed, and some of the comments are actually very astute and accurate.

http://skirsch.com/politics/globalwarming/ifrBerkeley.htm
This is a copy of the original IFR page at UC Berkeley before it became unavailable. Lots of great details about the IFR.

http://www.youtube.com/watch?v=4uJ4NaSVLn0&feature=related%C2%A0
Video interview of Tom Blees on the IFR. This is in 3 parts. Be sure to watch part 2.

http://www.world-nuclear.org/info/default.aspx?id=540

This is the page on fast nuclear reactors on the world-nuclear.org site. This page is one of the most comprehensive I've seen.

http://dl.getdropbox.com/u/390139/ifr/IFRKirsch.ppt
This is my catch-all slide prezo of all IFR slides.

http://prescriptionfortheplanet.com/
This is the book by Tom Blees that re-started it all when Jim Hansen read it.