THORIUM versus URANIUM

To: Signers of the Holdren Letter and others interested in nuclear energy

Ever since the Holdren Letter was created in January 2010, advocates of using thorium instead of uranium in nuclear power plants in the United States have pressed their case. I have worked with Dr. George Stanford, retired physicist from Argonne National Laboratory and other distinguished engineers and scientists to understand why the United States should use uranium, not thorium. The dialogue in the form of a letter between myself and an other engineer offers answers.

Should we be using uranium or thorium to fuel nuclear power plants?

For the United States, uranium.

For other countries, uranium or thorium. Your choice. There is enough of both fuels. Uranium nuclear power technology is well developed. For those wanting or needing to use thorium, the technology needs to be developed further. However, some thorium advocates often give inaccurate reasons for the need for thorium and the state of development of thorium based nuclear energy.

Read what Dr. Stanford says below.

To: xxxxx

Thanks for copying me on your discussion about thorium versus uranium reactors. See your e-mail below.

You and I had careers in uranium fueled Light Water Reactors in the 1970s and 80s.

I would like to share with you some information on this topic that I learned about since initiating the Holdren Letter dated February 1, 2010. Dr. John Holdren is the current Science Advisor to the White House. I've known him since 1970. He is against the use of uranium fueled fast reactors and has a list of other advances of the modern world that he would like to restrict civilization from using.

The Holdren Letter dated February 1, 2010 recommends that the United States continue use and development of uranium fueled nuclear power and promote domestic production of isotopes for nuclear medicine. See letter attached. This letter is currently signed by 358 people. Many are scientists and engineers with experience in uranium fueled power plants and production of isotopes for nuclear medicine. They come from 22 countries around the world and 39 states in the USA plus the District of Colombia. Some have unique experiences: Commanding Officer, first nuclear powered submarine and first nuclear powered ship - E. Willkinson. CA, US Navy retired. Only scientist to do scientific work on the moon, Dr. H. Schmitt, NM. Leading nuclear energy scientist in Russia, Dr. E. Velikhov. Only engineer in the world to receive the prestigious Global Energy International Prize from Russia in the category of nuclear power, an American with uranium fueled fast reactor experience - L. Koch. Director, Indira Gandhi Centre for Atomic Research, Dr. B. Raj.

The Holdren Letter is going to be the cornerstone document for a long effort to educate the public about the benefits of nuclear power and production of isotopes for nuclear medicine. It will be led by students and young professionals. See the Go Nuclear!, Inc. website: [gonuclear.net](http://gonuclear.net" \t "_blank). We are starting with two outstanding students majoring in writing and communications. They will have the opportunity to lead other non-technical and technical students in educating youth and the public about nuclear energy and nuclear medicine. There may be parallel movements in other countries, possibly Canada, France, and India.

Some countries, like India, will explore and possibly use thorium fueled nuclear power in the next hundred years. Many other countries will use uranium fueled thermal and fast neutron reactors that the United States led in the development of over the last 60 plus years.

The above information is by way of background of why I would like to talk to you about thorium versus uranium reactors, particularly for the United States. Other countries, like India, will explore the use of thorium reactors. For many technical, practical, and historic reasons the United States should focus on uranium fueled thermal and fast neutron nuclear power. The reasons are simple and numerous:

- The United States led the world in the development of uranium fueled thermal and fast neutron reactors.

- Inspite of LWR accidents at Three Mile Island, Pennsylvania and Fukushima, Japan, uranium fueled nuclear power has by far the best human safety and operating record of any energy technology and most other life style choices in history of the world.

- The United States developed and perfected the passively safe fast neutron reactor at Argonne National Laboratory called the Integral Fast Reactor. GE has engineered a commercial version called the S-PRISM, also called PRISM. Power Reactor Innovative Small Module is a nuclear power plant design by [GE Hitachi Nuclear Energy](http://en.wikipedia.org/wiki/GE_Hitachi_Nuclear_Energy%22%20%5Co%20%22GE%20Hitachi%20Nuclear%20Energy%22%20%5Ct%20%22_blank) (GEH) based on a [sodium](http://en.wikipedia.org/wiki/Sodium%22%20%5Co%20%22Sodium%22%20%5Ct%20%22_blank)-cooled [fast breeder reactor](http://en.wikipedia.org/wiki/Fast_breeder_reactor%22%20%5Co%20%22Fast%20breeder%20reactor%22%20%5Ct%20%22_blank)[[](http://en.wikipedia.org/wiki/S-PRISM%22%20%5Cl%20%22cite_note-0%22%20%5Ct%20%22_blank) . I recommend that everyone involved in energy policy for the United States buy and read the new book by Dr. Charles Till and Dr. Yoon Chang, "The Story of the Integral Fast Reactor: The complex history of a simple reactor technology, with emphasis on its scientific bases for non-specialists." It is available at Amazon.com for a bargain price. When I say everyone involved in energy policy, that means politicians, students, engineers and leaders in all walks of life. It was written for all educated people who want to be able to wisely select their choice of energy for the future.

- The United States has already mined and milled depleted uranium and has LWR spent fuel to provide all of this country's electrical energy needs at 1994 levels for over 500 years without requiring much more mining of uranium or coal for our country's use. Since change to a lot more use of nuclear energy including fast neutron reactors won't happen in a short time, the United States has enough coal, gas and uranium to power our electrical energy needs for well over a thousand years.

Now, I would like to address the topic in your recent e-mail, thorium fueled nuclear power, in particular the article, "The Other Nuclear Fuel. Why Not Thorium" by Marin Katusa, Chief Energy Investment Strategist

Is this another case of an investment strategist giving questionable advice?

I've asked retired Argonne National Laboratory physicist, Dr. George Stanford, to review Katusa's thorium article. Here are his comments:

=======================================================

John:

     Yes.  Very discouraging to see such ignorance promulgated.  Here are seven of the most egregious misconceptions in the Martin Kapusa piece.

(1)  He says, "Thorium reactors do not produce plutonium, which is what you need to make a nuke. . . . The fact that thorium reactors could not produce fuel for nuclear weapons meant the better reactor fuel got short shrift."  Nonsense.  The thorium cycle does not eliminate proliferation concerns, for two reasons.

     First, any (uninspected) reactor can be adapted to irradiate U238 to make weapons-quality Pu239.

     Second, it is fairly straightforward to extract pure U233 (an excellent bomb material) from a thorium reactor by chemical separation of Pa233 (the U233 precursor). Sometimes it's argued that removing Pa233 would deprive the reactor of needed fissile material. However, that deficit can be made up by substituting poor-quality Pu from LWR fuel, or by using uranium that is partly enriched. Thus a thorium reactor can be used as a device for converting lousy (for weapons) Pu or U into high-quality U233.

     Thorium reactors will need the same sort of safeguards as uranium-fueled reactors.

(2)  He says, "[U233 is] the same uranium isotope we use in reactors now as a nuclear fuel, the one that is fissile all on its own."  Wrong.  The fissile uranium isotope in current reactors is U235, of course.

(3)  He says, "The irradiated fuel can be unloaded from the reactor and the U233 separated from the remaining thorium. The uranium is then fed into another reactor all on its own, to generate energy."  Wrong.  A thorium reactor can barely breed enough fissile to keep itself going -- it can't generate enough extra U233 to start up other reactors.

(4)  He says, "Thorium is three times more abundant in nature than uranium."  Maybe true, but so what?  There's enough uranium OR thorium to outlast civilization.

(5)  He says, "All but a trace of the world's thorium exists as the useful isotope, which means it does not require enrichment."  Nonsense.  It means that, to get a thorium reactor started, the initial fuel loading has to be enriched with Pu or enriched U -- and to keep the reactor running, enrichment with U233 has to be maintained.

(6)  He says, "Thorium nuclear waste only stays radioactive for 500 years, instead of 10,000 . . ."  This is also true of IFR waste, of course.

(7)  He says, ". . . and there is 1,000 to 10,000 times less of it to start with." What on earth can he be thinking?  Any reactor will generate about 1 tonne of fission products per GWe-year.  The waste (compared with IFRs) is essentially the same.  Even in comparison with LWRs, the factor is about 5, in terms of repository volume needed.  And note that comparison with LWRs is irrelevant, since the thorium reactor would be a Gen IV (or later) critter.

     For various aspects of thorium versus uranium, I recommend the discussion to be found at [http://www.thesciencecouncil.com/george-stanford/195-the-ifr-vs-the-lftr-an-exchange-of-emails.html](http://www.thesciencecouncil.com/george-stanford/195-the-ifr-vs-the-lftr-an-exchange-of-emails.html%22%20%5Ct%20%22_blank)

     Lastly, Phillip Mannes says, "the current Uranium fueled reactors were initiated by the necessity of obtaining Pu for our war effort."  I don't know why he would say that.  All of the U.S. weapons Pu has been made in graphite-moderated, non-power-producing, special-purpose reactors.

     Best,

     George

========================================================

I hope this helps clarify why uranium, not thorium, should be the preferred choice of nuclear fuel for the United States, Canada and many other countries.

Thanks,
--
John A. Shanahan
Retired Civil Engineer

On Wed, Feb 8, 2012 at 6:06 PM, xxxxx wrote:

Many of us who are nuclear advocates have long known the virtues of thorium. You are quite correct in stating the that the current Uranium fueled reactors were initiated by the necessity of obtaining Pu for our war effort. The impact of Adm. Rickover’s nuclear navy and the implementation of Shippingport as a commercial entity also contributed significantly to our current nuclear technology And therein lies the problem. With the recognition of Th as a more desirable fuel, how does one change a well established, technically based industry with a new improved one. How would one approach the billions if $ invested in the current technology in the US for something better. For an analogy I would use our US transportation sector. The number of 4 wheel, 2 axle vehicles in our American fleet is over 250 million. If an engine type or superior fuel were discovered  (or found) which makes our current fleet not only inefficient and wasteful of resources but also was safer in operation. How would you transition from your current *internal combustion (IC) modus operandi* to the new technology. The response, not easily and, if you decided to do so, it would take decades to accomplish the change-over.

        I remember many years ago (probably decades) that while working on nuclear matters globally, some Indian friends indicated that Th was ubiquitous in India and should be their fuel of choice when and if India embarked on a nuclear power program. That’s what is happening today, although India is initiating their initial phase of nuclear power with the internationally accepted LWR U based nuclear power plants. As India moves forward with their program and initiates the development of Th fueled based nuclear power plants, all of us will be following that development. If successful it could be the most significant advance in nuclear power since the advent of U fueled plants. Incidentally, referring to the example cited above in the transportation sector, we will have found an alternative to the IC power drive.

**From:** yyyyy

**Sent:** Wednesday, February 08, 2012 11:03 AM

**To: yyyyyy**

**Subject:** The Other Nuclear Fuel

|  |  |  |
| --- | --- | --- |
|

|  |  |
| --- | --- |
| http://www.caseyresearch.com/live-assets/images/emails/cdd/cdd-em-logo.gif | Feb 7, 2012 |

 |

|  |  |  |
| --- | --- | --- |
|

|  |  |
| --- | --- |
| -- | The World of Energy |

 |

|  |  |  |
| --- | --- | --- |
|

|  |
| --- |
| **Today's Edition** |

The Other Nuclear Fuel**Why Not Thorium?** By Marin Katusa, Chief Energy Investment StrategistThe Fukushima disaster reminded us all of the dangers inherent in uranium-fueled nuclear reactors. Fresh news yesterday about Tepco's continued struggle to contain and cool the fuel rods highlights just how energetic uranium fission reactions are and how challenging to control. Of course, that level of energy is exactly why we use nuclear energy - it is incredibly efficient as a source of power, and it creates very few emissions and carries a laudable safety record to boot.This conversation - "nuclear good but uranium dangerous" - regularly leads to a very good question: what about thorium? Thorium sits two spots left of uranium on the periodic table, in the same row or series. Elements in the same series share characteristics. With uranium and thorium, the key similarity is that both can absorb neutrons and transmute into fissile elements.That means thorium could be used to fuel nuclear reactors, just like uranium. And as proponents of the underdog fuel will happily tell you, thorium is more abundant in nature than uranium, is not fissile on its own (which means reactions can be stopped when necessary), produces waste products that are less radioactive, and generates more energy per ton.So why on earth are we using uranium? As you may recall, research into the mechanization of nuclear reactions was initially driven not by the desire to make energy, but by the desire to make bombs. The $2-billion Manhattan Project that produced the atomic bomb sparked a worldwide surge in nuclear research, most of it funded by governments embroiled in the Cold War. And here we come to it: Thorium reactors do not produce plutonium, which is what you need to make a nuke.How ironic. The fact that thorium reactors could not produce fuel for nuclear weapons meant the better reactor fuel got short shrift, yet today we would love to be able to clearly differentiate a country's nuclear reactors from its weapons program.In the post-Cold War world, is there any hope for thorium? Perhaps, but don't run to your broker just yet.**The Uranium Reactor**The typical nuclear-fuel cycle starts with refined uranium ore, which is mostly U238 but contains 3% to 5% U235. Most naturally occurring uranium is U238, but this common isotope does not undergo fission - which is the process whereby the nucleus splits and releases tremendous amounts of energy. By contrast, the less-prevalent U235 is fissile. As such, to make reactor fuel we have to expend considerable energy enriching yellowcake, to boost its proportion of U235.Once in the reactor, U235 starts splitting and releasing high-energy neutrons. The U238 does not just sit idly by, however; it transmutes into other fissile elements. When an atom of U238 absorbs a neutron, it transmutes into short-lived U239, which rapidly decays into neptunium-239 and then into plutonium-239, that lovely, weaponizable byproduct.When the U235 content burns down to 0.3%, the fuel is spent, but it contains some very radioactive isotopes of americium, technetium, and iodine, as well as plutonium. This waste fuel is highly radioactive and the culprits - these high-mass isotopes - have half-lives of many thousands of years. As such, the waste has to be housed for up to 10,000 years, cloistered from the environment and from anyone who might want to get at the plutonium for nefarious reasons.**The Thing about Thorium**Thorium's advantages start from the moment it is mined and purified, in that all but a trace of naturally occurring thorium is Th232, the isotope useful in nuclear reactors. That's a heck of a lot better than the 3 to 5% of uranium that comes in the form we need.Then there's the safety side of thorium reactions. Unlike U235, thorium is not fissile. That means no matter how many thorium nuclei you pack together, they will not on their own start splitting apart and exploding. If you want to make thorium nuclei split apart, though, it's easy: you simply start throwing neutrons at them. Then, when you need the reaction to stop, simply turn off the source of neutrons and the whole process shuts down, simple as pie.Here's how it works. When Th232 absorbs a neutron it becomes Th233, which is unstable and decays into protactinium-233 and then into U233. That's the same uranium isotope we use in reactors now as a nuclear fuel, the one that is fissile all on its own. Thankfully, it is also relatively long lived, which means at this point in the cycle the irradiated fuel can be unloaded from the reactor and the U233 separated from the remaining thorium. The uranium is then fed into another reactor all on its own, to generate energy.The U233 does its thing, splitting apart and releasing high-energy neutrons. But there isn't a pile of U238 sitting by. Remember, with uranium reactors it's the U238, turned into U239 by absorbing some of those high-flying neutrons, that produces all the highly radioactive waste products. With thorium, the U233 is isolated and the result is far fewer highly radioactive, long-lived byproducts. Thorium nuclear waste only stays radioactive for 500 years, instead of 10,000, and there is 1,000 to 10,000 times less of it to start with.**The Thorium Leaders**Researchers have studied thorium-based fuel cycles for 50 years, but India leads the pack when it comes to commercialization. As home to a quarter of the world's known thorium reserves and notably lacking in uranium resources, it's no surprise that India envisions meeting 30% of its electricity demand through thorium-based reactors by 2050.In 2002, India's nuclear regulatory agency issued approval to start construction of a 500-megawatts electric prototype fast breeder reactor, which should be completed this year. In the next decade, construction will begin on six more of these fast breeder reactors, which "breed" U233 and plutonium from thorium and uranium.Design work is also largely complete for India's first Advanced Heavy Water Reactor (AHWR), which will involve a reactor fueled primarily by thorium that has gone through a series of tests in full-scale replica. The biggest holdup at present is finding a suitable location for the plant, which will generate 300 MW of electricity. Indian officials say they are aiming to have the plant operational by the end of the decade.China is the other nation with a firm commitment to develop thorium power. In early 2011, China's Academy of Sciences launched a major research and development program on Liquid Fluoride Thorium Reactor (LFTR) technology, which utilizes U233 that has been bred in a liquid thorium salt blanket. This molten salt blanket becomes less dense as temperatures rise, slowing the reaction down in a sort of built-in safety catch. This kind of thorium reactor gets the most attention in the thorium world; China's research program is in a race with similar though smaller programs in Japan, Russia, France, and the US.There are at least seven types of reactors that can use thorium as a nuclear fuel, five of which have entered into operation at some point. Several were abandoned not for technical reasons but because of a lack of interest or research funding (blame the Cold War again). So proven designs for thorium-based reactors exist and need but for some support.Well, maybe quite a bit of support. One of the biggest challenges in developing a thorium reactor is finding a way to fabricate the fuel economically. Making thorium dioxide is expensive, in part because its melting point is the highest of all oxides, at 3,300° C. The options for generating the barrage of neutrons needed to kick-start the reaction regularly come down to uranium or plutonium, bringing at least part of the problem full circle.And while India is certainly working on thorium, not all of its eggs are in that basket. India has 20 uranium-based nuclear reactors producing 4,385 MW of electricity already in operation and has another six under construction, 17 planned, and 40 proposed. The country gets props for its interest in thorium as a homegrown energy solution, but the majority of its nuclear money is still going toward traditional uranium. China is in exactly the same situation - while it promotes its efforts in the LFTR race, its big bucks are behind uranium reactors. China has only 15 reactors in operation but has 26 under construction, 51 planned, and 120 proposed. | -- |