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Trying To Unleash The Power Of Thorium

Proponents aim to tap vast nuclear energy potential of obscure natural resource

By **Mitch Jacoby**

Department: **Science & Technology**
Keywords: **thorium**, **nuclear**, **nuclear energy**, **molten salt**, **nuclear reactor**

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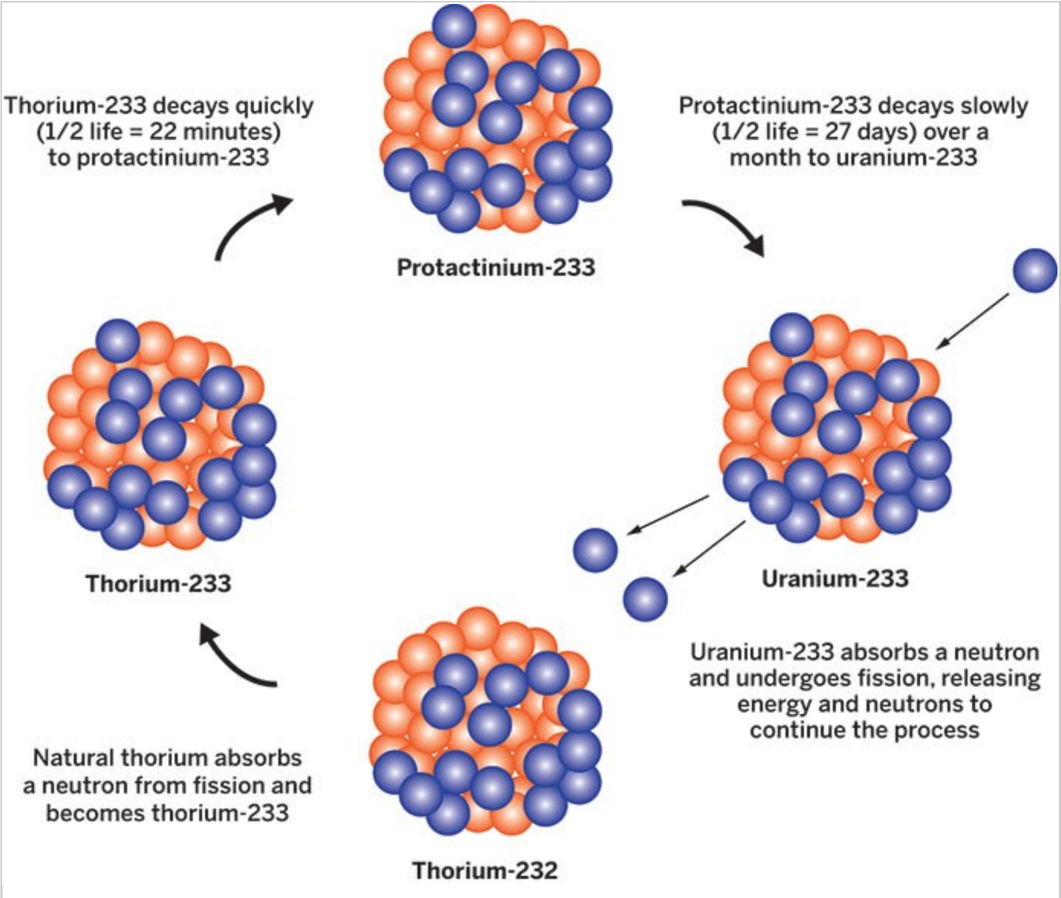
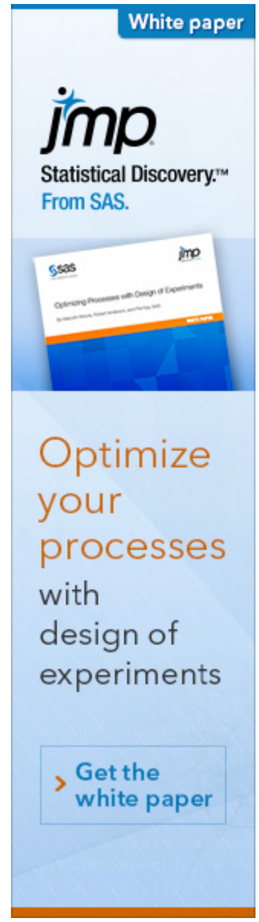


TRANSMUTATION

Thorium isn't a nuclear fuel, but it can be converted to one (^{233}U) by exposing it to low-energy neutrons.



John H. Kutsch never planned to be the world's number one proponent of nuclear energy from thorium. The cause found him.

"A company hired us to study a large number of materials from all across the periodic table," to look for possible investment opportunities, relates Kutsch, president of **Whole World**, a Chicago-area product engineering and design consultancy. Thorium was on the list.

After coming up to speed on thorium's uses—the oxide was once widely used to make mantles for gas lanterns, and some thorium compounds are still used today as catalysts for petroleum cracking and sulfuric acid synthesis—Kutsch gave his assessment to the client. "Thorium is basically garbage," he said, adding casually, "but it might just save the world."

The afterthought came from information Kutsch gleaned by studying thorium's history and from scrutinizing various nuclear energy websites and discussion boards. Although the element has little commercial use today, decades earlier people had recognized its potential for use in nuclear energy.

Studies conducted in the early days of the U.S. nuclear industry showed that thorium could be used as a precursor for nuclear fuel to run electricity-generating power plants. And the element, number 90 in the periodic table, offered numerous potential advantages in safety, cost, and environmental waste relative to uranium, which was another candidate to power commercial nuclear reactors. As history played out, uranium-fueled nuclear power became the standard, and except for a successful multiyear experiment at **Oak Ridge National Laboratory** (ORNL) in the 1960s, little was done with thorium. So it was largely forgotten.

But after learning about the nearly inexhaustible untapped energy potential of thorium, Kutsch concluded that the element could help satisfy growing global energy needs. He and other thorium enthusiasts are now spurring businesses and governments to tap into thorium's potential.

Thorium boasts several advantages over uranium, and the element's supporters call attention to them loudly. First, thorium is three to four times as abundant as uranium and potentially less expensive to process. A few grams of thorium could also produce enough energy to power an average American's life for a decade. The element could do this without generating material useful for making weapons, which sidesteps concerns about nuclear proliferation.

There are environmental benefits as well. Compared with coal- and natural-gas-fired power plants, thorium-fueled plants, like other nuclear plants, would not emit greenhouse gases, while generating power almost continuously, unlike solar- and wind-driven systems. And although thorium fuel would produce radioactive waste, its radiotoxicity would persist for just tens to hundreds of years rather than thousands of years, as is the case with uranium waste.

Thorium At A Glance

Natural Th: ~100% ^{232}Th

Abundance in Earth's crust relative to uranium: 3–4 times as great

U.S. reserves: ~400,000 metric tons, could produce same energy as ~ 1 trillion barrels of crude oil

World reserves: ~1.9 million metric tons

Mass needed to generate electricity needs of typical American for one decade: ~1/2 oz

Finally, thorium comes with safety benefits, its proponents claim. So-called molten salt reactors can use thorium as a liquid fluoride salt, which offers pressure and heat management advantages over today's solid-fuel comercial reactors.

One design for a molten salt reactor calls for surrounding a fluid core containing $^{233}UF_4$ in a lithium-beryllium fluoride solvent with a molten blanket of $^{232}ThF_4$ in the same solvent. The thorium is not actually the nuclear fuel. It is converted to the fuel, ^{233}U, when exposed to low-energy neutrons. As ^{233}U nuclei in the core fission, they generate heat that is transferred to a gas that drives a turbine to generate electricity. At the same time, the uranium nuclei emit neutrons that convert ^{232}Th in the blanket to ^{233}U. As uranium fuel accumulates in the blanket, it gets converted to UF_6 gas, separated, and fed into the core gradually and continuously as fresh thorium is injected into the blanket.

An advantage of this design is that unlike most of today's commercial uranium reactors, molten salt reactors would operate at low pressure and there is no chemical driving force that could lead to a dangerous buildup of hydrogen gas, says **David LeBlanc**, president and chief technology officer at **Terrestrial Energy**, an Oakville, Ontario-based start-up commercializing molten salt reactors. Further, because the fuel is liquid, the reactor's heat source is mobile and easily controlled, unlike the case with solid fuels. In addition, if the reactor leaked or was drained of its fuel, the molten salt would cool and solidify. In the event of reactor malfunction, this would terminate nuclear reactions and prevent the spread of radioactive material without the need for plant operator intervention.

So if thorium is safer than uranium and its nuclear energy potential was recognized decades ago, why has it taken people so long to start advocating for its use? Some nuclear aficionados suggest that when Cold War-era policy-makers chose to pour major funds into developing fuel for nuclear power reactors, they favored uranium, for which technology and know-how were more advanced than thorium. Others contend that U.S. leaders at that time were more interested in uranium reactors because they are better suited to breeding plutonium isotopes that were needed for making nuclear weapons. Over time, pressurized light-water reactors became the standard, and because they are fueled by uranium, thorium was left behind and has never been commercialized.

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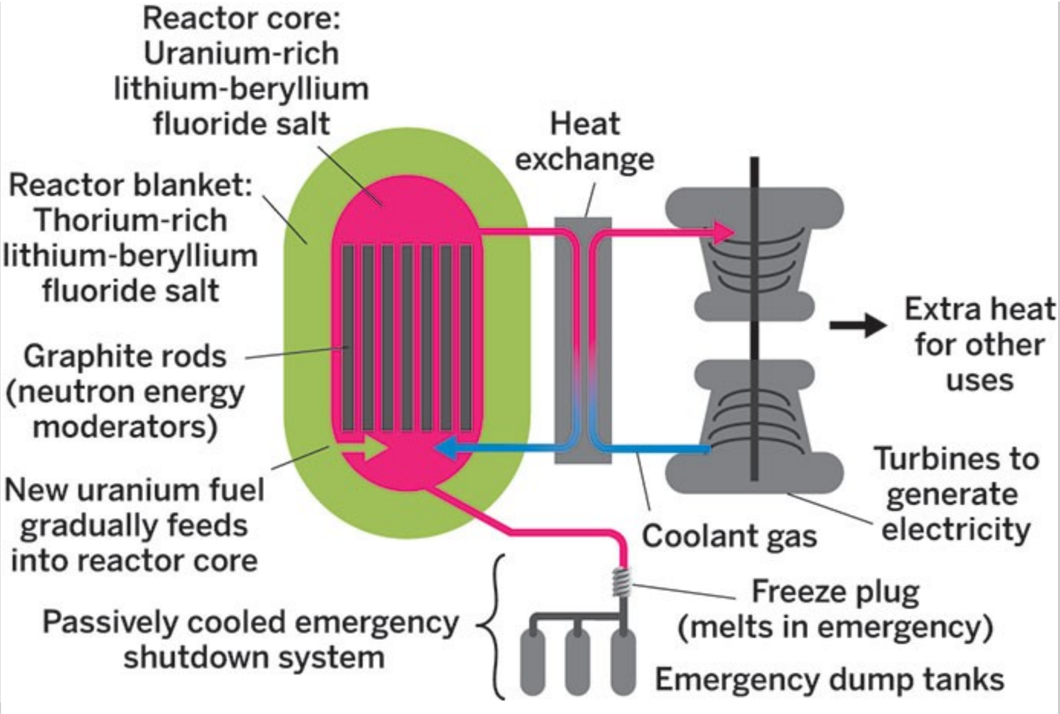

SALT POWER

The fission of ^{233}U nuclei in this proposed molten-salt nuclear reactor core liberates heat, which is used to generate electricity, and neutrons, which convert ^{232}Th in the blanket to additional ^{233}U fuel.

To try to put it back on the nuclear power menu, Kutsch formed the **Thorium Energy Alliance** (TEA), a nonprofit advocacy organization dedicated to educating government leaders and the public about thorium energy's merits. He then quickly organized TEA's first thorium energy conference, which was held in Washington, D.C. That was 2009. Last month, in Palo Alto, Calif., TEA held its seventh conference.

Progress during that period has come in small increments, but the word about thorium is certainly spreading. For example, a European group with the same goals as the U.S.-based alliance formed the **International Thorium Energy Organisation**, IThEO. This group will convene its **fifth conference this fall in Mumbai**, India, which along with China and Norway is one of the few countries actively pursuing a thorium nuclear program. Both organizations' conferences have grown, though they remain small—a couple hundred participants at each. But unlike the first conferences, the meetings now draw many nuclear engineers, materials scientists, and other technical specialists, as well as venture capitalists and other investors.

In the past five years, thorium has also taken small steps forward in business and government circles. For example, a few start-up companies have been launched and are working to develop molten salt nuclear reactors. And in a small way, thorium has also made inroads on Capitol Hill in recent years. After numerous lobbying trips to Washington, D.C., Kutsch and James C. Kennedy succeeded in getting thorium-related initiatives included in several recent congressional bills. Kennedy is president of **ThREE Consulting** and a mining specialist with expertise in thorium and rare-earth minerals, which tend to be intermingled geologically. The proposed bills, which were not passed, would have created a cooperative consortium capable of refining rare-earth minerals and separating and storing thorium for energy research and development.

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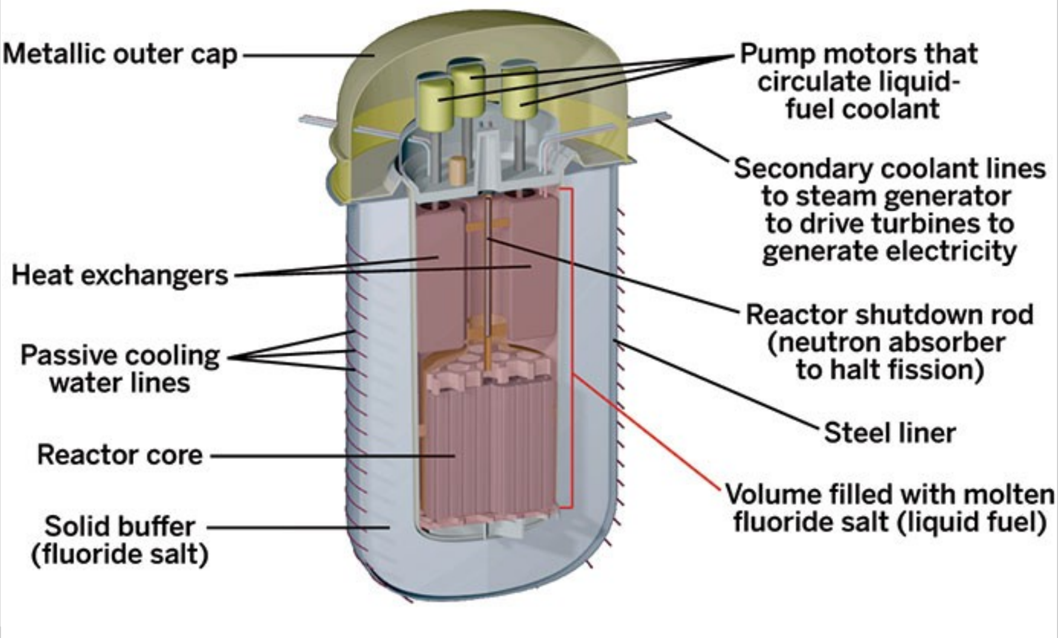

CLOSED SYSTEM

This reactor includes technology for passive cooling and integrates the reactor core and heat exchangers in a housing that remains sealed during the device's operating lifetime.

Credit: Adapted From Terrestrial Energy

But support for thorium-based nuclear energy isn't unanimous. Arjun Makhijani, a nuclear physicist and president of the Institute for Energy & Environmental Research, a Maryland-based science and environmental organization, counters a number of claims made by thorium supporters. For example, Makhijani contends that radioactive fluoride waste from thorium reactors will require expensive processing that involves risk of contamination and pollution.

And with respect to nuclear proliferation, Makhijani argues that molten salt reactors using thorium would be "much more vulnerable" than today's commercial uranium reactors. He explains that the process that converts thorium to ^{233}U proceeds by way of ^{233}Pa, which has a 27-day half-life. A country that does not have the nuclear materials needed to make nuclear weapons, such as ^{233}U, could separate out the ^{233}Pa from a reactor and then let it decay to the needed uranium isotope, he says. Thorium proponents counter that to carry out such a scheme, that country would need to develop protactinium separation and processing technology and apply it at home or commandeer other countries' nuclear facilities.

Moving forward with any new thorium reactor design will require major investments of time, effort, and money before a regulatory agency will grant a license for commercial operation. With this in mind, companies have adopted various design strategies.

Terrestrial Energy, for example, aims to speed the regulatory process and win public acceptance with a molten salt reactor design in which the primary reactor vessel is a permanently sealed system that houses the reactor core and the main heat exchangers. The unit would not need to be opened for repairs or refueling during its operating lifetime. Instead, plants would simply replace the reactors periodically and then let the old ones cool, thereby eliminating the risk of hazardous material escaping to the atmosphere. LeBlanc noted that the reactor could be fueled with fluoride salts of thorium or uranium blended with other fluorides.

ThorCon Power, another start-up developing molten salt reactors, also aims to move quickly. The company proposes to build scaled up versions of the 1960s ORNL reactor using shipyardlike assembly-line methods. That approach would enable ThorCon to mass-produce reactors that can be shipped modularly and assembled quickly. The proposed reactor design uses a mixture of sodium, beryllium, uranium, and thorium fluorides.

Another way to put thorium to use quickly is to use the metal to make fuels for today's commercial reactors. That's what McLean, Va.-based **Lightbridge** is doing with its "seed and blanket" design. These solid-fuel-rod assemblies appear identical to commercial ones used today but have a unique composition. Seed rods at the center of the assembly are made of a metallic uranium-zirconium matrix. Blanket rods positioned along the periphery contain thorium-uranium oxide pellets. As with the molten salt design, uranium fission generates heat and converts ^{232}Th to ^{233}U, thereby creating more fuel.

Lightbridge also has a preliminary design for a fuel with the same thorium-uranium oxide blanket but using a metallic plutonium-zirconium seed. This fuel offers an effective way to consume plutonium stockpiles created as waste from current light-water reactors. For the same reasons, Thor Energy, based in Oslo, Norway, also uses thorium together with plutonium in solid-fuel assemblies.

These business developments have been crucial in raising thorium's profile slightly. But one academic development may be even more significant. Last month at the TEA conference, **Thomas J. Dolan**, a professor of nuclear engineering at the University of Illinois, Urbana-Champaign, announced that the first textbook on molten salt reactors and thorium fuel was nearly completed and would be published next year. Dolan and others think that the book and associated curriculum could help train the next generation of students pursuing nuclear science and engineering in the logic behind thorium reactors.

"The human supply chain is probably the most critical thing," Kutsch told attendees at last month's conference. "If we built a molten salt reactor today, who would run it?"

Dolan, Kutsch, and other proponents hope to inspire those future plant operators through their efforts. "I don't have a dog in the race," Kutsch said. "I'm doing it because it's the right thing to do."

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Comments

Robert Orr Jr (Mon Jul 06 16:23:29 EDT 2015)
Hello,

In late January, 2011, I was at an impromptu meeting with John Kutsch and other proponents of Thorium Molten Salt Technology at Oak Ridge, where the technology was invented. While we were there, the Chinese Academy of Sciences announced an agreement, a "Memorandum of Understanding", with the US Department of Energy under the terms of which our DoE will assist the CAS to develop MSR technology in China. I filed a request under the Freedom of Information Act and obtained a copy of the MOU. Frankly, it is mostly jargon but the question remains - Why are we helping China develop the technology we invented at Oak Ridge, and sorely need in this country, while the DoE is doing next to nothing in this country to develop the technology? Ask your representatives in Congress.

Robert Orr Jr
Attorney-at-Law
» **Reply**

Ivi Grupp (Thu Jul 09 02:08:17 EDT 2015)
One answer is: Because a lot of Chinese people are being adversely affected by toxins in their air, & they deserve better air.
Another is: Because USA is very much in debt to China.

My guess is you feel China should pay for our ideas, preferably in license fees on MSRs that we'd supply. Make it so.

Meanwhile, until US NRC removes LWR-bias from its Approval Process, China [& S Korea, maybe] will likely continhe to attract more startups, who want to reduce their Approval Costs+Red-Tape.

My 2.2 cents.
» **Reply**

kareem jabbar (Sun Jul 12 01:18:36 EDT 2015)
China is part of the supply side revolution for GOODS and SERVICES - and as such a major consumer of electricity - helping CHINA reduce electricity costs maintains the status quo (cheap reliable supply of goods for major consumer markets) . It keeps the dollar strong , maintains a vast work force in the US (see Walmart) that needs minimal training to sell stupendous amounts of manufactured JUNK , and makes the world GO ROUND. And you want to change all that ?
» **Reply**

American Nationalist (Sun Sep 13 14:05:31 EDT 2015)
Because, unless the naifs at DOE, all good Communists know the Lenin quote: "The Capitalists will sell us the rope with which we will hang them"
» **Reply**

Felisberto P Silva (Mon Jul 06 22:03:23 EDT 2015)
I dont comment, but want receive information detailed of reactor.
» **Reply**

Ivi Grupp (Thu Jul 09 01:58:45 EDT 2015)
Current designs are very likely to be proprietary & unavailable. However, you can find PDF files containing Oak Ridge National Labs' early papers & reports. Talks & Q&A sessions may give you hints as to where some recent companies expect to go, eg, in changes to early designs. View all the conference videos you can find. Maybe attend some

conferences & ask others for tips, leads & plans.
» **Reply**

Neil Bryson (Tue Jul 07 16:16:53 EDT 2015)
How long before a design is available to be assessed by regulatory authorities?
» **Reply**

Carl Page (Mon Jul 13 19:20:16 EDT 2015)
Right Now! ThorConPower.com and Terrestrial Energy both have plans ready for review. But the NRC is incapable of reviewing anything other than an old fashioned cold-war PWR. They don't have any capability to innovate or understand it. It is like asking movie critics to make a movie. Not going to happen. The NRC says any novel reactor design, (such as the 1953 MSR) will take 20 years to review. That is nonsense. The first reactor took less than 20 MONTHS to build, including the submarine. What it would take is Leadership plus one year. But we don't have leadership, so you do the math...
» **Reply**

Carl Page (Tue Jul 07 23:38:32 EDT 2015)
Typo corrected...

Great article, Thanks!

The only problem with the molten salt reactor is that stuff moves around. So you need real chemical engineers and chemists to understand it. Solid reactors can be understood by simple physicists.

The reason industry neglected this is it was seen as too cheap. Solid fuel pellets are patented so once you buy a reactor, you have to get the fuel from the same monopoly, just like an inkjet cartridge or a razor blade. Liquid fuels on the other hand are inherently commodities and how do you make money on Thorium which doesn't even need to be mined. You just take it out of tailings and you can actually be paid to take it away. Plus there is probably enough to power your life in the soil beneath your feet.

The article doesn't mention that isotopic enrichment, the expensive part of making uranium usable in a reactor, is not needed for thorium. So it is way more plentiful than U AND ridiculously cheap to process. Anyone can do it. Who want's such a business to replace the existing one?

Now that nuclear power has pretty much failed in the USA with only a few plants under construction, and now that we know the climate is collapse is more dangerous than the communist menace ever was, it is time to find a form of nuclear power that can actually pay for itself without subsidies. Molten Salt Reactors can do it. Thorium is an afterthought which we only need if we ever run out of uranium, which we won't. MSR is the key. Thorium is just the back up plan.
» **Reply**

Craig Phillips (Tue Aug 25 18:21:41 EDT 2015)
I'm reading your comment way after the fact, and you make an important point about the fuel pellet side of the nuclear business being a "nice little earner".

However at the end of the day who cares about the current industry?
In the end, economics will be the driver!

If an approved LFTR design becomes available, and the Thorium is so easily obtained - meaning it would be low cost to obtain, and the reactors prove to be much lower cost to build than the LWR type currently used, then they will drive down the wholesale cost to produce base-load energy - and it will those who at the moment buy power from the nuclear plants who will tell the current nuclear industry to stick their LWR reactors and their specialised fuel, where the sun don't shine.

Also, if as expected the LFTR's can be built in a small and modular method then I also expect a lot mines, large factories, military bases, large hospitals, small towns etc to buy & run their own LFTR power generation.

The current LWR industry was scaled up to keep the capital cost down, but perhaps that model might soon become out of date if a small modular alternative gets going

Lastly, you mention at the end Thorium being a backup plan - you are right in saying that uranium MSR's can be developed - and since molten fuel cannot "melt down" then we could continue to use Uranium fuel in MSR form thereby solving the biggest public fear issue about nuclear power.

Although I'd suggest that since a uranium MSR is still a different method of nuclear power there would still be the design & approval hurdles as with Thorium, and the current industry would still drag the chain because their fuel supply method would need to change to suit the MSR reactors and I think they have given up & become fat & lazy, living off the work of previous generations.

So why not go for Thorium right away - yes, we COULD do both at the same time, but that was what was the plan back in the 60's when Alvin Wienburg believed that both types would be developed, but Thorium ended up being pushed into the background.

There are additional benefits with using Thorium such as it being a by-product of rare earths mining; the supply of which is a massive problem in most of the world, except China, from where the USA has to get most of its rare earths - even for classified military components (that works okay, until there war - not smart!). Another benefit was some specialised medical & scientific by-products from the process such as plutonium 238 (powers deep space probes but I think NASA has run out of the stuff) and also rare medical isotopes etc. I don't think these things are generally available from the uranium process (I could be wrong so I need to check it further).

There are lots of info & and lots of really interesting clips on the Thorium Energy Alliance website; I get the impression that you probably know more about the nuclear industry than I do, but I found those lectures informative & interesting and if you haven't viewed them before I can recommend them you as I reckon you'd enjoy them!
I just found them really interesting to watch even though I have no science or engineering background although it was hard work at times due to some of the science stuff. Cheers
» **Reply**

Brent Laird (Wed Jul 08 07:08:15 EDT 2015)
DOE would study it if it got funded.
» **Reply**

Marcelo Pacheco (Sun Aug 30 21:09:10 EDT 2015)
US Energy Secretary Enest Moniz has stated Thorium is more trouble than it's worth. That was during a Congress Energy Committee hearing. However he failed to provide a single logical reason.

Here's the very unfortunate fact. The US govt is incapable of doing anything that is cost effective as far as nuclear is concerned. Every DOE led effort to do anything goes over budget (often massively over budget). Anything the DOE touches is US$ 1 billion project.

US govt isn't genuinely interested in putting up first mover cost on a new type of nuclear energy source. The last time this happened, it was the 50s, and was done for pressurized water reactors.

If the USA was serious about nuclear power, the US would have operational plutonium fast reactors in full commercialization right now.

When we will stop thinking nice things about those that don't deserve our respect.

The democrats want solar+wind+... The Republicans don't want to invest a dime on new energy technology. Everything else is for show.

The DOE only does limited matching investments with established large nuclear corporations. Which means even if they genuinely wanted to make MSR reactors happen, there would need to be a serious private nuclear interest willing to put half of the money down.
» **Reply**

Philip Messina (Wed Jul 08 16:00:51 EDT 2015)
Back in the 1960/70's, USI (U.S. Industrial Chemicals) had a government contract to take monazite sand and convert it to a rare earth double sulfate salt and to thorium hydroxide. Large quantities of both materials were sent to the government. At that time, it was our understanding that the thorium portion was to be used for nuclear studies. Was it? I don't know. What happened? Does anyone know?
» **Reply**

Don Lay (Wed Aug 05 16:17:52 EDT 2015)
I believe the thorium was eventually "stored" in drums in the Nevada desert. There is a video on-line.
» **Reply**

kareem jabbar (Sun Jul 12 01:22:02 EDT 2015)
A working design has been available since the 1960's in ACADEMIC and MILITARY circles . For commercial exploitation , you would need a POWER GENERATOR (UTILITY) to commission supply (so you have the money to then DO WHAT IS NEEDED) . Governments have a hidden agenda , they want nuclear power for nuclear big bangs (the biggest bang there is). Its POLITICS holding things back , not technology or human reasoning or for that matter , 'regulatory' approval.
» **Reply**

William Ernest Schenewerk, PhD (Mon Jul 13 18:17:54 EDT 2015)
Believe the thorium-U233 fuel cycle has already been tested in CANDU D2O moderated piles. Also some testing was done in the Shipping LWR pile. CANDU/RBMK piles moderated with D2O can be thought of as fuel extenders as the thorium-U233 fuel cycle doubling time is probably at least 15 years. Compound doubling time should be less than 12 years if atomic power is to expand fast enough ~6%/a to replace fossil fuel by 2100. D2O extracted from water electrolysis and fuel-cell hydrogen consumers can provide sufficient moderator to expand CANDU/RBMK piles at ~6%/a. First fuel loads would be uranium, followed by switching to thorium-U233 cycle, depending on the availability of uranium.
Seawater uranium resource estimated at 4000 Mt (4000 mega-tonnes). Even once-through LWRs could provide 50 TWe (10 times present world energy consumption) for 8000 years. There is also the issue that U233 has to be handled behind shielding because

of high gamma emission. Uranium and plutonium fuels can be handled inside glove boxes once initial reprocessing is done. (see Silkwood movie) because most emissions are alphas. There is also the risk that U233 will fast-fission sufficiently well to make it a weapons proliferation issue.
» **Reply**

Jim Parsons (Sun Jul 19 17:20:58 EDT 2015)
Liked this. Interesting. I remember the arguments pro and con from the 60s. That was a conversation by various companies. Later, in the 90s there were some test reactors built for the Navy, I think that who they were for anyway that used thorium in part. Worked very good and did not have the potential to be coveted into a bomb maker to boot. Didn't catch on, and that's a puzzle. Maybe movers and shakers don't know that much about the chemistry of these elements? Probably wouldn't like pointed questions either. That's life.
» **Reply**

ChrisB (Mon Sep 28 17:32:17 EDT 2015)
For those who wish to delve more deeply into this subject, there are +5 hours of video from a single day Thorium conference held in the Netherlands this past April. David LeBlanc was one of the presenters. Lots of excellent information from several presenters - including an overview of ORNL's basic Molten Salt Reactor Tech for the benefit of media that was in the audience.
www.janleenkloosterman.nl/symposium.php
» **Reply**

F Sikkema (Sun Jan 31 11:42:57 EST 2016)
The lessons learned from the worldwide investment in renewable sources (wind and solar predominantly) are quite harsh. For example, Germany as of january 2016 has about 40 GW of solar power (photovoltaics) installed. At the most favorable, the cost directly associated with installation thereof is 80 billion euros.
Certainly you might think that for that money they would have substantially displaced fossil fuel electricity. However, only about 6 % of the national German electricity consumption is now provided with solar, and the actual CO2 emissions have gone up, because coal fired capacity is on standby as the sun shines, but primarily because Germany has decided to abandon nuclear generation after Fukushima.
Simultaneously, Germany exports sizeable quantities of electricity to other countries when the sun shines and there is wind at the same time.
So for German renewables, the question becomes, now what? Triple that amount of solar? Spend another 160 billion? That would only supply about 15 %, IF all that solar power can be accommodated in the grid, which it can't. So then what ? Batteries perhaps? Those are not available and would again at least double the cost of electricity.
This is a sharp lesson to take into account. The national grid in Germany is well developed and very flexible. Needless to say, countries without such infrastructure would be hard pressed to install such renewable capacity.
There is, therefore, an unabated need for reliable baseline generation. Thorium would be very suitable in the long run to displace uranium. Thorium could do what nuclear fusion probably never will.
» **Reply**

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