Rapid Computational Path for Sustainable and Renewable Nuclear Energy using Metallic Thorium Fuels

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Thorenco is pleased to announce results of its studies. I am Rusty Holden Thorenco's manager. Encouraging results have been obtained from Pacific Northwest National Laboratory. Our research employs thorium to shift the nuclear energy paradigm to a new one that is sustainable and renewable. When thorium-232 is used in nuclear fuels instead of uranium-238, plutonium and transuranic issues are avoided. When metallic fuels are used, fission products can be easily removed from used fuel. The renewable and sustainable paradigm shift moves thorium into the mainstream of nuclear science. Without thorium, the paradigm shift is impossible. With thorium, much cleaner nuclear energy is deliverable. It is sustainable because used thorium fuel is used over and over again after it is stripped of fission products. It lacks the transuranics that uranium-238 generates. The cycle is renewable because fissile uranium-233 is produced and merchantable heat is produced both commercially meaningful scalable quantities.

Our research has uncovered pathways for the next generation of nuclear reactors. Our computations show that metallic thorium fuels greatly reduce the production of undesirable plutonium isotopes and the other unwanted long-lived transuranic isotopes during reactor operations. We also have insight that the rate of neutron multiplication in metallic fuel can be controlled by passive features to prevent overheating calamities. We anticipate that used metallic thorium fuel rods will be easily recycled using existing zone refining techniques. Used thorium fuel will contain valuable amounts of fresh uranium-233 so that economics will favor reuse of fuel after the useless fission products are stripped from it. Fuel production during reactor operations is a renewable attribute. Reuse of the fuel alloy is a sustainable attribute because future generations are spared the stewardship costs of storing spent nuclear fuels.

For private industry, it is fair to say that thorium enables necessary high density energy technology to become benign. The fissile uranium-233 produced in the thorium reactor does not have to be mined. It does not have to be isotopically enriched. All of the thorium atoms that become uranium-233 atoms can be fissioned. Fission products can be stripped from used metallic thorium uranium fuel. Long lived

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transuranic isotopes are not produced. Ample quantities of new uranium-233 are produced in the metallic thorium-uranium fuel alloy during a decade of uninterrupted reactor operations.

Results of PNNL's computational modeling are persuasive. The results build a case for private investment and governmental support to advance the cleaner thorium paradigm. Only thorium fuels provide the simple technical pathway for the destruction of plutonium and other transuranic isotopes from both spent light water reactor fuel and from obsolete weapons. Secure government fast reactors could fission away these unwanted transuranic isotopes. Once fissioned and transmuted the transuranics no longer need to be guarded and stored for geologic ages.

I have estimated that the amount of energy locked up in spent fuel and in obsolete weapon pits to have twice the thermal energy equivalent of remaining US proved oil reserves. This equals the heat from burning about 40 billion barrels of crude oil. This calculation excludes the heat that would be generated from successive generations of fuel produced during many decades of reactor operations.

We outlined a rough draft fast reactor plan I call the plutonium eater for governmental applications. It uses a lightly doped metallic thorium plutonium fuel cooled by lead lithium-7 eutectic. The reactor produces 400 megawatts of thermal power. It burns a ton of plutonium-239 in a decade and produces a ton of uranium-233. It burns about half of the plutonium in the original fuel over a decade. Computations reveal that the fuel is stable over the decade of operations. This conceptual reactor provides an effective way to advance disarmament objectives, and it brings thorium front and center.

We also came up with a rough draft fast reactor plan I call the transuranic eater for spent fuel treatment applications. This reactor is the same as the plutonium eater except the fuel is doped differently and the coolant is lead. It operates at 400 megawatts. This one uses a more energetic neutron spectrum and burns out neptunium and plutonium and transmutes americium and curium. Recall these are the troublesome long lived isotopes from spent light water fuel. Like the plutonium eater, this reactor burns out a ton of plutonium-239 and produces a little more than a ton of uranium-233 per decade.

This technology removes the stewardship burden associated with plutonium containing materials from the future and allows our generation to start to clean up the spent fuel and obsolete weapons materials problems. I must emphasize that this next generation technology works only when thorium-232 is substituted for uranium-238 in nuclear fuels containing plutonium.

Now for worldwide industrial, commercial and municipal energy applications there are important advantages of metallic thorium-uranium fuel that I outline:

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Advantage One: Reduced Transuranic Load. Fertile thorium-232 atoms do not produce transuranic atoms by neutron capture as do fertile uranium-238 atoms. Thorium does not generate the transuranic load that generates significant long term health risks and risks of proliferation from explosive transuranic isotopes.

Advantage Two: Proliferation Hardening. Fissile uranium-233 produced from thorium is easily hardened against wrongful diversion to weapons uses. This is accomplished by blending the produced uranium-233 and uranium-232 with comparatively modest amounts of uranium-238. Uranium-238 is not fissile and when blended with either uranium-233 or uranium-235 it reduces the density of the fissile uranium atoms in the matrix and increases the critical mass of the extractible uranium. Uranium-232 coproduced with uranium-233 makes the produced uranium is very difficult to conceal and deadly to work closely with.

Advantage Three: Usable uranium is produced in the thorium matrix. Practically all of the uranium produced from thorium-232 is fissile uranium-233. There is no need to enrich any uranium-233 produced from thorium-232 to use it in fuel.

Advantage Four: Amenable to Zone Refining. Metallic thorium-uranium alloy can be remotely zone refined to separate the short-lived fission products from the fuel alloy after it has been used. This allows a simplified and direct production pathway for making fresh fuel from used fuel.

Advantage Five: Hydride friendly. Metallic thorium-uranium alloy can be doped with hydrogen enhancing passive safety attributes. The rate of neutron multiplication in hydrided metal fuels can be engineered to be temperature influenced so that when the fuel temperature exceeds good operating limits the hydrogen moderator migrates from the fuel which decreases the neutron multiplication rate. This feature combines with thermal expansion effects and the fact that hot thorium atoms capture neutrons better than ones at operating temperatures to reduce neutron multiplication. These passive features are additive and reduce risks of runaway scenarios.

Advantage Six: Long Lived. Metallic thorium-uranium fuel operating in an energetic neutron spectrum will last longer in the fast reactor than oxide fuels last in the thermal spectrum reactor. Metal fuel has a higher density of fertile and fissile atoms than oxide, nitride or carbide fuels have. Fission products capture fewer neutrons when average neutron energy in the fuel is epi-thermal or fast. This extends the longevity of fueling cycle to a decade or more.

There is no way to produce merchantable heat from fission without the production of fission products. Fission products are unstable isotopes, the remnants of the fissioned atoms, most of which have half lives 30 years or less. The trick is in getting the fission products out of the used fuel cheaply, easily and

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safely. We ruled out chemical processing because wet chemistry generates gaseous, liquid and solid waste streams. This ruled out oxide, nitride, and carbide fuels. Instead, we selected longer lived metal fuel because high temperature thorium alloys can be remotely zone refined to remove the fission product impurities from used fuel. Zone refining is a simple process where a thin slice of a metal rod is heated by an induction coil to a viscous liquid state and the thin slice of the melt advances from one end of the rod to the other. The melt concentrates and carries with it the fission product impurities that have lower melting points than the high melting point thorium uranium alloy. Zone refining can be done remotely so that fuel workers never have to be close to the fuel.

We came up with a smart reactor I call the Producer for domestic and overseas industrial markets. This one makes as much uranium-233 as it burns. It generates thermal power between 10 to 50 megawatts for five to ten years. It is a miniature encapsulated reactor core that is transportable. Its core is cooled by liquid metal either lead lithium-7 eutectic or lead bismuth eutectic. During travel the lead is solid providing a physical barrier and radiation shield. During operations the lead is liquid providing a thermal barrier and a radiation shield. The encapsulated core lasts for 5 years at 50 megawatts and 10 years at 10 megawatts. I prefer fissile uranium-233 and fertile thorium-232 as the fuel combination. Thorium-uranium alloy conducts heat well and has a high melting point. The Producer is designed to be slightly super critical in its operating range and sub critical at temperatures above its operating range. Metal fuel expands so fewer fissile atoms are in a unit of volume when the fuel starts to get too hot. Neutron capture by thorium is more efficient as the temperature of thorium atoms is elevated. Hydrogen in the fuel migrates away from the active zone when temperature is elevated, reducing moderator density and reducing the number of neutrons that are slowed down to fission uranium-233. These passive factors can be computationally optimized to work additively.

Traditional methods of control by neutron absorbing materials backup these passive safety features. The volume of liquid metal in the system is relatively large; it takes considerable time for the core to heat the large vats of lead alloy. This large thermal reservoir provides an additional margin of safety because there will be plenty of time to use traditional methods of control if the passive systems are ever overwhelmed.

There is no region of high pressure in the active part of the reactor core. There is neither pressurized water nor boiling water cooling the fuel. The liquid metal coolant does not boil. Being mostly lead, it does not react chemically with fuel or reactor materials, unlike the sodium and potassium used as coolants in early fast reactors. Lead alloy coolant does not react with any material used in the reactor. The liquid metal is secured by a redundant set of nested stainless steel cylinders and an overflow receptacle below the core contains the lead alloy if a leak develops. The liquid metal convects in the Producer to move heat to the power loop. The core is small enough so that pumps do not have to be

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used, reducing moving parts in the system. The Producer could be put on vessels to supply electric energy and fresh water to coastal cities. This would provide distributed energy and solve reactor placement issues near urban areas and solve seismic issues because the reactor is on a navigable floating platform.

Once thorium's salient advantages are understood by a broad community of interests, things will go fast. Los Alamos has started to develop advanced computational codes that feature thorium fuels. Computational optimization of safety issues will proceed more quickly after the new Los Alamos codes are finished. The NRC will have the benefit of these codes once a thorium program is properly funded. Fast spectrum reactors that "fission away" military plutonium should be developed using a small fraction of the billions that have been appropriated to support the MOX program, because spent MOX fuel will have to be treated. The Civilian Nuclear Waste Fund account has $20 billion in it. Spent civilian fuel will have to be treated to reduce its holding period. To treat plutonium and the other transuranic isotopes these will have to be fissioned and transmuted. A fraction of the $20 billion fund could demonstrate that used light water fuel is a resource not waste because plenty of electrify can be generated with the heat.

The private sector is urged to participate in the development of thorium fuels so that renewable and sustainable nuclear paradigm shift can be realized promptly. One small pilot plant can test the three metallic fuels we have looked at. Los Alamos D Division can get a good portion of the plans and specifications together for a pilot plant in 36 months using the best data libraries, best software and the world's fastest super computer.

Congress needs to understand that thorium has the potential to address plutonium related nuclear legacy issues at lower cost than existing governmental programs. Cost is lower because at least twice the energy content of US proved oil reserves can be extracted from domestic plutonium using thorium. In contrast, holes in the ground do not generate electricity. Thorium has potential to shift the nuclear energy paradigm to a renewable and sustainable one. Support for the Thorium Bill, S 3060 sponsored by Senators Hatch and Reid introduced March 3, 2010 must become widespread. The public needs to know that thorium is the key to cleaner nuclear energy and that the money has already been paid for the next stage of the work.

In conclusion I am grateful to Google and to the Thorium Energy Alliance giving me the opportunity to talk about metallic thorium fuels and their applications. I am available to go over your questions today at any time. My contact information is on every page of the handout and I will make time to get back to anyone interested in more detail by phone email and meetings.

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