Welcome to the second Thorium Energy Alliance Conference meeting. Thank you for coming to hear, present, and discuss about our energy future. I want to thank our hosts here at Google, for making their facility available for this conference, and especially want to thank Chris Uhlik, Iain McClatchie, and Cat Allred for making this happen. I want to thank John Kutsch, Vince Lackoski, and Tom Mick of the Thorium Energy Alliance for all their work to prepare for this event. And I want to thank all of you for coming. I know that many of you have traveled at your own expense, taken vacation time, or driven long distances to be here. Thank you.

As we have for most of human history, we stand at the edge of an energy crisis. The methods by which we have powered our society have come to a limit, and a change is necessary. Seven hundred years ago in England, the energy crisis was caused by massive deforestation and a lack of firewood. It was solved by turning to coal, a filthy, inexpensive, and abundant fuel. But as the skies darkened over the cities of England and the United States, people turned to gas and oil to improve the situation. Now all of these fossil fuels will have to be replaced due to the environmental damage they cause and the social, political, and financial instability they engender.

Fortunately, in 1939, humanity discovered the physical process that would allow us to replace fossil fuels forever—the fission of the heavy elements known as actinides. By 1944, we realized there were actually three different ways to use this physical process to provide us the energy we need. One of these approaches was relatively "easy". It involved the use of a substance almost as rare as gold—uranium-235. Even back then, physicists and scientists realized that uranium-235 fission was not going to be a long-term energy solution. There simply wasn't enough of it. The other two approaches were significantly more difficult but promised essentially unlimited amounts of energy. One was to fission the common isotope of uranium, uranium-238, and the other was to fission thorium, which was three times more common than uranium itself.

In one of the great historical tragedies of human history, this marvelous new energy source was discovered during a time of war, and was immediately put to work for destructive means. This colored and affected forever how world leaders and the public would view this incredible discovery, and is a legacy that we find ourselves, even seventy years later, still trying to move past.

We have taken the "easy" route. We have used nuclear energy based primarily on the fission of this rare-as-gold isotope of uranium. And as predicted, its effect has been significant, but not overwhelming. We still live on a planet where most of our energy comes from fossil fuels. Perhaps even more troubling, most of our fellow citizens and leaders don't even know about the other two approaches. They assume that "nuclear energy" means one and only one thing—making energy from nuclear fission the same way we have made it for sixty years.

Taking this approach has helped us in many ways, but it has also created enemies and easy ways to stir up the public against nuclear fission. One of the most commonly employed is the spectre of catastrophic disaster. While many of us know that such events are not possible in well-built, Western-style reactors, it takes a few moments to explain the defense-in-depth approach of our reactors to a regular person, while it only takes a fraction of a second for anti-nuclear forces to say “Chernobyl!” and stoke fear.

Another potent source of anti-nuclear anger surrounds the issue of so-called “nuclear waste”. We tend not to call it that because many of us realize that it’s simply spent nuclear fuel, with valuable materials inside that can be utilized to generate energy or provide benefit to society. As much as I’d like to think that our message is getting across, I still find over and over again that spent nuclear fuel is demonized as a toxic, dangerous, poisonous substance that will last forever and is intractable to solution.

Such a statement, is of course, untrue, but it is politically and culturally potent.

A slightly more sophisticated attack on nuclear power has to do with the costs involved in building a conventional nuclear power plant. They’re high. Really high. And once an organization commits to build one their uncertainty levels are high. Some endangered species might get discovered on their site. Some anti-nuclear group might rile up a local community or a powerful politician. Fossil fuel interests threatened by a loss of market share might quietly fund all manner of subversive efforts. Construction might be shoddy, oversight might be onerous, or public opinion might have a decided shift during the construction period. All of these factors combine to give pause to those who might consider building conventional nuclear reactors.

Several additional factors have come into play in the last few years. One is that the Obama administration has cancelled the US effort to built a permanent spent-nuclear-fuel repository at Yucca Mountain. Another is that both the Obama and Bush administrations have made efforts to provide loan guarantees to new nuclear power plants. Yet another is the severe economic downturn across the world and a general reduction in the appetite for energy that has led to temporarily lower fuel costs. Natural gas and oil seem cheap—for the moment.

All of these factors combine together to create what I like to think of as “boundary conditions”. If any of you suffered through a math class in differential equations like I did in college, you remember that boundary conditions establish where you start and where you might end, and they have everything to do with how your solution might come out.

Here’s our boundary conditions as I see them. First, we can’t keep using fossil fuels. They’re destroying our environment and exporting wealth away from our country. But those who control the fossil fuels have vast amounts of power and money and can make life very difficult for those of us trying to establish a new energy source.

Second, cancelling Yucca Mountain, continuing to operate our 100-odd reactors, and building new reactors in the future mean that we have to do something about what the public calls “nuclear waste”. And I think it has to be a lot more than just education, although I think that’s an important part of it. We need to address the problem in a satisfactory way. I know we won't satisfy everyone, but we need to satisfy most of the public.

Third, we have to do something about the cost of bringing new nuclear energy online. The old way is slow and expensive. We need a new way that's better, safer, simpler, and costs less. Fortunately all of these things don't have to be mutually exclusive.

Now what nuclear approach should we take? What about continuing to do things the way we do today—building more light-water reactors that use uranium fuel? Each one of these reactors consume about 250 tonnes of uranium for each gigawatt-year of electrical power that they generate. Each of them generate about 35 tonnes of spent nuclear fuel for each gigawatt-year of operation. Right now we get about 100 gigawatts of power from nuclear. To get off coal and fossil fuels, and to replace the transportation energy we currently get from oil will take about 1000 gigawatts of electrical power, or about ten times what we're getting from nuclear today. That means 250,000 tonnes of uranium produced each year and 35,000 tonnes of spent nuclear fuel generated each year. We're not even mining uranium anymore in the United States. We import all of our uranium. And considering that Yucca Mountain, which we're not even going to build anymore, was politically limited to about 70,000 tonnes of spent nuclear fuel, that would mean that we would be filling up a Yucca Mountain-equivalent every two years. It's pretty hard to imagine pulling off such a political solution in today's or even tomorrow's environment.

What if we reprocessed the spent nuclear fuel? We could recover the unburned plutonium and mix it with fresh uranium to provide fuel for nuclear reactors. Well, that doesn't change the story too much either, since it would take about two or three nuclear reactors' worth of spent fuel to supply another one. The basic problem there is that each current nuclear reactor isn't producing enough new fissile material to compensate for that which is being consumed.

What about fast reactors? These are reactors that don't slow down their neutrons so that they can get better fuel efficiency and fuel conversion. Fast reactors theoretically could fit the bill. If we assume that each fast reactor could consume about half of the energy in uranium then a thousand fast reactors would use about 2000 tonnes of uranium each year, and we have lots of uranium sitting around at enrichment plants. But there's a few other issues of concern with the fast reactors. First of all, depending on the specifics of the design, each one is going to take between 5-10 tonnes of fissile material to startup per gigawatt of electrical power production. The exact numbers aren't publicly available, but a pretty good guess at our current spent fuel inventory is about 70,000 tonnes, with about 1% of it as plutonium that could be used to start fast reactors. Then we would have about 700 tonnes of plutonium and that would start about 70-100 fast reactors. We would then need each of those 70 fast reactors to breed lots of extra plutonium so as to be able to start up more fast reactors, or we would need to enrich a lot of uranium to start fast breeder reactors. We would also need to build the reprocessing and fuel fabrication facilities to make all this happen. It's possible, but it's going to be very expensive.

Then there’s thorium. Thorium has a special property—it breeds to uranium-233 and uranium-233 fissions and gives off 2 or 3 neutrons that enable it to keep converting more thorium into uranium-233 and burning it. This means that once we start a thorium reactor we can keep it going indefinitely just by adding thorium. But how do we get it started? How much uranium-233 do we need? Well, most of the studies done by Oak Ridge in the 1960s indicated that we could start a one-gigawatt thorium reactor with about 1 tonne of uranium-233. How much do we have right now? About one tonne. So we could only start one reactor, right? With uranium-233, yes, but we need to go about quickly “converting” our fissile materials into uranium-233 so we can start more.

Why does it only take one tonne of uranium-233 to start a thorium reactor but it takes 10-15 tonnes of plutonium to start a fast breeder? Here’s why—things look different when you’re a slowed-down neutron versus a fast neutron. When you’re a fast neutron all of this fuel looks really small to you, and you have a lot less probability of causing fission. So you need a lot more fuel to insure that you get enough collisions with fuel to generate the energy you need. On the other hand, when you’re a slowed-down neutron each fuel nucleus looks a lot bigger and you have a much better chance of causing a fission. So having slowed-down neutrons makes your fuel go a lot further than using fast neutrons. This is the basic reason why a thorium reactor with slowed-down neutrons can start with a lot less fuel for a given power rating than a fast reactor with fast neutrons. Each little bit of fuel counts for a lot more in a reactor with slowed-down neutrons.

We don’t have to limit ourselves to just uranium-233 to start these thorium reactors. We can use the highly-enriched uranium that we’re recovering from all of the nuclear weapons that we are decommissioning to help us. We can use the plutonium we’re recovering from those weapons. We can use the plutonium that’s been generated in our reactors over the last sixty years to help us. By using slowed-down neutrons and thorium, the startup power of this fuel is magnified by about 1000 to 1500% over a fast reactor.

So what should we do first? Well, the first thing we should do is stop the Department of Energy’s effort to destroy the one tonne of uranium-233 that we already have. They don’t think that that uranium-233 has any value to their mission and are going to spend $500M to mix it with uranium-238 and throw it away in the desert. That’s a bad idea. We’re going to need that one tonne and a whole lot more.

The next step is to get going on the research and development of the liquid-fluoride thorium reactor. This is the machine that can burn thorium as a fuel and only needs about a tonne of U-233 or other fissile material to start it up. The US hasn’t invested any money to develop LFTR since 1974, the year I was born. Other countries are making investments. We need to get going before we get completely left behind on something that we invented.

At our enrichment plants around this country, we have 470,000 metric tonnes of depleted uranium hexafluoride. That’s a uranium atom with six fluorine atoms around it. We need to get that fluorine and convert the uranium into something that is chemically stable and can be buried. Uranium oxide is what it was when we dug it out of the earth, and that's what we need to turn it back into. Each time we do this we will free up six atoms of fluorine that we will need for the rest of our plan. That means that that 470,000 tonnes of uranium hexafluoride will be converted into 360,000 tonnes of uranium oxide and 150,000 tonnes of fluorine.

Next we use some of that fluorine, about 30% of it, to fluorinate all of the spent nuclear fuel we've already generated from running reactors. 95% of the spent nuclear fuel is uranium oxide and it will be converted to uranium hexafluoride, which is exactly the form we need it in for going to an enrichment plant. So we could go ahead and send it to an enrichment plant and use it that way if we so desire. I'm more interested in the other 5% of what's in the spent nuclear fuel. 1% is plutonium, americium, neptunium, and other actinides that are called "transuranics". These are the higher actinides that are generated when uranium absorbs a neutron and doesn't fission. These are also the substances that give planners such headaches when they think about building places like Yucca Mountain, because they are radioactive for tens to hundreds of thousands of years and comprise most of the long-term trouble. The other 4% are fission products, most of which are already nuclear-stable and could be partitioned and sold for the valuable materials in them, like neodymium and xenon gas.

With the transuranic fluorides we recover, we have to destroy them through fission. Waiting tens of thousands of years for them to decay isn't the right approach. We have to put them in a reactor and burn them up in fission. What's the right kind of reactor to do this? I think it's a fast reactor, but not the kind of fast reactors we generally hear about these days. I think it's a fast reactor that is a cousin to the liquid-fluoride thorium reactor, except it will be one that will use liquid-chloride salts that are chemically stable as a fuel and coolant, not the liquid-sodium-metal that is currently proposed. Again, just like other fast reactors it will take 5-10 tonnes of these transuranics to produce a gigawatt of power. So what have we bought by this approach? Just this—in these liquid-chloride reactors we will jacket the reactor with a thorium blanket and make new uranium-233 even as we are destroying plutonium. That means that for each year we burn plutonium, we'll make enough uranium-233 to start a new LFTR. Compared to the fast reactor approach where you're trying to breed plutonium to build more fast breeders, and it takes 20-30 years to produce enough new fuel in a fast reactor to start another one, we won't be using these chloride fast reactors to start other fast reactors. We'll be using them to make the fuel to start fluoride thorium reactors that use slowed-down neutrons.

With this approach, plutonium from weapons and reactor fuel will start about 70 chloride fast reactors. Each one will make enough uranium-233 each year to start 70 new LFTRs at a gigawatt each. That means that in less than 20 years we could have 1000 LFTRs online, generating all of the energy our nation needs, all the while we're burning down and destroying the plutonium we've generated over the last 60 years for weapons and from reactor operation. Compare that to the standard fast breeder approach where in 20 years the 70 fast breeders we started have generated enough new fuel for another 70 fast breeders and you can see really quickly how fast uranium-233 and slowed-down neutrons can let you move ahead and replace coal and other fossil fuels.

Remember all of that fluorine? It’s going to end up combined with lithium, beryllium, and thorium to make the fuel for the thousand LFTRs that we’re going to build. Those thousand LFTRs are going to burn about a thousand tonnes of thorium each year to make all of this energy, which is about a quarter of what one mine site in Idaho with a pit the size of a football field could produce. Again, thorium and slowed-down neutrons can let you be much more efficient in your nuclear strategy.

At the end of this effort, we will have destroyed our 100 tonnes of highly-enriched uranium from weapons. We will have destroyed our 100 tonnes of weapons-grade plutonium from decommissioned weapons. We will have destroyed the 700 tonnes of plutonium and other actinides in the spent nuclear fuel. We will have essentially eliminated the issue of spent nuclear fuel as a concern. We will have replaced the coal and gas electrical generation in the country. We will have added enough additional electrical generation to the nation’s grid to power electric cars rather than gasoline-powered ones. We’ll have cleaner air. We’ll have cleaner water. We’ll keep hundreds of billions of dollars in our country because we’ll be energy-independent. And we will have solved the energy crisis permanently.

All of this is unlocked by the fundamental properties of thorium. We can make it happen. May we have the wisdom to do so.