Episode 6 – "Advanced Nuclear Energy Technology"

Previously, on Energy Transition Crisis: Prior episodes explained the importance of energy transition, laid out a plan to replace fossil fuels with clean energy, explained why a global energy crisis is unavoidable in the mid-2020s, explained geothermal renewable energy, and considered the pros and cons of conventional nuclear power. Now, to show you how advanced nuclear technology completely changes the game, here's Erik Townsend.

Nuclear already offers the safest form of baseload power generation in existence. But I for one don't care how statistically safe it already is. The 2011 meltdown accident at Fukushima Daiichi left all of us with a very real memory of what can go wrong in a nuclear powerplant. I don't care that it caused less death and disease than routinely occurs in coal mines. I still don't want something like that to ever be allowed to happen, ever again. So as I began researching this subject, at first my attitude was look, we need to design some new technology to make such accidents impossible.

I was mistaken: The advanced nuclear technology needed to prevent accidents like Fukushima and Three Mile Island doesn't need to be invented; it was already invented before I was even born! Nuclear engineers recognized the need for new technology that makes meltdowns and hydrogen explosions completely impossible decades ago, and they already invented that technology decades ago. Not only did they invent the technology that could have completely prevented the Fukushima disaster long before the disaster occurred… They invented that technology before the Fukushima Daiichi plant was even built. In fact, they invented the technology that could completely eliminate meltdown risk six full decades ago!

Yet to this day, that game-changing technology, which my parents' tax dollars paid for, has never been commercialized and put to work. The story of how badly government corruption and political favoritism has compromised public safety and allowed accidents to occur that should have been prevented will knock your socks off! And I'm going to show you the whole story in this episode of Energy Transition Crisis.

As I explained in the prior episode, many of the worst things that can go wrong in a nuclear powerplant result from the choice of pressurized water as the coolant in the reactor core. So I strongly favor building new reactors with superior coolants that don't require pressurization and which can't cause hydrogen explosions.

But in fairness, the Pressurized Water Reactor has come a long way since 1967 when the boiling water reactors that melted down in Fukushima were built. Today's state of the art in Pressurized Water Reactor technology is known as Generation III+. The most important advances have been in the areas of automation and passive safety systems, and these advances make Generation III+ powerplants much safer than the reactors of yesteryear.

Automation is critically important because it eliminates human error, which has been the primary cause of all the serious accidents. Passive Safety is a buzzword that means safety systems are designed to rely on things like gravity, which always work no matter what, as opposed to things like backup generators that sometimes don't work as expected.

Even before these advances, Nuclear Power was already the safest baseload energy source in existence, and Generation III+ nuclear plants will be much safer, so there's no reason to hesitate to build new nuclear powerplants based on the latest Generation III+ reactor designs such as the Westinghouse AP1000. But we can still do much better, and the first thing to improve should be getting rid of water as the reactor core coolant.

As I showed you in the last episode, reactor core depressurizations, steam flashing, core meltdowns, and hydrogen explosions like the ones that blew the roofs off the reactor buildings in Fukushima all result from the choice of water as the coolant used to transfer heat from the reactor core to the heat exchanger that puts the heat energy to work making electricity.

Another shortcoming of water as a reactor coolant is that the need for pressurization puts a limit on how hot the water can get. This directly translates to more of the energy released from the nuclear chain reaction going to waste, and less of it being turned into electricity.

A far superior coolant is molten salt, which can operate at temperatures over 700C without pressurization. This makes molten salt cooled nuclear reactors far safer and far more efficient than water cooled reactors.

And here's the really exciting part: Molten salt reactors can be designed to dissolve the uranium fuel in the coolant mixture, completely eliminating the fuel rods, and thus completely eliminating the risk of core meltdown. In a liquid fueled molten salt reactor, if the coolant pumps stop, the nuclear fission chain reaction stops, and the coolant drains by gravity into an emergency reservoir. Fukushima-style meltdown accidents are impossible because there are no fuel rods to melt down. And hydrogen separation is never possible because hydrogen isn't one of the ingredients in the coolant mixture. Core depressurization and steam flashing is impossible because the core isn't pressurized to start with. No backup generators are needed to run the cooling pumps, so they can't fail. This design is inherently orders of magnitude safer than the pressurized water reactor, because all the worst failure modes of the pressurized water reactor are literally impossible in a liquid-fueled molten salt reactor.

Now comes the part that's going to make you angry, and justifiably so: Molten salt reactors were invented in the early 1960s at the Oak Ridge National Laboratory in Oak Ridge, Tennessee. The first liquid-fueled molten salt reactor was built by 1964, and it was first turned on in 1965. That's right: A new reactor technology that could have completely prevented the meltdown accidents at Fukushima, Three Mile Island, and Chernobyl, was tested and proven to work 58 years ago, in 1965. That reactor ran continuously for four years until it was shut down in 1969 after serving its purpose flawlessly.

I'll bet you're wondering… If a much safer nuclear reactor, that could have completely eliminated meltdown risk, and which could have prevented the accidents at Fukushima and Three Mile Island, was tested and proven to work way back in 1965, then why the hell didn't the government make that design the industry standard for all of our civilian nuclear powerplants built in the 1970s? After all, if it was a U.S. Government research laboratory that spent our parents' tax dollars inventing, testing, and perfecting the molten salt reactor design, wasn't it the U.S. Government's JOB to put that technology to work making atomic energy as safe as it could possibly be?

Now put your seatbelt on because you're not going to like this next part: The U.S. government identified a very serious problem with the molten salt reactor, which forced the entire program to be shut down completely. You see, molten salt reactors were invented in Tennessee. But President Nixon was a Californian, and many of the most powerful congressmen who oversaw the country's nuclear programs in the early 1970s were also Californians.

The Molten Salt Reactor Experiment in Tennessee was doing ground-breaking work and making terrific advances in nuclear reactor safety. But that project was competing for funding with another project called the Liquid Metal Fast Breeder Reactor. The Liquid Metal Fast Breeder Reactor was being upstaged by the molten salt reactor in Oak Ridge, because the Liquid Metal Fast Breeder didn't offer all the big improvements in safety that were being made in Tennessee. But far more importantly, the Liquid Metal Fast Breeder reactor was being developed in Southern California, President Nixon's home state.

Now if I were to tell you that the most important research program in the history of the nuclear industry, which made profound advances in nuclear reactor safety, was cancelled by President Nixon and all that groundbreaking research was literally thrown away and forgotten because it happened in the wrong state, for no better reason than the President wanting that money to be spent in his own state of California instead, you would probably think I'm a crazed lunatic conspiracy theorist!

But you don't have to take my word for it. If you're familiar with the Watergate scandal, you already know that President Nixon had an odd habit of tape recording himself at what would later turn out to be the most inopportune moments. So let's listen in now to President Nixon's June, 1971 telephone call with Congressman Craig Hosmer, also a Californian.

(PLAY RECORDING 12:06 – 13:36 in https://www.youtube.com/watch?v=bbyr7jZOllI&t=731s&ab_channel=GoogleTechTalks)

President Nixon and Congressman Hosmer succeeded in their plan to be “ruthless”, and “Playing it close to the vest”. They kept the research money in their own state of California. The other man President Nixon mentioned in the call we just heard was Chet Holifield, another congressman from—you guessed it—California. Holifield was one of the most powerful and influential men in early 1970s atomic energy policy. So too was Milton Shaw, who was running the Liquid Metal Fast Breeder Reactor project in southern California.

Alvin Weinberg, the father of the molten salt reactor design, headed up the Molten Salt Reactor Experiment at Oak Ridge, Tennessee. By early 1971, Weinberg was trying unsuccessfully to call attention to the profound advances in reactor safety that had already been made at the Oak Ridge laboratory. Meanwhile, the Liquid Metal Fast Breeder Reactor in Southern California was running massive cost overruns and making little progress. But when Weinberg tried to call policymakers’ attention to the much greater success that was occurring in Tennessee, this only angered President Nixon, Congressmen Holifield and Hosmer, and Atomic Energy Commission honcho Milton Shaw. Shortly after the call we just heard, they fired Alvin Weinberg, and then later completely cancelled the Molten Salt Reactor experiment at Oak Ridge. Here’s what Alvin Weinberg had to say about the experience in his 1994 auto-biography:

“Congressman Chet Holifield was clearly exasperated with me, and he finally blurted out, ‘Alvin, if you are concerned about the safety of reactors, then I think it may be time for you to leave nuclear energy.” Weinberg wrote that he was speechless. It was instantly clear that the powers-that-be were not interested in Weinberg’s focus on making nuclear reactor safety the top priority. Especially if the nuclear reactors in Tennessee were safer than those in California.

So the stated reason that Alvin Weinberg, father of the molten salt reactor, was fired, was specifically because of his pre-occupation with reactor safety, a concern that was not shared by the men in charge of the Atomic Energy Commission. But the circumstantial evidence suggests the real reason Weinberg was fired is that the groundbreaking advances being made at Oak Ridge were upstaging the Californians’ pet project, the Liquid Metal Fast Breeder reactor being developed in southern California. I can’t even decide which of those reasons is more infurating!

One way or another, Weinberg was fired in 1971, shortly after the phone call between President Nixon and Congressman Craig Hosmer we just listened to. The Molten Salt Reactor experiment was completely cancelled about 18 months later. The Liquid Metal Fast Breeder reactor project in California would run up over $700mm of cost overruns by 1973. That’s over $5bn in today’s dollars after adjusting for inflation. The project was eventually cancelled years later over weapons proliferation concerns, because the Liquid Metal Fast Breeder worked by breeding U-238 into Plutonium.

All the research papers from the Molten Salt Reactor Experiment somehow found their way into the storage room of a small Children’s museum not far from the Oak Ridge laboratory.

They were scheduled to be destroyed and would have been lost forever if not for the activism of Kirk Sorensen, a former NASA engineer who discovered the molten salt reactor design when NASA was looking for a way to power a colony on the moon. Sorensen launched a one-man effort to save the records from Oak Ridge, by having them scanned just before they were scheduled to be destroyed.

Breeder reactors will play a very important role in solving the nuclear waste disposal problem. As I explained in the prior episode, natural uranium contains less than 1% U-235, the fissile isotope of uranium that can sustain a nuclear fission chain reaction. The remainder is U-238, which is not fissile. Nuclear reactor fuel is made by enriching natural uranium to contain about 3 – 5% U-235. The remaining 95 – 98% is U-238, which is completely wasted in pressurized water reactors. But to say that 95% of the fuel is wasted is the understatement of the century. It's not just "wasted" in the sense it never gets put to good use. In the course of operating a pressurized water reactor for several years, the U-238 gets mixed with small amounts of Plutonium and other fission by-products called trans-uranics. That means the U-238 which was mined out of the ground and would have been perfectly safe to throw back into the ground is now contaminated with some really nasty stuff. The resulting mixture is high-level nuclear fuel waste, almost 250,000 tons of which are now in storage around the world. It only stays dangerously radio-active for about 50 years, but it still remains radio-active at a lower level of radiation for over 100,000 years!

Wouldn't it be great if we someday invented a nuclear reactor that didn't waste 95% of the fuel after first making it radio-active for 100,000 years? There's no need to wait for someday. It's called a breeder reactor, and it was invented, built, tested, and proven to work half a century ago.

A breeder reactor is a nuclear reactor that produces more fissile nuclear fuel than it consumes. At first that seems impossible, like an automobile that can start with 10 gallons of gasoline in its fuel tank, drive all day, and then somehow end up with 11 gallons of gas in the tank without refueling. Cars don't work that way, but breeder reactors do.

Imagine a magic automobile that consumes gasoline at the rate of one gallon for every 20 miles driven, but it can also transform ordinary water into gasoline at the rate of one gallon for every 18 miles driven. Although gasoline is being consumed, new gasoline magically made from water is replacing it even faster than it's being consumed. The result is that when you arrive at your destination, there's more gasoline in the fuel tank than you started with. All you consumed to make your trip was everyday water, which is much cheaper and more abundant than gasoline.

Here's how a breeder reactor works: it's consuming fissile fuel just as a car burns gasoline. But at the same time, it's also producing more fissile fuel by transforming some other fertile material into fissile fuel. When the breeder reactor is first fueled with the same low-enriched uranium that fuels pressurized water reactors, the 5% of the fuel which is U-235 sustains the fission chain reaction. But the 95% of the fuel that's U-238 doesn't go to waste in a breeder reactor. Instead, it is slowly transformed into Plutonium, another fissile fuel material.

From a given amount of low-enriched uranium fuel, a breeder reactor can literally produce 20 times more electricity than a light water reactor which wastes 95% of the low-enriched uranium it consumes. And the benefit isn't just fuel economy. Breeder reactors also reduce the nuclear waste produced by at least 95%!

But wait a minute… Plutonium? Isn't that the stuff they make atomic bombs with? Yep, that's right, and that's why breeder reactors have had a controversial history. Now to be clear, atomic bombs are made from weapons grade uranium or plutonium, and uranium breeder reactors used for making electricity only produce reactor-grade plutonium which isn't useful for making bombs. But the very idea that plutonium of any grade is being produced raises a lot of eyebrows.

To summarize, breeder reactors are a fantastic advancement, because they make it possible to use all the uranium fuel and reduce the amount of nuclear waste by at least 95%. But uranium-fueled breeder reactors work by breeding U-238 into Plutonium, and that brings rise to legitimate concerns about what could happen if terrorists or rogue nations were able to modify a civilian breeder reactor and somehow turn it into a plutonium production reactor capable of making weapons-grade plutonium. Now frankly, based on the research I've done, that's a pretty far-fetched scenario because military plutonium production reactors are incredibly sophisticated and expensive to design and build. But the risk still needs to be taken seriously.

There's a good way to mitigate that risk, but to understand it we need to first return to the revolutionary research that was done at the Oak Ridge National Laboratory in the mid-1960s.

Let's return to the subject of molten-salt reactors, which were pioneered in the 1960s in Oak Ridge, Tennessee. It's possible to build a Uranium-fueled molten salt reactor, but the molten salt reactor that was built at Oak Ridge in 1964 was fueled by another heavy element called Thorium. You see, Alvin Weinberg wasn't just obsessed with safety. He also understood that uranium is a scarce element that wouldn't last forever, and that uranium breeder reactors that produce plutonium would lead to weapons proliferation objections. Weinberg was truly decades ahead of his time.

Thorium is an element that's four times more abundant in Earth's crust than Uranium. Similar to U-238, Thorium is fertile, meaning that it can be transformed by a breeder reactor into another element which is fissile, meaning it can sustain a nuclear chain reaction. But here's the critical difference between Thorium and Uranium fuel, which has everything to do with overcoming weapons proliferation risks: Thorium can't be bred into Plutonium. Rather, breeding Thorium produces U-233, another fissile isotope of Uranium. A Thorium-fueled nuclear reactor generates energy from a uranium fission chain reaction, just like a pressurized water reactor. The difference is that the Uranium sustaining the fission chain reaction is U-233 rather than U-235. And that U-233 comes from breeding fertile Thorium fuel into U-233.

There's an urban legend on the Internet that Thorium completely and totally eliminates all nuclear weapons proliferation risks, because it's impossible to make a bomb from U-233. There's some truth to this sentiment, but it's an exaggeration. It's not "impossible" to make a bomb from U-233. A true statement is that U-233 is much less stable than U-235, and making a bomb from U-233 would be a whole lot more difficult than making a bomb from weapons grade high-enriched U-235 or weapons grade plutonium. So a fair statement is that weapons proliferation risks are much lower when Thorium is bred into U-233 than when U-238 is bred into Plutonium.

But wait, what if the bad guys got their hands on a Thorium-fueled breeder reactor? Couldn't they just throw away the Thorium fuel, fill it up with U-238, and breed the U-238 into Plutonium? The answer is a resounding no, and that's one of the most important benefits of Thorium as a nuclear reactor fuel.

To fully explain why a Thorium breeder reactor could never be repurposed as a plutonium production reactor would require going into nuclear physics in far more detail than we have time for. The executive summary is that breeding U-238 into Plutonium requires much faster-moving neutrons, and a much more sophisticated reactor design. If we were talking about a Uranium-fueled breeder reactor with fast neutrons like the one that was being developed in southern California when Alvin Weinberg was fired in 1971, there would be a very real risk of that kind of reactor being repurposed for weapons-grade plutonium production. But Weinberg's Thorium-fueled molten salt breeder reactor could never be repurposed for plutonium production because the much simpler reactor design simply isn't capable of breeding U-238 into Plutonium.

in the interest of full disclosure, this next bit is admittedly conjecture on my part. Recall that when Alvin Weinberg was fired, Chet Holifield exclaimed that there was no room in the Atomic Energy program for guys like Weinberg who thought reactor safety should be the primary goal. Now remember, 1971 was the height of the U.S.-Soviet cold war. Could it have been that one of the reasons Weinberg was fired and the entire molten sale reactor program was cancelled was specifically because Weinberg's team found a way to almost completely eliminate the weapons proliferation risks posed by Uranium fast breeder reactors capable of producing plutonium? Could it have been that President Nixon and the men running the Atomic Energy Commission didn't want the breeder reactor's weapons proliferation risk problem solved, because they wanted to be able to produce plutonium in civilian power production reactors to support the cold war arms race? That's just an uneducated guess on my part, and I acknowledge that it's pure conjecture. But how else do you explain Chet Holifield outright telling Alvin Weinberg that the reason he was being fired was that there was no room in the atomic energy program for guys who thought reactor safety was the most important priority?

The groundbreaking research performed at the Oak Ridge National Laboratory in the 1960s was easily the best and most important research in the entire history of the nuclear power industry. But after Alvin Weinberg was fired in 1971 and the entire project was cancelled in 1973, the team disbanded and the profoundly valuable research they did would have been forgotten forever, if not for the activism of former NASA engineer Kirk Sorensen.

Sorensen had already become passionate about commercializing the liquid-fueled Thorium molten salt reactor. When he learned that all the research papers from Oak Ridge were scheduled to be destroyed, he leapt into action and managed to get them all scanned just before they would otherwise have been lost forever. But despite having a vested personal interest in commercializing this technology himself, Kirk Sorensen didn't try and keep this invaluable research to himself. Instead, he published it on the Internet, making it available to everyone including people he knew would become competitors to his own startup company.

The result was the birth of a cottage industry of startup companies that are working right now to perfect and commercialize the molten salt, liquid-fueled, thorium-burning reactor designs pioneered in Oak Ridge in the 1960s. For the most part, these companies are the pet projects of billionaires who can afford to take an irrational investment risk building a machine which no nuclear regulator on earth even knows how to regulate. Why take that risk? Because advanced nuclear technologies we've known about for decades now have the potential to literally save mankind from the coming global energy crisis. I'll tell you all about one of these exciting startup companies that are commercializing molten salt and Thorium fueled reactors in the next episode.

I know what some of you are already thinking: If our tax dollars paid for all this groundbreaking research at Oak Ridge in the 1960s, then why the hell hasn't the U.S. Government gotten its shit together and recognized that promoting the commercialization of this technology could have prevented accidents like Fukushima and Three Mile Island? Ever since about 2011, Kirk Sorensen has been begging and pleading U.S. government officials, asking them to resurrect and embrace the Oak Ridge research, but he was completely ignored for many years. I personally find it maddening that research my parents' tax dollars paid for, which could have prevented all the major accidents in the history of nuclear power, was completely abandoned because it was invented in the wrong state, and because it upstaged President Nixon's pet project being developed in his own state of California.

Just in case hearing about how badly our government has screwed up nuclear energy policy hasn't pissed you off yet, please give me another minute of your attention. I promise to get you there. You see, eccentric billionaires hoping to save humanity from the coming energy crisis weren't the only people to take notice of Kirk Sorenson's videos, which he began publishing right here on YouTube around 2011. To their credit, government employees who saw those videos on YouTube also took a keen interest in Sorensen's message. They recognized how incredibly badly the U.S. Government had screwed up by cancelling the molten salt reactor experiment at Oak Ridge for purely political reasons. They recognized the immense value of the government research Sorensen had saved from destruction after it was recklessly discarded after the Oak Ridge project was cancelled in 1973.

So these government employees, who learned about all this from watching Kirk Sorensen's videos right here on YouTube, leapt into action and succeeded in persuading their superiors to launch a government-funded program to develop and commercialize Thorium-fueled molten salt nuclear reactor technology!

I know, that sounds at first like terrific news. But there's just one little problem: The government employees I'm talking about work for the Chinese government! As soon as the Chinese government learned how badly the U.S. government had screwed this whole thing up from Kirk Sorensen's videos, they wasted no time downloading every document they could get, and launching their own effort inside China to futher develop Thorium-fueled molten salt reactor technology.

And now, just over a decade later, they're in the lead. In 2018, the Shanghai Institute of Applied Physics began construction of its Thorium-fueled molten salt reactor, inspired by the Oak Ridge research, in Wuwei city, Gansu Province. That reactor has now been completed, and it was granted authorization for startup by Chinese regulators in August, 2022.

Meanwhile, back in the land of the free, some American nuclear energy entrepreneurs are actually leaving the United States and moving to Canada and other countries where nuclear regulators are more open to working with private industry to commercialize the advanced nuclear technology pioneered in Oak Ridge in the 1960s.

As for U.S. nuclear regulators, the tide has finally started to turn for the better, but only very recently, and very slowly. On April 12, 2021, the United States Department of Energy, Office of Nuclear Energy, issued a flyer titled "Three Advanced Reactor Systems to Watch by 2030". The three designs they describe in that paper are the Sodium-Cooled Fast Reactor, the Very High Temperature Reactor, and the Molten Salt Reactor.

That's right, the last one on their list is the very same molten salt reactor design which was built, tested, and proven by Alvin Weinberg's team at Oak Ridge in the 1960s, just before

Weinberg was fired by California congressman Chet Holifield and Atomic Energy Commission honcho Milton Shaw for making the outrageous statement that safety should be the top priority in reactor design.

Now, more than half a century later, the U.S. Department of Energy has finally declared in an official communication that the so-called “new technology” we should be keeping an eye on is exactly what Weinberg’s team perfected in the 1960s, and what China has successfully prototyped since 2011, after being inspired by Kirk Sorensen’s efforts to get the attention of U.S. government officials. But there is still no regulatory framework in the United states to even consider permitting a liquid fueled molten-salt cooled Thorium burning civilian nuclear power reactor. Now are you pissed off?

The United States Government is long overdue to recognize its duty to encourage rather than stand in the way of commercialization of advanced nuclear technology. And after decades of failing miserably in this regard, FINALLY, the Idaho National Laboratory has commissioned the National Reactor Innovation Center, whose mission is to work in partnership with private industry to commercialize advanced nuclear technology. This is the best sign we’ve seen to date that the U.S. Government just might do the right thing, after having first exhausted all other possibilities over the last five and a half decades.

I’ve only scratched the surface of the benefits of Thorium fuel and molten salt coolants. To fully do justice to that subject would require a docuseries at least as long as this one. And thankfully, Kirk Sorensen has already done that work with all the free videos you can find at his energyfromthorium.com website.

There is now almost 250,000 tons of spent nuclear fuel waste in storage. It came out of once-thru water-cooled non-breeder reactors, and 95% of it is perfectly good natural uranium than can and should be recycled and used to make fuel for other nuclear reactors. That both eliminates the need to continue stockpiling more and more nuclear waste, and it avoids wasting perfectly good natural uranium which, if we continue wasting it indefinitely, could eventually lead to a global shortage of the natural uranium needed to fuel the nuclear reactors of tomorrow.

France has been recycling its spent nuclear fuel waste for years with great success, and Russia has made significant advances in the process for waste recycling. But most other countries including the United States have failed to follow suit. It seems that the same great minds that literally discarded the Oak Ridge research—arguably the most important research in the history of nuclear energy—those same brilliant minds have failed to recognize the opportunity to recycle our spent nuclear fuel waste rather than stockpiling it indefinitely.

When spent nuclear fuel waste is recycled, 95% of it is perfectly good natural uranium that can be recovered and used to make new fuel rods. The remaining 5% is some pretty nasty stuff. If it came from a Thorium-fueled reactor, it will only need to be stored for about 300 years. That's one of the major benefits of Thorium fuel—it dramatically reduces the storage period for nuclear fuel waste. But if we're talking about waste from a uranium fueled reactor—and most of the quarter-million tons of waste in storage worldwide falls in that category—then it would need to be stored for as long as 100,000 years.

Remember, recycling reduces the volume of uranium fuel waste by 95% and yields a whole lot of perfectly good recycled natural uranium in the process. But that last 5% is really nasty stuff, and I personally don't like the idea of leaving future generations with the burden of storing anything for tens of thousands of years. Fortunately, another advanced nuclear technology solves that problem.

A close cousin to the Breeder Reactor is the Burner reactor. This is, quite literally, a nuclear reactor that's designed to take the nastiest nuclear waste leftover from the recycling cycle—the 5% that's really nasty stuff—and literally consume that waste as fuel to run the reactor and produce electricity. This means we have the technology to recycle all 250,000 tons of nuclear waste now in storage, recover 95% of it as perfectly good natural uranium we can use to make fuel for tomorrow's nuclear reactors, and then burn the remaining 5% as fuel in waste-burner reactors designed specifically for that purpose.

But we're not doing any of this today. Instead, every civilian nuclear reactor in existence continues to use a once-through Uranium fuel cycle, where we waste 95% of the fuel. And with only a few exceptions such as France, we let all that waste pile up in expensive nuclear waste storage facilities. We're currently doing absolutely nothing to adopt and use the advanced nuclear technologies that could completely solve the waste disposal and weapons proliferation objections the public rightfully holds against nuclear energy.

The final advanced nuclear technology I want to cover is Nuclear Fusion. Fusion is a profoundly interesting technology, that could potentially enable another profound advance in the abundance of energy. But for the sake of this docuseries, which is about solving the energy transition needed by 2050, all you need to know about Nuclear Fusion is that it won't be commercialized in the timeframe needed to solve the coming crisis and break our addiction to fossil fuels.

I still encourage you to learn all about nuclear fusion, but it's going to be a 22nd century story, or maybe a late 21st century story. It's still a very long way from commercialization, and it won't help solve the coming crisis. To solve the crisis and achieve energy transition by 2050, we need to stay focused on getting our governments to get their shit together and commercialize the technology our parents' and grandparents' tax dollars already paid for at Oak Ridge in the 1960s.

Core depressurization, steam flashing, fuel rod meltdown, and hydrogen explosions are all fully solved by the liquid-fueled molten salt reactor designed, built, and tested at Oak Ridge in the 1960s. All we need to do to solve these objections is to put that proven technology to work, but right now regulators are standing in the way of progress.

Human Error, the real cause of the accidents at Chernobyl, Three Mile Island, and Fukushima, is solved by automation and passive safety systems. As much as I'm not a fan of water-cooled reactors, the fact remains that the latest Generation III+ reactors are perfectly safe and their automation systems are designed specifically to prevent the kind of human error problems that caused all the major accidents.

The waste disposal problem can be completely, totally solved with the combination of spent-fuel waste recycling and waste burning reactors to consume what cannot be recycled. Our goal should be to recycle every ounce of the 250,000 tons of nuclear waste now in storage, recover 95% of it for making new reactor fuel, and use the remaining 5% as fuel for waste-burning reactors. This completely solves the waste disposal objection.

Thermal spectrum thorium-fueled breeder reactors, which are not capable of breeding Plutonium, and which could not realistically be re-purposed to breed plutonium, even with heavy modification, solve most of the weapons proliferation objection. In the next episode I'll show you how the remaining concerns can be alleviated as well.

Solving these safety challenges is only half the problem. Construction cost Overruns and decommissioning cost are the main reasons that nuclear energy is so much more expensive today than it needs to be. We need cheap and abundant energy, so in order for Nuclear to supply it, the cost problem has to be solved for once and for all. I'm convinced the best solution to this problem is to build nuclear reactors in factories, on assembly lines. And that subject is so important warrants an entire episode, which is coming up next on Energy Transition Crisis.