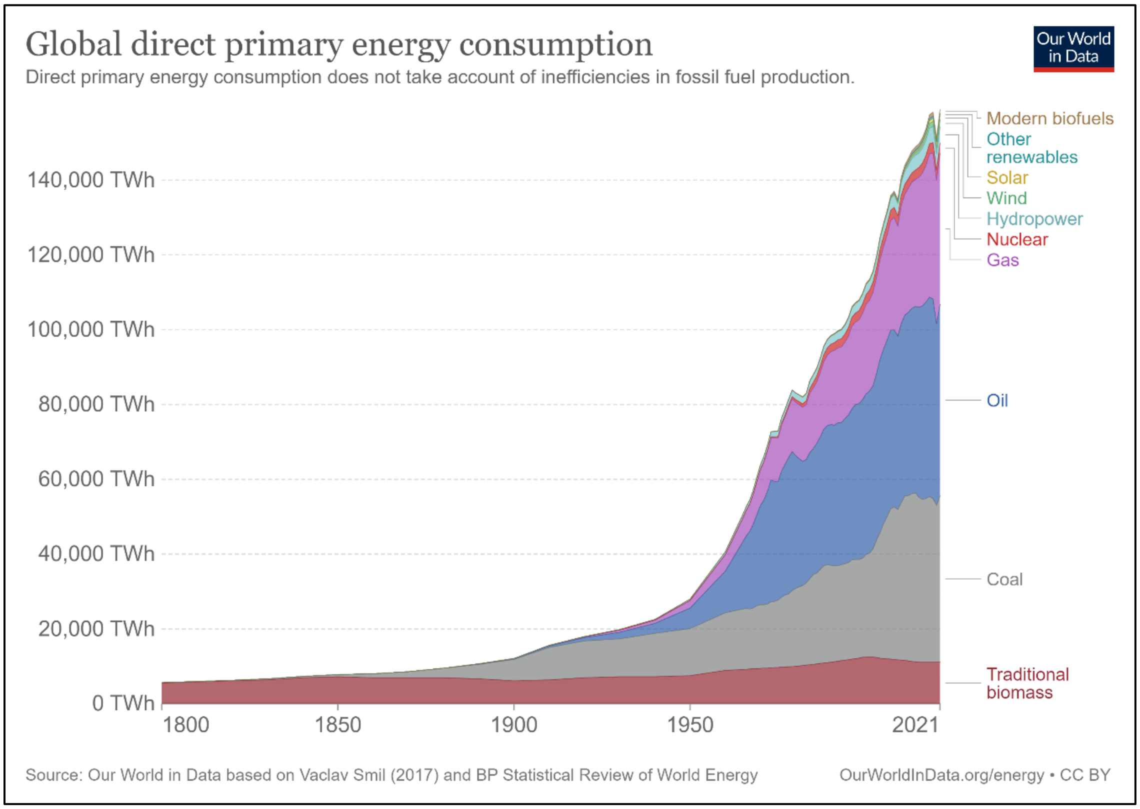
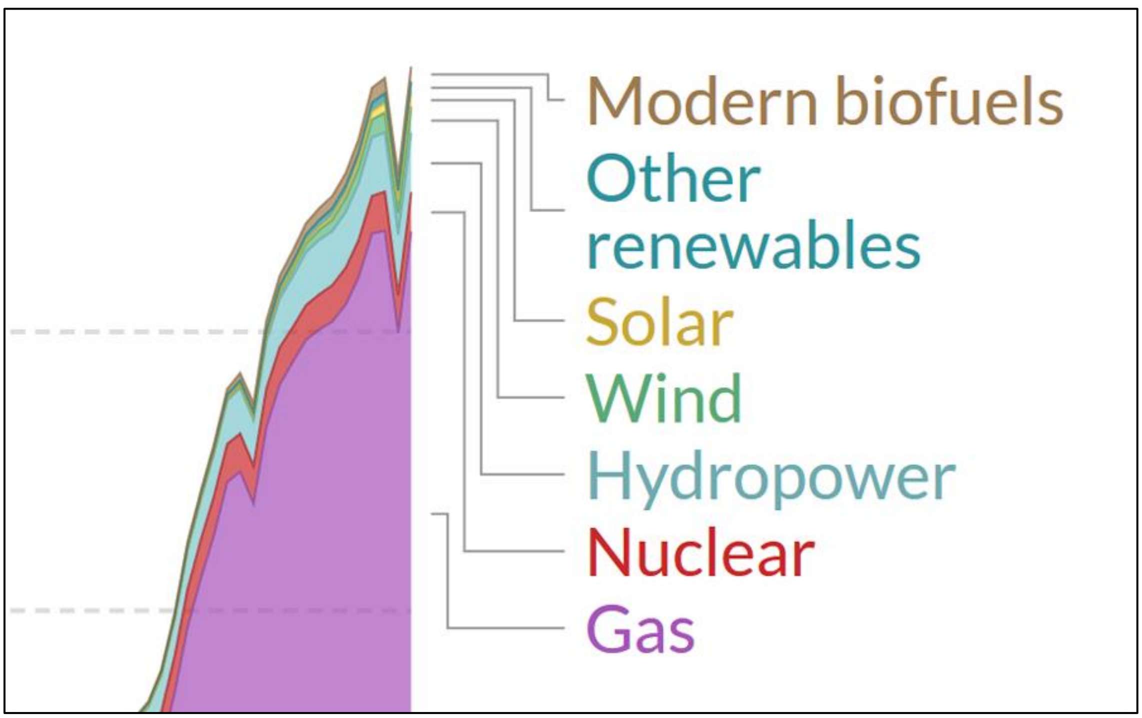
[*Solving the 2020s Energy Crisis*]





Sample of the video aesthetic intended for the YouTube Version: https://t.co/SNjvHRXDpF

Narration Script

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Episode 5: Advanced Nuclear Solutions & Prescriptions for Solving the Crisis

I'm Erik Townsend. In the final episode of this docuseries, we'll explore more advancements in nuclear power technology, and then bring all the concepts we've covered together to lay out a roadmap for solving the coming energy crisis by building out clean energy at scale, allowing fossil fuels to finally be phased out.

For several decades, almost no progress was made on advanced nuclear technology. That's not to say that there's been no progress on improving *old-school* nuclear. Automation and passive safety systems have improved the industry-standard pressurized light water reactor considerably over the years. But until very recently, there's been almost zero progress moving beyond light water reactors toward better, safer designs such as molten salt or liquid fuel.

The latest generation of pressurized light water reactors are known as Generation III, and a variant known as Generation III+ is even better. An example of Generation III+ is the Westinghouse AP1000, that company's current flagship product. But unfortunately, we're still talking about pressurized light water non-breeder reactor technology where 95% of the uranium fuel goes to waste that must be stored for 100k years.

The primary reason there's been no progress on molten salt, liquid fueled, breeder, or Thorium fueled reactors is that there's been virtually no capital investment in advanced nuclear technology. The small handful of startup companies I mentioned in the last episode, which are already working on exciting advanced nuclear technologies, are usually the pet projects of billionaires who can afford to lose their entire investment. So far, institutional investors haven't been interested in advanced nuclear because they haven't seen a path toward profitability.

But finally, the tide is starting to turn! In January 2023, regulators approved the first Small Modular reactor, built by a company called Nuscale, for operation in the United States. Hopefully that event will send a signal to institutional investors that advanced nuclear is a field ripe for investment, and desperately needed capital will flow into the industry so that irrational billionaires competing with one another to be perceived as the guy who invented the technology that saved the world from the coming energy crisis aren't the only source of funding for these exciting new companies.

I'm nowhere close to being a billionaire myself, but I'm proud to say that in late 2022, I joined the *irrational advanced nuclear investor club* by making a private equity investment in a company that's already building a prototype small modular **waste burner** nuclear breeder reactor fueled by a combination of Thorium and nuclear waste left behind by the current fleet of light water reactors. I'll tell you more about that company later in this episode.

Other startups are already prototyping molten salt and Thorium fueled breeder reactors, and hopefully regulators will soon open their minds to those technologies as well. We're still very early in this story, but the tide is finally turning and it looks like Advanced Nuclear technology is set to really take off.

Nuscale's SMR, the first approved in the United States, is a very traditional pressurized light water reactor design, with relatively little advanced technology. But we had to start somewhere.

In this final episode, I'm going to explain the most important advanced nuclear technology concepts you need to understand, and then I'll lay out an overall game plan for solving the coming crisis and building enough clean electric power generation capacity to *realistically* phase out fossil fuels by 2050.

Let's start with an explanation of heavy water. The prior episode explained why ordinary light water has several serious drawbacks as a moderator and coolant for nuclear reactors. A superior alternative moderator is heavy water.

Heavy Water is just like regular water, except instead of regular hydrogen atoms, heavy water contains a special isotope of hydrogen called deuterium. The only difference is that the deuterium atom has a neutron inside its nucleus, whereas the regular hydrogen atom doesn't. This causes heavy water to weigh about 11% more than the same volume of light water, hence its name.

Heavy water has several benefits over light water. Canada's nuclear energy program relies on heavy water as the preferred moderator.

To fully explain the benefits of heavy water in full detail would require a longer lesson on nuclear physics than we have time for. The gist of it is that heavy water does a better job of slowing down all those neutrons flying around inside the reactor core. If you have an appetite for learning about nuclear physics and want to know more, start by reading the Wikipedia article titled Neutron Economy.

Heavy water has a negative stigma associated with it because India's nuclear weapons program built and then test-detonated a bomb in May 1974 that was made from plutonium that was manufactured in a breeder reactor that used heavy water smuggled into India from other countries. This resulted in a perception in foreign policy circles that heavy water was the "secret sauce" that allowed India to get the bomb.

I don't profess to be expert in this field, but so far as I can tell, this is like saying that because hand guns that kill people in violent crimes are made from steel, that makes steel an evil metal that should be banned. Heavy water is used for lots of things other than making plutonium for bombs, including making commercial reactors *safer* by eliminating several risks inherent to light water moderators. And there are plenty of ways to make plutonium for bombs without heavy water. So, to my thinking, this negative stigma that heavy water can be used to make bombs is undeserved, but it still persists and sometimes affects policy decisions.

Bottom line, what you need to know about heavy water is that it's a better moderator than light water, but in some jurisdictions there is a perception that it poses a higher proliferation risk.

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. Natural uranium consists of less than 1% U-235, the fissile fuel source that powers light water reactors. The rest is U-238, which is completely wasted by light water reactors because it's not fissile, meaning that it can't help to sustain a nuclear fission chain reaction. That's why Uranium needs to be enriched to bring the U-235 content from less than 1% up to about 5% so that there's enough fissile fuel to sustain the nuclear reaction.

The result of wasting the 95% of the low-enriched uranium fuel that isn't fissile is that 20 times more nuclear waste is created than would be necessary if all the uranium were being consumed as fuel. Now here's the key: While U-238 isn't fissile, it is *fertile*. That means it's possible to transform *fertile* U-238 into a fissile element that can be used as fuel, by bombarding the *fertile* U-238 with neutrons in a certain way.

In a fast breeder reactor, the neutrons aren't slowed down by passing them through a moderator. Instead, all those fast neutrons flying around are used to transform the U-238 into Plutonium, which can be used as fuel to power the fission chain reaction. Put another way, the 95% of the low-enriched Uranium that went to waste in light water reactors because it wasn't fissile doesn't have to be wasted in a breeder reactor. Instead, it's transformed, or *bred* into Plutonium fuel which works just as well as U-235 to sustain the ongoing nuclear fission chain reaction.

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 plutonium, and uranium breeder reactors used for making electricity normally produce only reactor-grade plutonium which isn't useful for making bombs. But the very idea that plutonium of any kind is being produced raises a lot of eyebrows.

When Alvin Weinberg was fired in 1971, his team was hard at work on a breeder reactor of their own design. The breeder reactor being developed at Oak Ridge was molten salt cooled and didn't use a water moderator or coolant. But it wasn't fueled by uranium. Instead, it was fueled by Thorium, another element which is four times more plentiful in the Earth's crust than uranium. Instead of breeding U-238 into Plutonium like the Californian reactor, the Oak Ridge design worked by breeding Thorium into U-233, another fissile isotope of uranium which can be used to power a nuclear chain reaction and produce electricity.

In order to breed U-238 into Plutonium, a so-called "fast-neutron" reactor design is required. Neutrons that get slowed down by a moderator to create a sustained fission chain reaction won't do the trick; breeding U-238 into Plutonium requires fast neutrons, and that makes the overall reactor design much more complicated and expensive. A distinct advantage of Thorium as a fertile fuel source is that it can be bred into U-233 using slow neutrons—the kind of neutrons found in less complex reactor designs.

The point is that in order to build a Uranium breeder reactor you need a much more complex and expensive fast-neutron design, but a much simpler and more economical slow-neutron design can be used to build a Thorium breeder reactor. But just to confuse the rest of us, nuclear engineers don't use the word 'slow' to describe the slower neutrons. They call them *thermal* neutrons instead.

The liquid metal fast breeder reactor that was being developed in California eliminated the water moderator and therefore, the need for pressurization of the core. But aside from that it didn't offer any other safety benefits. Yet it was allowed to run *five billion* inflation-adjusted 2022 dollars of cost overruns. The Thorium breeder reactor in Tennessee had already delivered groundbreaking advances in **safety**, and it offered a much more efficient way to achieve the benefits of breeder reactors without requiring the complexity and expense of a fast-neutron reactor design.

And there was another significant difference between the two designs. The Uranium-fueled breeder reactor in California generated less nuclear waste than light water reactors, but that waste still needed to be stored for 100,000 years. In contrast, the nuclear waste produced by the molten salt Thorium breeder reactor that was being designed in Oak Ridge only needs to be stored for 300 years, because it doesn't contain the longer half-life transuranics produced by the Uranium breeder cycle.

A myth that's been widely circulated on the Internet is that Thorium completely and totally overcomes weapons proliferation risks because, according to urban legend, it's completely impossible to make a bomb from U-233. There is some truth to this argument in the sense that Thorium breeder reactors that operate in the thermal neutron spectrum are completely unable to produce plutonium of any grade, so therefore, they don't pose the risk of putting plutonium into the wrong hands. But the perception that it's completely impossible to make a bomb from U-233 is an exaggeration. A correct statement is that it would be much more difficult to make a bomb from U-233 than from weapons grade plutonium, so therefore, the weapons proliferation risk is lower. And presumably, bad guys intent on making a nuclear bomb would be much more likely to try and get their hands on some weapons-grade plutonium rather than tackling the complexities of trying to make a bomb from U-233.

The way this story ultimately ended was that the guys who insisted that **safety** should be the top priority in designing nuclear reactors, and who were working on a breeder reactor 20 times more fuel-efficient than even today's Generation III+ light water reactors, and which would have generated 1/20th as much nuclear waste that was only radio-active for 300 years instead of 100k years, and who figured out how to partially overcome weapons proliferation concerns with a breeder reactor that didn't make any plutonium—those guys all got fired back in 1973. But the Californians building the liquid metal fast breeder reactor capable of producing plutonium would go on to spend $700mm in cost overruns by 1973. And the cost overruns had only just begun at that point.

In case there's any doubt about whether the Thorium Breeder Reactor on Alvin Weinberg's drawing board could ever work, that was proven on August 26, 1977, when Uranium-233 fuel bred from Thorium was loaded into a breeder reactor and President Jimmy Carter personally turned it on. That reactor ran for 5 years, and at the end of those 5 years, the core was found to contain 101% of the initial fissile fuel load, proving that more fuel was produced than consumed.

Nixon and Holifield's liquid metal fast breeder reactor program would eventually be cancelled years later, after controversy arose about the weapons proliferation risks of using uranium breeder reactors that breed U-238 into Plutonium for civilian electrical power generation. Massive cost overruns were another factor.

The Oak Ridge designs for a much safer Thorium-fueled molten salt breeder reactor were all but forgotten, and eventually somehow wound up in a storeroom in a rural children's museum near the Oak Ridge laboratory. They would have been lost forever if not for the activism of Kirk Sorensen, who led an effort to get the documents scanned just before they were scheduled to be destroyed.

Is the problem that nuclear power is inherently dangerous? Or is the problem that for all its history, the development of the civilian nuclear power industry has been strictly controlled by government, and for most of the last five decades, government's priorities were not optimally aligned with the needs of the people?

For a full half-century after Thorium-fueled molten salt reactors were built, tested, and proven to work in Oak Ridge, Tennessee, the nuclear power industry has built nothing other than water-cooled uranium fueled reactors. The vast majority are the pressurized light water type, plus a few heavy water designs, particularly in Canada's nuclear program. But there has hardly been any substantive advancement of nuclear reactor design in the last 50 years, or even adoption of the best reactor designs that had already been proven half a century ago.

Most of the progress that has been made involves better automation and passive safety systems for pressurized light water reactors. But switching to a different coolant than water or a different fuel than uranium hasn't been in the cards until very recently. Nuclear power is so heavily regulated that no progress is possible unless the government is driving the bus and encourages that progress through policy. And no such progressive policies have existed for decades. **I contend that's the *real* problem with nuclear energy.**

But *finally*, just in the last 5 years, the tide is finally starting to turn, and we're starting to see signs of changing attitudes from regulators. The U.S. Department of Energy's flyer promoting 3 exciting reactor designs including the molten salt cooled reactor, is a long-overdue but very welcome sign of progress. In January 2023, Nuscale was the first company to have its SMR design approved by U.S. regulators. Finally, the tide is turning, and the future looks bright.

To solve the impending energy crisis, we need a new policy imperative that calls on the Nuclear Regulatory Commission to aggressively work in partnership with the private sector to define a new regulatory framework that actively encourages the development and commercialization of advanced reactor designs, particularly in small modular reactors that can be built in large numbers on assembly lines. The January 2023 approval of Nuscale's SMR design was a great start. Now we need to keep the momentum going and approve molten salt cooled reactors, liquid fueled reactors, and Thorium fueled thermal breeder reactors.

The most exciting news is that the private sector has already begun to anticipate the coming energy crisis, and already knows that wind and solar alone can't replace fossil fuels for baseload electric power generation. There are already upwards of 50 small modular reactor designs being proposed. In many cases, entrepreneurs are so certain of society's need for advanced nuclear technology that they're taking the risk of building advanced reactor prototypes right now, knowing full well that there is currently no regulatory framework to allow turning them on.

These startups are taking a really big gamble. They're betting the farm that if they can figure out the right technology to save humanity from the coming global energy crisis, government will eventually catch up and recognize the need to modernize its regulatory framework to permit using that technology. And close to a dozen of these startups are planning to use Thorium rather than Uranium as fuel, despite that so far, governments are completely unprepared to even consider permitting a Thorium-fueled commercial electric power plant.

One example of a leader in this exciting new field is Copenhagen Atomics, a company I invested in personally in late 2022. Copenhagen Atomics' **waste burner** is designed to consume a combination of Thorium and nuclear waste left over from the light water uranium reactors of yesteryear. It's a molten salt reactor design inspired by Alvin Weinberg's research at Oak Ridge.

Copenhagen Atomics' design is revolutionary because it completely separates the moderator from the coolant. In other molten salt reactor designs, the moderator is either dissolved into the molten salt or is installed inside chamber containing the molten salt. That means the moderator gets super hot, along with the molten salt. But Copenhagen Atomics completely separates the molten salt coolant, which the fuel is dissolved in, from the moderator.

That means the water moderator in the waste burner reactor never gets as hot as the water you shower with, so it doesn't need to be pressurized. The result is that the waste burner can be moderated by either light or heavy water. The company favors heavy water as a moderator because of its superior neutron economy, but if there's sensitivity to use of heavy water, the waste burner runs almost as efficiently using a light water moderator.

The waste burner is a modular design, built in the form factor of a standard 40' shipping container, meaning that it will be possible to ship waste burners anywhere on earth using the existing commercial shipping infrastructure. Building a large Gigawatt powerplant on the scale of today's massive nuclear power stations is as simple as erecting a building to house any number of modular reactors, which are each designed to produce 100MW of thermal energy. Those modular reactors are combined to build an electrical generation plant of any desired capacity.

Waste burners are designed to produce heat, not electricity. Part of the reason is that Copenhagen Atomics recognizes that thermal efficiency of producing electricity from heat is a field that needs improvement, as I explained in the first episode of this docuseries. So they leave the business of converting heat to electricity to Siemens and the various other companies that are already well established in that market. The second reason Copenhagen Atomics chose to focus on being in the heat business rather than the electricity business is that this allows them to target several other markets such as seawater desalination and ammonia liquid fuel production, which require great amounts of heat rather than electricity.

Ammonia liquid fuel can be used as a direct replacement for diesel fuel, but it doesn't produce any carbon emissions when you burn it in a diesel engine. So being able to produce ammonia liquid fuel with high thermal efficiency is a really important part of the energy transition. Copenhagen Atomics' desire to be part of that story is a big part of the reason the company prefers to be in the business of making heat rather than electricity from Thorium and spent nuclear waste. If electricity is desired, it's easy to hook one or more waste burners up to another company's steam turbine electric generator, creating a Gigawatt electric powerplant from off-the-shelf modular components without the need to custom-design or -build anything.

Copenhagen Atomics' vision is to eventually produce at least one waste burner per day on an assembly line, and then ship them anywhere in the world where they're needed. Each waste burner runs continuously for many years. Then it's de-fueled and moved to a storage area to allow the reactor core to cool, before it's eventually shipped back to the factory to be recycled.

The company believes its waste burners could, in theory, remain in continuous service for as long as 15 years. But the company intends to introduce its first waste burners with a 5-year continuous service life in the interest of proving the technology with ultra-conservative safety parameters, before eventually extending the service life incrementally to ultimately approach the theoretical limit of 15 years' continuous duty.

Copenhagen Atomics is just one example of more than 50 startup companies working on advanced nuclear technology. Right now, the only available source of investment capital for these startups are private investors like me—people who are so passionate about the prospect of saving the world that we're making what we know to be questionable investment decisions, because the products being developed by these companies aren't yet legal to operate anywhere in the Western world.

So long as institutional investors considering investments in this field conclude that a 100% loss is a significant risk due to government standing in the way of commercializing advanced reactor designs, there's simply no possibility of the technology advancing as quickly as we need it to solve the coming crisis, because there won't be sufficient investment capital to fund it.

We cannot continue to allow government bureaucracy to stand in the way of progress. The stakes are too high. We need to solve this energy crisis to continue feeding the 8 billion people we already have living on planet Earth. And if we get it right, we could usher in a whole new era of accelerated human prosperity thanks to cheap and abundant energy. It's possible to literally lift billions of people out of poverty if we get this energy transition right.

There are even a few startups that have intentionally made what they know to be poor technology choices in designing their small modular reactors, because their design goal is to favor what can realistically be approved by regulators, as opposed to more advanced approaches they know are better, but which they fear regulators are not yet ready to permit. You heard that right: They're intentionally pursuing what they know to be sub-optimal designs, because they're focused on building something the regulators might be persuaded to approve rather than designing optimal solutions for our energy needs. *Government is literally standing in the way of progress.*

We desperately need to reverse this situation with new policy directives from the highest levels of government! This industry cannot possibly save us from the coming crisis without a massive injection of investment capital, and that can only happen when investors see a viable path for the revolutionary products being conceived by these pioneering companies to be commercialized and put into operation.

One we overcome a few hurdles, nuclear is the ideal energy source for the baseload power needed to completely phase out fossil fuels by 2050.

Nuclear power requires only a tiny fraction of the land required by wind and solar to produce the same amount of energy, and that makes Nuclear the most realistic and economic baseload energy source to complement the intermittent sources of wind and solar. In theory, deep geothermal is just as good if not better. But supercritical deep geothermal depends on technological breakthroughs that haven't happened yet. The needed breakthroughs in nuclear technology were made half a century ago. We just need to start taking advantage of them.

In theory, uranium shortages could be a real problem if we tried to do it all just by building more once-through pressurized light water reactors. But that would be crazy for other reasons we've already covered. By recycling the quarter million tons of nuclear waste we already have as fuel for new breeder reactors, and including Thorium-fueled reactors in the solution, fuel scarcity won't be an issue and the nuclear waste storage problems we already have will be solved.

Custom-building 50 times more nuclear power generation capacity than we have today by 2050 through large bespoke public works projects like the Vogtle powerplant in Georgia is a thought that causes me to take serious pause. But tooling up assembly lines to build small modular reactors that can quickly be deployed in modules to build large multi-gigawatt power plants using the approach proposed by Copenhagen Atomics seems much more plausible.

The final advanced nuclear energy topic I want to cover is nuclear fusion. Unlike nuclear fission, which involves *splitting* a very heavy atom such as Uranium or Thorium to release energy, nuclear fusion works by compressing two very light atoms such as hydrogen or helium together to form a new heavier atom. This process releases energy while also overcoming many of the drawbacks of nuclear fission.

Nuclear fusion has the potential to eventually become the primary energy source to fuel the advancement of humanity for the next several centuries. But since this docuseries is about solving the mid-2020s energy crisis and achieving a clean energy transition by 2050, there's really only one thing you need to understand about Nuclear Fusion: **It's still a long way off, and unfortunately, it won't be commercialized for several more decades.**

Fusion is an incredibly promising technology, and it makes sense to watch its progress closely. But scientists have been wrestling with finding a way to harness the energy potential of fusion for more than 70 years now. It was only in late 2022 that a major breakthrough was made when the first experiment ever to produce a net positive energy result was conducted. It will be decades before this technology is perfected into something we might actually build electric power plants with or use to build engines for the next generation of spacecraft.

So unfortunately, Fusion won't help us get through the coming crisis. We're going to need to rely on the nuclear technology we already know how to harness, and that's nuclear fission using Uranium or Thorium as the fuel, both of which were proven to work more than half a century ago.

There's plenty more to learn about advanced nuclear technology and Thorium fuel. The benefits of Thorium are so great that fully explaining them would require another docuseries at least as long as this one. And thankfully, Kirk Sorensen has already done that work at his energyfromthorium.com website. The world nuclear library at world-nuclear.org is another great resource for learning more about advanced nuclear technology, as is whatisnuclear.com.

Now I want to discuss a controversial topic: The *over*-regulation of the nuclear power industry. For most people, the very suggestion that nuclear power might be *over*-regulated will seem absurd if not maddening. After all, given the history of Chernobyl, Three Mile Island, and Fukushima, it *intuitively* seems that if anything, much *more* regulation is needed in order to make nuclear power safer!

The fallacy of that line of thinking is the presumption that government regulation has been effective in making the industry safer. I contend that the reverse is actually true. The United States Government spent a lot of its taxpayers' money on the Molten Salt Reactor experiment at the Oak Ridge National Laboratory. The result of that research was breakthrough advances in **safety** which completely eliminated the risk of meltdowns, hydrogen explosions, and steam flashing in core depressurizations.

The mission of government regulators should be to embrace and commercialize the best government research and use it to make the industry as safe as it can possibly be. Instead, they fired Alvin Weinberg for the specific *offense* of making reactor *safety* his team's top priority. So let's consider how well nuclear regulation has served *we the people* in subsequent decades.

Recall the words of my investment mentors who told me that the whole problem was that nuclear power is the most tightly regulated industry in existence, and that for that reason, much safer molten salt and Thorium-fueled reactors could never be permitted unless the Government was driving the bus and pushing for their commercialization.

Three Mile Island and Fukushima are the most well-known meltdown accidents in the western world, but there have been quite a few others over the years. All of them could have been prevented had the U.S. Government embraced the breakthrough research from Oak Ridge and promoted the commercialization of only the safest molten-salt cooled reactor designs which avoid pressurization and are completely immune from meltdown, steam flashing, and hydrogen explosion risks. But instead, nuclear regulators have quite literally *stood in the way of progress* on nuclear safety, because their insistence on keeping the government in control of which reactor designs can be approved has prevented the private sector from commercializing much safer designs that were proven decades ago, in the government's own research labs.

The rules for decommissioning nuclear power plants serve as another example of how well-intended but ill-conceived regulations can undermine rather than advance the interests of the people. Decommissioning rules were born from the noblest of intentions. Regulators were concerned that if a utility went bankrupt and just abandoned a nuclear power plant without first undertaking all the steps required to safely remove and properly dispose of radioactive materials, an environmental disaster could ensue.

So rules were put in place requiring nuclear power plant operators to pre-pay the cost of decommissioning the plant at the end of its lifetime, and set that money aside in a decommissioning fund. The whole idea was to ensure that even if the operator went bankrupt, money would be available to clean up the mess they left behind. So far, so good. These rules were conceived for good reason and with noble intentions.

But unfortunately, the regulations weren't crafted to consider their unintended consequences. The effect has been to create financial incentives for utilities to retire perfectly good nuclear plants which could easily serve their communities for several more decades. To the utility that owns and operates a nuclear power plant which already has a fat decommissioning fund built up, they can get paid top dollar to decommission a perfectly good nuclear powerplant, because the decommissioning fund can afford to pay the utility handsomely for the work required to shut the plant down. Decommissioning that perfectly good operating nuclear powerplant takes desperately needed electric generation capacity off the market, causing electricity prices to rise, allowing the utility to make higher profits from their coal-burning powerplants which pollute the atmosphere with carbon emissions!

Yet another example of over-regulation standing in the way of progress will come into focus as SMRs are commercialized. The most popular vision for SMRs that futurists fantasize about involves small communities being served by their own small modular reactor that provides them with all the power they could ever need. So when I noticed that Copenhagen Atomics focuses on a very different vision where dozens of SMRs are hooked together to form a single very large multi-Gigawatt powerplant, I asked them why. Their answer was simple: Just obtaining the *site license* from regulators to operate a reactor in a particular location costs more than one of Copenhagen Atomics' reactors is expected to cost! They concluded that the only rational way to cope with the very high cost of regulation is to put several reactors in a single building to spread out the cost, and then operate several reactors under one roof.

These are all examples of a much larger trend. The overall problem is that public hysteria about the safety of all things nuclear has led to the creation of an incredibly ineffective and inefficient government bureaucracy. Don't get me wrong. I'm not suggesting that nuclear energy doesn't need to be regulated. It does. But what we need are sensible regulations that proactively make nuclear energy safer without losing sight of the importance of keeping nuclear energy cost-efficient at the same time. Instead, we have a mountain of bureaucracy that makes nuclear energy much more expensive than it needs to be, **without** really delivering on the safety benefits all this regulation is supposed to achieve.

What's needed is a joint effort between government and private sector interests to *modernize and reform* nuclear power regulation. I'm not suggesting it should be de-regulated completely. I'm saying there's a mountain of regulation that serves no useful purpose, while at the same time, *better regulation* could do a lot to improve safety.

Government is *standing in the way* of making nuclear power safer, by failing to provide a regulatory framework for certification of molten salt, Thorium, and other advanced nuclear technologies. We need to reverse that situation, because it's the main thing preventing nuclear power from solving our fossil fuels addiction. And it's the main thing preventing advanced nuclear startups from getting the investment capital they need to save the world from the coming energy crisis and provide the baseload electric power needed for energy transition.

Now I'll lay out my prescriptions for how to solve the coming crisis, get the energy transition on track, and forge a path toward a whole new era of human prosperity enabled by cheap and abundant energy.

I'll describe what needs to be done in numbered steps, but just to be clear, these steps need to be undertaken immediately, simultaneously, and in parallel, not sequentially. The numbering is intended to denote priority, not order of execution.

Step #1 is critical to stabilizing the global economy, but it's one that many of you don't want to hear. We need to aggressively invest in new oil and gas exploration & production, to bring energy prices back down and build up some spare production capacity so that we can ***continue breathing***.

The cause of the coming energy crisis was trying to phase out fossil fuels *before* viable replacements were phased in to replace them. Ill-conceived ESG policies penalized institutional investors for investing in new oil & gas exploration and production desperately needed to replace declining production from aging oilfields already well past Hubbert's Peak.

The resulting supply-demand imbalance has already exhausted almost all of OPEC's spare production capacity. Meanwhile, both commercial and strategic inventory have already been drawn down to generational low levels globally.

We cannot possibly solve the *real problem* of bringing new clean energy sources online if we're ***not breathing***. Without investment in new oil & gas production, the global economy will suffocate due to energy starvation. Resource wars and a global depression could result. Millions of people could die of starvation. Without energy from fossil fuels, we can't run the modern farming equipment needed to feed ourselves. The situation really is *that* serious.

We can arrest the dramatic energy price increases that will come in the mid-2020s by reinvesting in new oil production, but over the long run, prices will continue to trend higher no matter what, thanks to moving higher up the apple tree as we consume a finite natural resource.

An abject disaster would ensue if we allowed ourselves to reach the top of the apple tree, meaning the point of being unable to produce enough oil & gas to run our society before we phase in viable long-term replacements for oil & gas. And that's exactly where we're headed if we don't change our ways and change them now.

Step #2 is to learn to conserve energy and prepare for a rough ride. What's coming isn't going to be pleasant.

We've always been wasteful of energy. At the dawn of the age of oil, when finding the next gusher required little more than drilling an oil well in the right part of Texas, we became spoiled by the illusion that energy was so plentiful that conserving it wasn't necessary.

Human *prosperity* is at its highest when energy is abundant and cheap. But human *nature* is prone to complacency, and the illusion that energy would stay cheap forever led society to form all sorts of wasteful habits.

The oil & gas supply crisis was man-made and can easily be reversed by reversing the policy mistakes which caused it. But there's a lag time of several years from initial investment in exploration and production until new oil supply comes online. That means this problem, which took several years of failed policy to develop, is going to take several years to cure, even just temporarily.

When we eventually complete the job we should have started 30+ years ago and roll out sufficient new clean energy sources to enable the phase-out of fossil fuels, it will mark the dawn of a whole new era of human prosperity and societal advancement. But until then, we're going to be in for a bumpy ride, and the sooner we learn to conserve energy and use it more efficiently, the better.

Step #3 is to aggressively and systematically roll out as much nuclear electric power generation capacity as we possibly can. The only way this can happen is with a top-down decree from the highest levels of government. The top priority for all developed nations on earth should be to aggressively invest in building nuclear powerplants. That's not a departure from the current global governmental degree to solve climate change by going net-zero by 2050. Rather, it's the very best way to *achieve* those net zero policy goals.

The current status quo is that government sets the rules, and the rules are that conventional light water reactors fueled by low-enriched uranium are the only thing regulators know how to regulate. We must reverse this in favor of government policy that actively promotes rapid adoption of the latest and safest technologies, starting with molten-salt cooled Thorium-fueled breeder reactors.

The question of whether to build more conventional large-scale pressurized light water nuclear power stations like the Vogtle powerplant in Georgia versus the much more compelling but less commercially mature technologies such as molten salt, breeder reactors, and Thorium fuel is a real mind-bender. On one hand, the benefits of advanced reactor designs over pressurized light water reactors are so compelling that it's tempting to say we should just invest heavily in fast-tracking their approval.

On the other hand, the nuclear power industry has been stunted for decades, and unfortunately, all the industry knows how to do right now is to build more large-scale nuclear power stations based on already approved Generation III+ pressurized light water reactor designs like the Westinghouse AP1000.

At first, that trade off seems daunting. The safety, weapons proliferation, and nuclear waste advantages of the advanced nuclear reactor designs are so compelling that it seems crazy not to choose that path forward. Yet time is very much of the essence, and we cannot afford to wait to act while a whole new generation of advanced nuclear technologies go through the process of proving to regulators that they are safe and worthy of being permitted to deploy in commercial operation. How can we possibly resolve this conundrum of which path to follow?

The answer is simple: We need to do both, in parallel, starting immediately. If the promise of the newer designs is realized, and particularly, if we can succeed at tooling up assembly lines to produce small modular breeder reactors at a pace of one unit per day as Copenhagen Atomics has proposed, then it's plausible that we'll have solved this problem with a new fleet of small modular reactors before the new fleet of large-scale power plants reaches completion. If that happens, it's cause for celebration, not disappointment.

But if it takes longer than hoped to scale up assembly line production of small nuclear reactors while still maintaining strict nuclear quality standards, we're really going to need those big new powerplants to hold us over. And it might eventually be possible to modernize those new Westinghouse AP1000-based power stations by later upgrading the reactor cores to molten salt Thorium breeder designs while still retaining the investment in the rest of the powerplant.

So Step #3A is to build as many new large-scale nuclear power stations as we can possibly build using conventional nuclear technology, and Step #3B, which should be undertaken simultaneously, is to fast-track certification and approval of small modular reactors based on advanced designs including molten salt cooling, liquid fuel, Thorium fuel, and breeder reactors in both the fast and thermal neutron spectra.

It makes perfect sense to allow the new fleet of SMRs to compete with the new fleet of large-scale conventional nuclear plants to see which can be first to provide sufficient electric generation capacity to truly phase out fossil fuels.

The key to all of this is government *leadership*. The Private Sector is already more than ready to build advanced new reactor designs and make nuclear energy much safer than it ever was before, while at the same time, burning up the existing nuclear waste we thought we were going to have to store for 100,000 years, and replacing it with cleaner waste that only needs to be stored for 300 years.

The only reason this didn't happen in the 1970s was that governments are in charge of all things nuclear, and without their active leadership, the industry cannot advance. It's time for governments around the world to step up to the challenge and start being part of the solution rather than the heart of the problem. U.S. approval of Nuscale's SMR was a very welcome first step in that direction.

Step #4, which should occur in parallel with the prior steps, is to prioritize and fund more research and experimentation on deep supercritical geothermal energy. The logical path forward for the oil & gas industry is to commercialize deep supercritical geothermal energy and make it cost-competitive with nuclear and other power sources. The same team that pulled off the shale oil revolution needs to repeat that performance with a clean geothermal renewable energy revolution.

We subsidize wind and solar, so why not geothermal? Supercritical deep geothermal is even more compelling than nuclear power if we can break through the technological barriers which make it impossible today. It's time to invest more in breaking down those barriers so the geothermal industry can really flourish.

Step #5 is to continue aggressively building wind and solar energy capacity. No matter how much of these intermittent sources we build, it won't be enough. We still need 24/7 baseload power, and a combination of nuclear and geothermal are the best way to complement wind & solar to address that need.

Step #6 is to figure out a more efficient way to convert heat energy into electricity. No matter what energy source we choose, increasing thermal efficiency is just as important as increasing energy supply. More research and investment are needed in this important field.

Step #7 is more research and development of synthetic fuels. We need to figure out how to efficiently turn the heat energy we get from geothermal or nuclear into liquid fuels that can run vehicles. Hydrogen and Green Ammonia liquid fuel are a good start, but they each have serious drawbacks. More research is needed in this area.

The reason I began developing this docuseries in 2022 is the old adage 'never let a crisis go to waste'. My sincere hope is that public awareness of the true cause of the crisis provided by this docuseries, alongside the work of others like Kirk Sorensen, will help people recognize the need to hold our elected leaders to account.

All we need to cure the crisis and usher in a new era of human prosperity is a realistic, viable strategy to phase in sufficient clean energy to replace fossil fuels by 2050. So far all we've gotten is lip service and empty promises that wind and solar alone can solve everything, with no attention paid to critically important needs like building out new higher-capacity electric grids. It's time to get serious and focus on what this energy transition is really going to take, rather than just telling people what they want to hear.

Now I'm going to ask for your help. I already reached into my own pocket to fund the docuseries which you're watching right now, because I'm passionate about doing my part to help solve the coming global energy crisis. Don't worry, I'm not going to ask you for money. The time and money I spent putting this docuseries together was proudly donated in the interest of doing my part to help save our planet from the coming crisis, and I'm not interested in making money from this.

But I need your help getting the word out! Since I'm funding this out of my own pocket, there's no budget for advertising or promotion. The only way to promote this docuseries is word of mouth, and that means I need *your* mouth to encourage your friends and family to watch it. And then I need you to spread the word on social media, starting with hitting the like and subscribe buttons right now, which make a huge difference attracting more viewers. We need to make this free docuseries go viral to make a difference, and I can't do it without your help.

I'm not selling anything, and I have no profit motive. So please, do what you can to help get the word out by posting links to the first episode all over social media.

The millions of people around the globe who are passionate about climate change have their hearts in exactly the right place. But most people don't understand the realities of scale that are involved. They think that wind and solar alone can solve all our problems within just a few years time, because for well over two decades now, that's what politicians told them to believe. To truly solve this problem and save the human species, and to open the door to a whole new era of human prosperity, we really need to get the word out about how big the task at hand really is, and we need to get it out quickly.

So if you've enjoyed this docuseries, please do your part by spreading the word far and wide. All it will take to get the whole world on track to **solve** this problem is to start by getting people to ***understand*** this problem.

We ***can*** solve this crisis and we ***must*** solve this crisis. And you can help by getting the word out about this free docuseries.

For people who prefer reading over watching, this docuseries is also available in book form. Just put my name, Erik Townsend, in the search box at Amazon.com and you'll find it in your choice of kindle or paperback format.

My goal is to replace this low-budget YouTube docuseries with a broadcast quality version for release on Netflix or another major streaming service. I already have a mental plan for how to design it, replacing my voice which you've been listening to for five hours now with a celebrity narrator, and including on-camera interviews with pioneers in the geothermal and advanced nuclear energy industries who already have the vision needed to usher in a whole new era of human prosperity based on clean, abundant, and cheap energy.

So, if you work in Hollywood and know people who have the skill, experience, and industry contacts needed to transform the docuseries you've just watched into a broadcast quality version for the streaming services, please ask them to send me an email if they want to talk about collaborating to produce the Hollywood version. They'll find the landing page for this project and a treatment for the Hollywood version along with my contact details at www.macrovoices.com/energydoc.

Thanks for watching, and thanks in advance for your help spreading the word! I hope you've enjoyed this docuseries, and I hope it's helped you better understand what we're up against. I'm Erik Townsend.