Episode 7 – "Small Modular Nuclear Reactors"

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 small modular nuclear reactors fit into the story, here's Erik Townsend.

As we've seen in the last two episodes, there's a massive disconnect between nuclear energy perception and nuclear energy reality. The public's perception is that nuclear power is still unsafe, as evidenced by the Fukushima accident. Critics of nuclear power cite core meltdowns, hydrogen explosions, weapons proliferation risks, and nuclear waste disposal as their biggest objections.

In reality, nuclear power is already the safest form of baseload power generation in existence. The coal mining industry has killed 820 times more people than the nuclear power industry.

And all the problems of core meltdowns, hydrogen explosions and nuclear waste disposal were solved decades ago. But those solutions were never adopted and commercialized, thanks to government bureaucracy standing in the way of progress.

So the primary problems the public perceives about nuclear power have already been solved. But that's not to say nuclear energy is without very real problems! The much less often mentioned problem of cost and schedule overruns on nuclear powerplant construction projects is very real, and it would be foolish to assume we can build 50x more new large-scale nuclear plants between now and 2050 than have ever been built before, and get that done anywhere close to on-time and on-budget. That's just not realistic.

The solution is to manufacture nuclear reactors on assembly lines, in factories, with state-of-the-art quality control. This formative trend is known as Small Modular Reactors, or SMRs.

And there's even a ray of hope on the government bureaucracy front: In January 2023, U.S. regulators approved the first SMR design for operation in the United States, in a move that signaled U.S. regulators might finally be coming around and opening their minds to advanced nuclear technology adoption.

A modern automobile would cost at least a million dollars if you had one custom designed and built to your personalized specifications. Custom-building anything using one-at-a-time construction techniques is very expensive. But thanks to the efficiencies of scale inherent to assembly-line manufacturing, our automotive industry produces millions of vehicles at affordable prices.

We need to do the same thing for the nuclear reactor that Henry Ford did for the automobile. Or perhaps a better analogy would be to say that we need to adapt the world-class leadership that both North America and Europe have shown in aircraft manufacturing, and apply that talent to mass-producing civilian nuclear power reactors in factories, just as we mass-produce airliners in factories today, under the tightest safety standards.

The nuclear power industry's track record for getting large bespoke construction projects done on time and on budget couldn't be more abysmal. The 2018 bankruptcy of Westinghouse in the wake of cost and schedule overruns at the Vogtle project in Georgia proves this. So, in order for Nuclear to solve the coming energy crisis, we need to take a completely different approach. SMRs eliminate the need for bespoke on-site construction, and could offer the nuclear power industry the same gift of economy of scale that the automobile industry received from Henry Ford's invention of the assembly line.

Another advantage of SMRs is that they can be designed so that the SMR itself contains all the nuclear waste, meaning that when the building the SMR occupies is demolished someday, the rubble won't need to be treated as low-level nuclear waste. This difference alone will dramatically reduce the cost of nuclear plant decommissioning, and therefore, reduce the cost of nuclear-generated electricity. It also has the side benefit of centralizing nuclear reactor recycling at the reactor manufacturer's facilities.

Small modular nuclear reactors built on assembly lines in factories are not a new trend for the 2030s. This is a 70-year old trend with a proven track record. You see, the original small modular nuclear reactor was the propulsion system for the Nautilus nuclear submarine which entered service in 1955. Today the United States' nuclear navy includes both nuclear powered submarines and aircraft carriers, and several other countries' navies have nuclear powered ships as well. That means we already have a well developed small modular nuclear reactor industry. You just never hear about it because all the deals to supply modular reactors to the navy for use in submarines are classified top secret. But we've been building and servicing small modular reactors for the nuclear Navy for decades now, and without a single serious safety mishap in the U.S. fleet.

All of these military ships' nuclear powerplants are examples of small modular nuclear reactors which have been manufactured in factories on assembly lines for decades. All we need to do is modernize the nuclear technology and scale it up to produce SMRs for the civilian power market, like a new product line in addition to the SMRs that have been powering military submarines for decades.

The opportunity that lies before us is to fast-track the launch of an entirely new industry that manufactures all the small modular nuclear reactors we need to solve the coming crisis,

thereby paving a path toward much greater human prosperity. That means building nuclear reactors on assembly lines, in factories.

But just building more once-through pressurized water reactors that way isn't enough! We should also embrace advanced nuclear technologies including molten salt coolants, liquid fueled, waste burning, Thorium fueled, and other technology advances. The SMR industry is brand new, so it should embrace the best of both conventional and advanced nuclear technology.

I contend that this now-formative industry, which will eventually mass-produce hundreds of thousands of small modular nuclear reactors using the latest advanced nuclear technology, is quite literally THE single most important industry of the 21st century. It's the industry that will rescue us from the coming global energy crisis, and enable a new era of human prosperity built on clean, abundant green energy from Thorium and recycling all 250k tons of nuclear waste already in storage. So controlling that industry and making sure we're first to benefit from the new line of safe clean modular reactors fueled by Thorium and spent nuclear fuel waste is of utmost importance to U.S. National Security.

But the fact is that China is currently in the lead. By a lot. And to be clear, I'm not just trying to scare you with fear-mongering about how we might all wind up having to buy our nuclear reactors from China someday, potentially rebalancing global trade so that China replaces the United States as the global economic super-power.

I want to be clear in saying I'm concerned about something much worse than that! I'm concerned that we're already in a new space race where what's at stake is that whichever nation develops a small modular nuclear reactor industry and gets it up and running to the point of building dozens of SMRs every day—whoever does that first will solve the late 2020s global energy crisis for anyone they choose to share their tech with. And that will also guarantee their ability to assert economic dominance over anyone they choose not to share that tech with.

So we shouldn't fear the scenario where we're forced to buy our nuclear reactors from China. We should instead fear the scenario where the Chinese dominate the world's SMR manufacturing capacity, but are unwilling to sell their reactors to us at any price, because they reserve their entire manufacturing capacity for themselves and their strategic partners such as Russia, India and Iran, who might even enjoy access to Chinese SMRs at subsidized discount prices. That's the scenario I want you to worry about.

I'm using strong language because that's how big of a deal I think this is. Whoever gets their SMR industry up and running first, building dozens of SMRs per day with state-of-the-art quality

control—whoever achieves that first, they win the most important technological battle of World War Three.

Because whoever gets the lowest cost energy enjoys the most economic benefit, and therefore has the most money left over to build up their military. So if you're China and you wake up one morning and realize that your own Thorium-fueled SMR industry is light-years ahead of the West, you don't just use that to your economic advantage. You use it to your strategic advantage. China has been curiously silent about its plans in the Thorium energy space ever since regulators approved startup of their Thorium-fueled molten salt reactor back in August of 2022. Please ask yourself why they've gone silent.

SMRs enable a new system of weapons proliferation risk management. With SMRs it's no longer necessary to decide whether to "allow" a nation to develop its own uranium enrichment facilities in order to have a civilian nuclear power program. Instead, we could establish an international system in which virtually any country can buy or lease an SMR and then have it fueled and operated under a system of oversight that ensures the licensed international fuel supplier maintains a chain of custody over its fuel right up to loading it into the reactor, and then continues that chain of custody for nuclear waste, from leaving the reactor all the way to the recycling facility. This would assure that the operator cannot re-purpose fuel intended for the SMR or retain nuclear waste from the SMR for potentially nefarious uses. The SMR itself can be designed to stay in constant data communications with its manufacturer, and to report any unscheduled de-fueling events or other attempts to access the reactor's critical systems in real time, as they happen.

It's impossible to build an SMR that's completely tamper-proof, but it's well within reach of current technology to design one that is both tamper-resistant and tamper-evident, with real-time network monitoring. That means the reactors' automation systems maintain continuous data communications with their manufacturer. If someone breaks open an SMR hoping to re-purpose the parts it contains for Plutonium Production, the SMR's manufacturer will know instantly that their product is being tampered with, allowing them to notify international nuclear enforcement officials the instant trouble begins. Equipping all SMRs with GPS location trackers that allow authorities to monitor their whereabouts offers further opportunity to automate monitoring of the location, condition, and security of every single SMR operating globally.

The possibilities I've just described combined with the inherent benefits of Thorium fuel relative to weapons proliferation come together to form a vision for weapons proliferation risk management that delivers much lower overall risk to society than the system we have in place today.

There are now more than 50 advanced nuclear startups around the world. Some are building molten salt reactor prototypes while others are drawing plans for revolutionary new advanced reactor designs in CAD systems. About a dozen are planning to use Thorium rather than Uranium fuel.

For the most part, the SMR companies reaching beyond pressurized water coolants are all the pet projects of billionaires, because nobody else is crazy enough to invest in building machines that cannot legally be turned on anywhere in the world. These entrepreneurs see what's coming, and they're betting the farm that having a solution to the coming energy crisis designed and engineered before the crisis even arrives is quite literally the business play of the century. But institutional capital won't touch these companies because their product is something that no regulator on earth is prepared to regulate.

But advanced nuclear technology pioneers aren't the only ones starting up SMR companies. The opposing approach to SMR design is to keep it simple, focusing on designing reactors that can be built on assembly lines, without trying to introduce ANY advanced new technology. This "don't rock the boat" category of SMRs uses pressurized water reactors and once-thru low-enriched uranium fuel cycles that waste 95% of the natural uranium and create more nuclear waste. The business strategy of this second category of SMR start-up is not to embrace all the latest technology for the sake of making the best possible SMR. Instead, they focus on whatever they think is most likely to be approved by regulators, and avoid rocking the boat by straying away from the pressurized water designs regulators are already experienced with. Their goal to get to market sooner by avoiding new bleeding-edge technology that has yet to be approved by regulators.

Let's examine two companies at opposite ends of this spectrum. In the interest of full disclosure, I'm a stockholder in both of the two companies I'm about to describe.

The first is Nuscale, which recently went public after obtaining ticker symbol SMR on the New York Stock Exchange. Nuscale is the only pure-play SMR investment available to the public at the time of this recording, and Nuscale was first to go public because they took the "don't rock the boat" approach to certification, knowing that keeping it simple would help them be first-to-market. Nuscale has already earned the prize of first private company to win regulatory approval for an SMR design from U.S. nuclear regulators, making it likely that Nuscale will be first to operate an SMR in the United States.

So far as I can tell, the most forward-looking, innovative thing Nuscale has done as a company was to obtain the ticker symbol SMR on the New York Stock Exchange! Their reactors are not particularly small, so non-trivial assembly is still required on-site. Their reactors are not particularly modular either, and the reactor design is conventional pressurized water, meaning

that 95% of the low-enriched uranium fuel still gets wasted and goes to creating even more nuclear waste.

But these are not criticisms! Nuscale is doing exactly what it should be doing: they're focusing on being first to market with a small modular version of the same kind of nuclear reactor that regulators already know how to regulate. Even if their first model isn't all that small or modular, it's still likely to be the first product in what will eventually become the most important new trend in the history of the entire energy industry. So what Nuscale should be focusing on is being first to market with any SMR design regulators will permit, and Nuscale is doing a terrific job of keeping it simple. Their January 2023 approval from U.S. nuclear regulators was a huge win, not just for the company, but for this formative and critically important new industry as well.

At the opposite end of the spectrum is Copenhagen Atomics, a company that seeks to embrace all the very best advanced nuclear technology at once in a single product. The good news is, this means their product will be one of the safest, most advanced nuclear reactors ever conceived. But the downside is that Copenhagen Atomics will face more headwinds from regulators than their competitors with lesser ambitions.

The Copenhagen Atomics WasteBurner is an SMR that fits in the form factor of a standard 40-foot shipping container, allowing wasteburners to easily and efficiently be delivered anywhere on earth. It's fueled by a combination of Thorium and recycled spent fuel waste from the nuclear reactors of yesteryear. The small amount of waste produced by the Thorium-fueled waste-burner only needs to be stored for 300 years, compared to 100,000 years for waste from Uranium-fueled reactors.

The WasteBurner uses a thermal-spectrum Thorium breeder design, which is a fancy technical way of saying that because it's a relatively simple design, it can't realistically be re-purposed by bad guys to make weapons grade plutonium.

The Waste Burner is Molten Salt Cooled and liquid fueled by Thorium, so it fully embraces all the major safety advances pioneered at the Oak Ridge National Laboratories.

Building a gigawatt powerplant is as simple as delivering a bunch of waste burners and hooking them up to a steam turbine to make electricity. And the best part is that the building doesn't need to be made of nuclear concrete, nor does the rubble from its eventual demolition need to be treated as nuclear waste. This markedly lowers the total cost of electricity produced and also dramatically reduces the time horizon from new powerplant approval to completion of construction..

This vision of multi-gigawatt powerplants comprising numerous SMRs that collectively produce as much or more electricity than today's biggest conventional nuclear powerplants should be

our future. The SMRs will evolve over time, and when individual reactors in this scenario reach end of service life, the replacement units will likely be of a newer generation with even greater benefits.

The benefits of modularity are profound. A huge cost savings is achieved just by eliminating the need for the building containing the SMRs to be built and later demolished according to nuclear construction standards. Another major benefit is time to market. A gigawatt powerplant can be built in a small fraction of the time normally required for old-school nuclear, because all that's needed is a building to house several SMRs and a steam turbine to make electricity from the heat energy supplied by those SMRs.

Copenhagen Atomics Waste Burners are designed to produce heat rather than electricity. To produce electricity, Wasteburners can easily be connected to steam turbines made by Siemens and other companies. But they can also be used to directly supply heat energy to advanced new processes for seawater desalination and the production of ammonia liquid fuel. These applications of SMR technology could be as important to humanity as the more obvious electric power generation applications. So the approach of supporting both electricity generation and other applications such as desalination and ammonia liquid fuel production is an important feature that should become the industry standard for most SMRs.

Copenhagen Atomics' WasteBurner has a design service life of 15 years continuous duty, meaning the reactor is designed run continuously for up to 15 years without being shut down. But the company intends to introduce its first WasteBurners de-rated to 5 years' service life, for the sake of conservatively gaining experience operating a fleet of Waste Burners.

The Waste Burner is fully automated. It's designed not to require any human operator whatsoever. The entire fleet of WasteBurners is securely managed remotely by the company, and each wasteburner is designed with full automation to handle any emergency, even if data communications with the company are lost due to network outages.

Copenhagen Atomics doesn't intend to sell a single wasteburner reactor. The company intends to sell energy as a service, rather than selling nuclear reactors to its customers. The entire fleet of wasteburners will be owned and operated by Copenhagen Atomics, so that the company can strictly control the maintenance and care of the fleet.

Recall the true causes of the Fukushima disaster which I described in episode 5 if you want to better understand why Copenhagen Atomics' management might prefer not to entrust others to operate its wasteburners properly and responsibly, instead reserving those functions under its own direct management and control.

So in every respect, Copenhagen Atomics is at the head of the pack in terms of technology innovation and adoption of the most advanced nuclear technologies. But that also means the company will face the highest regulatory hurdles, and therefore can't possibly hope to beat its less ambitious competitors to market.

Between these two extremes of Nuscale and Copenhagen Atomics are more than 50 more start-ups proposing SMR designs at various degrees of technological sophistication. For example, some Molten Salt cooled SMR startups are intentionally avoiding Thorium fuel in their first-generation products because they know that a new fuel will take much longer for regulators to approve. So their first-generation products will be Uranium fueled molten salt reactors--they're saving Thorium for the next chapter of their company's development. These companies are springing up all over the world and a few are finally even starting to get VC funding. We're witnessing the birth of the most important industry of the 21st century, live as it happens, right now in 2023!

Copenhagen Atomics' vision for their Waste Burner SMR is to produce at least one unit per day on multiple assembly lines around the world. That sounds like a very lofty goal, but on closer analysis, it's woefully insufficient! For context on the scale of the problem we're trying to solve, it would take about 50,000 Copenhagen Atomics WasteBurners to completely replace all the electricity we get from coal today, which is by far the biggest greenhouse gas polluter. So even if Copenhagen Atomics achieves its goal of making one Wasteburner per day, this one company alone still won't be nearly enough. We need the SMR industry overall to make at least 14 Generation IV SMRs per day, 7 days a week, 365 days a year, for 10 years straight, just to make enough electricity to replace what we get from coal today. And we'll need twice that many by 2050 to completely eliminate our dependence on fossil fuels.

That's a LOT of quality-critical manufacturing that needs to happen in the next 25 years, and I predict that whichever nation is first to tool up for high-volume manufacturing of SMRs embracing advanced nuclear technology will gain tremendous military and geopolitical advantage from having that industry under its control.

Right now, China has the lead on Thorium-fueled molten salt reactors, and it doesn't take a rocket scientist to figure out that they could easily leverage their early progress on Thorium to upstage the West with a big initiative to build Thorium-fueled SMRs at scale.

China has the opportunity to seize immense geopolitical advantage if they can dominate and control the SMR business by beating everyone else to market, and I fear that's the most likely outcome.

Remember, it's not just a risk of The West having to buy our reactors from China. The bigger risk is China not being willing to sell its reactors at any price to anyone other than its strategic

partners, leaving the West cut out of an important new energy market that could transfer the balance of world power from West to East, such that China replaces the United States as the global economic and military superpower.

The fact is that the only proven way to take down a nuclear superpower is to defeat that nation economically. The collapse of the Soviet Union proved that. Right now, China is completely dependent on imported energy, and literally cannot survive without its oil-exporting trade partners. China would derive immense military advantages if they could somehow achieve energy independence. Just the economic advantage of lower energy cost guaranteeing its manufacturing sector the ability to undercut the West on cost would be a major win for China. But more importantly, if China were to gain monopolistic control over the global SMR market, that by itself could easily tip the balance of global power to China, effectively taking the prize of global top-dog both economically and militarily--which the United States has held since the end of World War II, and re-awarding that prize to China, because China's leadership on nuclear energy is about to upstage American hegeomony, just as the U.S. took that title from the British Empire a century earlier.

Which nation or nations control the global SMR industry is going to make a very real difference in the course of world history, so we need to pay very close attention to China and other nations' efforts in this industry.

Meanwhile, back here in the West, the challenge is not innovation but rather, capital investment. Most SMR companies working with advanced nuclear technologies are the pet projects of billionaires, who are choosing to make what they know to be a dubious financial investment in a company building a machine that cannot legally be operated in any country on earth, without regulatory approval that there isn't even any precedent for obtaining!

If we're really going to achieve energy transition by 2050, the now-formative SMR industry needs to become the next big thing Wall Street is obsessed with investing in, like .com stocks in the late '90s. The nascent but vitally important SMR industry is not yet flourishing because investors have yet to figure out that SMRs will ultimately play a far more important role in energy transition than wind and solar combined.

Eventually the market will figure out that SMRs will be even hotter than AI stocks were in late 2022, the capital floodgates will open, and too much money will be chasing not enough good SMR companies. But for now, there is virtually no institutional capital available to most SMR start-ups.

The ESG crowd still thinks nuclear is bad, and few portfolio managers dare risk upsetting a high-profile investor who has an irrational anti-nuclear obsession. So ironically, the reason we're not investing in molten salt reactors, the technology which completely solves meltdown risk, is

specifically because so many people are obsessed with meltdown risk being a horribly bad thing that investors want nothing to do with companies building anything related to nuclear in any way, INCLUDING something that's already PROVEN to completely solve meltdowns? And so completely solving meltdowns is off limits to invest in, because nuclear is bad, because of meltdowns? The logic doesn't add up but human emotion is what it is.

So progress in this critically important field is, by definition, put on hold until that capital starts to flow more freely. That means solving energy transition is on hold until we figure this out. That's a real problem, because getting a new SMR through regulatory approval to the point of being approved to run a commercial-scale reactor with a real nuclear fission chain reaction--that costs at least 250 million bucks just to get through the regulatory approval process.

So all these little companies building prototypes are still just in their infancy, proving their concepts in hopes that investment capital will someday be available to take these new designs through the painfully expensive regulatory approval process. Only then can they begin to build the assembly lines, which will eventually build all the SMRs we need to solve the coming crisis.

A whole lot more investment capital is needed to get from here to there. And most institutional investors can't touch anything with nuclear in its name due to "perception management" challenges investing in nuclear would create for their investor relations department.

Until such time as institutional capital is available for these little companies to spend a quarter-billion each on turning their visions for our energy future into approved product lines, we can't even start to tool up to build SMR assembly lines at scale.

The cost of regulatory compliance alone is staggering, so energy transition won't come without significant investment. Right now there's institutional interest at the Nuscale end of the spectrum. But at the Copenhagen Atomics end of the spectrum where the most strategically important technology advances will eventually be made, there's no sign yet of institutional capital getting interested in molten salt, Thorium fuel, wasteburning, or any of the other leading edge technologies. There can be no meaningful progress on the state of the art in this field until funding is available to the companies defining the state of the art.

Getting the advanced nuclear SMR industry up and running is arguably the single most important thing we can do in support of energy transition, and in the case of the United States, in support of national security as well. Wind and Solar alone will never be enough to fully solve the problem, even with batteries for energy storage. Deep Geothermal isn't quite ready for prime time yet. New-school Nuclear is by far our best hope, but old school nuclear, where it takes a full decade and several bankruptcies just to build a nuclear powerplant? That isn't going to solve all our problems by 2050.

The only viable path I can see for humanity to survive the coming energy crisis is to quickly spin up a Small Modular Nuclear Reactor industry that can produce at least 15 Generation IV SMRs per day globally, and for at least some of those SMRs to be waste-burning designs.

We should settle for nothing less than a credible plan to eliminate all 250k tons of high level nuclear waste now in storage, in less time than it took to accumulate it. 2060 would be a realistic target date by which we could eliminate every single ounce of high-level nuclear waste now in storage. That would be achieved by recycling all 250k tons of that waste, yielding 237k tons of recycled Uranium that can be used to fuel new reactors. The remaining 13k tons of trans-uranics and fission by-products will be consumed as fuel in Copenhagen Atomics Wasteburners or other manufacturer's waste-burning breeder reactors.

We don't need all the SMRs to employ waste-burning designs. We just need enough waste-burners to get rid of all 250k metric tons of waste now in storage, and to dispose of new waste created by the growing global fleet of SMRs, many of which will be Uranium fueled and prone to wasting 95% of the low enriched uranium fuel they consume. The rest of the SMRs don't need to be waste-burners, and could either be Thorium breeders or thermal spectrum uranium reactors. There's room in the SMR market for lots of designs with different features to meet different needs of different users.

Unfortunately, pressurized water will be the core coolant used by the first wave of SMRs, but hopefully the pioneering companies already working on molten salt SMRs will soon establish molten salt cooling as the gold standard everyone expects from any credible SMR. The industry should eventually dispense with pressurized reactor core coolants entirely, but it's far too early to expect that to happen any time soon.

The successful launch of the SMR industry I describe will deliver to society an army of fully automated SMRs that will provide all the energy we need to solve the coming global energy crisis and achieve energy transition goals by 2050. Competition in this important market will assure that electricity prices are as low as possible, allowing society to thrive as lower cost of energy accelerates the pace of human advancement.

But SMRs alone won't solve energy transition. We need a comprehensive, integrated plan that embraces the terrific progress that's already been made on Wind and Solar, puts more emphasis on Deep Geothermal research and development, and which embraces both old- and new-school nuclear as the primary baseload power solution. And I'll lay out that comprehensive plan in the next and final episode of Energy Transition Crisis.