Episode 1

Let’s Get Nuke-Pilled

Albert Wenger

I think people vastly underestimate how much cheap energy does for us. It's kind of strange that we underestimate it, because it was such a huge unlock when we discovered fossil fuels. There's an early unlock in human history that's also related to energy and people completely underestimate, which is when we figured out that we can cook meat over fire. When you eat meat that's cooked, you get a lot more calories out of it.

This was the first huge human energy unlock. Your body needs to spend energy digesting a rare or raw piece of meat, and so you only get the net calorie gain. But when it's cooked, you get a huge net calorie gain. So our invention of fire is part of what made human civilization possible.

We have this history of making vast civilizational leaps that are based on energy, and then we get ourselves into this low energy trap, we're like idiots walking around going 'we have seem to have a lot of problems...' No, what we need is a huge energy unlock, and that will make a lot of these other problems maybe not go away, but it'll make them solvable.

Packy

Hello, and welcome to our first ever episode of Age of Miracles. I'm Packy McCormick, a venture investor and writer of the Not Boring newsletter, where each week I dive deep on the companies and technologies driving humanity forward. Not Boring's mission is to make the world more optimistic, and I believe a big part of that is making new technologies and the companies behind them more understandable. I love writing essays on complex topics. I've done it practically every week for nearly four years. Some topics, though, are too complex and nuanced for me to capture in a single newsletter. They require insights from experts, investors, and founders who spend every day focused on how to build new products and maximize their impact. That's what Age of Miracles is all about. Each season, we'll explore an industry that's going to play an important role in creating an abundant future for humanity.

The title Age of Miracles is a little tongue in cheek. We can live in an age of miracles, but it's going to take an enormous amount of work. For our first season, we're starting at the root of progress and prosperity: energy. We're going to be focusing on nuclear fission and fusion energy. That clip you just heard was from Albert Wenger, a legendary investor at Union Square Ventures and the author of The World After Capital. Albert articulates something I've noticed more and more and more over the past couple of years: a realization that to unlock the next stage of human progress, we're going to need a lot more energy. It's easy to underestimate the role of energy in our lives today. Especially if you, like me, live in a country in which energy flows freely.

For decades, when regular people like you and me talk about energy, its been to complain about higher prices at the pump or to demand that we use less of it in order to stop climate change. The war in Ukraine has begun to change the narrative. As the narrative has changed, the public's attitude towards energy has begun to change with it. Yes, we need to emit less carbon into the atmosphere, and we need to pull gigatons of it out of the atmosphere. But that doesn't need to come at the expense of energy usage or human progress. Quite the opposite. We have the technology to consume much, much more energy while also fighting climate change.

When technology goes right, we can have it all. I personally want a future of energy abundance, and I want that future to come as soon as possible.

More energy raises the floor and the ceiling. It can help pull billions of people up to a western standard of living, and power all of the futuristic technologies entrepreneurs can dream up: the GPUs that power AI, electric cars, supersonic jets, robots, water desalination, 3D printing, even transportation among the stars. You name it, more energy helps. We're going to bust some nuclear specific myths today. But the first myth that we need to bust is that humans need to consume less energy. That belief, which has held sway over the past 50 years, has caused countless deaths and untold human suffering. Its held humanity back from reaching our potential. It should make you angry. More energy means more human flourishing. Nothing else translates quite so directly.

So how do we make more energy without fucking the planet? Renewables like solar and wind, paired with batteries, are a big part of that solution. The growth and cost declines in solar and batteries in particular are a modern miracle. If they continue on their current trajectory, their supporters believe that they can totally replace the need for fossil fuels by 2050. Thats very aggressive, but I love the optimism. But if we want to access 10 or 100x more energy, we're going to need to produce a lot of it by splitting atoms apart and fusing them together. We're going to need to go nuclear. Thats what we're going to dive into in this season of Age of Miracles. We're going to go very deep on both the incredible opportunities and dizzying challenges to harnessing atoms for energy.

We're going to talk to world class experts in science, policy, investing, founders, and the government. You'll hear from them each episode. "Packy", you might be saying, "you're not a nuclear expert." While I did start my career interning on an energy trading desk, you'd be right. So each season I'm going to be joined by a cohost who actually knows what they're talking about. And I've got an incredible cohost this season, Julia DeWahl. Julia wrote an essay called "Nuclear energy: past, present, and future" that was my go-to guide as I began to explore nuclear energy over the past year. She has experience building really hard things. She was an early employee at Opendoor, ran business operations for Starlink at SpaceX, and has joined the founding team of the microreactor company Antares. Welcome, Julia.

Julia

Thanks, Packy. I'm super excited to be doing this with you. There is so much to learn and unpack with nuclear energy. This is going to be a blast.

I can't wait for our listeners to hear from all the experts, entrepreneurs, and investors that we have coming on the show. We've talked to a whole bunch of people and packaged it right up for the season.

Packy

Me too. I'm always happiest when I'm the dumbest person in a conversation, and I think we've achieved that in every single episode and interview. So I'm pumped for that.

Before we dig into this episode and talk about how we each got into nuclear, do a little myth busting, and list some common objections, we wanted to give you a little preview of what to expect from this season of Age of Miracles.

Josh Wolfe

And now it costs about $10 billion for a gigawatt power plant. It's just insane.

Isaiah Taylor

Elon Musk has something called the idiot factor with nuclear construction. It's as bad as 99-1 in a lot of cases.

Bret Kugelmass

With the Vogtle plant, a regulator came up and put a little flag on that, and made them tear up a billion dollars of concrete when they poured it just 1/8 of an inch off.

Angelica Oung

Do we have enough resources, the technology, the desire, or the need for nuclear? Absolutely. We tick all those boxes in the US and we can get it done. We really want to.

Julie Kozeracki

We are in a very special moment right now that won't last forever. We cannot wait, so I hope that folks don't let the moment pass.

Packy

There are two big themes in our first season about nuclear energy. One, what really went wrong with nuclear fission and what can be done to unstick the stagnation? Can nuclear ride the same kind of learning curves that solar has?

And two, when will we get to commercial fusion energy? If we do, will it obsolete the need for any of the other energy sources we discuss, including fission? Of course, these are age old questions in technology. Will the new technology disrupt the old? How do we get from innovation to impact at scale?

But the complexities, nuances, and surprises in nuclear are unlike anything I've ever encountered. I pride myself on being able to explain complex, nuanced topics in easy to understand ways. Julia has literally helped launch satellites to get us fast global Internet. We're used to these kind of complex, hard problems, and this one is a brain bender.

Julia

It really is. On this season of Age of Miracles, we are going to unabashedly nuke pill all of you. Fundamentally, we believe that we don't get to energy superabundance and better futures without popular support for more clean energy. We need nuclear in the mix. That's not to say we're zealots here. There's a lot to like about different energy sources too, for different reasons. Nuclear is going to have to get a lot cheaper to compete in the market.

But we think that the historical fear of nuclear is misguided, that more energy powering more growth is a good thing, and that a nuclear powered future is possible. We'll have been successful if you leave this season believing that more nuclear power is a good thing, that we'll need to figure out how to produce it economically, and that you're deeply aware of the roadblocks that need to be overcome to do so.

As technologists and builders ourselves, we know that an idea or a vision or a scientific discovery is worth next to nothing without all the hard work on the ground by the founders, scientists, engineers, investors, activists, and even the regulators and people from government. The bigger the impact to humanity — and clean, abundant energy is one of the biggest things we can do as a species — the bigger the collective effort for many people, and the more clear eyed we have to be about challenges and creative solutions.

We're going to spend the season diving into all of this. On this episode, we're just at step one of our journey here to nuke pill you and to help us all move forward towards the future of energy superabundance. Let's talk nuclear fission.

Packy

This summer, on August 11, the Illinois chapter of the environmental group Sierra Club tweeted a celebratory tweet along with a smiling picture of Illinois Governor JB Pritzker. It said "BREAKING: Today, Governor Pritzker vetoed SB76 — a bill that would have lifted Illinois's moratorium on new nuclear plants. Thank you, Governor Pritzker!" Five years, or maybe even a year ago, the tweet would have been largely ignored. It might've been celebrated by environmentalists and the passively climate supportive, booed by the hardcore niche of nuclear advocates, but mostly ignored. In the year of our lord 2023, the Sierra Club got ratioed: 113 likes to 424 quote tweets and a bunch of replies. I'll read you a sampling.

Paul E. Williams, the executive director of the Center for Public Enterprise, tweeted "Good news for coal and natural gas burning thanks to Sierra Club Illinois." Value Drict, an anon account, tweeted "Environmentalists must be stopped, for the good of the environment." Armand Domalewski tweeted "You people are climate arsonists. An absolute disgrace." Even Jason Calacanis, the host of the All In Podcast, got in on the action, tweeting "Really, Governor Pritzker, what's your thinking here? Because we need to be energy independent in the US — and the planet is basically on fire." I looked through the hundreds of replies and quote tweets so that you don't have to, but we will put a link in the show notes in case you want to because it's kind of fun.

Mark Nelson, a nuclear advocate, summed it all up. He said, "These frauds are hopefully not going to be with us much longer." Twitter is not a perfect microcosm of reality, but the response to Sierra Club's tweet reflects a huge shift in the United States' growing support for nuclear energy. According to the latest Pew poll, in April 2023, 57% of American adults say that they favor more nuclear power plants to generate electricity in the country, up from 43% in 2020. Nuclear power has bipartisan support: 67% of republicans now want more of it, as do 50% of Democrats.

The dunks on Governor Pritzker were blind to party lines. The war in Ukraine certainly played a role in nuclear's growing popularity. It made energy security a real and present issue and forced people to take a look at the facts. When they did, they saw that nuclear fission is the cleanest, safest form of energy we have. All of a sudden, people want to consume more energy. Or rather, they want to do a lot of the new things that mean that they'll need to consume a lot more energy, not less.

In the course of a couple of years, conservation is out and energy superabundance is in. That's good. Energy is a positive sum game. The more we have, the better people do. Give us more solar, wind, geothermal, and nuclear.

Julia

Nuclear energy has gone from controversial to just about consensus in the last couple of years, at least within tech circles. As Eade Bengard recently tweeted, "Pro nuclear is an atrociously obvious stance. I don't want to have the 'is nuclear bad' convo. I want to have the 'how and where will cost incentives point to nuclear over other sources' convo."

That's exactly the conversation we're going to have in the first half of this season as we dive into nuclear fission. We're going to try to untangle the web of issues that make nuclear so expensive to build in the US today and spend a lot of time talking to the people on the front lines of who are trying to build nuclear more cheaply.

Should we build more of the same large scale design over and over again so we can do it more quickly, cheaply, and predictably? Or should we experiment with new reactor designs to take advantage of advances in our knowledge and technology?

Do we need to rally to change regulations, or is the regulatory burden issue just overblown? Should the government play a more active role in the development of nuclear capacity, or should we let the free market do its work? The answer is often "it depends", or "both". We'll present the best thinking we can find.

As with any of the best educational content, this show will work best when you engage with it, dig deeper, and come to your own conclusions. To help, we'll put together a resource guide that we'll update with each episode, which you can find at ageofmiracles.co.

Packy

Julia, you're kind of the archetype here. You're someone who's been interested and involved in technology broadly, and who's gotten up to speed on nuclear really quickly. The goal of today's episode is to condense into one episode everything that you've learned in the past couple of years diving into nuclear.

We'll address some of the most common myths and the 101 stuff that we just need to do to clear the decks, and then we'll set the stage for the 201 stuff, the stuff that I don't think anybody has the complete answer to, but that we'll spend the whole season talking to experts about.

To start, how'd you get nuke pilled?

Julia

It goes back about a year and a half. I was working at SpaceX at the time, and we were trying to get Starlink into Ukraine after the war broke out in February. It really got me thinking about energy in that region and the fact that Russia provides so much natural gas to much of Europe, and how it probably wasn't going to look all that pretty based on what was going to unfold there.

Simultaneously, I just happened to be reading Michael Shellenberger's book "Apocalypse Never", where he's debunking the whole doomer climate movement. He talks about how we actually do have all these great tools that we can use to fight climate change, with nuclear energy being one of them. We just need to go out there and figure out how to do those things. It just got me thinking a lot more about nuclear energy as a power source, and I realized I basically knew nothing about it. No one was talking about it either.

I had no idea, for example, that nuclear energy accounts for almost 20% of the electric grid. I thought at the time it was maybe 2%.

Packy

I had no idea either, because one of the narratives about nuclear is that we just don't build it anymore. I assumed that we don't even use it anymore before I started digging in.

So when I saw that 20% number, that shocked me.

Julia

And since then, I've actually gone out and polled friends, and just about everyone thinks it's less than 5% too. So it's clearly just this under appreciated, under celebrated source of energy. It's actually almost 50% of our carbon neutral, carbon free energy as well.

It just got me thinking, "We have this great technology, and we're under leveraging it. The narrative needs to change here. We need to celebrate this great technology that's clean. If we're serious about decarbonizing, energy security, and diversity of energy sources, we need to figure out how to do more with nuclear."

Packy

Thanks for listening so far. Hang on, we'll be right back after a quick word from our sponsors. It's fascinating. As we mentioned, Ukraine probably was a wake up call for a lot of people, me included. When electricity prices in Germany were spiking, I remember seeing those charts that were all over Twitter of electricity prices looking like Dogecoin, and they're shutting down nuclear and turning on more coal. That's when alarm bells started ringing.

When I did that energy trading internship, I worked for a group of ex Enron power traders. They were assholes, but as a trading intern, you couldn't really do much. You weren't allowed to actually trade. So one of the things I did was check the weather in key areas each day and run models on how long we expected different markets to have to move from cheaper base load power to more expensive peaker power. Electricity prices spike in periods of high demand when you move to the peakers, which are typically natural gas turbines. So if you had a good sense of when that was going to happen, you could trade it. All that came flooding back, and it made me realize how insane it was that Germany was intentionally shutting down cheap, clean, baseload power. So I started reading a lot more about nuclear and realizing that I hadn't thought nearly enough about energy more broadly and nuclear more specifically.

As I started digging in, I realized there are three myths about nuclear that I just accepted before researching them. So I thought it would be useful to address those up front. To be clear, nuclear is a crazy, complex topic, but the common objections are not real reasons that nuclear should be avoided. You shouldn't be scared of it. We want to get those out of the way now so we can go deep on the real challenges that we think will really matter. So, I'll bring up a common objection to nuclear, and you tell me what people get wrong. Sound good?

Julia

Let's do it.

Packy

All right. Myth #1: Nuclear is unsafe, and as a result, a lot of people have died from nuclear disasters.

Julia

This is a popular one, and let's just go through the three nuclear disasters people think of. First is Three Mile Island in Pennsylvania. In 1979, there was a core meltdown there. The amount of radiation that leaked out of the plant was tiny, about the amount of a chest x-ray that you'd get at the doctor. Negligible, but the government there and the facilities overreacted, and they actually evacuated the area. This media and government overreaction caused a complete misunderstanding of what was actually going on and how dangerous the situation actually was. It was almost a miseducation of the public on what actually happened and what the risks actually were. There was this hangover related to this in 1979 that people still reference to this day. It didn't help that twelve days prior, Jane Fonda's movie "The China Syndrome", which was about a nuclear plant melting down, had just come out and terrified the people on the topic right beforehand.

The second incident is Fukushima in 2011, and this one's completely overblown. It's debated whether zero or one people actually died from any sort of radiation at Fukushima. The bigger thing I think people miss here is the fact that 15,000 people died from the tsunami there. That is a ton of people. There was so much damage because of the huge tsunami that hit. The actual radiation piece of it is tiny relative to the rest of the tsunami.

Packy

When I think of Fukushima, I had always bucketed those 15,000 people who died as having died from radiation or from some sort of explosion at the plant. How did they actually die?

Julia

I mean, it's really related to all the flooding that happened from the actual tsunami hitting shore. And this happened all along the coast. The power plants obviously had just a tiny area of that. But what happened at the plant is the generators, which were the backup power support for the system, went down. This led to a core meltdown. The cooling systems couldn't stay online, and radiation leaked from some of these reactors. But there was a containment dome. You had first responders ready to react to the situation, suited up, equipped to handle it. Again, this is one of these things where the media and the reputation of what happened here is far larger and worse than what actually happened. And it was able to be contained and taken care of.

Then there's Chernobyl. I actually would call this one a true disaster. Dozens of people died there. But I think what's misunderstood here is that the scenario in Chernobyl is so unlikely to occur in the US. You had this shoddy soviet technology that was out of date, you didn't have any of the basics of safety there, and there was no containment dome, which is safety 101. You had a group of people who were operating the plant that decided to run a safety related experiment that they shouldn't have been authorized to do. That messed up and caused a meltdown to occur. Then the worst thing that happened is that people tried to cover this up. So you had all of these things compounding together into what did actually turn out to be a true disaster. A lot of radiation leaked out, but again, this is not something that I think we would ever see in the US given the regulatory and safety environment that we live in here.

Packy

I wanted to ask about that one first, because safety is actually the thing that got me. I always thought that there was this trade off between "we have this really great clean source of energy, but it's actually pretty dangerous and there's these meltdowns that happen occasionally, and they kill thousands of people." The thing that got me to take nuclear more seriously was this great Our World in Data chart where they show the most dangerous sources of electricity, starting with brown coal at the top, responsible for 33 deaths per terawatt-hour produced. Then you go all the way down the chart, past oil, gas, and all these other sources. Right down to the bottom, between wind and solar, is nuclear energy at 0.03 deaths per terawatt-hour produced versus 33 for brown coal.

So, three orders of magnitude less than brown coal. Solar, wind and nuclear are in a league of their own when it comes to safety. And yet in Germany, they're taking nuclear off the grid and putting coal back on. It's just absolutely nonsensical. So I'm glad that we addressed the safety one first. Okay, myth #2: we have no safe way to dispose of nuclear waste.

Julia

This is a big one, and you'll hear about this one a lot. I like to just flip this one entirely on its head.

Packy, what if someone said to you that "the nuclear industry is the only industry that manages their toxic waste?" Wouldn't you be impressed?

Packy

Yeah.

Julia

But that's not the way anyone sees it. Unfortunately, there are all these other industries that do pollute toxic waste. There are no stringent regulations the way there are in the nuclear industry, so really, no one is taking care of their waste the way that the nuclear industry does.

And the first thing I'll say about the nuclear waste itself is that it is tiny. It takes up a really small amount of space. All of the nuclear waste that's been produced in the US can fit inside a football field stacked 10 meters high, and we contain all of it. It is sitting there at nuclear power plants within concrete canisters, and it has never caused any injuries or death to anyone. So we're doing just fine. That's just the status quo, the way we do things today.

An even better solution would be to bury our waste deep underground, where uranium actually comes from. We've had plans to do this at a place in Nevada called Yucca Mountain. Unfortunately, this is one of these massive bureaucratic boondoggles, and it's just sitting there because of too much infighting about how to get this done, and it's completely caught up in red tape. We know that in other places, Finland, for example, has just finished building one of these geologic deposits, and it's a great alternative. Keep your waste underground, and it's going back to where it came from.

The last thing I'll say about nuclear waste is that people talk about "oh, it's going to exist and be dangerous for millennia." It's true that the alpha radiation will be around for millennia, but that's not harmful to people. The gamma radiation is what people are worried about in nuclear spent fuel, and that's actually only going to be around for about 500-600 years. And we have some great solutions to do that today with the cast setup we have or with those geologic deposits.

Packy

The thing that sticks in my mind is that image of Maddi Hilly, who's a nuclear advocate, pregnant and hugging one of these giants cement things filled with spent fuel saying to the world "Look, I'm putting myself and my baby at 'risk' here by doing this."

I think the images are so powerful on both sides of the nuclear debate. So I like to see her fight back a little bit with images of her own.

Julia

Totally. I think it was really cool she did that because nobody really knows what nuclear canisters look like and how we store waste. We've had the Simpsons that showed green goo spewing out of containers.

But in reality, it's all very neatly contained and safe on the premises of the reactor site.

Packy

I love the Simpsons, but I do wonder how much the Simpsons have contributed to anti nuclear sentiment, because when I think of nuclear now, I picture two things. One, that there are people like Homer Simpson operating nuclear plants. Two, that one Homer operating a plant could cause a huge meltdown.

Neither of which is true. So I don't know. I love the Simpsons, but I'm a little conflicted on that one.

Julia

I don't think it was worth it.

Packy

I don't know. All right, myth #3. Nuclear power facilitates nuclear proliferation.

Julia

Proliferation is something people worry about, and they should. There's mostly just been this association of nuclear energy with nuclear weapons, but they actually couldn't be more different. It's virtually impossible to create nuclear weapons from nuclear fuel. The processes that you go about to create each of them are just so different. Nuclear fuel has actually gone through many steps to go from its original raw uranium format to its fuel format. To build a bomb requires a completely different set of processes and equipment, and you need to have a lot of money and know-how to do this.

Step two is the fact that domestically and internationally, we have set up multiple organizations, for example the IAEA, that keep their eyes on everything related to uranium mining, enrichment, and all the processes that you would go about to even get close to creating nuclear weapons. We've done that international peacekeeping on this front. It's just one of those overblown topics. It's certainly something to take seriously, but I think we've shown that this topic is solved. We know how to handle it and we can handle it.

This is actually a fun fact here that I love to share with people because I was blown away when I heard about it. So let's flip this on its head once again, where you take nuclear weapons and the uranium and the plutonium in those, and you actually turn them into nuclear fuel. There was a program called Megatons to Megawatts that started in 1995, where we took Russian nuclear weapons, disassembled them, took out the enriched uranium, and created fuel. That powered almost 10% of our grid for almost 20 years in the US. It's almost like the counterpoint here. There's probably some opportunity to take these weapons and turn them into fuel instead of people constantly worrying about the other way around.

Packy

Yeah, that's absolutely incredible. Atoms for peace, USA. I love it. So to recap, myth #1, nuclear is unsafe, and as a result, a lot of people have died from nuclear disasters. That one's false. Either zero or one people died from radiation at Three Mile Island and Fukushima combined. And while Chernobyl was a real disaster, it was a result of bad soviet technology and procedures that we would never use today.

Myth #2, we have no safe way to dispose of nuclear waste. This one is also busted. The amount of nuclear waste is tiny. We know how to handle it. You can hug the concrete around nuclear waste and be totally fine. There are now even companies using waste as fuel.

Myth #3, nuclear power facilitates nuclear proliferation. One, this is less than a concern than people think because of the physics. But two, we've set up a watchdog and regulatory framework around the world that ensures that it's just not an issue.

Julia

Right. And I don't want to hand wave these issues away. A big reason that these three areas are now myths is because people put in the work to address them. We'll put links in our resource guides so y'all can learn more as we'll talk about in the next episode. One of the mistakes that early nuclear advocates made was over promising, and we want to give the issues the nuance and the depth that they require.

But I really think at this point, these three issues don't present cause for concern, and certainly aren't enough of a basis for serious people to oppose nuclear. We wanted to speedrun these 101 issues so that we can spend more time on the real challenges and opportunities for nuclear.

Packy

Ok, so what are those real challenges and opportunities? We've gone through the easy myths. Now lets dig into the realities. We'll talk about the potential of fusion in a few minutes, but lets go a little deeper on the biggest issues for the miracle technology we have at hand today: fission. This is a wildly complex topic, which is why we're devoting four episodes to fission alone. But based on our discussions with experts across the spectrum, there are three main themes to the challenges with building more nuclear fission.

First and probably thorniest is the cost and economics of nuclear plants. Nuclear is undeniably more expensive to build initially than any other energy source today. Can we bring those costs down? Where are those costs coming from? Are there efficiencies to be found in building a bunch of large reactors? What about new solutions like small modular reactors? We talked to a lot of people trying to bring costs down, and a few things came up consistently that we'll dig into. One is that large reactors, the gigawatt reactors that can power about a million homes each, need to be built more consistently. But there are all sorts of challenges that utilities, who are the buyers, face when deciding whether or not to build out a nuclear plant, from construction complexity to financing costs that make it an unappealing prospect. Nuclear has been called a utility killer.

Two, what needs to happen on the financing side for new nuclear to be built? For large reactors, should the government insure against cost overruns or provide more incentives for nuclear build outs that recognize its role as reliable baseload power? Should utilities team up and share the costs, risks and upside? For startups, is venture the best source of capital for such capital intensive projects?

And then number three, small modular reactors (SMRs) and advanced reactors show a ton of potential, but they face regulatory challenges like the fact that the Nuclear Regulatory Commission is more comfortable with designs that it's already approved. And uncertainty. For example, should SMRs have the same requirements as large reactors around security, including armed personnel on site? Can smaller reactors make a dent in our very large energy needs in time? Can advanced reactors get the necessary supply chains up and running? These are some of the questions around economics that we'll dig into more.

One big topic that we'll dig into is whether we should build more of the same large reactor design over and over again until we can do it quickly, cheaply, and predictably. Or should we experiment with new reactor designs that take advantage of advances in our knowledge and technology?

Julia

The second big challenge is on regulation more broadly. We thought this would be the overwhelming concern, but it's actually only one piece of the puzzle. These are the questions we'll tackle with our guests across both government and the private markets.

Do we need to rally to change regulations or is the regulatory burden overblown? Should the government play a more active role in the development of nuclear capacity? Or should we let free market capitalism work its magic?

And third, is it up to entrepreneurs to push hard and prove what nuclear can do in order to gin up the support needed to change regulation? Or should we have Congress and other people saying, "this regulation is not working for us today"?

Packy

And finally, the last big challenge we wrestled with in the first half of the season is that issue of popular support. Is it necessary? What would be the knock on effects that increase popular support for more nuclear? We have it now a little bit. It's diffuse. We talked about it earlier. The numbers are good, but there's not this burning passion and people actually getting up off the couch and going to fight for more nuclear that it might take to build more nuclear.

We go back and forth throughout the season on whether or not that popular support is necessary. In the next episode, we trace the history of nuclear in the 20th century, and popular support (or lack thereof), plays a critical role. But where does that leave us today?

Julia

It's funny. I love this topic. I know it's an area that people disagree on. If you look back, lack of support is one of the driving reasons for nuclear to stagnate. But now that we see popular support surging again, will that have the impact we want it to have?

Will that actually mean that a utility is going to go sign up to build a nuclear power plant? I find that a little hard to believe. That said, there could be other areas that we'll get into in further episodes about where popular support might actually be a bit of the tailwind that's needed to get some of these nuclear projects over the line.

Packy

Yeah, it's probably hard to untangle the impact that Tesla had on the EV market and on powering things with electricity. So that popular support alone doesn't do anything, but then that translates into subsidies. All these things kind of snowball and move in favor of a new technology, which nuclear just hasn't had.

It has these regulations that, overblown or not, are at least working against building it fast. I think there were some subsidies and incentives for nuclear in the IRA. So the government's kind of coming around, but not nearly enough to get developers and utilities over the edge to actually build more nuclear.

So one of the questions that I'm excited to dig into is just how much popular support do you need and where do you apply it? Is it better as this diffuse thing that we all tweet about and want to see happen in the world? Or do we need to form groups and PACS to direct that support at a few key areas? Hopefully this podcast helps at least build nuclear support and understand where those pressure points could be.

Julia

Right. And alongside the explicit support for nuclear fission, it's clear that there also needs to be a change in the conversation about energy more broadly. We need to go from energy conservation and degrowth to a mindset of energy abundance and that the more energy we have, the better for the prosperity of humanity. That's ultimately what we all want.

We haven't come across anyone who supports this abundant growth and opposes nuclear, although we will talk to some people who think that solar in particular will play a much bigger role than people expect.

Packy

There's not going to be one easy answer. One of the questions that I want to ask everybody that we talk to is "what do you think the mix of energy sources will be in the United States by the year 2050?" and get a sense for how people think about it. I don't think it's all nuclear or all solar. I certainly hope it's not all oil, gas and coal. It's probably a mix of all those things. Or maybe it's all just fusion.

Neither of us — and maybe nobody — is an expert in how to deploy commercial fusion because it doesn't exist yet, but I think it's going to be a really fun one for us to dive into because people seem to be really excited about fusion energy. I know I'm excited about it. It's like this utopian thing now because it hasn't actually met the reality of all the stuff that we've been talking about (ie the challenge around economics and regulation). Julia, as someone who's been interested in and passionate about pulling energy from atoms, what's your view on fusion energy?

Julia

I'm super excited that we're going to take on fusion alongside fission in this season because they're just at such different places in their history arc. We're looking at a fusion industry that's in its very early innings. It's R&D; right now. It's looking at what approaches are even viable. What's the best way to eventually get something

that's commercially viable? It's a really exciting stage.

It couldn't be more juxtaposed from fission in a lot of ways, because fission is matured from a technology perspective, but it got bogged down from all these other sorts of cultural, economic, and regulatory issues. It's just a different set of issues in terms of what's going to allow each of these technologies to be commercially viable, if not flourishing, going forward.

It's a really interesting contrast here in terms of two different industries that are basically two sides of the same coin. One is splitting atoms, the other is merging atoms together to create energy. It's going to be really exciting.

Packy

Yeah, they're both super clean and safe. To your point, they were born kind of at the same time. Then the histories look very different from there because we pretty quickly started commercializing fission in the country. For the past 70-80 years, we've been trying to figure out how to make a fusion reaction without using nuclear fission or a bomb to start the fusion reaction in a way that produces more energy than you have to put in.

The National Ignition Facility at the Lawrence Livermore lab last year generated a ton of excitement by shooting lasers to spark a fusion reaction that achieved a Q-factor greater than one, which means that we got more energy out of the fusion reaction than we put in. It was a battery's worth of energy, but it was a historic moment that is still a long way from commercializing.

So I'm excited to dig in with the people who are taking all sorts of different approaches. I think there's as many different approaches to creating commercial fusion as there are startups in the space. Somewhere in the 30-40 startup range.

Julia

I think that's right. You wrote a great piece about the marathon going on in the fusion industry. Can you give us just a little overview of what you learned when writing that piece and what's the state of the union right now with Fusion?

Packy

All right, so with the caveat on the whole season and this in particular, I am not an expert. That's why we're talking to the experts. But fusion is in this really exciting spot. So the joke about fusion, like the joke about autonomous vehicles before it, is that fusion is always just 30 years away. Every year, fusion is 30 years away. I think we're in a spot where that's actually not true anymore.

The thing that sparked me to the piece was that Helion Energy, a fusion company backed by Sam Altman — the OpenAI guy — announced that they'd signed an agreement with Microsoft to provide them with fusion power to run some of its servers by 2028. Which is wild, because most of the best and super optimistic estimates are that maybe we'll have commercial fusion by the early 2030s. They went out and said 2028. I have no idea if Helion is going to be able to deliver. I think there's definitely some Silicon Valley chutzpah on that and saying, "we're going to do this thing by this totally improbable time in the hopes that we can actually go out and do it" is a little Elon-y.

But as I looked more into it, I think we're in this really interesting spot in the history of fusion. So the idea for fusion power started right around the same time as nuclear fission. They were both born out of the Manhattan project at Los Alamos. This Hungarian physicist, Edward Teller, took the atomic bomb and said "What if we use the impact of a fission explosion and use that to ignite a fusion explosion and develop a hydrogen bomb?" And it worked. Luckily, we've only done it as a test bomb — the Ivy Mike test bomb — and it blew a crater into the middle of the island of Enewetak Atoll where they tested it. We're going to dive into the history of fusion energy later in the season in episode seven. What's interesting for now is that it mirrors the history of fission.

It started at the same place, and then early on, just like in fission, there's all sorts of experiments on different designs and reactor types. In fusion, there were concepts called stellarators and z pinch and magnetic mirrors. You can look at them like they're these twisty, complicated, wonderful brain children of these beautiful physicist's minds. Then of all people, the USSR came up with this design called the tokamak. The tokamak

essentially just looks like this big donut. Compared to all these other twisty, crazy designs, it's this relatively simple thing. They're able to use it to achieve higher temperatures and greater pressure, which are two of the biggest inputs into kicking off a fusion reaction.

The tokamak is a simpler design and easier to scale. So after all this experimentation, the world converged for a while on the tokamak design. This international race became cooperative. There's this project called ITER, or the International Thermonuclear Experimental Reactor, where all sorts of competing countries like India, China, US, Russia, and some 30 countries, are all involved in putting their best people towards this huge reactor in the middle of France. The goal is that hopefully by 2035 or 2040 — the date keeps getting pushed back because imagine building something with this many countries as part of a committee — at some point a reaction will be produced.

But recently, maybe because of SpaceX's example, advances in software and materials science and the quality of magnets, or maybe just because there was more funding available during the ZIRP era of the 2010s, there's been this explosion of startups. They're reanimating all these cool designs where the physics worked on paper, but we just didn't have the software or the materials to actually make them work in practice. A bunch of fusion energy startups are now taking all sorts of different approaches. That's where we are now.

I don't know if Helion is going to succeed. Commonwealth Fusion Systems is another one of the leaders. I hope we get a chance to talk to somebody from the team over there because what they're doing is fascinating. But my dumb, optimistic take is that one of these companies that are saying that they're going to get something done in 2030 are actually going to start producing commercial fusion in the early 2030s.

Julia

Got it. So you mentioned tokamaks. What are the other approaches out there that we're seeing in this fusion race here?

Or how are things going for these different approaches?

Packy

So there are a bunch of different approaches that people are taking now, and we're going to have to talk to the scientists and the founders to really get the nuts and bolts of what's really going on. But broadly, there are two categories: inertial confinement and magnetic confinement. The National Ignition Facility used inertial confinement. That's essentially just having a high powered laser shooting a ton of energy at a fuel pellet to spark the fusion reaction.

Then there's magnetic confinement, which is the approach that ITER and companies like Commonwealth Fusion Systems are taking. In this approach, magnetic fields are used to contain the hot plasma and keep it stable for long enough for fusion to occur. Tokamaks are the most common approach here, but there are others like stellarators, z pinch, magnetic mirrors, and levitated dipoles. There's also all the things they were trying to do back in the 50s and 60s that never worked, or worked on paper but were too complex. People are now trying them again, whether it's because we have better magnets or better modeling and simulation software. So that's magnetic versus inertial confinement.

Within each there are a bunch of different designs. Helion is actually trying a hybrid magneto inertial, and then there are a number of different fuel types like Deuterium, Tritium, and Helium-3. So I think of the 30 or so companies that we're tracking in fusion, all of them are different combinations and permutations of these different inputs. Just like nuclear fission, what we're seeing is that they're trying to apply to a wide range of applications.

From companies like Avalanche Energy that want to have a small reactor that you could essentially bring on a camping trip with you, all the way up to Commonwealth Fusion and Tae and Helion that are trying to go grid scale, it's just a bunch of people taking different approaches. We'll see what happens.

Julia

Super interesting overview. I am so excited to hear more from the founders themselves and the investors who are thinking about this space. One other angle I'm curious excited to learn about is what the regulatory framework will be like.

How far are we in developing that? How are people thinking about standing up a regulatory framework for this new industry?

Packy

The thing fusion has on its side is the fact that it's clean. I'm using that word kind of intentionally, but fusion is clean from a branding and reputation perspective. It hasn't had the same issues and challenges that you have to deal with when you're actually operating in the real world like nuclear fission has. During the environmental movement of the 60s and 70s, fusion wasn't a thing to protest against because it just wasn't a thing that existed. So I think it skipped a lot of that.

The way people are viewing it now is as this hope for a clean, safe, energy abundant future. It's viewed the way that I think fission would be if fission were developed today. I hope we can take that support and some of the work that people in the fission industry are bearing the brunt of, and establish a clear framework where fusion hopefully should be able to plug into something even cleaner and easier than fission had to do. But I think it's too early to tell. We need to actually produce this stuff first.

Julia

Totally. I was going to go right there, with the public sentiment piece. It does feel like it's a totally clean slate for nuclear fusion right now. It makes me wonder if they should drop the nuclear altogether and just go with fusion solo.

Packy

Yeah, I think branding is important. Josh Wolfe, who we talked to in the season, wants to rebrand nuclear as "elemental energy" to give it a clean slate. I think names do matter, and I think people within the fusion industry are just going with "it's a fusion company or a fusion energy company". I hope that they do that without throwing fission under the bus.

I think when I was doing research for that piece, there was a lot of "No, fusion is the actually safe and clean one." There's no waste. I think fusion is maybe trying to separate itself a little bit from fission at the expense of fission. I just want all of our energy sources to get along.

Julia

Absolutely. Well, we've covered a lot of great ground this first episode, and I'm super excited for the rest of the season.

Packy

We hope you come out of this episode nuke pilled enough to want to learn more, like we've become. We hope that you understand the basics, that we've put some myths out of your mind, and that you have a good idea of the type of questions that we're going to be wrestling with throughout the rest of the series. We can live in an age of miracles, but it's going to take a lot more than technological innovation. We have a lot of work to do.

So in the next episode, we're going to start wrestling with these questions by unpacking the history of nuclear in the US, where we went wrong, and what lessons we can take away. I'm excited to do that one with you, Julia. I'll see you on the next episode.

Julia

See you then.

Packy

Thank you for listening and watching to this episode of Age of Miracles. If you like what you hear, please rate, subscribe, and share. And if you're feeling really generous, tell us what you think in the comments.

Plus, we have a ton of resources and references in our resource hub if you want to go deeper, and we've linked them all in the show notes below. See you next week.