

The Great Simplification

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[00:00:00] **Chris Keefer:** Energy crises have a way I think of rubbing our faces down into the foundations physiologic needs, you know, fire, shelter, water, heat, security. We are in interesting times again, and the way I try and understand this historical moment is to go back to the energy shocks of the 1970s. The driver of the great nuclear buildup that we saw in the past two thirds of them were built in the seventies and the eighties.

[00:00:22] One tanker load of LNG is equivalent to about a month's nuclear capacity. So if you're running a nuclear power plant for a year, that's 12 tankers of LNG. You don't need, as we face down another energy crisis, nuclear has a very important role in places where it's not nice to have but need to have.

[00:00:44] **Nate Hagens:** Today I am pleased to welcome back to the show, Dr. Chris Keefer to discuss how recent events in Iran and the Middle East especially damage in the natural gas fields and infrastructure are reprioritizing energy security everywhere, and how nuclear power could possibly fit into those changing strategies.

[00:01:02] Dr. Chris Keefer is the host of the Decouple podcast, as well as a practicing emergency physician in Toronto, a medical instructor and a lifelong advocate for social and environmental causes. He is also the founder and president of the grassroots nonprofit Canadians for Nuclear Energy. In this conversation, Chris offers a depth of very rapidly spoken information on our changing global energy portfolio, including how unique decisions over the past few decades have shaped for better or for worse the energy situations of various countries today.

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[00:01:41] Drawing parallels to the energy crisis of the 1970s, Chris highlights how similar circumstances have brought about the rapid construction of nuclear power plants in the past, but questions whether western nations have the political will, the financial capability, the civic capacity to repeat this again today.

[00:02:01] Ultimately, Chris emphasizes that by looking to our recent energy past, we might actually be able to glimpse some of the forces shaping our energy future. As we crest the peak of the carbon pulse. Before we begin, if you enjoy this podcast, I invite you to subscribe to our substack newsletter where my team and I will increasingly share written content about the more than human predicament.

[00:02:24] You can find the link to subscribe in the show description. With that, please welcome my friend Dr. Chris Keefer. This is a good one. Dr. Chris Keefer. Welcome back to The Great Simplification,

[00:02:37] **Chris Keefer:** Nate Hagens, it's, great to be back in times that feel anything but simple.

[00:02:41] **Nate Hagens:** I love that you're actually a doctor, and that you're doing this, for pro-social, pro future, your own curiosity, non-professional reasons to get this story out.

[00:02:56] So, you were on the show, maybe two years ago to talk about nuclear power and, this past week. We were initially set to record this episode, on broader nuclear energy, but events in Iran, and I will timestamp this conversation. It is Sunday morning, March 22nd, 9:00 AM Central, kind of completely turned our original script, on its head as this war is doing for much of the world.

[00:03:32] in the last couple days, the United States slash Israel bombed one of the largest natural gas fields in Iran. and then there was a retaliation to Qatar gas

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field, sending the world further into the throes of an energy crisis. Your expertise. and the other reason I've invited you is there's a lot of nuclear experts or nuclear bashers in my universe, but you've kind of risen above the fray in my estimation, because you know a lot, but you're pretty balanced and you know the arguments from both sides.

[00:04:08] So I'm glad to have you back. but, we, before we dig into nuclear power, I'm wondering how you think the events of the past several weeks are now affecting national priorities in terms of energy resources and energy security as opposed to low carbon and, the conversations we've had in the past decade, and how are we seeing that shift play out across different countries in the world?

[00:04:36] **Chris Keefer:** I mean, I think we're coming off of a period where we've been at the lofty heights on top of Maslow's hierarchy of needs. we've, you know, I think it's the 20 tenths to the 2020s. Every source of primary energy, went from peak to trough, decreased by about 90% the cost of capital. It's almost free.

[00:04:54] after the, global financial crisis. we had some pretty, I think, easy times and we were able, had the great privilege to be able to spend a lot of that time, I think, worrying about higher order issues. This discussion itself is a product of energy surplus. Yes, But, you know, themes of esteem, self-actualization, like this is where our heads have been in terms of, you know, politics, ideology, you know.

[00:05:20] The cultural motif of, this era, the zeitgeist, if you will, and energy crises have a way I think of rubbing our faces, down into the foundations of that pyramid. Maslow's hierarchy, physiologic needs, you know, fire, shelter, water, heat, security. So we are in interesting times again and. You know, the way I try and understand this historical moment is to go back, to the energy shocks of the 1970s and my God, same cast of characters, US, Israel, Iran, and, and to look at the response to it because I think our modern, energy infrastructure is so deeply

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explained by that initial set of shocks in the seventies and the responses that we had to them.

[00:06:03] some of those were nuclear looking at Europe, for instance. France didn't build nuclear reactors for fun or because it was easy or because, you know, phishing heavy atoms, is cool. they did it because they didn't have coal. They didn't have, well, they didn't have much coal, they didn't have gas.

[00:06:20] they had ideas as they famously said, they had a engineering state. They had a political economy that enabled them to build 54 large gigawatt scale reactors. in something like 20 years. The UK Norway, went gangbusters, you know, taking offshore drilling into deep water, shall we say, cold deep water.

[00:06:39] Germany, carried out a masterful bit of diplomacy, locking in, gas from the evil empire across, the iron Curtain, and really securing Europe and building a lot of resiliency into that system. In the us you know, we had a, an oil to, to, coal transition. basically every part of the world responded, to, to a crisis and created what ended up being an energy glut.

[00:07:07] And again, that frames this kind of easy times we've had, in the early two thousands. And so in terms of predicting the future, I don't feel like I'm much good at that. but I try and understand the future by understanding the past and, I think I'm a little scared, Nate, because I don't think Europe, for instance, is in the same, doesn't have the same sort of preconditions, to respond as skillfully as it did.

[00:07:29] And I think it really did respond masterfully to the 1970s oil shock. I don't think it's got, you know, the same amount of oil and gas in those drained reserves, or the same amount of human capacity, human resources, that it did that again, was able to do something as, magnificent really as the French nuclear build out

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[00:07:46] **Nate Hagens:** or ability to expand debt or the complexity of the materials that are required and, the social license and all those things.

[00:07:55] Yeah, you're right.

[00:07:56] **Chris Keefer:** Yes, sir.

[00:07:57] **Nate Hagens:** There's so much to talk about. Chris. let's, let's, start here. The energy conversation of the last few weeks in the news has been primarily dominated by crude oil disruptions and the strain of Russia. but why is natural gas and especially liquified natural gas, LNG also huge and important levers in the rapidly changing global energy situation?

[00:08:26] **Chris Keefer:** Well, I mean gas, I'm not speaking just about liquified now, but gas in general is about 20% of global primary energy, liquified natural gas. Three 4% sounds marginal, but it's become incredibly important, to a number of, different countries. And paradoxically, this is kind of for energy security reasons.

[00:08:43] And you know, in the context of a volatile Middle East, it's hard to think of something as energy insecure as the Ras Lahan industrial city, the site of the LNG. Natural gas, electrification, trains, that are, you know, concentrated on this little peninsula off of the Arabian, peninsula itself.

[00:09:04] It's about 80% the size of Connecticut. that little Qatari, I don't wanna say something like a pimple, but it's like a little bump off of, Saudi Arabia, the Arabian Peninsula. and this gas field, I believe the largest in the world. and this incredible concentration of, high technology in order to densify that by 600 x, put it on ships and carry it across the world.

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[00:09:28] **Nate Hagens:** Wait, just, so when we have natural gas, as a gas, yeah. When they liquefy it, it's a 600 times compression.

[00:09:38] **Chris Keefer:** Yes, sir.

[00:09:39] **Nate Hagens:** Yeah.

[00:09:40] **Chris Keefer:** Yeah. It's, marvelous and it's happening in a hot country, right? 40 degrees c sometimes they have to get it down to minus 162 degrees Celsius. If, my memory serves me,

[00:09:51] **Nate Hagens:** and presumably they use some of the natural gas to do that.

[00:09:54] **Chris Keefer:** 10%. 10% of it, yeah.

[00:09:56] **Nate Hagens:** Yeah.

[00:09:57] **Chris Keefer:** And I mean, they've got plenty lying around. So, it's not really an energy return, energy invested, kind of anxiety for them.

[00:10:04] **Nate Hagens:** Right.

[00:10:04] **Chris Keefer:** but each of these natural gas trains maybe \$10 billion a pop of capital investment. And I believe the Qatari have 14 now, and they were in the midst of a big expansion, 77 million tons per annum produced, last year.

[00:10:19] They were aiming to get up to about 140 million tons per annum. By 2030, we were, told that we were about to have a gas glut, a liquified natural gas glut. And so more and more developing countries were signing up and saying, okay, well, you know, we. Have in insufficient energy reserves ourself. This looks like a great way, for us to bake in energy security.

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[00:10:39] Again, Qatar had been a very reliable partner, for instance, to Pakistan, which currently imports 99% of its LNG from Qatar. Well, currently imports none because of force majeure, and now, Iranian missile attacks on the complex. But all that to say, this had become a really, important part of the equation for countries again, like Pakistan, like South Korea, like Taiwan, like Japan.

[00:11:02] I mean, Japan has, you know, been the source of capital that's really financed and, you know, caused I and G to lift off. have all been looking at this as a really useful commodity. Again, one liquified natural gas tanker carries as much energy as a nuclear plant running for almost a month.

[00:11:21] **Nate Hagens:** What?

[00:11:22] Wow.

[00:11:22] **Chris Keefer:** Yeah. Yeah. I mean, that works both ways. it boggles the mind both ways.

[00:11:26] **Nate Hagens:** You know, it boggles the mind both ways. you know, you live in Canada. I'm in the US and we can't help but look at the news and look at how it impacts prices and responses and reactions in our countries. But there are many countries in the world that the, percentage of their GDP that is energy imports is quite high.

[00:11:51] Yeah. And so what's happening here with both oil and gas has massive impact. You mentioned Pakistan, Thailand, you know, many Latin American, countries and islands have a very large percentage of their GDP has to go to energy. So all of a sudden energy security becomes an important question. But you mentioned force majeure.

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[00:12:18] How many people were thinking that was plausible, especially Europe. They signed these huge long-term deals with Qatar and now, okay. Sorry. There was a act of God, a war and we can't deliver it to you. What's going on there? what do you think?

[00:12:37] **Chris Keefer:** I mean, it's major, it's, a shock. And it's not just energy.

[00:12:40] I mean, LNG is used for a lot of things. it's, you know, during the 1970s oil crisis, oil was used for electricity generation. now LNG is used for that purpose in countries again, like Pakistan, South Korea, Taiwan, but it's also things, critical petrochemical feed stocks, various plastics, one of us left's meals, you know, pillars of, civilization, ammonia, fertilizer.

[00:13:03] So the second and third order effects are just massive. But I wanted to take a second, Nate, just to go back again to why these importing countries thought it was a good idea to build, gas infrastructure. Yeah. And if you make that assumption that Qatar is a firm source of supply, and again, they prove themselves to be reliable partners to poor countries like Pakistan during the Russia.

[00:13:24] Energy crisis. they honored those contracts, those long-term contracts to Pakistan, which they, you know, got a little premium on, 'cause Pakistan was, you know, didn't have great credit. but they continued those shipments. But so why are these important countries doing that? And I think a key thing about, gas liquefy natural gas that really makes it distinct from oil is that on the producer's end, it is incredibly complex and difficult.

[00:13:51] So we just talked about that, like \$10 billion of investment per liquified natural gas train. These are the, you know, industrial processes that compress and freeze, that well liquefy that gas, get it down to a hundred minus 162 degrees

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Celsius. massive investment, massive concentration of capital investment and complexity.

[00:14:08] But on the receiving end, it's relatively simple. Right. You can have this floating storage and regasification unit, basically an LNG tanker. and it receives a gas shipment coming from Qatar. And on the deck of the ship there's the infrastructure to warm the gas back up. It's a lot easier to warm something up than cool it down to minus 162 degrees centigrade.

[00:14:29] You can just do that running sea water over a heat exchanger, re gasify it. You gotta manage pressure and things like that. But then you have a short little pipeline, over to a combined cycle gas turbine and of all thermal power plants. if you just are looking at this from thermodynamics, it is a beautiful thing.

[00:14:47] We're talking about getting towards 60% efficiency. For reference, a nuclear plant is about 33% thermally efficient. A coal plant may be 40, 45% if it's, you know, ultra super critical steam. but the fact that you have two thermodynamic cycles, that you have a gas turbine, and then you're capturing that waste heat, boiling water and then running it through a Rankin turbine, a steam turbine, you get, you capture so much of that energy.

[00:15:11] And while that sounds really complex, combined cycle gas turbines have actually proven to be the easiest thing to build when it comes not to renewables, you know, wind and solar, very easy to build. But in terms of you're gonna build a thermal station, nukes really hard, coal, pretty damn hard. Combined.

[00:15:26] Cycl gas turbines pretty easy because they truly are made in factories. You know, the, most expensive component is that gas turbine, you know, made by Siemens Mitsubishi, GIA Renova, shipped to site and really snaps together like Lego on site in. 24 to 36 months, you have, a incredibly thermally efficient power plant.

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[00:15:46] And if you are living under the illusion as Pakistan and Korea and other countries were, that LNG was a reliable energy, secure form of energy because we have freedom of navigation and we've had this wonderful end of history period that we seem to be coming to the end of. that was a good bet.

[00:16:02] But again, I think that duality is really important. Oil, I think really simple on the production side, especially conventional oil complicated when you receive it and refine it. And LNG sort of flips that script. And so that's why again, a bunch of, well rich and also medium and even low income countries like Pakistan, decided to make a big gamble on LNG.

[00:16:22] And why in the context of this crisis, not just the force majeure, at RAs Lahan, but also the Ukrainian drone strike on the Russian LNG tanker, the Arctic seas and the Mediterranean about to transit through the sw. Just are, I think, sending such shockwaves, through, LNG markets and through the core assumptions, of, end users of this form of energy and why they might reconsider nuclear, but, we'll, talk about that some more.

[00:16:49] **Nate Hagens:** Did you go to Tim Horton's this morning, doc?

[00:16:53] **Chris Keefer:** No, I have a Nespresso machine. I'm only one Nespresso one.

[00:16:55] **Nate Hagens:** Holy cow. That was like a nonstop, your own LNG, frankly, my friend, one thing I've seen in the news recently is Pakistan. Yes, you just discussed that. But the, their imports, their needs for LNG and gas are much, much lower than they would've been five or 10 years ago because they scaled solar so much.

[00:17:18] Any thoughts on that?

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[00:17:20] **Chris Keefer:** Definitely. I think that's a part of the story. something that's interesting, of course, solar's, intermittent batteries, pair very well with solar. no doubt. but solar

[00:17:29] **Nate Hagens:** is natural gas,

[00:17:31] **Chris Keefer:** so does natural gas. The other thing that Pakistan's been developing is coal and One of the real challenges, though, that's interesting, again, and, points towards why they're importing LNG, despite having coal, if you have coal in your backyard and energy security is your fundamental issue.

[00:17:45] And, you know, climate is the top of the Maslow hierarchy of needs, sort of, concern. And you're stuck there at the bottom dealing with physiologic needs and, safety needs. you're gonna burn your own coal. But the issue with Pakistani coal is it's wet coal in a dry place. So it's in, this region of Pakistan called D.

[00:18:03] It's they don't have, they don't have a lot of cooling water and they've got this wet lignite coal. It's thermally inefficient. You gotta air condensed cool. Your, your, Rankin cycle. and so that's not been a reliable source of them. That's why Pakistan went in on solar, has gone in on LNG has gone in on nuclear as well.

[00:18:22] so there's always this kind of per country. There's always interesting factors as to why they're making the energy choices they've made. But I would say absolutely no doubt solar has played a role. but you know, they got a little freaked out because while Qatar did deliver reliably throughout the Russian energy crisis, Pakistan did have a number of contracts that were a little more flexible with European trading houses.

[00:18:43] And the Europeans outbid them on the spot market. And so they were gas starved in that period and they, did learn a bit of a lesson there

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[00:18:49] **Nate Hagens:** while switching to Europe. What are they gonna do with the force majeure with they. Got cut off and chose to cut off, their big neighbor Russia with the, natural gas pipelines, and they replaced that with long-term contracts with, Qatar and other places, including the us.

[00:19:12] How does this change their landscape? broadly?

[00:19:15] **Chris Keefer:** So at last count, according to my math, Europe, consumes about 38 exes of hydrocarbons, oil and gas, and produces six exes. So they have an import dependence of hydrocarbons, of something around 80%. in the good old days, as I said, they were producing in the North Sea, in the grine and gas field off of the Netherlands, and had a, what seemed to be, you know, geopolitical proof relationship with Russia that's no longer there.

[00:19:45] As you mentioned, interestingly, despite not taking much, pipeline gas from Russia, Europe's still taking LNG deliveries from Russia. they're making, again, a sort of virtue signaling, top of Maslow's hierarchy, position of we're gonna, you know, stop that now. and they've become incredibly dependent, Partially on Qatari, but really on us LNG. And it's very interesting in the context of Trump, you know, making moves on Greenland. I put the Europeans in a bit of a sticky position when they've now shifted from one eval, evil empire to another in terms of their energy dependence.

[00:20:17] **Nate Hagens:** This is Sunday, March 22nd.

[00:20:19] On Friday, two days ago I looked at the, natural gas strip futures prices, and 18 months out in Europe, it's still over \$20 per million BTU versus three in the USA

[00:20:33] **Chris Keefer:** and ne negative three in the Permian Basin right now, my friend,

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[00:20:36] **Nate Hagens:** negative three.

[00:20:37] **Chris Keefer:** Yeah.

[00:20:38] **Nate Hagens:** Why is that?

[00:20:40] **Chris Keefer:** Well because, when oil gets hot, you know, there's pure, gas plays like the Marcellus, but there's co-production plays like the Permian and they don't really want the gas, they want the oil.

[00:20:51] That's what's really valuable right now in the US

[00:20:53] **Nate Hagens:** and there's nowhere for it to go. So it's negative.

[00:20:55] **Chris Keefer:** So they'll pay people to take away the gas that's negative.

[00:20:58] **Nate Hagens:** So in a world that is approaching the peak of the carbon pulse, not only is income and wealth and climate and other things unevenly distributed, but there are places that are starved for natural gas just for basic needs.

[00:21:15] And there are other places, like you just mentioned, the Permian that are having to flare it or dump it or not produce it because we have too much,

[00:21:22] **Chris Keefer:** they pay people to take it away right now. I mean, that's where the data centers are gonna go, I guess. Right.

[00:21:26] **Nate Hagens:** I didn't know that. Wow. so. Seven times the natural gas price, not just today, but forecast for a year out as, of now could go different than that, in either direction.

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[00:21:43] How do you maintain an industrial, economy with a pretty central input to it? at those prices.

[00:21:52] **Chris Keefer:** I mean, you don't, frankly, in Europe's been undergoing pretty drastic in de-industrialization, really, I mean over the last 20 years. But it's really sped up, with energy, price prices spiking. I mean, Germany's the kind of industrial heartland managed to resist, a lot of the de-industrialization that the rest of the western world, allowed to happen as a result of globalization.

[00:22:14] They managed to again, I guess kind of admirably, hold on to economic complexity and heavy industry, and buoy up the European Union. but, you know, energy prices skyrocketed after the Russian invasion. they come down a little bit. but we're not gonna see this LNG glut anytime soon.

[00:22:30] That was sort of forecasted three months ago, with Qatar upping production with the US upping production. And, you know. England, for instance. I believe they closed their last primary steel plant. I mean, this is the heartland of the Industrial Revolution. The,

[00:22:45] **Nate Hagens:** prices for England are almost the same

[00:22:47] **Chris Keefer:** in my opening.

[00:22:47] What I was mentioning is, again, in response to the 1970s, energy crisis, Europe had an incredible amount of capacity. and they had a number of resources. They had, you know, intellectual capacity of their nuclear engineers, and state capacity and finance capacity to again, build 54 reactors and electrify heating, electrify the te jve, the high-speed rail.

[00:23:11] electrify a lot of industry and get off oil. similarly again. The UK and Norway, became, exporters, 1995 was this sort of zenith in, Europe in terms of

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their response, to, to the oil crisis. Their import dependency on hydrocarbons was 20%. Then, again, I'm sort of counting Russian gas as part of that.

[00:23:31] but it's 80% now. They're, in a world of pain and, I, worry for my European friends.

[00:23:37] **Nate Hagens:** So I don't know if you know Jean Mark Kochi. He's been on, my program a couple times. I can introduce you. You should have him on decouple. the last time he was on, he said that there are three ways to approach what's coming.

[00:23:52] one is efficiency. Using the energy we have, better. That was before this crisis, right? So we're gonna have less energy with which to be more efficient. The second is so Brite, which is choosing to do things differently, using energy differently, walking or biking instead of taking a car and all the other things.

[00:24:13] And the third choice is poverty. So I actually think that's a pretty good, framing. and Europe may have to, be the test run of The Great Simplification, on some of the things that we've been discussing, over the last few years.

[00:24:32] **Chris Keefer:** You know, it's, it is interesting, European, energy, like hydrocarbon use, peaked, I believe in about 2005 at 46 exes.

[00:24:41] We're down to 38 now by reference in terms of that hydrocarbon dependence. And yeah, there were reductions from efficiency. there were reductions, due to some energy transition to renewables. and, you know, but the big one was deindustrialization. And again, that's taken them, from 46 exo joules down to 30, so about eight exes.

[00:25:01] you know, it's, been a, slight reduction. but it's come at the cost again, of industry. and I think we're becoming less comfortable as we deglobalize, as the

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world fractures as freedom of navigation is threatened. With the idea of not producing the core ingredients of civilization, VAs left mills, you know, four pillars of civilization, steel, cement, ammonia, fertilizers, and petrochemicals and plastics.

[00:25:27] if you don't have those basic abilities, like Trump said, if you don't have steel, you don't have a country. There's truth to that. Trump occasionally says things that are true. and, you know, I also don't wanna be chicken little saying the sky's falling, but I'm just saying I think Europe's in for, you know, decades of pain and they responded admirably in the last oil crisis.

[00:25:42] I think they're really gonna struggle, to mount a similar response.

[00:25:46] **Nate Hagens:** I, agree with you. how are these disruptions of the. The, strait of Horus, Israel, Iran, USA Nexus, how are they changing discussion surrounding, the topic of your, passion and expertise, the viability of nuclear power?

[00:26:05] **Chris Keefer:** I mean, I think it's early days for that.

[00:26:07] the nuclear industry moves slowly. but certainly, the, driver of the great nuclear buildout that we saw in the past, you know, currently that we have 440, nuclear reactors operational, putting out about close to 400 gigawatts, of capacity. what's interesting, Nate, is if you look at the construction timeline of when those nuclear power plants were built, two thirds of them were built in the seventies and the eighties.

[00:26:32] What right? Yes. And that's one of the issues is we have an aging fleet. Luckily these things age well, they age like a fine wine. Often they're actually performing better, as we learn how to operate them better. but, yeah, most, mostly I think the average age of a nuclear reactor in the world is 30, 40 years.

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[00:26:48] And that's getting you back, towards the, seventies and eighties, certainly when construction was started. and so yeah, as we face down another energy crisis, nuclear's going to become, something that it will be sought after by places like Taiwan, South Korea, Japan, the restarting reactors.

[00:27:04] If you have reactors to restart, do that right away because that's gonna, decrease your LNG exposure.

[00:27:09] **Nate Hagens:** Does that apply to Japan and Germany?

[00:27:13] **Chris Keefer:** Yeah, well, I mean, Germany, people think it's too late, but, you know, what does it cost to build a new European pressurized water reactor? How long does it take? what have we seen at Hinkley Point?

[00:27:24] Alto we've seen, you know, construction periods of 15 years. we've seen on the order of, I don't even know, 15 to 20 billion per reactor. Germany has reactors, they've started decommissioning, but for, you know, some of them, the ones that have been lightly decommissioned for an investment of, you know, two, 3 billion, they could have 1.3 gigawatts back online in three or four years.

[00:27:45] **Nate Hagens:** Yeah. So this is a topic I know very little about

[00:27:48] **Chris Keefer:** and just listen, to this for one second if you will, humor this. as I mentioned earlier, one tanker load of LNG is equivalent to about a month's nuclear capacity. So if you're running a nuclear power plant for a year, that's 12 tankers of LNG you don't need

[00:28:02] **Nate Hagens:** or 20 years, that's 240 tankers you don't need.

[00:28:06] **Chris Keefer:** yes.

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[00:28:06] **Nate Hagens:** So, I know that there are so many different bells and whistles and shapes and sizes and technologies on nuclear, but if you take a standard nuclear power plant, if there is such a thing,

[00:28:20] **Chris Keefer:** there is.

[00:28:21] **Nate Hagens:** Okay. Right now in the world with the best technology, assuming, and this is a big if that we have capital, and assuming a bigger if that we have the titanium and which is a rare earth, that China is no longer exporting and the whole complex supply chain, assuming those two things, how long would it take to build on an all out, like, let's do this, under the gun, let's do everything we can.

[00:28:51] **Chris Keefer:** Well, kind of in the hubris of the now where we go, you know, those guys had slide rules, we have ai. I think there's this delusion that we could match the pace, say of, the French, in the 1970s again, is it historically it was possible 54 reactors in 20 some odd years, that's not happening now. like Europe was building at a Chinese level.

[00:29:09] Like we looked to China now and we're in awe and we forget that, you know, in the 50 sixties, seventies, eighties, our grids were going by 8% per year. Now we were doubling the grid every 10 years. Wow. We used to build at the, scope and scale that China builds now

[00:29:25] **Nate Hagens:** 8% a year. What is it growing per year now, roughly?

[00:29:28] **Chris Keefer:** Well, electricity has been pretty stagnant and flat. Like 1% maybe per year. Yeah. So if you're a utility executive working in the eighties, you had doubled the size. You'd built multiple thermal power plants and you were in a rhythm to do that, you'd or you'd built two or three coal plants. You wanna build a nuclear plant.

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[00:29:46] There's some differences, a lot of similarities. You move that craft labor over those project managers over, you've got a development organization that can pull it off. You build fast, right? The west can't do that right now. Can they restart it? Yes. It's gonna be slow and painful.

[00:29:58] **Nate Hagens:** Well, first of all, a answer my question, like roughly how long would it take if there were no other constraints and we dedicated full on resources to it?

[00:30:07] **Chris Keefer:** To do what though?

[00:30:08] **Nate Hagens:** To build a brand new from scratch nuclear plant.

[00:30:13] **Chris Keefer:** A one nuclear power plant. Yes. Yes. Okay. So China is currently pulling that off in five to six years per gigawatt.

[00:30:19] **Nate Hagens:** And we know how fast and efficient they are.

[00:30:22] **Chris Keefer:** They are very fast, very efficient. Russia on their exports is, getting close to that 6, 7, 8 years.

[00:30:29] you know, there's a bit of a, you. In terms of how we say, how fast does it take to build a nuclear power plant? the, the numbers are duped a little bit here because, what that measures when we say start to finish is first nuclear safety, concrete, pour to opening the breaker and feeding the grid.

[00:30:46] There's a lot of work that goes into prepping a nuclear site beforehand, huge amount of excavations, et cetera, and then planning, permitting, all that kind of stuff. Th that stuff's flexible, right? when we, fall to the bottom of Maslow's hierarchy of needs, the bottom of the pyramid, we get different ideas about permitting and the speed at which we can and, you know, nimbyism and things like that.

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[00:31:04] **Nate Hagens:** Yeah,

[00:31:04] **Chris Keefer:** That being said, what is my honest answer? I mean, we're, currently building here in Ontario, the only new nuclear construction underway in North America, including Mexico. Right. So there's none in the us Right. Is one small mod Yeah. Is one small modular reactor. We've dug a great big hole for that.

[00:31:19] and that's projected to take. Four to five years, I think, actually, let me, yeah. From first nuclear concrete to, to grid open, about four or five years. I think most of us are a bit dubious about that and are thinking 5, 6, 7.

[00:31:33] **Nate Hagens:** So there's no plants being constructed in the USA,

[00:31:37] **Chris Keefer:** none. Zero.

[00:31:39] **Nate Hagens:** I thought there's just so much.

[00:31:41] **Chris Keefer:** Bill Gates has got approved the news. Oh yeah. The news cycle will, will have you fooled there. There's a lot of talk. A lot of talk, and there's a lot of efforts to, to reinvent the wheel, right? Because nuclear has run into serious headwinds in the west. And the reason really is we've run into headwinds building any kind of mega project.

[00:32:01] We suck at building airports. We suck at building bridges, we suck at building subways.

[00:32:05] **Nate Hagens:** We suck at using less energy.

[00:32:07] **Chris Keefer:** Sure. we're good at, installing Chinese solar panels. that's an easy low risk construction project. Right. We're, you know, windmills a little more complicated, but we're pretty good at that.

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[00:32:18] building combined cycle gas turbines, as I mentioned, the complex piece of machinery, but pretty easy to snap together. I'd say probably one of the more complex things we've done is building LNG export terminals. but all that being said, we, are no longer good at these. We. Very, challenging, mega projects, in the West.

[00:32:37] And so the western industry has been trying to, you know, sort of cheat that, or, I'm trying to think of the sports metaphor. Football field kind of run around that big obstruction, by chasing, some fantasies and really. You know, I just put out a piece this morning and it has to do with sort of nuclear having CCGT envy, envying, the, the combined cycl gas turbine, all this stuff I just mentioned to you.

[00:33:00] It's modular, it's built in a factory. I mean, a gas turbine's tested in a factory. It snaps together like Lego. That's kind of true of these combined sickle gas turbines. That's why they take 24 to 36 months nuclear power plants. Very different. You know, you need. Incredibly, strong, civil works, right to, to insulate it, seismically, you need, cooling systems.

[00:33:23] you have a lot of quality assurance. You have a lot of regulatory, you just have a lot of onsite labor. and I think we've been sort of desperately trying to, and nuclear engineer ways out of a problem. That's not a nuclear engineering problem. We have great technology in the form of the standardized heavy and light water reactors we've deployed around the world.

[00:33:40] they work great, but if you can't build them, quickly, it kills you. 'cause, this is CapEx, and, if you blow out your, timeline in terms of construction, your cost of electricity goes pretty high.

[00:33:53] **Nate Hagens:** And that has a multiplier effect, in society as we're seeing, in places like Germany.

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[00:33:59] So, This conversation would be very different. if this was February 22nd instead of March 22nd, because the, story and the zeitgeist of that time was, oh my God, AI is just gonna be energy hungry, monster and continue. And there was no LNG Qatari Field War with, Iran. So. Back then. and clearly the headlines are different now.

[00:34:30] I saw lots of stuff that we're gonna build nuclear to, and we're gonna, it's the, energy is gonna be all the above strategy for data centers and, everything else. And so many very suave, articulate, expositions on how nuclear is the answer. And this is gonna be the, new Renaissance. What are your thoughts on all that?

[00:34:54] Because I know you actually believed that until you dove deeper into it.

[00:35:00] **Chris Keefer:** I'm still a believer, Nate, but, but I'm, no longer an evangelist. okay. What I'll say is, again, nuclear has a very, important role, in places where it's not nice to have, but neat to have. So let's go back to Taiwan for a second.

[00:35:13] In that piece I mentioned earlier, Taiwan had about seven gigawatts of nuclear power capacity. About 21% of its grid nuclear powered. It actually built two advanced boiling water reactors. That's 1.3 gigawatts each. It put them through cold and hot functional testing. It never fueled them or turned them on.

[00:35:31] It had a referendum and said, we don't wanna turn these things on. They phased out the nuclear they had on, and they replaced that with LNG imports. And what's, the absolute arithmetical poetry here is if you do the math, the amount of Qatari LNG, which is 35% of the LNG that Taiwan uses to power its grid, 50% of that grid is powered by LNG.

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[00:35:49] Now, the amount of power that those nuclear power plants, if they just turn them back on, can provide, is equal to all of the Qatari, LNG that're importing.

[00:35:58] **Nate Hagens:** Why aren't they doing that? Turning them back on.

[00:36:00] **Chris Keefer:** You know, they did have a referendum, just recently in October of 25, where the vast majority said we should turn 'em back on, but they didn't hit quorum.

[00:36:08] You need to have 25% of the po the voting public participate. they're gonna turn it back on. Trust me.

[00:36:14] **Nate Hagens:** Let's just pause here for a second. so the basics of nuclear energy are not the main focus, especially with world events, but I do encourage people to watch your previous appearance, on TGS if they wanna dive more deeply into that.

[00:36:29] But maybe let's just pause here and you can briefly lay out. Aerial view, the general positive and negatives that come with nuclear power. For new listeners that are unfamiliar with that, and to refresh my own, views.

[00:36:44] **Chris Keefer:** I mean, I, it all comes back to the world's most famous equation that no one really understands or like has if you actually punch the numbers and it gets bonkers.

[00:36:52] Right? But E equals mc^2 , so it's, energy density. And when it comes to energy security, there's nothing like energy density. So let, me run you through some numbers relevant to that equation, Nate, to illustrate this concept. If you think about how much fuel you need to stick in a one gigawatt, nuclear power plant, it's a hundred tons.

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[00:37:13] Does that sound like a lot or a little to you?

[00:37:15] **Nate Hagens:** How much fuel?

[00:37:16] **Chris Keefer:** Yeah,

[00:37:17] **Nate Hagens:** that sounds like a lot.

[00:37:19] **Chris Keefer:** Right. A big, number. A ton is big. A hundred sounds big. Yeah. What's interesting is uranium is the most, heavy, naturally occurring element on the periodic table, right? And so the volume of a hundred tons of that, uranium dioxide is about 2.5 to three meter sphere.

[00:37:35] So if you imagine you're at a playground, what? And there's a climbing structure that's a hemisphere, right? But you've probably seen those kind of geodesic climbing structures that kids play on. that's the kind of volume we're talking about.

[00:37:46] **Nate Hagens:** That's a hundred tons.

[00:37:48] **Chris Keefer:** That's a hundred tons, right? Lemme keep going with this.

[00:37:51] Okay. So you have a hundred tons. So even when fabricated, not as a ball of uranium dioxide, but fabricated into those elements, it doesn't even take up a shipping container to have a fuel, a full fuel load for a nuclear power plant for the fuel load. For how long? 18 months.

[00:38:06] **Nate Hagens:** Okay,

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[00:38:06] **Chris Keefer:** so let me, lemme just quickly do, I suck at quick mental math, but if we said that, you know, an LNG tanker a month is what a nuclear power plant displaces.

[00:38:14] So one container on a ship, is the equivalent of what now we're talking 18 LNG tankers of, gas. Right. But stay with me here. So a hundred tons goes into that reactor every, single day we're fishing a little bit of that. We're fishing about three kilograms Okay. Of, of that uranium heavy metal. And there'll be some plutonium that generated, but we'll just focus on that.

[00:38:39] This heavy metal. Right. So how much is three kilograms of uranium, what's the volume of that? A baseball is what's being efficient every day.

[00:38:46] **Nate Hagens:** So we're carving off a baseball from a hundred ton chunk of

[00:38:50] **Chris Keefer:** That's what's being efficient. Yeah. Yeah.

[00:38:52] **Nate Hagens:** and that, that create, that provides the energy and it gets turned into waste.

[00:38:57] **Chris Keefer:** But we're still not at equals mc squared yet. So of that baseball, that three kilograms that's being fished every day, a tiny amount of mass is being converted into energy. This is the, phenomenological difference of, nuclear and why, you know, unleashing the strong nuclear force, right? So if you actually do the calcs, how much mass is being converted to energy?

[00:39:18] Three grams. Wow. Three grams. and okay, so energy equals mass times the speed of light squared. How big's the speed of lightning?

[00:39:30] **Nate Hagens:** No idea.

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[00:39:30] **Chris Keefer:** 300 million meters per second. When you square that, that's 90 quadrillion meter squared per second squared. So when you, multiply three grams by 90 quadrillion meter squared per second squared, you end up, with an extraordinary number of joules and the number of, megawatts or gigawatts you get out is 25 gigawatt hours per day.

[00:39:53] Electricity. So that equals the plant putting out a gigawatt of electricity. How much power is a gigawatt of electricity? Hard to get your head around. That's a million American homes or 3 million European homes off of three grams of mass being converted to energy according to Einstein's equals mc^2 equation.

[00:40:11] **Nate Hagens:** Well, that is also indistinguishable from magic, but of course fossil fuels enabled the construction of all that you just said. a hundred percent. That, that's impressive. I had not heard it presented that way.

[00:40:22] **Chris Keefer:** I just came up with it this morning after, you know, drinking that espresso, Nate, but I, got the numbers fact checked

[00:40:27] **Nate Hagens:** and some people think you're only an ER doctor.

[00:40:30] **Chris Keefer:** Yeah, that's right. That's right. alright, so

[00:40:33] **Nate Hagens:** keep going.

[00:40:34] **Chris Keefer:** Yeah.

[00:40:35] **Nate Hagens:** So the energy density. Fossil fuel enabled? yes. 'cause we can't use nuclear energy to build a nuclear plant.

[00:40:44] **Chris Keefer:** Oh. We can't do anything without fossil fuels. Let's be honest, Nate, other than sort of scratching the ground and do permaculture. but

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even then, in most permaculture, I know, are hooked up to some fossil fuels in one shape or form.

[00:40:55] **Nate Hagens:** So one of the big positives of nuclear power is its unbelievable energy density.

[00:41:01] **Chris Keefer:** Yes.

[00:41:02] **Nate Hagens:** what are some other positives and some negatives?

[00:41:04] **Chris Keefer:** so other positives, I mean, you know, when I organized with a number of, colleagues and friends to save our local nuclear power plant here in Ontario, we said, obviously climate, air quality.

[00:41:18] There's no emissions produced by nuclear power plants. no air pollution. medical isotopes are, can do nuclear reactors. in Canada. Our unique design has this property of producing, enormous amounts of medical isotopes, which enable modern healthcare by medical instruments. yeah. We, put in, cobalts, 59.

[00:41:37] We get Cobalt 60 out and we use that to sterilize 40% of the world's single use medical devices. So you have absolutely come in contact.

[00:41:43] **Nate Hagens:** I have no idea about that.

[00:41:44] **Chris Keefer:** Yes. Yes.

[00:41:45] **Nate Hagens:** And what, would we have done if we didn't have the nuclear plant?

[00:41:49] **Chris Keefer:** So there's other ways to sterilize things. You can obviously do an autoclave but end up melting plastic.

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[00:41:53] So you're simply use medical devices.

[00:41:55] **Nate Hagens:** Other things are more

[00:41:55] **Chris Keefer:** cost. You use fos gene gas. but then you have to get that gas sort of surface area in contact with everything you're trying to sterilize. It's nasty process. but if you have some really powerful gamma rays coming off of, this Cobalt 60, you can just, you know, sort of like putting a bunch of materials on a coat hanger and, putting it on a little tramway, past this radioactive source.

[00:42:17] And you, can sterilize an enormous amount of medical equipment. jobs, I'll say jobs is another huge one. just like, you know, an auto plant in Detroit built in the 1920s provided intergenerational employment for three, four generations until, you know, globalization hit. But that's, a narrow

[00:42:37] **Nate Hagens:** boundary view of jobs because yes, we need jobs to build and maintain these plants, but the larger thing is, if those plants provide that amount of electricity.

[00:42:49] For how many

[00:42:49] **Chris Keefer:** homes did you say? Well, it depends if you're American or European, but a million homes, if you're Amer, if you're American, two to 3 million if you're European.

[00:42:56] **Nate Hagens:** Yeah, so if it provides electricity for a million homes, that's doing things for humans that they used to have to do themselves yard.

[00:43:03] So it, it frees them up to do other jobs.

[00:43:06] **Chris Keefer:** Yes, exactly.

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[00:43:07] **Nate Hagens:** Yeah, exactly.

[00:43:08] **Chris Keefer:** Anyway, we're on the pos, we're stuck on the positive side here. Let's talk about some negatives. Alright,

[00:43:10] **Nate Hagens:** we'll go for the negatives.

[00:43:11] **Chris Keefer:** You know, in terms of what's holding back all the positives, right? Is that, this is a CapEx heavy technology, right?

[00:43:19] So again, in terms of you're looking at the LCOE, we're talking 70, 80% of the cost of electricity is paying for the construction, which is complex. big parts, specifications are wild, right? You're sort of building a massive construction project to sort of space level QA

[00:43:36] **Nate Hagens:** in its long duration.

[00:43:37] You don't get your payback for quite a while, whereas natural gas you get it in the 18 months

[00:43:43] **Chris Keefer:** doesn't fit well in, in terms of private markets. Yeah, absolutely. So if you can, deliver on schedule on budgets, it takes you 20, 30 years to pay it off and then your power is dirt cheap after that.

[00:43:56] And that's why this lunacy of closing perfectly good nuclear power plants that are 30, 40 years old is. It's just insane.

[00:44:02] **Nate Hagens:** Yeah. From, an energy perspective and a energy surplus and monetary perspective, letting outside the other perspectives. Yeah, it makes no sense. You're absolutely

[00:44:12] **Chris Keefer:** right. It's insane.

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[00:44:12] It's completely insane. So all that to say, I mean, wind and solar are CapEx heavy. They're 90, 95% CapEx, but the construction risk is nil. Right. And so, and the marginal cost is no. Nuclear is very cheap to run. Once it's operating, your operational expenses are low. Your fuel, because again, you're using, you know, one third of a shipping container of fuel every year.

[00:44:32] it's 10 13% of cost natural gas. You know, you build it cheap, but then your fuel cost is huge. and that used to be a problem before we had negative \$3, per million BTU in the Permian.

[00:44:41] **Nate Hagens:** Yeah. So it's, just a totally different puzzle. Yes. All the costs are upfront and then eventually it's like virtually zero.

[00:44:49] **Chris Keefer:** So that doesn't work in neoliberal capitalism, Nate. That works when a country like France in the sixties, a kind of deje social democracy says We have an energy security emergency and we are gonna pull out all the stops. And we're not building this purely for commercial reasons. Yes, it's gonna underpin our economic wellbeing for the next 30, 40 years and power our tave.

[00:45:08] Are the countries that have that attitude now going to outcompete? Well, 100%. You have state capitalism in China, you have some version of state capitalism in Russia. you have countries like Korea, where there's a mixed model, right? The market is not absolute king there. and there's an, there's a capacity within the state to mobilize around, around certain needs that we have.

[00:45:30] and we're seeing that political and economy shift. I mean, what we've on decoupled podcasts started to refer to in terms of some of the emerging trends in, US political economy, we call it MAGA industrial socialism. So the government taking a direct state and mountain pass, rare earth mineral mine, for instance, or, Looking at taking a direct state in Westinghouse. so there, there's interesting things going on as we deglobalize and start to say, Hey, Ricardian,

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economic theory, works great in an end of history world, where there's freedom of navigation and everyone's friends with each other. but as we deglobalize, as we start doing piracy and, you know, blowing up each other's shipping, we better make sure we have the basics, the base of Maslow's hierarchy of needs, taken care of as much as possible within our country, within a, to a tight network of allies.

[00:46:18] and so that requires a different political economy. And so I think as that political economy reemerges, nuclear will become more viable. But this isn't an overnight thing. This is gonna take a while. And what we're gonna see in terms of nuclear additions, we're gonna see basically countries that have nuclear running it.

[00:46:32] To the end of its functional life, which is looking to be, you know, arbitrarily, it was determined. Okay, power plant, a coal plant, it's, dead in 40 years, so we'll just assume that happens to a nuclear plant. What we're seeing when we actually do the QA and look at these plants and do the capsule data of the reactor pressure vessel is, man, this thing is, doing very well and has another, we're relicensing 10, 20 years.

[00:46:52] These plants are going 80 years, 90 years.

[00:46:54] **Nate Hagens:** What are the components of a nuclear plant that eventually would degrade to the point that it does need to be totally shut down and decommissioned. The concrete or on it? Like what parts?

[00:47:04] **Chris Keefer:** No, in the most, widely deployed nuclear reactor system in the world, the pressurized and boiling water reactors, that the US bequeathed the world, that's the reactor pressure vessel.

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[00:47:12] So it's like a pressure cooker and it's what contains the nuclear fuel. and over time neutron bombardment and starts to brittle metals, you start getting corrosion and things like that. the Russians interestingly used a bit of an inferior alloy for a while and they've been, Anne kneeling their reactor pressure vessels and getting them back into, a very good condition.

[00:47:32] And the US style reactor pressure vessels, as we do very careful analysis of them are holding up exceptionally well, such that the regulators saying, yeah, you can run this thing another 10 years, another 20 years. so in terms of the actual life determining feature, it is the reactor pressure vessel.

[00:47:45] But we're now looking at these things kinda like a hydro dam as a potentially century asset. So in any case, what's gonna happen, Nate is countries that have nuclear are going to. Maintain those plants and keep them going. Countries that were foolish enough to shut down their nuclear, if they're not suicidal, like the Germans are going to restart as much as they can.

[00:48:02] But we've already seen reversals of phase outs saying Belgium, even France was starting to move towards, phasing out some of its nuclear fleet. Those days are over. Taiwan's gonna restart. Its nukes. Japan's gonna restart as many of its nukes as possible. And then countries, I believe in the west as well, are gonna embark and they're gonna start building nuclear.

[00:48:17] It's gonna be a struggle fest. It's gonna take a while to get good at it. Hopefully, you know, with enough, necessity, as the mother of innovation, we're gonna start. Performing well again, and again in localities that need it, I'm not convinced the US is gonna need it 'cause they've got so much cheap natural gas.

[00:48:33] But in Ontario, we're gonna build some more nuclear power plants for sure. In Europe, they're gonna build more nuclear power plants struggle fest for a while, but who's gonna dominate is China. And right now China has about 60

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gigawatts of nuclear power installed. That's 5% of their, capacity. Not much, frankly 5%.

[00:48:49] It's less than solar, less than wind, less than everything else. they're in a major upswing right now where they've standardized on two reactor designs. they have these industrial clusters as much as they do for iPhones or anything else they build. and they are now stamping these things out.

[00:49:03] So we're looking at them hitting something like 200, 250 gigawatts by 20 40, 20 50 versus how many today? We have about 390 gigawatts of nuclear right now globally.

[00:49:15] **Nate Hagens:** So they will build almost as much or two thirds as much as we the whole world has now.

[00:49:20] **Chris Keefer:** Yeah, in the next 20 years.

[00:49:21] **Nate Hagens:** There are some people who think that it's a race for energy access between the US and China broadly for ai.

[00:49:30] And there's gonna be one winner of a GI and all that. And because they have an all the above, although they don't have the natural gas and oil that we do, but they're, they have such cheap electricity and they're building and fueling all this stuff.

[00:49:46] **Chris Keefer:** Yeah.

[00:49:47] **Nate Hagens:** That they're definitely winning in that race because, like you said earlier, the market doesn't, The market prices, efficiency and just in time profit, and doesn't look at energy security and complexity of the way that you're describing

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[00:50:02] **Chris Keefer:** China's in a whole different cycle, to what I described in the EU since, you know, the nineties when they really peaked in terms of energy sufficiency and then became, you know, to be a bit, provocative, decadent. you know, Maslow's hierarchy of needs being at the top of the pyramid, like China over the last 20 years has been planning for an energy blockade. they know that when they act on t on Taiwan, as I think the consensus is, they will eventually in one shape, way, shape, or form.

[00:50:28] The geographically they are screwed. there's this island chain, which really limits their maritime access. There's the Straits of Malacca through which, you know, all of that straits of Horus oil has to get through one strait then another, unless it wants to go all the way around the Indo-Pacific.

[00:50:46] and they're very prone to blockade.

[00:50:48] Part of why they want Taiwan is so they can have, some access and get out freely into the Pacific Ocean. As you know, Canadians and Americans, we forget that, you know, we have this unhampered access to two major oceans with no, no threats of blockades. So China's been planning for this, from day one.

[00:51:02] Nuclear is part of that strategy, although I said only 5%, even when they get to 200 gigawatts, that's a tiny fraction of their total installed capacity. I mean, the thing about nuclear is you run at 90, 95% of the time, so it ends up being a decent amount of Jews. but again, what China has done is, is plan completely around energy blockade.

[00:51:20] So that is, it's not just a sort of green revolution. Yes, they built a lot of wind and solar, but they're still 60% coal. they have these energy bases in inner Mongolian jinjiang where they have, you know. Five, six gigawatts of solar, two gigawatts of wind, some batteries, and four gigawatts of coal.

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[00:51:37] They hook it up to a high voltage DC transmission line, send it to Beijing to run the EVs. Why do they have all the EVs? Well, 'cause cars use liquid hydrocarbons, which they're short on. And so they've electrified their economy, not for climate, but all in this energy security frame, because they.

[00:51:51] Considering things at the bottom of Maslow's hierarchy of needs as you do. I think if you're responsible in this era, and if you're, you know, a Chinese state that has some degree of central planning can go a variety of different ways. But if you have a hybrid system, you can benefit from the market, but then also subordinate the market, to these things.

[00:52:09] You do things that are a little inefficient. You have a coal to chemicals industry. You make your fertilizer with coal. you make your methanol, feedstocks or plastics with coal, it's less efficient. It costs more, but you do it because you're preparing for just the kind of thing that we're seeing in the Gulf right now.

[00:52:23] **Nate Hagens:** I think a lot of people listen to The Great Simplification podcast and turn up to 1.2 or 1.3, for best, information digestion. They're gonna have to maybe slow it down on your podcast. You throw a lot of, very articulate words into a minute, my friend. So clearly. Well, not clearly, because I think the leadership in my country is energy and systems blind.

[00:52:50] Otherwise, they would've looked at the second, third and order effects of what's going on right now. Yes. But what can the West learn from non-Western countries in terms of the energy security comparisons between l and g and nuclear power, et cetera? I mean, again, I think I'm, gonna beat a dead horse here, but, I think what we fundamentally need to learn is that we have a political economy that's not adapted to the current moment.

[00:53:17] **Chris Keefer:** you know, this electricity markets, deregulation, which has, not incented reliability in energy, secure in our systems or, you know, slack in

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the system. Is, not suitable to the times that we live in right now, particularly in Europe, but to some degree in, in, the us and Canada. And so I'm not saying, you know, I'm not providing any moral judgment here.

[00:53:38] I'm not saying, you know, the Chinese are great. we should emulate them, but we're fundamentally going to need a different political economy in order to meet the base of Maslow's hierarchy of needs, which we have globalized away and de-industrialized away. and so I think that's gonna be, you know, something that's gonna be very interesting to watch and see how that happens.

[00:53:56] Unfortunately, you know, someone who kind of emerged on the political left, the left is in the dizzying clouds at the top of Maslow's hierarchy, obsessing over self-actualization and, value signaling. you know, we had an environmentalism that was, you know, based upon needs and security, focused on clean air, clean water, et cetera.

[00:54:16] And we've turned into things like climate's important, but a lot of it is value is virtue signaling. It's the solar panels on your roof. it's deciding what you eat, being a vegan, et cetera. Right. We're gonna have our faces rubbed back into the base of the pyramid and what we need, in order to endure as complex societies for as long as we can endure as complex societies.

[00:54:36] and the political right, the populist right. they're the ones talking about affordability, about energy prices, about the price of gasoline, et cetera. And so likely, this response is going to be, be coming from the political right, and it's gonna have, it's gonna be flavored in that, way.

[00:54:52] so, you know, it's gonna be interesting. Nate, what would it take in your opinion, Chris to take the West, and I include Europe, in that moniker to get back on track for a true nuclear renaissance and is that even possible today? Yeah, I

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mean, and it's honestly, it's part of, you know, the mission of what I do here at Decouple, right?

[00:55:14] I say. It's easier to build a nuclear plant on budget and time than it is for a camel to pass through the eye of an eagle. Right. and it's funny because, I'm still pronuclear, right? I think I'm a lot more subtle and nuanced and honestly within the nuclear industry and the nuclear ecosystem and the advocacy space, you know, culture wars, energy wars.

[00:55:35] Not energy wars, sorry. Culture wars are a dangerous thing. They're, not where we do our best thinking. E energy wars are also a dangerous thing. They're a very dangerous thing. But, you know, when it comes to thinking about what's the best way to deploy technology that's difficult to deploy, in my mind we have to really carefully look at history and carefully analyze, particularly category errors.

[00:55:55] As I mentioned, the attempts, to do the small modular reactor revolution. Very much sort of looking over at combined cyclo gas turbines without even knowing it and saying, Hey, I wanted to do that. I want that stuff. how can I make that happen? you know, nuclear because of, what I call a bunch of inherent costs.

[00:56:12] So again, the incredible seismic, it's qualified civil works that are required. You gotta dig a big deep, you gotta pour a lot of concrete and steel. You have to build a lot of auxiliary infrastructure, for cooling water for emergency, core cooling systems. there's a lot of regulatory, there's anti proliferation concerns.

[00:56:30] All that's baked into the cost of a nuclear power plant. And none of that goes away or gets, you know, proportionally or linearly smaller as you decrease reactor output. and so we've had this whole fetishization of small

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reactors, the entire history, the iron law of nuclear power and how it's gotten to be economic is by going big.

[00:56:48] So I really don't see a future for small reactors unless you're willing to pay a pretty high price premium because you have a tiny grid and you still, you need it so badly because you have no coal, gas, LNG, you don't trust anymore. You'll pay that premium for a small reactor, but otherwise you build a big reactor.

[00:57:02] Similarly, we have a fetishization of, advanced, advanced technologies, right? Molten salt reactors, high temperature gas reactors, sodium fast reactors. They're called generation four. They're generation one. These were concepts tried in the fifties, sixties and seventies. They're not advanced reactors.

[00:57:18] They failed to advance, they weren't economic. Wait, isn't Bill Gates doing some terror power thing on a sodium fast reactor? Yes. That's not a new thing. no. Sodium fast reactors. I mean, EBR one and EBR two. The first, Alex, nuclear produced electricity turned on a light bulb. But EBR, that was a sodium fast reactor.

[00:57:36] Okay. so these are ancient technologies. they're cool, they're innovative. You can, they have an interesting narrative and promise. I mean, with a sodium fast react, you can breed fuel, you can put fuel in and generate even more fuel than the reserve to begin with. it's really cool stuff in terms of theoretical energy returns and energy invested, it's neat technology.

[00:57:54] There's compelling and beautiful narratives to all this. But when rubber meets the road and when reality hits, what we've seen is that these reactor technologies, have not. Not been competitive. There's hurdles to jump across, which maybe you'd get to if you poured enough money into r and d and work in the national labs.

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[00:58:09] But private investors and utilities are only willing to do so much of that work until they have a product that's competitive. Light water reactors, heavy water reactors cleared that hurdle. And have pursued under their own momentum. And unfortunately, these advanced technologies have not. But because we're just, in the space where we're not wanting to look at, hey, the issue here is project management, project delivery.

[00:58:29] that's not cool and sexy. You don't get VC money saying, Hey, I wanna, you know, have a, disruption in project management skills. No, you say, Hey, I come from, you know, Y Combinator and, you know, I have invested in a hundred different companies and one of 'em, you know, a thousand XD because they had a, nifty little, piece of software that was more user friendly and everyone went over to do that.

[00:58:52] And I could ship minimal viable product and fix it as it went. That's not how nuclear works. Nate. So clearly there is a reason, or at least a narrative and a perception why people in Germany and Taiwan and elsewhere have referendums to shut down nuclear. So you didn't get to the other, yes, Negatives of radioactivity and, things like that. truth or fiction. on that give us a summary. Both. Both. So, you know, when it comes to the bogeymen, like nuclear waste, I'm the first to acknowledge, nuclear waste, you know, freshly irradiated nuclear fuel. Take it out of a reactor, stand next to that unshielded lethal dose in seconds.

[00:59:32] And then just a brutal, gruesome death acute radiation syndrome. Your bone marrow dies, overwhelming sepsis, infection, bleeding. You shed your whole gastrointestinal tract lining. Not pretty, right? I somehow, I didn't mean that, but thank you. I mean, I'm a doctor. You humor me a little bit. in the 70 years of operating civilian nuclear power plants and handling spent nuclear fuel, we haven't had any, deaths related to, radiation.

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[00:59:57] And that's because it's something very easy to measure and we make dangerous things. Safe people dial the time falling off of ladders because we think ladders are safe. We make dangerous things safe at when we're at the top end of Maslow's hierarchy with complexity and social stability. When we have skills.

[01:00:14] When we have skills, yes. So in any case, radiation's a real thing. We need to acknowledge it and it makes, handling and storage of waste, a challenge. But by, by no means our most challenging waste stream by a long shot. We have, again, you, I mentioned the density of the fuel going in. you know, one third of a shipping container fuel goes in.

[01:00:32] That's so much comes out. That's not a large volume. It's solid. It's a ceramic that's not water soluble, it's clad and zirconium, which is corrosion resistant. there's not a mechanism for it to really get out and harm people, and it gets safer as we go, right? So in 500 years, the penetrating radiation is gone.

[01:00:47] You have to find a way to ingest or inhale, you know, hard ceramic pellets that are clad and sheathing and then put in these casts after 500 years. Yeah. But after 400 years, there's still some risk. there's some, yeah. Yeah. But again, it's sitting on a parking lot in a bunch of concrete steel containers.

[01:01:05] It's not leaking into the atmosphere. It's not, you know, PM 2.5 particulate pollution that's being inhaled and causing heart attacks and strokes and cancers. and it's on a, you know, it's on a basketball sized court, at a nuclear plant with a fence around it, with a security guard. Well, but, you know, my, my whole, I mean, again, I'm, I've never really had the time, to delve into this in my own research, but my view of the fragility of our economic social system is I worry that if there are disruptions that we don't.

[01:01:39] **Nate Hagens:** Have the complexity to do all the behind the fence and get people to go there and do all the things and the diesel fuel to keep the

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generators on. And that sort of gift that keeps on giving, sort of Chernobyl ish thing is always in the back of my mind. Sure. What is your thought on that? Well, I mean, again, ev every.

[01:01:58] **Chris Keefer:** Human activity generates a waste stream. And what's harder to manage, you know, human sewage or a security guard with a chain link fence and a basketball sized court with a bunch of stealing concrete canisters on it. I agree. I share your concerns about a great Simplification, but some things are easier problems than others.

[01:02:15] Or maintaining a coal ash pond that's, you know, eventually that's the reservoir's gonna give away and flood, you know, a whole watershed with mercury and other contaminants. Or you can come up with any other number of hypotheticals for other sources of waste. So yes, that exists. But new Nate, I want to humor you.

[01:02:30] And I want to go into like the really scary shit, right? We're in a time of war. you know, Iran has an operating power reactor, producing energy. I mean, today, tr my president said we're gonna attack, the, your power plants. Yeah. And if that happens, and again, I don't know when this episode will air Chris, probably in a couple weeks, but.

[01:02:53] **Nate Hagens:** Danny Ron is gonna retaliate to the detail plants and other plants. I mean, it's like right before coming on this, show, they, the Iranian, I'm not sure what ministry released, here's all the power plants throughout the Gulf that will attack if you attack our stuff. I don't believe that the Barack and Nuclear power station in the United Air entrance, was on that list.

[01:03:12] **Chris Keefer:** But, you know, if, the Israelis and Americans are dumb enough to target, the Iranian, again, gigawatt scale nuclear power reactor, who knows? Who knows. So, let's talk about that hypothetical, because that one's

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probably got you. Got you, scared. So, first off, we have, some pretty good data in terms of worst case scenarios and Chernobyl.

[01:03:32] Really is the worst case scenario. So this is, an RBMK reactor, Soviet style reactor. it's nothing like we build, in the west. And what happened there was you had this crazy power excursion 'cause they were moving a bunch of safety systems running at low power. And then you had a quirk of the technology, which is as water sort of boils off, reactivity can go up.

[01:03:53] So you had this power excursion, it melted a whole bunch of fuel, there was no containment. So in that explosion it kicked the lid off. and then the whole thing caught on fire because it was moderated with graphite, which is basically carbon, which is basically coal and it burned for 10 days and spewed an enormous amount of, we call the source term the efficient products.

[01:04:12] The radioactivity that had accumulated in that fuel were rejected into the atmosphere on a massive plume of smoke. and. Went far wide. It went towards Europe, right? And it was detected at a nuclear power plant in Sweden where someone set up a radio radiation detector at the plant and said, what the hell is this?

[01:04:27] Right? so that's kind of our worst case. Even if you drop the bunker buster on a light water reactor, it doesn't catch on fire because the moderator's water, not carbon, not graphite. So, what were the health consequences of Chernobyl like? you have a variety of different, sources of information.

[01:04:45] Greenpeace did a study, the EU green parties did a study, unsurprisingly, they found, you know, million or tens or hundreds of thousands of, premature deaths from Chernobyl based upon, their studies. Okay. Then you had the UN scientific committee on the effects of atomic radiation. You had the Chernobyl forum, tremble forum's, interesting UN Chernobyl forum.

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[01:05:03] That's eight UN agencies, 30 countries participating, including those maximally impacted Russia, Belarus, Ukraine. And what were their findings? So 30 people died directly from Chernobyl in terms of, two of them just from explosive injuries, blast injuries burns, and 28 from acute radiation syndrome of 134 people that got really high doses.

[01:05:26] And those are firefighters and plant operators. So of the 134 people that had their bone marrow die and their intestine intestinal lining slough off, basically, 100 of the, 136 survived roughly. Right. what ended up happening to them as we followed them and tracked their health along the way, we barely even see an uptick in cancer in that group of maximally exposed people that, you know, shed their linings and, their bone marrow died.

[01:05:55] they're dying in, car accidents of liver cirrhosis, heart attacks, and their cancer rates are really because 40% of us get cancer. If one extra person gets cancer, it's hard to detect that. It's not to say it's not happening in that maximally exposed group. Hold on a second. 40% of us get cancer. 40% of us would get cancer in our lives.

[01:06:11] Yeah, I actually didn't know that. Or if I didn't think about it. Yeah. Right, right. So, so in any case, what was the main harm that we saw from Chernobyl? it was iodine release. Iodine 1, 3 I. And why is that so dangerous? Well, little kids', thyroid glands are growing and the thyroid gland concentrates iodine 50 times higher than what's in the bloodstream.

[01:06:32] So it just slurps up iodine. If you're in an area that's kind of iodine deficient and a whole bunch of radioactive iodine enters, the food chain by settling out in fields and cows, you know, eating grass and concentrating their milk and kids drinking milk, then the kids got a high, iodine dose, radioactive iodine.

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[01:06:49] And so what we have seen, is thousands of excess thyroid cancer cases, in tragically in people who were kids in adolescents at that time. Within what sort of a surrounding vicinity of Chernobyl? I mean, this is in Belarus, Ukraine, and Russia in those areas. Okay. so what they anticipate seeing, over the full course of this is there'll be 15,000 extra thyroid cancer cases. The one silver lining here is that thyroid cancer is the most treat, one of the most treatable cancers that there is. And what's, the weird poetry about this is the treatment is actually radioactive iodine. Because again, if this cancer metastasizes all of your body, and unless it differentiates like crazy, it still retains that, facet of concentrating and picking up iodine.

[01:07:32] So if you give it more radioactive iodine, you kill the cancer. So in any case, I'm not trying to make light. but I do wanna put in perspective what the health impacts of Chernobyl were. The other main contaminant, cesium 1, 3 7, you know, the most affected areas outside the exclusion zone. Saw doses of something like 10 milli cts over 20 years.

[01:07:49] That's one trauma CT scan. Like if I do, if I were to scan your whole body 'cause you were in a car accident, Nate, I'd give you 10 milli cts in three seconds. you know, those surrounding areas got that dose. Day by day, over 20 years. So we, we, have not seen a measurable increase in deaths from the worst case scenario, which doesn't mean we should be blase and we shouldn't have lots of protections in place.

[01:08:07] But I do wanna calm people and I do wanna agree with you that if we were to wipe, if Iran was to wipe out, the desalination plants, in the Middle East, that would have a much higher, health burden on the public. But while many orders of magnitude higher, yes. let us hope by the time this airs in a few weeks, that has not happened.

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[01:08:26] Jesus Christ. Yeah, it could. Yeah. So, You're so good at this, Chris. you're so articulate and on top of the different issues, let me switch gears just a little bit. As many of your viewers, my viewers know, I'm of the mindset that human society is gonna have to be forced to simplify at some point in the future.

[01:08:49] **Nate Hagens:** yeah, that's safe as our biophysical reality just can't support the complexity required to be at what you were referred to the top of, Maslow's hierarchy based on that amount of energy surplus. So in the scenario of a great Simplification, which I chose that name roughly be, or specifically because of a financial disconnect, but you could apply it to broader society, I think it's gonna be important to distinguish between technology.

[01:09:18] That's nice to have. And technology that we need to have in order to survive. So in your opinion, in your expert opinion, is nuclear a need to have technology in order to maintain a certain level of a complex industrial civilization? Yes and no. And the, and that really depends on energy security. So in places that don't have coal or gas or tons of sun, then yes, and countries will continue to invest in it and maintain that for as long as these societies, are complex.

[01:09:50] **Chris Keefer:** And, you know, in terms of complexity, like you said, this sounds like one of the most complex technologies on planet Earth. I mean. But we developed it in the sixties and seventies and we have nuclear plants. Yeah, that's that. Were built in the sixties and seventies, still running. And we have can reactors, which were built even to get around some of the complex bottlenecks of having heavy forges, capable of forging massive ingots into reactor pressure vessels or enriching uranium.

[01:10:13] so I do think this is technology that's gonna be around for a while. you know, obviously there's, some bounds on this Great Simplification. I agree. Like at some point, I mean, everything that is born grows old and dies. And that will be

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the case with complex human civilization, whether we're annihilated by ai, nuclear weapons, energy crises, or just exhausting our resources.

[01:10:33] but in terms of, you know, the, I guess the deceleration rate of that, I think we will see nuclear power, maintained and grown in areas that really do need it. it is a complex technology, but listen, so is solar. You know, if you look at, you know, the spruce pine mine in North Carolina mm-hmm.

[01:10:52] Where the ultrapure quartz is taken to make the crucibles so that you can pull monocrystalline, so silicon and make, chips, but also solar panels. this is a very complex process. that's very, you know, there's one mine in the world, I believe they're bringing a couple on their own. The solar panels themselves aren't that complex, but to get them to your house installed, or your grid is.

[01:11:17] Yeah, well, manufacturing them is very complex. I think we just, you know, fail and a lot of my work in the last five or six years is just trying to get in and you know, ed Conway's book, the Material World was such a great deep dive of this, but like, we take all this stuff for granted at the top of the Maslow's Hierarchy, pyramid.

[01:11:32] Pyramid, and when you do educate yourself, you read Valo smi, you get down there and you understand how this stuff, all, everything is crazy complex. Nuclear is complex in its own ways, but you mentioned titanium, not really titanium zirconium, you know, there's issues. But, suffice to say it's a need to have technology in some places.

[01:11:48] it'll be maintained and grow in those places. and, you know, but it's not gonna happen everywhere for sure. So. In your opinion, what sort of lifestyles and technologies might also still disappear even if we were able to scale nuclear, well beyond our current levels? Yeah, and I mean, Nate, I think like when we talked two years ago, I was, under this delusion.

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[01:12:12] and I think it's easy to fall into these delusions when we face existential crises, right? To want a magic machine that's gonna solve all their problems. I used, and when I was very young, I thought there would be a magic political system that would solve all their problems, right? I mean, that's kind of a, it wasn't a Marxist mindedness, but I was pretty far left, right?

[01:12:28] but you know, when we, confront these existential crises, you know, we search around for a solution and we put all of our hopes into it and we don't wanna accept that there might not be a happy ending. So we force a happy ending, by imbuing, you know, in this case nuclear energy. which has a phenomenal narrative.

[01:12:45] With the capability to solve climate change, energy poverty, and create a utopia. I mean, it sounds so foolish, but that's where I was probably two years ago. I was coming off of that two years ago with you, but that's when this podcast started, you know, the decoupled podcast. That's, that was my frame.

[01:12:58] And so, you know, looking forward at, what life may look like in a Simplification, with or without nuclear, I mean, nuclear's not gonna scale and save the day. Absolutely not. It's gonna be niche, it's gonna be important where it's needed and it's gonna be deployed for energy security reasons.

[01:13:13] But that's the kind of lifestyles, I think that's just a broader question of what does a deglobalize world look like? Like we've grown really use, again, because aridian comparative advantage and economics and free trade, have provided really cheap goods, right? So we've gotten used to that. We've gotten used to cars with all sorts of widgets and wing ds in them.

[01:13:31] I mean, cars are probably gonna get a little bit simpler as supply chains constrict. Maybe we have less rare earth magnets and we're gonna have to roll the windows down ourselves, right? So it's really hard for me to, to sort of understand

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that and communicate that in really broad terms. But hopefully, you know, that little, car metaphor might be helpful.

[01:13:47] **Nate Hagens:** So what's been your, experience deep in this conversation? where there has certainly been a surge in hype. About nuclear, and yet, as you mentioned earlier, nuclear deployment is not exactly reflected this, uptick in discussion. Why do you think the discourse around nuclear is accelerating so much faster than it's actually deployment?

[01:14:12] And what's your general take on. Other people like you that are pro nuclear, but they're raging enthusiasm, for it, in the media. Yeah. I mean, narrative drives so much of this, and particularly in the startup space, like we've seen what I call nuclear meme stocks take off, so. There's a advanced reactor company called Oak Low, who are inspired by this, EBR, the experimental Brady Reactor two, which was this fantastic experiment, sodium fast reactor that, you know, treated its own, waste stream to extract even more energy and run through. It's a great narrative. It's a really cool idea that you'd be able to take, the stockpile of nuclear waste that we've generated, which is actually volumetrically very tiny.

[01:14:53] **Chris Keefer:** but there's potential energy still in there. We could unleash and power the country for maybe a hundred years just off of the nuclear waste that we've produced. It's, a great story. and you take that story and you, run into Sam Altman at Y Combinator and Sam says, you know, tech disruption, that's my frame.

[01:15:09] these stupid nuclear engineers, like, why is it they're struggling? this is a transformative technology. Again, three grams, of masses converted into enough energy to power a million homes. what's the, what's, what can I do here? How can I disrupt this? Maybe it's regulation.

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[01:15:25] Maybe I need to kind of deregulate it and it'll set the technology free. Maybe we need to try these technologies. Maybe they were just abandoned for lack of imagination or conspiracy theories. and so Sam Altman gets together with the founders of Olo and organizes a special purpose acquisition company merger, and they've worth 500 million.

[01:15:43] And then we're off to the races. And so that, that company, which, attempted a design to try and get it through the Nuclear Regulatory Commission and was rejected because of just how unprofessional they were, peaked in a market cap of over \$20 billion. What, in fall of last year and with 125 employees operating out of a small office, with no reactor design that's anywhere near approval.

[01:16:10] and, but you know, with Trumpian connections, Chris Wright, the, the Secretary of Energy was also on the board. They had a star-studded board. Does kind of whiffs of Theranos going on here. Yeah, we've seen this exuberance and we've seen retail investors pouring money into these things because they know that we're gonna need energy and nuclear.

[01:16:30] **Nate Hagens:** And so they just, and the narrative name, the narrative is good, right? So, AI needs 24 7 power. nuclear provides that in spades, 95%. And, you know, the hyperscalers used to be climate concerned, that's really slipping, as, Trump's policies have come into place, but there's still that hangover.

[01:16:47] **Chris Keefer:** and so there was a real interest in nuclear by these tech companies. And these tech companies have not spent six years, you know, deep diving in the technology and really understanding its history, but are caught up in, I think, some of their hubris and some of the narratives, and are category errors.

[01:17:01] It's just all over the place. But that, key one is between companies selling software and nuclear, which is the hardest of hardware. So again, if you are a tech.

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valley silicon, valley investor, and you've made pots of money off of, startups, gutsy startups with good narratives that have shipped, you know, minimal viable product and then debugged it as they went and turned into something that's, you know, like Airbnb or Uber.

[01:17:25] you kind of look at nuclear in that light as well, and you start trying to apply that same playbook, but you're talking about two fundamentally different things. Software, and again, the hardest of hardware. There's no putting a buggy product out and debugging it as you go with the nuclear power plant.

[01:17:38] **Nate Hagens:** So there's a lot of different types of nuclear technology, including, we've also heard that AI is gonna crack nuclear fusion, kind of. Can you give us a brief overview of the different possibilities, micro reacts, small modular reactors you mentioned earlier, like what are the benefits and drawbacks and what are, what's in the middle of the fairway, the things that are most likely gonna be viable, affordable, and built?

[01:18:09] **Chris Keefer:** Yeah. Yeah. No, what's incredible is the kind of zeitgeist we're living in is so full of this hype around small modular reactors and advanced reactors that, you know, the position I take, which I think is very evidence-based, which is, you know, what has risen to the top and proven itself economic, you know, with the purves of you've gotta build it on budget on time.

[01:18:25] And we used to be able to do that are large gigawatt scale water cooled reactors. Right? and my thesis is that's still the case. and the burden of proof is on the people saying, no, it's tiny little reactors, or It's my molten salt reactor, it's my sodium fast reactor, which was tried and didn't do well.

[01:18:43] Now it's not impossible that they're right, but. What's funny is I face a lot of, well, you know, prove it keefer. And I'm like, well, the proof's lying all around me. So we talked a little bit about small modular reactors and this kind of iron law

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of scaling. You have so many inherent costs. You have death by a thousand cuts in nuclear, right?

[01:18:59] so you need a big blood volume. If you've got a thousand cuts in your body, you know, those are regulatory or imposed by seismic qualifications or, you know, quality assurance or, you know, non-proliferation monitoring by the Atomic Energy Agency, et cetera. micro reacts are even dumber than small modular reactors because you're getting even smaller.

[01:19:19] So you have a tiny revenue. So if you start looking at it, and just an easy way to do this, is if you have a micro reactor that's producing, say, like 10 megawatts of electricity. So 10,000 American homes. if you're paying them, like \$130 a megawatt hour, you're generating about \$13 million.

[01:19:37] and then, and then you have to start dividing that by, what are the costs to pay back the cost of capital, to, you know, on an hourly rate, pay your operators and you end up crunching those numbers and you barely have enough money to pay your operators and security guards, let alone pay back the cost of capital, let alone build the mega factory that's supposed to be banging out these micro reacts.

[01:19:59] **Nate Hagens:** And if fossil fuels because of this Iranian war, have a new floor, all of these projections in proformas are gonna probably be more costly. Agree. So, I mean, again, suffice it to say, micro reacts, they've been tried. The US Army had a, micro react program. There was a famously this cool story here.

[01:20:22] **Chris Keefer:** They had a micro reactor that they made a snow fort with in Greenland. they buried a reactor under the Greenland, ice sheet back when they were thinking, of being sneaky with the Russians and having, intra continental ballistic missiles under the ice cap. it sounds, like some doctor evil stuff, but, they did a micro react there.

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[01:20:39] They had a micro react in the Panama Canal. There was a drought. The hydroelectricity wasn't so hot there. They moved a micro reactor down there. It powered the Panama Canal for a while. But all these things, were just horrib uneconomic. What does it say, I mean, you're a physical doctor, not a psychiatrist, but what is this sort of energy optimism that repeatedly surfaces, in our energy debates, especially during periods of perceived existential risk?

[01:21:04] **Nate Hagens:** What does that say about us? Or what, do you, think. it says, we're afraid of dying, Nate. Okay. Yeah, that's true. Right? And we're in denial. We're in denial a little bit. you last came on the show, I believe, two years ago, April, 2024. let me ask you, Dr. Kiefer, has anything changed substantially about your general worldview, that you'd like to share?

[01:21:29] **Chris Keefer:** yeah. I mean, I've gone from being an idealist to a realist in two years. Yeah, for sure. Part of that is a, is psychological coping mechanism to deal with the, the difficult times that we're in. you know, I've been called a nuclear Mormon because, I wear this cheap suit and pack, you know, reports about saving Canadian nuclear power plans and go to Ottawa and talk to politicians and knock on doors.

[01:21:50] you know, I still think there's a lot of value in the work, that I do and have done. but it's less, you know, I'm gonna save the world. It's more I'm gonna save, you know, 7,200 jobs. I'm gonna keep a flow of medical isotopes that are gonna sterilize 40% of the world's medical instruments. I still feel very passionately and I've probably come across as almost anti-nuclear in this talk, but I think there's a massive value proposition.

[01:22:11] but I think I've, adjusted, You know, the grandiosity down several notches in terms of the impacts that the technology have and that I can have. but I think ultimately that's a much healthier place to be in. I hear you. I mean it, this conversation we didn't even mention climate change, which is something both of

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us care deeply about, but funny how that fades when we're into an energy security crisis.

[01:22:33] **Nate Hagens:** Exactly. Yeah. and we were always headed to this moment. I just didn't think it would happen quite so soon. Which is then because of dumb human decisions, brought it closer. so do you have any closing thoughts for our viewers, that we haven't covered in this too? Brief conversation? things you might encourage people to hold as they I do continue through their everyday lives.

[01:22:59] **Chris Keefer:** You know, we live in dark times. and I think, you know, I'm, an Eastern European, I'm half Ukrainian. I've been diagnosed. I, didn't know that. Yeah, I've been diagnosed with defensive pessimism. So, as Ukrainians, you know, our national anthem is, we are not dead yet. you know, we're this flat country surrounded by great powers, you know, whether it's the Mongols, the Russians, the Germans, you know, the tartars, whoever else is coming through, we get our asses kicked.

[01:23:22] and so the safe thing psychologically is to assume the worst. And if it's not quite as bad as you thought, then it's a good day, right? And so I do have a, probably a bit of a propensity towards doism and, you know, having obsessed over climate for a long time I've been there, right? being, increasingly energy literate.

[01:23:39] I'm there having listened to The Great Simplification, I'm there. but wait. I'm in an incredibly positive psychological frame right now, and it's actually like I've readjusted the ordering of what I feel are existential threats. and I may have to now with Iran again, but AI has become something I've become quite preoccupied with and I'm diatribe there.

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[01:23:57] This is gonna sound completely ridiculous. but there, you know, there are thinkers who are saying human extinction by AI is possible in X number of years. Let's just pick three years. That sounds crazy to some, not to others. It probably is crazy, right? But I'm sort of choosing to live my life as if that's the case.

[01:24:13] And, you know, I've spent a lot of time not just doing emergency medicine, but palliative care and I've taken care of a lot of dying cancer patients. And the kind of clarity that comes with an understanding of your mortality, is a beautiful thing. And the potential to live your life better and every moment having poignancy and choosing how to spend your time better, has been really powerful.

[01:24:32] And, this is where it gets really dark and into stoic practice when I think not only of my own mortality in three years, but my son's mortality. He's seven now, he'll be 10, then I want that kid to have the best goddamn possible life for the next three years. So how am I living my life constructively, coming from a bit of a place of psychological doom?

[01:24:49] I mean, my kid doesn't rotten aftercare anymore. I get there as soon as school's over and pick 'em up and we go and do stuff, right? I really am trying to cherish time and spend it wisely, having idyllic times with my family, petting the dog more. I'm sure you feel for that. And so paradoxically, I'm in a very psychologically healthy space, despite how dark the times are.

[01:25:10] But in any case, I'm ranting here. Nate. enjoy the time you have, spend it wisely. see, the beauty in that. and that's really where I'm at and how I'm getting through, you know, these, difficult times. You're a good dude, Chris. Thank you for all your, passion and dedication to these topics and, to be continued, my friend.

[01:25:30] Sounds good, Nate. Thanks for having me back. If you'd like to learn more about this episode, please visit [The Great Simplification dot com](http://TheGreatSimplification.com) for

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references and show notes. From there, you can also join our Hilo community and subscribe to our Substack newsletter. This show is hosted by me, Nate Hagens, edited by No Troublemakers Media, and produced by Misty Stinnett and Lizzie Ani.

[01:25:55] **Nate Hagens:** Our production team also includes Leslie Balut, Brady Hyen, Julia Maxwell, Gabriela Slayman, and Grace Brun. Thank you for listening, and we'll see you on the next episode.