Nate Hagens (00:00:02):

You're listening to The Great Simplification with Nate Hagens. That's me. On this show, we try to explore and simplify what's happening with energy, the economy, the environment, and our society. Together with scientists, experts, and leaders, this show is about understanding the bird's-eye view of how everything fits together, where we go from here and what we can do about it as a society and as individuals.

(00:00:33):

Today's guest is James Fleay, an Australian engineer and energy project manager with over two decades of experience in designing, delivery, operation and carbon sequestration in the power, oil and natural gas sectors. He is also the founder of DUNE, Down Under Nuclear Energy, with a purpose of studying the case for nuclear energy in Australia, and understanding the parameters for its success.

(00:01:03):

This is the first guest I've had on The Great Simplification to address the often polarizing topic of nuclear power. James gives, what I believe, is a balanced view of the opportunities and constraints of nuclear power as it pertains to our current and future human predicament. Please welcome James Fleay.

(00:01:39):

Hello, James.

James Fleay (00:01:40):

Good morning, Nate. How are you?

Nate Hagens (00:01:42):

I am well, thank you. We are in different hemispheres, different time zones, different seasons, same minds thinking about the future of energy and society. You are the first guest I've had to discuss nuclear energy. Nuclear is a polarizing issue, and I think you, in our prior discussions, have a balanced approach. So I would like to ask you about all things nuclear power today. Maybe you could start by giving us a little bit of background of your educational and professional experience that brought you to this moment.

James Fleay (00:02:16):

Sure. Thanks very much for having me on, Nate. Might be aware I'm a longtime listener and fan and been quite affected by your work over the years. My background is, I'd studied electrical engineering and practiced designing and building industrial electrical infrastructure, including combined-cycle gas-fired power stations. Was involved in sort of large desalination water projects, and particularly the utility scale solar sector for quite some time.

(00:02:45):

We had a small business, a couple of business partners and I, providing owners engineering services for the solar sector. And we were actually developing our own project. This is probably about five and a half, six years ago. We'd done the design. We'd sort of initially it looked quite prospective. And as we were getting to the point where we were trying to raise capital, we had the necessary approvals that we needed, we reran the financial model and despite the fairly generous subsidies that were available to solar investors in Australia at the time, we couldn't make the economic model stack up.

(00:03:21):

I couldn't really understand why this was the case when electricity prices were high and rising, and there was a demand for zero carbon energy. Anyway, this started a deep dive, and that deep dive wound up with me coming to the realization that nuclear energy has a role to play globally, but also in my home country of Australia. It's not a silver bullet for reasons I'm sure we'll get into. It doesn't solve all problems, but it has an important role to play as we decarbonize and as we get to the, I say the twilight years of the age of hydrocarbons.

Nate Hagens (00:04:05):

Not to go down too many rabbit holes because I expect 14 rabbit holes at least, but what is the energy independence situation of Australia? I'm not real familiar with that. You have a ton of coal. I know that.

James Fleay (00:04:18):

We do. We have a lot of coal, and in that sense, our electricity system has traditionally been very strong, both low cost and high levels of energy security. As we've moved towards renewables more and more, that requires us to import the technology, we don't manufacture it, so that sets up some dependencies, but at least not on fuel,

which is positive. And we also have fairly significant gas reserves. We haven't developed them in a way that is very sensible in some parts of the country, but we have fairly significant gas reserves and we have the capacity to get more out as needed.

(00:04:53):

Where we're really exposed is liquid fuels. We went from being independent and producing all our own liquid fuels in the sort of early mid '90s, to now importing the vast majority of liquid fuels as finished products. Not so much as crude oil, but a lot of it is finished products. And so we have an enormous energy security issue there.

Nate Hagens (00:05:13):

Is there any talk or projects of Fischer-Tropsch, turning coal into oil, or not really?

James Fleay (00:05:20):

Not on the books.

Nate Hagens (00:05:21):

So why don't we start with a brief overview of some bird's-eye pros and cons of nuclear power for energy for humans.

James Fleay (00:05:31):

Sure. So nuclear energy produces no carbon dioxide or other airborne pollutants. Its waste form is solid and very, very compact. So that's good. The land usage requirements are very modest and has very modest material requirements compared to other sources of energy. And that's true of both solar and wind, but it's also true of the material requirements that go into coal and hydro plants, for example.

(00:06:02):

The plants last a very long time. Okay? This plant's been licensed for, the license extensions to 80 years and people in the industry are confident that some of these plants will get to a hundred years. Time will tell, I suppose. During that time, the price of the electricity that they can supply is very stable and is very predictable. So low volatility.

(00:06:25):

Nuclear does not need to be close to its fuel source, and so you have quite a bit of flexibility with siting. A fresh fuel load every two years. About a third new fuel comes in, can come in on about half a dozen large trucks, so you don't need to be near pipelines or coal mines or really large ports. There's some social benefits to nuclear as well. I mean, the jobs at a nuclear plant are well-paid, they're multi-generational jobs, and so you get that good continuity within a community as well. So there's some of the pros that we highlight.

Nate Hagens (00:07:01):

Okay, so let me ask you a question about that. You said that nuclear electricity is stable as far as the prices, but how much of that is dependent on the two year re-upping of uranium inputs and how much of it is dependent on the massive capital that goes into a plant that might last 50, or you said 80 or more years?

James Fleay (00:07:21):

Good question. So the vast majority of the cost of nuclear electricity is to do with the capital cost, the upfront capital cost, and in particular, the financing costs associated with that upfront capital cost. The cost of nuclear fuel and its consumption and reactor is really quite modest. I've seen calculations that sort of say between six and 10% depending on where you are in the world.

Nate Hagens (00:07:50):

So the way that I see that then instantly, and I hadn't thought about this before, is nuclear would be considered, in financial terms, a long energy duration asset. Meaning that in finance, if you expect interest rates to drop, you want to own things that have a lot of exposure to interest rates like 30-year bonds because then you make the most money.

(00:08:12):

If we are in an environment, which you and I probably think we are, that energy prices are about to get substantially more expensive over coming decades, you would want to lock in something like this that has that stability that as prices go up, the electricity price won't fluctuate that much. Does that make sense?

James Fleay (00:08:34):

It does make sense. And a good example of this is Hinkley Point C in the UK. When that project was sanctioned, the contract for difference, the strike price was 92 and a half pounds per megawatt hour. And at the time, that was expensive electricity, no question.

(00:08:53):

Most of that was driven by the way that the project was financed. Fast-forward to the present day, and that 92 and a half pound strike price actually looks pretty good at prevailing wholesale prices. And so you can see where that stability, that price stability becomes a real benefit for the grid.

Nate Hagens (00:09:13):

So those are some of the pros. What are some of the cons?

James Fleay (00:09:15):

We talked about the large upfront costs. There's no getting away from that. It is an expensive form of power generation to build up front. And it comes with, particularly in Western nations who have fallen out of practice for building large complex projects, it comes with some significant delivery risks. This can take the form of budget escalation, really significant budget escalations. It can take the form of pretty atrocious scheduled blowouts. 15 to 20 years for some of the most recent Western reactors, particularly in Europe, looking at Finland and France is extraordinary. So that's one challenge.

(00:09:56):

You require a really high level of technical sophistication as well. So the availability of the workforce to both build and operate these plants is not assured. The big thing as well is when uranium and also plutonium fission inside a reactor, they do release an enormous amount of energy, but the resultant products, what we call fission products, are highly radioactive, they're very dangerous. And different aspects of the different nuclear waste can stay radioactive for long periods of time, thousands of years. So the waste is manageable, but it's certainly something that needs to be confronted and dealt with.

Nate Hagens (00:10:39):

Okay, so I'm going to have probably more questions than you have answers for, but I'm going to just interject here. How many nuclear power plants are there in the world, and how many are under construction? Just ballpark.

James Fleay (00:10:51):

So this last count, I think there's about 440 operating reactors. And under construction is between 50 and 60. And that includes obviously a fairly significant number in developing nations being built by Russians and Indians. So that's where most of the work's being done.

Nate Hagens (00:11:10):

And how many of those use uranium versus plutonium, roughly?

James Fleay (00:11:15):

The vast majority of them use uranium. A decent portion of the French fleet use what we call mixed oxide fuel, which uses some plutonium, but most of them use naturally available mined and enriched uranium.

Nate Hagens (00:11:32):

So one of the cons is the complexity and the long lead time to build a plant which you don't get any energy until the plant is finished. So is nuclear power, knowing what we know now, knowing the work of Joseph Tainter and Dennis Meadows and the societal complexity that we face, is nuclear power something that we should have built and scaled when societal energy surplus was high and increasing, not at the time when we're approaching limits to peace and finance and other things? That is a non-trivial assertion and question, yes?

James Fleay (00:12:14):

Yeah, it certainly is. I don't think the challenge lies with the technology. I don't believe the technology, even the current form, much less future forms of the technology need to prove itself, as such. I think the onus lies on, in particular Western nations and our methods for political economy and financing. The onus lies on us to prove that we are capable of deploying it and managing it through multiple generations, including to a safe decommissioning.

(00:12:49):

And if energy becomes more expensive, and there's every reason to think that it will, and if our economic complexity and our technical know-how and knowledge starts to decline, then our ability to build and safely manage nuclear infrastructure, not just the power stations but also reprocessing infrastructure, enrichment infrastructure and of course, disposal infrastructure, yeah, definitely becomes less certain.

(00:13:16):

I don't think this is going to be as much of a challenge for, I would say some other nations. I'd look at particularly Northeast Asia, Japan, South Korea, China, probably the Middle East as well. I think they are more unified and they'll probably have the ability to safely manage that infrastructure, but it's not clear that Western nations are cohesive enough to do that.

Nate Hagens (00:13:40):

So I want to get back to more of the cons. But here's, from my standpoint, the biggest con for nuclear of all, is it kind of... and this will get back to your waste observation. There's this implicit assumption of societal continuity for decades or centuries or even millennia that somehow humans will piece together our civilization and complexity and connectiveness.

(00:14:09):

But if that were to one day change from an EMP pulse or from a nuclear bomb that cuts out internet cables or whatever, we have these 440 plus 60 nuclear plants that, what happens? Within a couple weeks if they don't have diesel, the backup generators that cool the spent fuel rods work out to some Chernobyl like event? Or what is the risk there? How would it manifest? And am I right about that or are there ways to mitigate that?

James Fleay (00:14:44):

If you genuinely believed that industrial civilization could rapidly decline, or even end abruptly in the case of sort of an EMP event from outer space, then you'd pause before building new nuclear power stations. So I agree with that. But then that's true of a lot of things that humans do. And that's true of a lot of different aspects of industrial society, not just nuclear energy.

(00:15:11):

And so I'm not sure that keeping an open mind about what could go wrong, that's a prudent thing to do. And again, it's not really catastrophizing, but you have to plan for continuity. You have to work towards that and accept that there are some things that may happen that are outside of our control that may compromise that. And in that event, does nuclear energy and its legacy infrastructure and particularly spent fuel present a particular challenge? It does, but lots of other things do as well. It's certainly not sitting in the corner by itself. I think we'll have bigger issues if we revert to a pre-industrial way of life than just managing those legacy assets.

Nate Hagens (00:15:50):

Well, I think you're right. First of all, I'm not planning on an abrupt end to civilization, but I certainly do think it's under the curve of possibilities. We could argue about the timing. But even if it's a hundred years from now, there's still those spent fuel rods that the waste is radioactive for millennia, you say, right? Is that an exaggerated risk or is that a big risk, if such an event were to happen?

James Fleay (00:16:23):

Our current approach globally to managing spent fuel from reactors leaves a lot to be desired. In the short term, it's very safe. It's proven. So particularly in Western nations, but I think this is also true more broadly that there has simply not been any accidents with spent fuel from commercial nuclear power stations.

(00:16:48):

I think weapons programs have probably had some more issues. But it doesn't mean we are doing the hard work necessary to prepare spent fuel for final disposal. Now, there's lots of pathways for this. It could be deep geological storage as is. So no reprocessing, no closing of the fuel cycle to burn the long-lived waste, to create more energy, and also significantly reduce the final volume of waste that has to be stored. There's lots of options that we have, but for political reasons in the West, we're not actively getting after them.

(00:17:26):

This is changing. I think there's reasons to be hopeful. I mean, you look at Finland, they have started construction on their deep geological repository. The Joint Research Centre, so the scientific advisory body to the EU have concluded in work, I think that

finished in 2021, that method is both appropriate and safe. I think that's pretty definitive language for that type of organization.

(00:17:48):

So it's not that solutions don't exist, it's that we don't seem to be in any hurry to begin to implement them at scale.

Nate Hagens (00:17:55):

Is that because we don't recognize that the risk is that high and that therefore it's not that important? Or is it because we're kind of borderline insolvent and that would be more money that has other priorities to be used?

James Fleay (00:18:10):

No, it's not an issue with money. The money is there. The industry has been putting aside money more or less since its inception to pay for final disposal of fuel. The issue is politically, it's much easier to kick the can down the road. Because of the fear and stigma that has been attached to nuclear energy, it's very difficult to site - you've got to locate one of these deep geological repositories. I mean, look at Yucca Mountain in the US. That's a perfect repository. Billions were spent on developing and the early construction of it.

(00:18:47):

At this stage, it's never going to be used. And that's purely for political reasons. So that's an example of where we're not doing a good job to manage one of the downsides of nuclear energy, which is the waste. But that's a political issue, not a technical issue.

Nate Hagens (00:19:01):

And not to catastrophize, because I don't, I just try to look at different risks. Would you say that the pro-nuclear lobby, the fanatic emails I get from people saying, "Nuclear's the answer, how come you don't mention it?" Would you say that most of those people implicitly believe there will be societal civilizational continuity for centuries? Is that not even discussed? It's so obvious to-

James Fleay (00:19:31):

It's an assumption.

Nate Hagens (00:19:32):

... that... Really?

James Fleay (00:19:33):

Definitely.

Nate Hagens (00:19:33):

Okay.

James Fleay (00:19:33):

Sorry. No, I'll just point out, we don't have a political basis for assuming otherwise.

Nate Hagens (00:19:38):

Well, I hear you, not only on this issue, on many other other issues. Because it's almost like we're playing this complicated strategy game in real time, because obviously your experience with the solar scaling, there are problems with solar and wind. There's certainly problems with flammable fossils. Not only do they have CO2, but they're also depleting. There's problems with nuclear, but there's also benefits of nuclear.

(00:20:06):

Then the other energy source is conservation and maybe choosing something other than GDP as a cultural metric. There is no perfect thing, which is why we're playing whack-a-mole somehow to figure out how all this stuff fits together.

(00:20:22):

But on nuclear power, let's just say that largely people agreed that nuclear was the least bad and that the risk could be managed. I almost think that the long development time, 12 years or so, makes it that the market can't choose to scale nuclear to the level that would be required. Because now a government could or maybe there could be some crash plan with subsidies or some joint corporate government initiative like a Manhattan Project for electricity, but it seems to me that the market itself, by choosing at the margin every quarter, every year to five X our nuclear plants, that would never happen. Do you have any thoughts on that?

James Fleay (00:21:11):

I think you're exactly right. There's no indication that the market is capable anywhere in the world. This is not just in Western nations, but any market anywhere is capable of the long-term thinking and planning and investment necessary for a nuclear program. And it's not just the construction of a standalone power station, it is the infrastructure required to support a program, a fleet of reactors.

(00:21:39):

If this is to be successful, it will require a very active government. And in those places we see active farsighted governments, we see healthy nuclear programs. We see it in South Korea, we see it in Japan. We see it particularly in China, also in the Middle East. I mean, you look at the UAE and they've got ample hydrocarbon reserves, plenty of sun. On the surface, it wasn't obvious that they had to urgently adopt nuclear energy, but they have a far-sighted and active central government that decided, for reasons to do with primarily carbon emissions, but also diversity of fuel, that they were going to go down that route. And they have, and they built a really successful program.

(00:22:21):

So I think it's less of an issue in places with strong, active, competent government, but the market will never deploy nuclear by itself.

Nate Hagens (00:22:33):

So again, let's look at the possible bullish case for a big build out of nuclear. Uranium is the majority of the fuels of the 440 plants with a little bit of plutonium, you said. Uranium is still non-renewable. And technically, so is any other fuel we could think of, no matter how plentiful it might currently seem. How much uranium is reasonably recoverable? And if society did somehow manage to go to nuclear power in a much larger way than we have today, how fast would this deplete and would there be limits on that?

James Fleay (00:23:15):

So the World Nuclear Association, I think they updated their calculations last year or the year before, have estimated that with the nuclear plants we have in the world today, including those that are under construction, due to come online and factoring in lifetime extensions, that known reserves of uranium that are profitable to recover at prices three times today's spot price, that we have about 90 years of supply, okay?

(00:23:41):

Now that's increased from 80 years of supply when they last did the calculation a decade ago. So we've discovered more in the meantime. And that's despite very anemic exploration. So uranium is quite plentiful. And as the price goes up, we will certainly discover more. But it is true it's not renewable, right? We're consuming it.

(00:24:05):

We've got better at extracting the energy more efficiently from a given quantity of uranium. From 1980 to 2008, the electricity that was generated by nuclear power increased globally, I think it's 3.6 times, but the amount of uranium that we used only increased by a factor of two and a half. So there are things that we are doing to get more energy from a given quantity of uranium.

(00:24:30):

There's lots of uranium in the oceans. It requires a much higher uranium spot price than we have today. I think at least 10 times higher.

Nate Hagens (00:24:38):

And when it gets 10 times higher, then it's going to need to be 15 times higher?

James Fleay (00:24:43):

Yeah, it's a risk.

Nate Hagens (00:24:45):

Well, just the concept of receding horizons.

James Fleay (00:24:47):

Yeah, it's definitely-

Nate Hagens (00:24:48):

Because all the other inputs will also go up at that time.

James Fleay (00:24:51):

It's a good point. I mean, the Japanese estimated that I think they said you'd need a price of about $300. And that's for a pound of yellow cake. That was back in the early

2000s. And by the mid 2010s, I think the US Department of Energy has said, "Oh no, we think you'd need closer to 600." So there's something to be said for that.

(00:25:13):

But the uranium is there. That is known. It's also produced as a byproduct for certain types of mining, particularly agricultural phosphates. There's some particular types of shale, particularly in Sweden where uranium's been produced as a byproduct. That's not counted in world uranium reserves. So we do have quite a bit left.

Nate Hagens (00:25:31):

So we'll get to alternatives to uranium in a second. But if we're just using uranium technology, we have a century, but not millennium. So we talk about nuclear power in our current form, it will extend a couple generations, but it's not unlimited based on uranium.

James Fleay (00:25:55):

Well, it depends what type of uranium you're talking about. Okay, so all the discussions today and all the technology that we have commercially deployed today is based around uranium-235. Uranium-235 is a very precious, in my view, uniquely precious resource. And the truth is we're consuming it in a fairly inefficient way, not really with an eye to the future.

(00:26:21):

So about 0.7% of naturally occurring uranium is this special isotope, U-235. It is the only naturally occurring isotope that is fissionable. Okay? Which is what you need for the current generation of reactors.

Nate Hagens (00:26:35):

What does the 235 stand for?

James Fleay (00:26:38):

So that's to do with the number of neutrons within the nucleus of the uranium. So all uranium isotopes will have the same number of protons, but they have different numbers of neutrons. And so uranium-235 has slightly less neutrons than the much more common uranium-238, which is three additional neutrons. Very slightly heavier, and that's why you can separate them using centrifuges.

(00:27:01):

Now that uranium-238 is not fissionable, but it's what we call fertile. And you and I briefly touched our correspondence on the possibilities of thorium. Thorium-232 is also what's known as fertile. And what this means is when it captures a neutron, it goes through a couple of stages of beta decay, and it will transmutate into a fissile product, a fissile fuel. Now these are synthetic elements like plutonium-239, okay, or uranium-233. But in this way using breeder reactors, we can massively extend and close the fuel cycle.

(00:27:46):

And the estimates are that you could increase the amount of energy for a given quantity of heavy metals by about 60 times by using alternative types of reactors. Now, back at the start of the Nuclear Age, there were real concerns around how much uranium-235 was available in the world. They thought we would run out.

(00:28:03):

And so a lot of work was done, and many of these fast neutron reactors were built in the US, UK, Russia, other places. There were some technical challenges with them, but the science was proved up and the engineering was understood. But it turned out that we had much more uranium-235 than we realized, so they were abandoned. But if we are to confidently assign a role to nuclear energy that extends past, say a couple hundred years, we will need to make use of uranium-238 and thorium at some point in the future.

Nate Hagens (00:28:40):

Hey, what's the deal with thorium? I hear a lot of that in the news, sometimes in combination with molten salt reactors. Can you first explain how thorium differs from uranium, and what would be some of the advantages and disadvantages of a thorium molten salt reactor?

James Fleay (00:29:00):

So thorium is more abundant than uranium. I think it's about three times more abundant. And it's more widely spread around the world. So it's not as concentrated in places like Canada, Australia, Kazakhstan, for example. It is slightly lighter than uranium, but it's still a heavy metal. It has some advantages over uranium if you use it in a breeder reactor, a fast neutron reactor, but it also can be used with thermal

neutron reactors. So we talk about different speeds of neutrons and different isotopes are more likely to catch a neutron of different energies, right?

(00:29:38):

So we talk about thermal, which is slow. We talk about fast neutrons, which are high energy neutrons. Thorium has some real advantages. And there's a great piece that was put together by the IAEA back in 2005 that talks about the benefits of it. It has intrinsic proliferation resistance because the fission products are very difficult to… Well, not the fission products, but the uranium-233 and uranium-232, which is what thorium evolves into. Very difficult to handle, so much less harder than plutonium, for example.

(00:30:10):

Better thermal properties, better chemical properties, so more stable. The waste form is more stable. You've got fewer longer lived actinides. So thorium's got some real advantages. And we have built reactors in the past that have given us a lot of confidence in our future ability, provided we can maintain our sort of economic complexity and technical know-how to build these reactors.

(00:30:35):

We don't have any operating in the world at the moment. There's non-trivial engineering issues that have to be worked through. And there's certain things about the technology we have to shake down. There's lots of different thorium concepts. So we need to sort of round out on those thorium concepts that we think are the most promising. But there's no question that in time, thorium will become part of the fuel cycle.

Nate Hagens (00:31:01):

Isn't China building some thorium plants now?

James Fleay (00:31:05):

I understand they have an experimental reactor to utilize the thorium fuel cycle and to do basically what we really need to be doing in the Western nations, which is shake down the technology to get it ready for commercialization. But I don't think they have any commercial plants.

Nate Hagens (00:31:20):

So uranium-235, uranium-238, some hybrid mix, the French are using with plutonium. Thorium, molten salt reactors. Are there any other theoretical ways or innovation using nuclear power to generate electricity on the horizon?

James Fleay (00:31:38):

If we're just talking about fission, then you sort of got the main ones there. There's lots of different reactor designs that use different types of coolant, different moderators, different fuel forms, some that will purposely consume the sort of long-lived transuranics. There's synthetic elements that are heavier than uranium, which can also be utilized for large amounts of energy.

(00:32:03):

Many more types of reactor on paper that we're ever likely to build. Okay, we'll have some clear winners and they'll become more obvious as time goes on. Fusion, that's not something I really know much about, to be honest. It still seems a long way off in my view.

Nate Hagens (00:32:17):

So the advantage on the surface for thorium is it's more abundant and the waste is more easily handled?

James Fleay (00:32:26):

It's more stable and it's less longer lived. It's not all beer and skittles and skills for thorium. It too has some challenges. What makes it proliferation resistant, also makes it reprocessing and handling waste very difficult, which is extremely active gamma radiation from uranium-232.

(00:32:48):

So yeah, particularly if we were going to use a solid fuel form of thorium, we would have to develop really sort of sophisticated techniques for remotely handling that irradiated fuel. I think there are some liquid fuel designs, particularly molten salt where you may be able to avoid some of that handling. So some of those are quite perspective, but I think they've got at least a couple of decades of development ahead of them before we're likely to see commercial reactors. They're not ready to go, put it that way.

Nate Hagens (00:33:20):

So safety risks aside, depletion of uranium and thorium aside, there are people who quite vocally argue we should become a society that is 100% powered by nuclear energy. Is this even possible? What are your thoughts on that?

(00:33:40):

And if not 100%, what could the role, assuming all the innovation, assuming the complexity, assuming the capital costs, all that works out, what could the role of nuclear power be best case?

James Fleay (00:33:52):

We'll have to come back to liquid fuels because that's a different type of challenge. But if we think about electricity, we think about process heat, maybe maritime transport, could we get to a hundred percent nuclear energy? I don't see why not, but I don't think it would make much sense. It's got many wonderful attributes and characteristics. It's ideally placed to make a significant contribution to future energy mix, but in its current form, in particular, it definitely has some limitations. And these are more to do with the fact that economically get the most out of these plants.

(00:34:31):

You don't want to be operating them in sort of on and off power cycling, basically. You don't want them to be load following. They don't act like that. You just want them to provide a constant amount of base load energy, and they've got a real role to play there. I think the discussion around energy, future energy mix, probably needs to move beyond saying, "This technology's better than that or more well suited than that." It really needs to get to a point where we're talking about how to intelligently combine technologies in full awareness of both their attributes and their shortcomings.

(00:35:07):

So we need to allow them to play to their strengths. And that's really to do with how we combine them and how we operate them on the grid. So making them compete against each other, that's a little bit of an economic.

Nate Hagens (00:35:23):

Well, you hit the nail on the head. We look at the world like it's an economy. And the economy is powered by money and technology. We don't look at the world like it's a

system, and how the parts and the processes fit together. For instance, nuclear combined with solar and wind is not a good combination because nuclear is flat line, on or off, like you said, and solar and wind fluctuates.

(00:35:49):

Both of them, either nuclear or solar and wind, are great in tandem with natural gas-combined cycle, which you can turn on and off, or the peaker plants relative to current human demand. So I wonder if there will be a day in coming decades where it's the human demand that changes more to fit the energy mix that our society or our country has available.

James Fleay (00:36:15):

That's an interesting thought experiment. And I wonder what the implications are, and maybe the unplanned sort of consequences are of trying to adapt our society to natural energy flows. I think that would be quite difficult, actually. I think the way the grid is set up at the moment to provide the amount of energy that we need when we need it based on working five days a week, based on coming home and cooking of an evening, based on the seasons, is better suited to human prosperity and human needs. It just means we need to intelligently combine technology.

(00:36:54):

So we need to remember that with a system, an intelligent system design can and should exhibit performance characteristics that are better than any individual part of that system could achieve by themself. It should give rise to new attributes and new dynamics and better performance, if you intelligently combine all the bits. And what could look like a fair amount of nuclear energy, particularly legacy nuclear energy at the sort of bottom of the mix providing that stable power, is probably going to include a fair amount of solar and wind combined with medium duration thermal storage to allow us to better manage those natural flows and map them to daily demand profiles.

(00:37:40):

So if you look at some of the hot rocks technologies and oil and concrete type thermal technologies, storage technologies, I think they will open up a lot of opportunity to expand the role of renewables. I find it hard to believe we're going to get away from gas rapidly. Gas is just so useful and so versatile. And I think it's going to fill holes and niches in our power system for a long time to come, actually.

Nate Hagens (00:38:07):

I agree. One of my PhD papers 15 years ago was I applied a financial metric called the Sharpe ratio to the EROIs of different fuels, and natural gas was by far and away the highest return because it could be used to plug the gaps in all these other things. It smoothed out everything. So I happen to agree with you on that.

(00:38:30):

So it seems like it will be a country by country basis how they can build the grid that's most assimilable to their situation. Your country and mine have advantages there because we live in provinces that were ancient oceans and have the geology of stored hydrocarbons, but other countries like Japan don't have indigenous energy resources. So nuclear is more of an option for those countries without hydrocarbons, or how do you expect that to play out? I'm not asking you any easy questions, James.

James Fleay (00:39:10):

The Japanese and South Koreans have understood for a very long time by necessity of their pretty precarious position at the end of global energy supply chains, that fuel diversity is essential to them. Fuel diversity means they have traditionally... Let's say, take South Korea. About 30% nuclear, about 30% gas and about 40% coal. Now renewables, they've got fairly minor hydro reserves, every little bit of land in South Korea is consumed with something, whether it's agriculture, whether it's industry, whether it's housing. There's just simply not large tracks of vacant land like there is in a place like Australia.

(00:39:55):

So solar and wind are going to have challenges in South Korea. So the question becomes what can replace the 30% gas and 40% coal? Well, I think nuclear can make a fair dent in them. I think South Korea, if it were ever to have better relationships with China, may consider also buying some renewable energy from China over the borders. But I find it very difficult to imagine a country like South Korea, and this is true of Japan, can truly give up the security, the energy security that comes with fuel diversity. And I think gas and coal will have some role to play. Probably a diminished role, but some role to play in those nations.

Nate Hagens (00:40:35):

So electricity globally is around 20% of our energy use. The rest is heat, transportation, liquid fuels, things like that. In a perfect world, a country like South Korea or Japan that could build out nuclear, could they increase that 20% so that something like nuclear could provide a much higher percentage than just the electricity via different heat schemes? Or what are your thoughts on that?

James Fleay (00:41:09):

Nuclear is well suited to providing heat. At the moment in its current form, because of the limitations of the fuel, it's reasonably low temperature heat, say 300 degrees. That will satisfy a fairly large range of industrial heating applications. But there's many things that it won't do. There's a lot of heating applications that require in excess of 500.

(00:41:35):

If nuclear plants with new fuel forms can be brought up to 500 to 800 degree range, then they'll make a real dent in process heat. And there's every reason to think that they will be able to do that.

Nate Hagens (00:41:47):

But they still wouldn't be able to make steel or those sorts of arc furnaces that are much higher.

James Fleay (00:41:54):

No, not at that temperature. But they can make electricity, which can be used in those applications. Now on an energy balance, that's a pretty inefficient way to do it. You always want to try and utilize the heat as heat if you can. If you simply don't have the temperatures needed, then you can electrically create that.

(00:42:13):

I think liquid fuels, particularly trucking, personal transportation and aviation and rail present an enormous challenge. And it's not clear that... I've heard and done quite a bit of research into the possibility of both high temperature steam electrolysis using nuclear to produce hydrogen and then ammonia, and using that as a liquid fuel, as well as sort of more Fischer-Tropsch type processes, and the creation of synthetic fuels using the nuclear energy as the primary heat source. That's fine. We know it's possible. It's just the implications of that.

(00:42:59):

That form of liquid fuel will never be as cheap. There is no reason to think it will ever be as cheap as what we currently have. And I think it's very optimistic to think that it would get to a point that's sort of between three and five times the price of liquid fuel today. And so that has implications for global supply chains, it has implications for the way we live and the extent of our mobility, regional mobility, global mobility.

(00:43:29):

I've got an interesting story to tell you. During COVID when China blocked down and shipping rates, container rates, everything like that went through the roof, a friend of mine was doing a renovation out in his garden and he had to go and buy some washed pebbles from our hardware store. We've got a big chain here called Bunnings. So he goes to Bunnings, he buys them. Anyway, caught up with him. He said, "Well, guess what I heard from the fellow at Bunnings today?" I said, "What's this?"

(00:43:55):

He said, "I went and bought these four or five bags, about 15 kilograms each of washed pebbles." And he was very excited to tell me that for the first time in 15 years, it was cheaper to get those pebbles in Australia, to source them in Australia, to wash them and to bag them and to take them to the store, than to get those washed pebbles from China. And so you think about how cheap liquid fuel has been, and you think about the sorts of staggering implications of what it's enabled. I mean, moving very low value washed pebbles from one side of the world to the other, and those sorts of things just won't be viable with fuel three to five times the price it is today.

Nate Hagens (00:44:39):

Yeah, not only are we energy blind in that we don't understand how important energy, particularly liquid fuels are to our culture, but, well, we're also blind to the fact that this stuff is not interest, it's principal that we're drawing down. But we're also blind to energy fungibility and energy properties because there are a lot of people that just think, oh, solar, oh, nuclear, just get rid of coal and gas and we'll get this other energy source.

(00:45:11):

But liquid fuels are the king. And as those deplete, we are not running out, but we will be running out for the amount of complexity and financial claims that currently exist.

So in my book, nuclear is a lower layer down on the questions that we should be discussing. We need to plan for what I think is an end to growth and deal with that. But simultaneously, there need to be people working on the 30 to 50-year plan, and I think nuclear could play a role in that, but it is not one of the things that's going to solve what's happening this coming decade. That's my stance on it.

James Fleay (00:45:54):

I agree that in this next decade, if we start to see the decline of the reliability of supply of oil and increase in prices, I think there's a case we made that we will see that. Maybe we could disagree about the exact timeframe, but that's sort of at the margins.

(00:46:14):

Then nuclear is not well positioned, nor is anything else, mind you, to come in and replace oil. Oil's not a hard act to follow. It's actually an impossible act to follow. Anything that comes after will be more expensive. It will be, initially, anyway, less available and less reliable. And that is going to have profound impacts on our ability to sustain economic growth, to pay down debt, to service debt, all those things, I mean.

Nate Hagens (00:46:44):

So is there a deeper problem within our energy system that goes beyond what type of energy we use, and goes more towards the question of how do we use it? How do humans use these non-renewable, complex, amazing energy things that we have access to today?

James Fleay (00:47:07):

So when you talk about the phenomenon of energy blindness, and I love that, I think combined with some of our prevailing economic ideas, energy blindness has led us to become incredibly wasteful, not just of energy, but also materials, wealth and even our own time. So thrift and frugality in living memory were sort of preeminent virtues in our culture. They still are in some other cultures. And by virtues, that sort of means that they were intrinsically good in their own right, not just because they were practical.

(00:47:40):

That way of looking at the world, and you talked about principal and interest, and we're drawing down hard capital in the way of our hydrocarbon reserves. We don't think about it like that. We think about it as more or less a never-ending resource that will always be available and will hopefully get cheaper over time. And there's no basis for that outlook.

Nate Hagens (00:47:58):

Other than the psychology in our minds the last 50 years, that's the basis for it.

James Fleay (00:48:03):

Yeah. I sort of look at some of the prevailing economic ideas. I look at the impact of advertising. There's lots of reasons why that might be, and I'm probably not the right person to discuss what they could be. But it's undeniable that the levels of consumption that we have of just raw materials is unsustainable. And I think a lot of this has got to do with mobility, actually.

(00:48:27):

So we can talk about consumption of non-discretionary items. We can talk about the fact that we build cars that with care and maintenance can last half a million miles or more, and that we habitually get rid of them when they've done a small fraction of that and replace them. So that sort of throwaway culture. We can talk about all those things, but mobility is the big challenge for humans. We have become really accustomed to moving ourselves and our goods, the things we produce, all over the world rapidly.

(00:48:58):

I mean, you only need to look at the rise of air cargo in the last few decades to sort of go, "Wow, that's an awful lot of material we move by air now." Without doubt, the most energy intensive form of transportation. So I think a world where we have declining availability of liquid fuels is one where we move around a lot less, and the goods that we produce will have to be produced much closer to home.

Nate Hagens (00:49:26):

So given that Australia, although it's a continent, is also an island at the end of global supply chains, is there a emotional, psychological awareness of climate supply chain

energy depletion that's a little more present in your country than maybe the rest of the world? Or what's been your experience?

James Fleay (00:49:51):

I don't think so. No. Australia is a high consumption nation. It's not obvious that concerns around energy security and availability and supply chains is given much thought by many people, including, it must be said, a couple of generations of policymakers. There's signs that that's shifting though. And our extreme lack of energy security, when it comes to liquid fuels, is entering the public conscious more and more. So I would say that that's one thing.

(00:50:26):

There's also been a long and really vocal environmental movement in Australia. And it's overwhelmingly been a force for good. I mean, we're certainly not perfect in many ways and we don't recycle as much as we should, but environmental preservation and not littering and high environmental standards for industrial projects and mining projects have been in place in Australia for a long time. So I would say we're pretty environmentally aware as a country. But no, we consume just as much as anyone else, probably more.

Nate Hagens (00:50:57):

So you have been recently particularly active in attempting to get nuclear power implemented in Australia as a larger percentage of the energy mix. Are there any lessons from those experiences that you think could be applied to more countries?

James Fleay (00:51:12):

It's a really silly idea to drag matters of technology and engineering and complex systems into political culture wars, because then it becomes very, very difficult for the respective sides of that culture war to change their position. And that's the biggest challenge we have really in Australia, is nuclear energy was an early casualty of the culture wars and the people that are running the country today are finding it very difficult, they're only human like the rest of us, they're finding it difficult to back away from those prior positions.

(00:51:50):

And so avoiding contaminating technical issues like that, issues which need a rational sort of scientific approach, contaminating them with the culture wars and introducing things, concerns around safety and waste, many of which are unfounded, that's put us back decades in this country. So avoid doing that.

Nate Hagens (00:52:13):

But I'm trying to educate people in the United States government about energy depletion and limits. I think you're right, though, people, it used to be they would listen to the facts and the science. Now they look and see, well, who are you aligned with? What is your political affiliation? They hear that first before they hear your facts. Then the messenger has become more salient than the message, and that is a problem as we approach tougher times.

(00:52:48):

So this has been a good first pass on some of the opportunities and constraints with nuclear power. Do you have any of your own personal experience or writing and thinking and speaking about these issues? What are a couple of the biggest misconceptions or common myths that you hear about nuclear power, either good or bad, that give you the most frustration or annoyance? Or have we covered them already on this conversation?

James Fleay (00:53:20):

Particularly in Australia, it used to be that waste and the options we have for safely disposing of the waste, as well as safety concerns were the main objections. And those two objections are particularly susceptible to scare and fear campaigns, and misinformation. Actually, I've noticed though in recent years, that that seems to be changing. The political debate now in Australia doesn't seem to be around waste anymore, because we're going to get nuclear submarines off the US and they will produce waste. So we're going to deal with it one way or another. And it doesn't seem to be around safety. I mean, you can't say that it's safe for young men and women to traverse the oceans in close proximity to a nuclear reactor and say, "Yeah, but it's too dangerous for us to have one to provide carbon free power."

(00:54:10):

So I think the misinformation that we're struggling with at the minute is really around the cost of nuclear energy. The claim is it's too expensive to be relevant. Then if you

look at sort of recent Western performances, that's not entirely baseless. The nuclear energy industry has not covered itself in glory with reliable project delivery in Western countries. But then, you go to China, South Korea, Japan, not to mention some Western European nations and more recently the UAE, who have been able to build plants on time to a high standard for a predictable price. And you can see that the price of nuclear electricity in their cost stack is at the bottom. This is also true in Canada.

(00:54:55):

We recently went to Ontario and got that from the independent system operator up there. It's the cheapest source of power except for hydro on the grid. And so countering misinformation around the cost of nuclear energy has become very difficult because it's complex, there's lots of nuance, and it's nearly impossible to have a nuanced discussion in the sort of maybe the five minutes you'll get to discuss these things in mainstream media.

Nate Hagens (00:55:21):

And is the reason that it's cheaper in South Korea and China and UAE and some of the places you mentioned, is because labor is cheaper or just because they're more organized and focused and disciplined and less political? Or what is the cost differential?

James Fleay (00:55:38):

Primarily, the second of those things. I mean, labor costs in Japan comparatively expensive compared to the rest of the world. Don't think they're quite as expensive as the US and Australia, but they're not far off. But they plan, they build programs thoroughly. They complete the designs. They have really, really careful plans for how they construct the plant, when things are delivered to site, how the plant's going to be started up. And they do things in a sequential, logical, orderly fashion. It's pretty simple.

(00:56:10):

The magic combination of things that make mega projects work around the world are well known, but we just seem to refuse to do them in Western nations. We have a disposition to rush projects. We want to get to site as quickly as possible. We don't want to finish the design. We don't want to get all of our regulatory requirements

squared away ahead of mobilizing to site. And we also don't plan the replacement of our legacy power generating assets very well.

(00:56:39):

I mean, we've got an enormous capital stock of existing infrastructure. We know roughly when it's going to reach its end of economic life, and we do not carefully plan to replace it in a timely fashion. We sort of get to, in Australia anyway, we get to five minutes to midnight and go, "Gosh, that's an awful lot of power that's about to disappear from the grid and we really haven't done very much about it." And then hit the panic button.

Nate Hagens (00:57:04):

Humans, often clever seldom wise. So this has been a great overview, James. Thank you for your balanced opinions and expertise on nuclear and power in general. If you don't mind, I would like to ask you some personal questions. You've listened to my podcast so you probably know what's coming. But you've thought about and are now working on these issues as a career choice. Do you have any personal advice to viewers of this program who understand The Great Simplification and oil depletion and energy properties and the carbon pulse and what we face?

James Fleay (00:57:47):

I guess firstly, don't despair because that's not a good plan of action. It doesn't achieve very much. I think activism is not always wasted, I think sometimes it's very useful. But when you're dealing with complex systems across multiple sort of domains of expertise, I don't believe you can hope to make substantial and positive change through sort of activism that is got a really a sort of scratch-the-surface understanding of the underlying issues.

(00:58:17):

And so my plea, I suppose, for people identifying these issues or hearing about them for the first time and want to do something about it, is take the time to understand the issues. And that might require you to, it certainly requires some education and a lot of reading, but I don't think there's any substitute for experience, actually, and practice and working in the energy sector for the last 17 years across multiple different parts of it, really just by luck has provided me with a basis to approach these issues

from a much more practical and nuanced perspective. So it's much more complex than just trying to pick winners and being partisan on technologies.

(00:59:00):

We can talk about education another time I suppose, but I don't think we'd do young people any favors by asking them to believe the things that we tell them in school and in the media and social media and that sort of thing, but not giving them the tools to discover the truth of things for themselves and to critically assess what they're being told. Because then they're forced into a position where they have to trust people. And you pointed out earlier, what that means is they're assessing the messenger more than the message. And that has come from a place, I believe has come from a place of not having enough knowledge and education and confidence to assess the message on its merits.

Nate Hagens (00:59:43):

So you have three children, they're younger than college age, but what do you recommend high school, college age humans who become aware of this stuff?

James Fleay (00:59:54):

Well, I mean, I would start watching The Great Simplification podcast or YouTube channel would be a start. But don't start too young because you might despair.

Nate Hagens (01:00:03):

Seriously, it's a real challenge. I don't know how to navigate that. I'm not forcing people to watch it. People that want to learn these things show up and I'm fine with that. Sorry, go on.

James Fleay (01:00:16):

No, I'd also say get some practical skills early. And I would encourage people to consider skill trades as a gateway method into being able to have a bigger impact into all the dynamics and all the disciplines and all the areas of human endeavor that are kind of wrapped up in The Great Simplification at the end of cheap oil.

(01:00:39):

And if not, there's professions that are sort of more practical in nature. So that could be medicine, it could be nursing, it could be engineering. It's probably not studying

economic theory because I think that discipline in particular, in my view, seems to have done... has been more effective at obscuring understanding of underlying system dynamics than any other.

(01:01:03):

So stay practical, don't despair and give yourself time to build your knowledge before you start trying to make change in the world. You can't possibly hope to make change that doesn't leave you worse off if you haven't taken the time to understand all the complexity and nuance below the surface.

Nate Hagens (01:01:20):

I like that answer. I agree with you. What do you care most about in the world, James? I have no idea because I've only spoken with you once.

James Fleay (01:01:28):

My three sons and my wife. My brothers and sisters. I'm the oldest of six kids. I've got wonderful brothers and sisters and mum and dad, and I've got a very close long-term group of friends, some of whom I've known since I was eight years old, and they're still the people I choose to spend time with. So it's always connections of the sort of heart and mind, and not economic connections that are the most important to people. That's the same with me.

Nate Hagens (01:01:50):

Hear. Hear. What issue are you most concerned about in the coming decade?

James Fleay (01:01:56):

I guess education provides the biggest opportunity that we have for correcting some of our issues. If we can improve the quality and remove the ideology from both the content and the pedagogy in the education system. So that's one. But the other thing, too, is it's going to become very obvious, I think over the next 10 years, that globally traded commodities or the way they have been globally traded over the last 50, 60 years, let's say, since the end of World War II, is going to disappear, maybe more rapidly than even you and I are anticipating. And we will see the strategic use of comparative commodity advantage play out.

(01:02:35):

It's hard for me to believe that Saudi Arabia aren't going to try and make the most of their remaining hydrocarbon reserves and get the highest best possible dollar for them. Underwriting Western economic stability is probably not going to be a top of priority for them. The same will be true of natural gas, I think.

Nate Hagens (01:02:53):

Yep, I agree with that. If you could wave a magic wand and there was no personal recourse to you or your reputation, what is one thing you would do to improve human and planetary futures?

James Fleay (01:03:08):

I'd probably have to come back to education again. I know I sound like a broken record, but removing ideology from education and making it more practical and orienting it towards what works, what's proven, not necessarily what's the most palatable. I think if we can give future generations of children an education where they can critically assess, from a basis of reasonably solid sort of technical and practical knowledge, claims for themselves, instead of having to believe the claims from missionaries on social media and even mainstream media, advertising as well, increasingly corporate CEOs, then I think we'd be in a better place. So I think education holds many of the opportunities for improving our outlook.

Nate Hagens (01:04:00):

I happen to agree, which is why I'm doing the work I'm doing. Thank you so much for your time, early morning Australia time. This was a good first overview of a little bit of energy systems and a little bit of your views on nuclear. If you were to come back for a second interview, what is one topic that you are very into, passionate about that you could potentially take a deep dive on?

James Fleay (01:04:27):

I think an area that I've struggled with and continue to struggle with is why the world and the solutions to some of our biggest problems. And I'm talking about energy here. We have obviously massive other problems that I know nothing about, particularly mental health, particularly I think mental health and addiction are two of the big ones, but let's just talk about energy.

(01:04:49):

Why the world and the solutions look so different to economists than they do to engineers. I find myself talking to economists about energy, and it's nearly impossible to have a meeting of the minds on anything. I think there are some really troubling implications from the time value of money, the concept, which is at the heart of modern finance and investment. And I think some of the implications of that are disturbing.

(01:05:15):

So our ability to make change grows as we take a longer term view. So we can't do anything about the price crisis of electricity and gas in Australia today. The decisions that led to it were taken 20, 30, 40 years ago in some cases. But what that means is things that we do today can have a profound impact in 30 to 40 years time. It can't have a profound impact in five years time. That really is at odds with the time value of money. And I don't know how we reconcile that. I'd love to hear your thoughts on it one day.

Nate Hagens (01:05:52):

Yeah, I mean, my initial reaction is we are living now on the downstream carryover of very high EROI stuff that was built 20 or 30 years ago. And at the same time, we're susceptible to the not good decisions of sustainable pathways from 20 or 30 years ago.

(01:06:16):

So it's this constant crux of living in the moment and planning for the future. To be continued, James. Thank you so much for your time. And what are the odds that you will see at kangaroo today in your travels around your community?

James Fleay (01:06:33):

Pretty low.

Nate Hagens (01:06:34):

Pretty low? Okay.

James Fleay (01:06:35):

Pretty low.

Nate Hagens (01:06:35):

You have to go to the country?

James Fleay (01:06:37):

You do. You have to go to the country, which is not far away, but I won't be going there today.

Nate Hagens (01:06:41):

Okay.

James Fleay (01:06:42):

As we depart, I'd also like to say thank you for everything you do. As I mentioned, I'd sort of came across your work long before you started Great Simplification. And because I was working in energy and particularly upstream oil and gas at the time, it had an extraordinary influence on me many years ago. And I just want to thank you for what you do and continue to do.

Nate Hagens (01:07:03):

Thank you. I feel it's an important role and I will continue to play it as long as I'm able. And it will take a village, as they say. Thanks so much, James.

James Fleay (01:07:13):

Thanks, Nate.

Nate Hagens (01:07:14):

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