Scott Tinker (00:00):

Next on Energy Switch, we'll explore the controversial topic of whether the US needs more or less nuclear power.

Michael Shellenberger (00:08):

The picture that people have of radiation as a super potent toxin that creates Godzilla monsters when you're exposed to it, is just wrong. The real risks with these accidents are often that we overreact to them.

Arjun Makhijani (00:20):

Nuclear is absolutely not a circular economy. Because all the material, other than the very tiny, tiny fraction that became energy, is waste.

Scott Tinker (00:31):

Coming up on Energy Switch. Is it time for more nuclear power?

Speaker (00:36):

Funding for Energy Switch was provided in part by Microsoft, and by the University of Texas at Austin.

Scott Tinker (00:48):

I'm Scott Tinker, and I'm an energy scientist. I work in the field, lead research, speak around the world, write articles, and make films about energy. This show brings together leading experts on vital topics in energy and climate. They may have different perspectives, but my goal is to learn and illuminate, and bring diverging views together towards solutions. Welcome to the Energy Switch.

Scott Tinker (01:18):

The US has over 50 nuclear power plants that produce about 20% of our electricity and 50% of our carbon-free electricity. Yet nuclear's future is uncertain and controversial. Today, we'll talk about the three nuclear accidents that have occurred, the link in some people's minds between nuclear energy and nuclear weapons, and we'll talk about nuclear waste.

Scott Tinker (01:41):

My expert guests are Dr. Arjun Makhijani, a nuclear engineer against nuclear power. He's president of the Institute for Energy and Environmental Research, and co-author of Nuclear Wastelands. Michael Shellenberger is founder and president of Environmental Progress, the best selling author of Apocalypse Never and San Fran-sicko, and a former anti-nuclear activist. On this episode of Energy Switch, is it time for more nuclear power? Part one.

Scott Tinker (02:13):

We're going to start with safety. A big topic, big public concern around nuclear, for sure. Let's talk about real accidents that have happened. Three Mile Island, Chernobyl, Fukushima Daiichi. What happened? What happened in those?

Arjun Makhijani (02:27):

In Chernobyl there was a nuclear reaction, a runaway nuclear reaction, and the reactor exploded. It didn't have a secondary containment. There was a meltdown, a similar different mechanism, slightly, in Three Mile Island, but it had a secondary containment. And while the hydrogen caught fire or exploded, it was contained inside, so the releases of radioactivity were limited. In Fukushima, of course there were three explosions and a massive release of radioactivity, but there, the people were evacuated right away. Both Fukushima and Chernobyl implied massive costs. The cost of cleanup at Fukushima are somewhere in the 300 to 700 billion range.

Scott Tinker (03:15):

Amazing. Amazing.

Arjun Makhijani (03:15):

Yeah. That's a huge number.

Scott Tinker (03:17):

The drivers of these things, though, Chernobyl was in the plant, Fukushima, different thing happened there. What went on there, Michael?

Michael Shellenberger (03:26):

I should say that I was born 1971, so Three Mile Island occurred in 1979, when I was eight years old, Chernobyl in 1985. And so I grew up in real fear of these nuclear accidents. And in fact, remained in real fear about them until I spent time reading the best available science on the accidents, particularly Chernobyl, and also interviewing public health experts.

Michael Shellenberger (03:48):

In particular, I've done a lot of work profiling the founder and head of something called the Chernobyl Tissue Bank, Jerry Thomas, who's at Imperial College London, who's done the most comprehensive review of the public health literature. And what's so shocking when you read the research on Chernobyl, is just how few people have died. Fewer than 50 people died, putting out the fire after it occurred, and then a few months afterwards.

Scott Tinker (04:13):

And that's the worst of... Chernobyl is way worse than Three Mile Island.

Michael Shellenberger (04:17):

Oh, yeah.

Scott Tinker (04:18):

Yeah, yeah. That's the bad one.

Michael Shellenberger (04:18):

Yeah. Nobody died at Three Mile Island. According to Dr. Thomas, nobody received a dangerous dose of radiation at Fukushima, much less died. You have to put it in context where, according to the World Health Organization, six million people die every year, premature deaths, from ordinary air pollution.

Two to three million of those are from people breathing smoke from burning of biomass in poor countries in Sub-Saharan Africa or south Asia.

Michael Shellenberger (04:44):

So for sure, we should always be concerned about these accidents, but I think the picture that people have of radiation as a super potent toxin that creates Godzilla monsters when you're exposed to it is just wrong. The real risks with these accidents are often that we overreact to them. So in the case of Fukushima, when I visited, and I've been there twice now and interviewed people nearby, went right up to the reactor core, they were washing trees, washing tree trunks, which is absurd. They were scraping top soil off, which is absurd. And we knew it was absurd and pointless to do that, because the British Medical Journal had done a study of people who lived near the so-called contaminated top soil and found no dangerous levels of radiation.

Michael Shellenberger (05:27):

So there was a huge overreaction. So really when we talk about the wasted billions spent on the cleanup, that's the cost of fear of nuclear power, not the cost of nuclear power.

Scott Tinker (05:38):

So Fukushima was driven... I'm a geologist. An earthquake, big tidal wave type thing.

Arjun Makhijani (05:45):

Yeah. Absolutely, yeah.

Scott Tinker (05:46):

So it wasn't a reactor problem like Three Mile Island and Chernobyl.

Arjun Makhijani (05:51):

Yeah. The actual causes of the accidents were different, but all the reactors have severe accident vulnerabilities. They actually need power grid supply to operate all their cooling systems. So when that's gone, the emergency diesel has to come on to operate the cooling system. Now, when the tidal wave came, the emergency diesel went.

Scott Tinker (06:13):

Because it was above ground.

Arjun Makhijani (06:13):

And so they lost cooling. And that's when you start to get a meltdown. Let me give you an example of what a nuclear reactor really is. It's a tank that generates heat equivalent to about 30 million people in one tank. When you switch it off, you can't turn off the fire. There's about 7% residual heat the moment you switch it off. That's the heat equivalent to two million people. So it's very, very, very hot. And so if it's not cooled, that's when you start to get steam, reactions that generate hydrogen, and the potential for explosions. And hydrogen been a common factor in all those accidents, and what we had in Fukushima was hydrogen explosions.

Scott Tinker (06:58):

Talk to us, Arjun, a little bit about this next generations of reactors. Are they safer? Is there some inherent safety in them? The radioactive waste, is it lower volume, lower heat? What do you see there?

Arjun Makhijani (07:13):

Each type of reactor has its pluses and minuses. One reactor that's talked about, for instance, is a liquid fuel molten salt reactor, liquid thorium fuel. And they say it can't have a meltdown because it's already molten fuel. And that's true. But there are four barriers in the current reactors between the fuel, the radioactivity, and the environments. In a molten salt reactor, all the volatile radio nucleotides already evaporate, so there's one barrier between.

Arjun Makhijani (07:47):

So it's got some safety advantages, it's low pressure and so on, but now your safety margin is lower and your waste is a fluoride, which is unstable, and that's created its own problem.

Scott Tinker (08:01):

Interesting.

Arjun Makhijani (08:01):

There's been one small reactor built like that at Oak Ridge. It worked pretty well most of the time. But the decommissioning cost of that reactor is estimated at many, many times the cost of the reactor.

Scott Tinker (08:13):

Interesting. Well, just coming back to, you're both talking a little bit about the actual impacts, deaths and radioactivity we can measure verse the public perception of these things. How do you see that nuclear, and maybe compared to other sources of electricity, even?

Michael Shellenberger (08:31):

On the straight issue of the risks of different sources of energy, we have been studying this. Scientists have been studying for decades. The most recent study was published in Lancet. And it found that nuclear has the fewest deaths per unit of energy, of any reliable power source. So that may seem surprising, but just think about coal and petroleum and natural gas. They emit air pollution. And air pollution shortens the lives of six million people a year, according to the World Health Organization.

Michael Shellenberger (09:01):

Nuclear power does not emit air or water pollution during the normal functioning of nuclear plants. When there are accidents, a small amount of radiant particles escape that you have to contain and manage. But as we saw, no deaths from Three Mile Island, no deaths from Fukushima, and somewhere between 50 to 200 deaths total from Chernobyl. On the facts. It's, it's pretty straightforward.

Scott Tinker (09:24):

Do you see it the same way, Arjun?

Arjun Makhijani (09:26):

I think when you talk about safety, there's no question that fossil fuels are extremely polluting, they cause a lot of disease, they cause a lot of death, they cause asthma, and so on. We're not talking about that. We're talking about low-carbon energy sources, nuclear, solar, wind. Now, solar and wind are variable, but they don't cause radiation. Every nuclear reactor generates about 30 bombs worth of plutonium every single year. We've got more than a hundred thousand bombs worth of plutonium sitting in the spent fuel at reactor sites, just in this country.

Scott Tinker (10:03):

When I think of a bomb, I think of something big, but the plutonium in the bomb is not much.

Arjun Makhijani (10:07):

About 1% of the spent fuel is plutonium. And you generate about 20 tons a year, so the math is not complicated. It's about 30 Nagasaki bombs with the plutonium.

Scott Tinker (10:18):

Now that plutonium isn't weapons grade, you have to do more to it.

Arjun Makhijani (10:21):

You have to separate it from the spent fuel chemically. It's a big, dangerous process. But it's been done commercially in France, Britain, Japan, India, Russia, Soviet Union. There's today, more surplus plutonium in the civilian sector that's separated than in all the nuclear weapons throughout the world. More than 300 tons. And nuclear weapons stocks are about 250 metric tons. So yes, most of the plutonium, fortunately, is in the spent fuel, unused, because it's so expensive to use.

Scott Tinker (10:58):

Right. But is that concern, given that there are nuclear weapons in the world, for better or worse, no judgment, is that really a concern when it comes to generating no emissions, high dense electricity from nuclear? Does that offset it, or how do you feel about that?

Michael Shellenberger (11:19):

All of us who were born after 1945 were born into a world with nuclear weapons. Before we even invented nuclear weapons, we knew that we wouldn't be able to get rid of them. And the reason for that is because, say two countries that had nuclear weapons did decide to get rid of them, and then if they went to war, what do we think would happen? Everybody knows the first thing they would do would be to try to reconstruct their nuclear weapons. So political scientists have been aware of that issue since before 1945. So we can't get rid of nuclear weapons, so then the question is, what do we do with this technology? So one approach would be, well, you just try to do as little as you can with it. You wouldn't want to allow the technology to be used.

Michael Shellenberger (12:03):

That was my view for most of my life. I changed my mind, really because I came to see the limitations of renewables. I was a major advocate for renewable energy in the early 2000s. I helped persuade Obama's campaign team to make a big investment in solar and wind. But at that same time, I was encountering conservationists in California who were explaining that to build industrial solar farms, it requires 300 times more land than a nuclear plant.

Michael Shellenberger (12:30):

So I was concerned by the land use and ocean impacts of renewables. And some friends said, take a second look at nuclear. When I did, I realized that, really, much of my own anxieties and fears, and those of so many others, really had to do with fears of nuclear weapons. So then the question is, does the risk of nuclear weapons being used go up by using more nuclear energy? And the answer is no, of course not. You're talking about a completely different technology. It's nuclear power plants that produce electricity. In the future, they'll produce hydrogen gas, desalinate water for fresh water. But if we have a hundred nuclear power plants or one nuclear power plant in the United States, it doesn't change how many nuclear weapons we have. And it certainly doesn't change the risk of nuclear war.

Arjun Makhijani (13:17):

Well, let me correct a few things.

Scott Tinker (13:20):

Different perspective.

Arjun Makhijani (13:21):

Land area is a very important issue. So we've got thousands of square miles of mining waste throughout the Navajo reservation, which has devastated living over there for many, many people. The main problem with land use with nuclear and fossil fuels, especially, is that you have to continue mining them.

Scott Tinker (13:46):

In all fairness, you have to continue to mine solar panels, because they wear out. And we can recycle some of it, but it's not renewable in that sense. Panels, turbines, the batteries, we have to mine, manufacture and dispose.

Arjun Makhijani (13:59):

Mining, definitely. Of course, you're building up any industry, you're going to have some mining. We have lots of mining with nuclear. We have lots of mining with the materials. We have lots of mining with the fuels. The big difference is, solar and wind don't need fuels. And with conventional, today's energy technologies, the land use footprint expands forever, because you continue to need fuels, which are mainly mined.

Scott Tinker (14:27):

Yeah. Let's come back to the third part of safety here on the waste. What are the options for storing spent fuel? Where have we come with that?

Michael Shellenberger (14:38):

What's remarkable about nuclear energy is that it's so energy dense. So, this amount of uranium can provide me with all the energy I need for my entire life, including all my jet travel, all of the energy intense activities as fuel rods made out of uranium. At the end of the process, this is what we call waste. So as an environmentalist, this is exactly what you want. You want to have a small amount of fuel and a small amount of waste that's easy to manage.

Michael Shellenberger (15:08):

So all the nuclear waste ever produced in US civilian power plants can fit on a single football field, stacked 50 feet high. It's just stored in steel and concrete containers at the site of production, which is the other thing, if you remember from your high school or college ecological biology class, what you want for circular economy is to have the waste stored at the site of production. When you externalize that waste into the natural environment, that's pollution, that's what causes damage. So right now only nuclear waste is safely contained. It's never hurt anybody, never will.

Scott Tinker (15:44):

So the density is really important. Volume is small. It's contained. Dry cask or in pools, spent fuel rods.

Michael Shellenberger (15:54):

You got it. It's about 18 months in the nuclear reactor. It's another couple of years in a pool of water, where it cools. It's then put in steel and concrete, right at the site of production. As an environmentalist, that's what I want to see.

Scott Tinker (16:06):

Yeah. So on the nuclear waste, Arjun?

Arjun Makhijani (16:10):

This is a completely wrong idea of what a circular economy looks like. If you have waste that's highly radioactive and you store it on site, it doesn't mean you're reusing it or recycling it. It stored on site. Now in France, they do recover the plutonium, which is 1% of the waste.

Scott Tinker (16:28):

At La Hague.

Arjun Makhijani (16:29):

At La Hague. Uranium is 94% of the waste. That uranium now contains trace metals that makes it practically unusable. It's unused in France. So, that's not recycled. So let's put some numbers on the table. It's true that the fuel pellets are very concentrated waste. And there are not a lot of fuel pellets for Michael's lifetime of energy consumption. But every pound of fuel that's in a reactor requires about 800 pounds, or if it's 1% ore, which is good quality, sometimes 1600 pounds.

Scott Tinker (17:09):

Uranium ore.

Arjun Makhijani (17:09):

Uranium ore. You've got roughly an equivalent amount of mine over burden. So if you've got 20 tons of fuel coming out of a reactor every year, that spent fuel, you've got about 20,000 tons of uranium mill tailings, and an equivalent amount of mine waste. We have got more than 400 million tons of uranium mill tailings and mine waste just in the United States between weapons and power.

Michael Shellenberger (17:39):

May I ask a question?

Scott Tinker (17:40):

Yeah. Sure.

Michael Shellenberger (17:40):

Twice now, you've mixed together the waste byproducts from nuclear weapons and nuclear energy. What makes you do that?

Arjun Makhijani (17:48):

It's not a question of me mixing together. Those establishments were created. First was the weapons establishment, and the Atomic Energy Commission oversaw both weapons and power. And the upstream part of the weapons and power system as a matter of truth, were the same. The enrichment plans were the same. The mining was procured by the Atomic Energy Commission at a fixed price of $8 a pound. And some of that went into weapons. And some of that went into power.

Scott Tinker (18:18):

And then you've also pointed out that the tailings from the mining process is a lot more than the actual uranium. But now, all mining has tailings.

Arjun Makhijani (18:27):

Yes, absolutely.

Scott Tinker (18:28):

Whatever we're mining for.

Arjun Makhijani (18:31):

Metals that go into generators and nuclear power plants, coal fired power plants, steel, copper, it's all mining.

Scott Tinker (18:38):

If we don't grow it, we mine it. And so this is a big challenge. I think your point was, dense energy has a lot less of that.

Michael Shellenberger (18:46):

Yes. The empirical research supports the basic physical nature of this. So the higher, the energy density, the less resource use. What we've seen over the last 75 years is that uranium mining has become remarkably clean. What we discovered is that in fact, the biggest driver of making uranium mining cleaner has been the nuclear industry. It's just gotten better at it. It's an incredibly safe industry. So now we don't even have open mines. We're just shooting hot water into the ground and pulling the uranium out. It's incredibly safe.

Scott Tinker (19:22):

Is that rich world stuff, or is that globally?

Michael Shellenberger (19:24):

Yes.

Scott Tinker (19:24):

Is it safe all over the world?

Michael Shellenberger (19:26):

It's becoming that way. It's becoming that way. And of course we'd love to see it that way everywhere, but we're responsible for what we do here. The other interesting thing is that when you do life cycle analysis, comparing the mining impacts of renewables to the mining impacts of uranium, there is more radiation exposure in the mining for renewables.

Scott Tinker (19:44):

Solar and wind?

Michael Shellenberger (19:44):

Yes. And why is that? It's because they require much more rare earth's highly toxic elements that are required for solar wind and electric cars than required for nuclear.

Arjun Makhijani (19:55):

You're mixing up different things here. Uranium is the fuel for nuclear power plants. Coal is a fuel for coal fired power plants. There's no fuel for solar and wind. So once you've built a plant, you're done. The first materials impacts of building the power plants themselves can be very reasonably assessed. They're all materials intensive. When you look at the capital investment of materials intensive industry, wind, solar, nuclear, coal, the initial capital investment is the same order of magnitude, less for gas, because-

Scott Tinker (20:31):

To capture the same amount of actual generation?

Arjun Makhijani (20:34):

The best simple way to understand the materials impact of a unit of output in all materials industries is to look at how many dollars you need per megawatt equivalent of nuclear. We need about three megawatts of wind for one megawatt of nuclear equivalent output, and four or five of solar. When you add that all up, you find that their materials impacts are roughly the same order of magnitude. So you need more rare earths for wind turbines, for the magnets, and so on. You need more copper for the kind of generators that you have in a nuclear or coal fired power plant.

Scott Tinker (21:16):

The amount of metals and wind turbines and solar panels is tremendous, because it takes so much to collect the same amount of energy. This is just physics, right? Power [inaudible 00:21:26].

Michael Shellenberger (21:26):

Viewers can Google this on their own, but the International Energy Agency just did a major study of the materials impacts of different energy sources. And in fact, solar and wind require an order of magnitude

10 times or more, 15 times, more steel and concrete than natural gas or nuclear plants. And again, you don't need to take anybody's word on it, this is all easy to find. It was a major report that was done.

Michael Shellenberger (21:51):

Solar panels last between 10 and 20 years, nuclear plants can operate for 80 years or longer. All of the big parts are replaceable, whereas the solar panel itself is replaceable with a whole new solar panel. So that's where these differences are coming. I think there's a picture that sometimes I hear people presenting, and I used to have this picture in my mind, which is, that once you build a solar farm, then that's it. You're done. And that's going to be there for hundreds of years or something. No, you have to go and replace those panels. That means all of those big materials requirements are coming back in. You have to replace those panels every 10 or 20 years. And that's simply not what you have to do with a nuclear or natural gas plant.

Scott Tinker (22:31):

Look, we've had-

Arjun Makhijani (22:31):

Let me say, solar panels don't last for 10 or 20 years. This is just not the facts. Solar panel lifetime is in the 30 to 40 year range. France actually recycles its solar panels. So we're throwing them away. That is a problem.

Scott Tinker (22:51):

We can do better.

Arjun Makhijani (22:51):

We should not be throwing them. We're throwing away lead, we're throwing away lots of things that we should not be throwing away, under reason [inaudible 00:23:00].

Michael Shellenberger (23:01):

There's some experimental projects to recycle solar panels, but the country of France simply does not recycle all of its solar panels. Nobody does. And the reason is because it's too expensive. It's much cheaper to buy the raw materials than to recycle them. And it will always be that way.

Scott Tinker (23:16):

The same that goes all [inaudible 00:23:18].

Arjun Makhijani (23:17):

Solar is a new industry. Almost all solar installations have been built in the last 10 years. Almost all. There's not a lot of solar panels to recycle. So of course, if you're recycling solar panels, that's going to be on a small scale, because there are not a lot of panels to recycle.

Michael Shellenberger (23:36):

One final fact. Harvard Business Review just published a major study that found that when you factor in the cost of disposing of solar panel waste, it will increase the cost of the electricity from solar four times from what it is today. Don't take my word for it, google Harvard Business review solar panel waste. This is not complicated physics, this is just, low energy densities require much more significant material throughput, much more waste, and then all of the costs associated with power.

Scott Tinker (24:06):

It's the challenge with recycling in general. We recycled five to 10% of our lithium ion batteries today. It's cheaper to make new ones. We're terrible at the circular economy. It is absolutely aspirational. And we need to go this way, but it's not without its cost. It is expensive to-

Arjun Makhijani (24:23):

Nuclear is absolutely not a circular economy, because essentially all the material, other than the very tiny, tiny fraction that became energy, is waste. You've got the uranium waste, the mining waste, the milling waste, the spent fuel, the depleted uranium. And what we are doing is really the most problematic in an extractive economy. We're using the electricity, and we have now created waste with plutonium in it that will last for tens of thousands of years. That's not recycling. Let me tell you.

Scott Tinker (24:56):

All right. I'm going to have to call a stop. We've had a lively conversation-

Arjun Makhijani (25:01):

Yeah. It's been good.

Scott Tinker (25:01):

... about nuclear power and its safety. We've looked at accident potential. We've talked about weapons and proliferation, and we've talked about waste. What do we do with it? What are some of the options? And we're going to take a little break, and we'll be back with the Energy Switch.

Scott Tinker (25:15):

I didn't expect this to become a battle between nuclear and solar and wind, but they're some of our leading options for carbon free electricity. Nuclear energy and nuclear weapons are indeed different technologies. But fear that one might lead to the other may block nuclear power development in some countries. Nuclear waste is indeed minute compared to the energy it produces, but there are large scale mining concerns. I found the studies Michael mentioned, showing nuclear, solar, and wind have the fewest numbers of deaths per megawatt hour. And similarly low amounts of greenhouse gas emissions. I also found the study showing solar and wind require about 10 times the material of nuclear per megawatt generated. Clearly there's more to discuss, which we'll do in part two of, is it time for more nuclear power?

Speaker 4 (26:36):

Funding for Energy Switch was provided in part by Microsoft, and by the University of Texas at Austin.