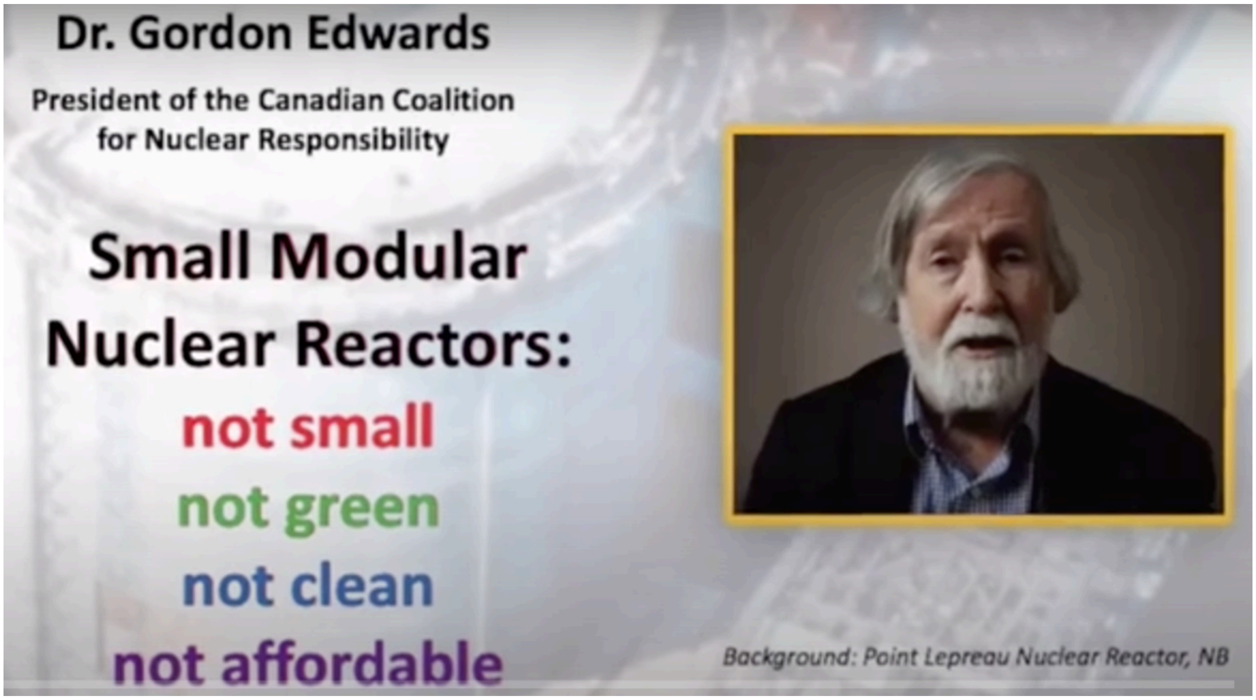


In March 2020, a collaboration of groups in New Brunswick invited Dr. Gordon Edwards to visit the province

Council of Canadians, Saint John

Urban and Community Studies Institute
University of New Brunswick, Saint John

Sisters of Charity, Saint John

Rural Action and Voices for the Environment
(The RAVEN Project)
University of New Brunswick, Fredericton

Council of Canadians, Fredericton

Sustainable Energy Group, Carleton County

NB Media Co-op

Edited Transcript of Webinar - March 13, 2020

SMNRs: not clean, not small, not green, not affordable

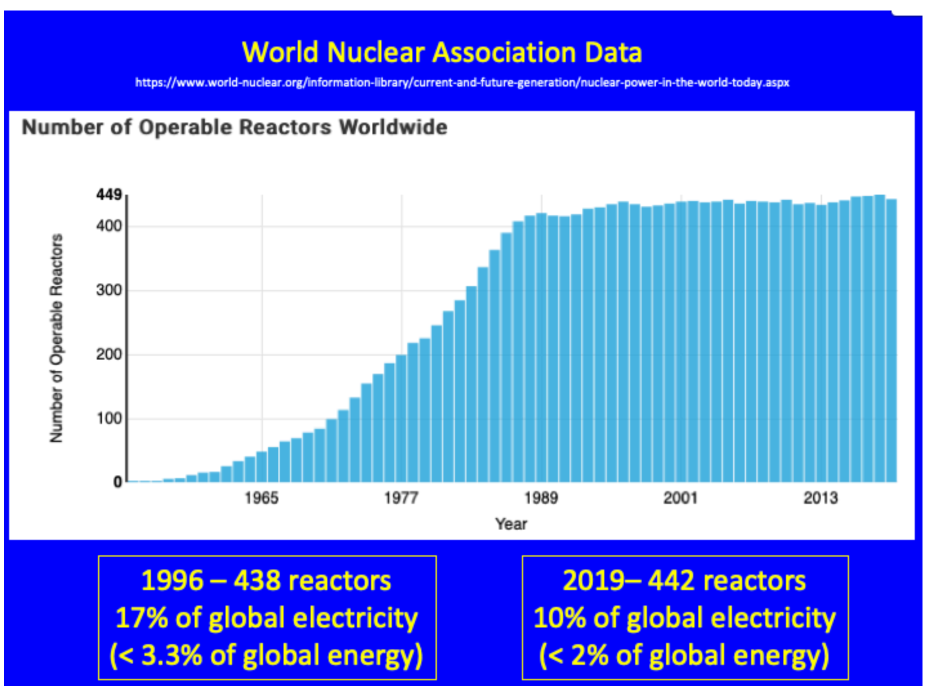
a lightly edited transcript of the webinar by Dr. Gordon Edwards on March 13, 2020
https://www.youtube.com/watch?v=Z-L4QvN3QIA

Gordon:

I think we're all very concerned by the push for small modular reactors, not only in New Brunswick but in many different parts of the world and in many different parts of Canada, supported as it is by the government of Canada through the Natural Resources Minister. As you know, there are three provinces that have announced that they would like to cooperate in developing small modular reactors.

In this talk, I want to broach the subject of what is the background to all this – Where did this initiative come from? What does it mean? What kind of questions does it pose for us? – and at least take a first step at beginning to answer those questions. There's a lot more to be said on these topics so we should continue the dialogue afterwards. I don't by any means suppose that I am giving definitive answers but just, you might say, a first step.

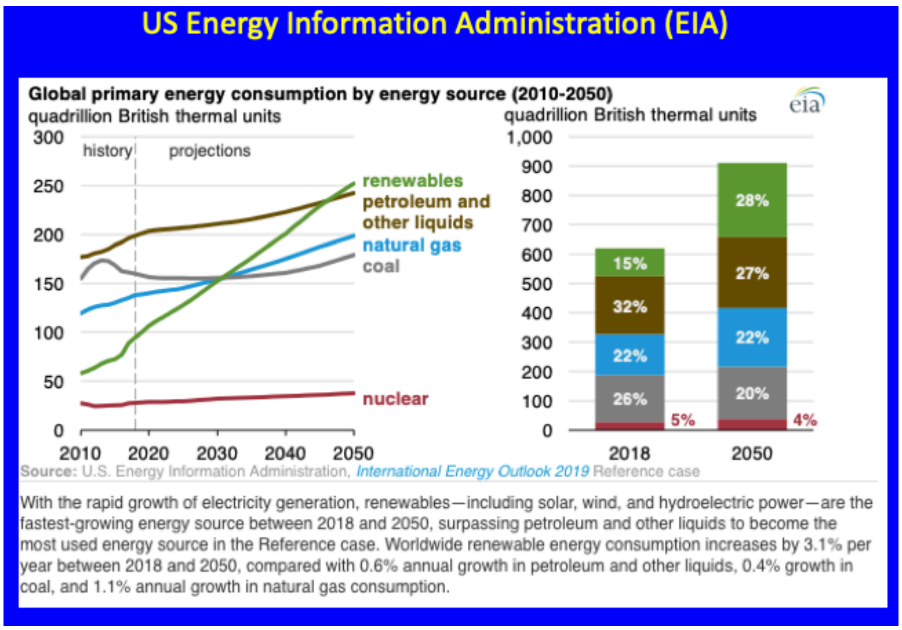
Small modular reactors. I claim they are not clean, and not small, they are not green, and they are not affordable. I'd like to give you some background on this.



My introduction has to do with the status of the nuclear industry in the world today. Here is a graph from the World Nuclear Association that shows how the number of nuclear reactors in the world, now about 440 in number, has plateaued for the last 30 years. There really hasn't been any significant increase in nuclear reactors worldwide in all that time. As a matter of fact, if you look at 1996, there were 438 reactors, compared with 2019, with 442 reactors – only 4 more in over a quarter of a century. They are barely keeping themselves alive. And they realize that, that they are in trouble. They've realized it for quite a while. For at least the last 25 or 30 years.

In 1996, those 438 reactors represented 17 percent of global electricity use, whereas today, almost the same number of reactors represents only 10 percent of global electricity use. So there has been a sharp and steady decline in the importance of nuclear in terms of global electricity supply. And remember, electricity is only one slice of the energy pie, so 10 percent of global electricity use really means less than 2 percent of global energy use.

So when you think about nuclear energy replacing fossil fuels, you realize what an incredible task that would be. We're really nowhere close to that point in time.



Here's another graph, from the US *Energy Information Administration*. It's mostly projections to the year 2050, but it starts off in 2010, and you can see that even in the initial part of that graph, the green line representing renewables is very steeply growing, and they expect it to continue to be, by far, the sharpest growing curve on energy supply. If you look at the bar charts on the right, even in 2018, renewables in all their different forms were about 3 times more significant than nuclear, whereas in 2050, they expect renewables to be 7 times more significant than nuclear. And that's with nuclear steadily declining, going from 5 percent to 4 percent on their chart.

Now, the nuclear industry, realizing that they are in deep trouble, launched a "nuclear renaissance" – and there was a lot of hype about this – around the year 2000. Many of you might remember this. There were promises that there were going to be thousands of nuclear reactors, large nuclear reactors, ordered around the world – "because we have now developed reactors which are superior – generation 3 reactors, even generation 4 reactors – which are going to be much safer, much cleaner, much less expensive and quicker to build." Because, of course, delays in building add to the cost and detract from the benefit.

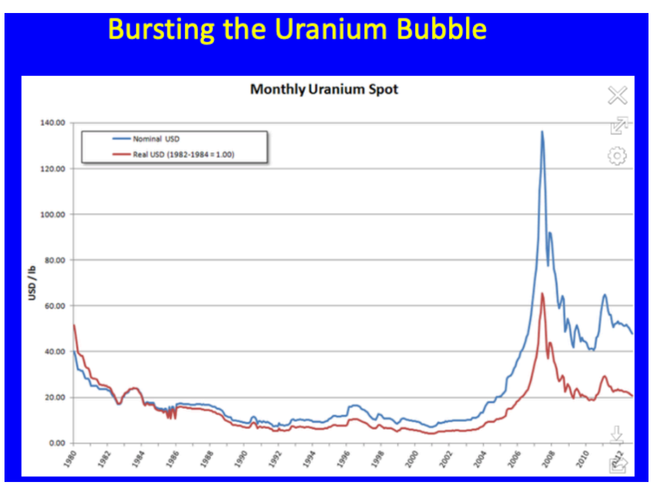
The trouble is, this nuclear renaissance was a gigantic fiasco. It just never took off. There was a collapse of the French giant Areva, the giant nuclear company. One of the stars of the nuclear renaissance was the Finnish reactor, the Olkiluoto reactor, 1,400 megawatts, built by Areva. It was supposed to be operational – having started in 2005 – in only 4 years, by 2009, at a cost of $3 billion euros. But the latest estimate – it's still not operating today – is sometime this month but next year, 2021, it might start operating, but at a cost of $8.5 billion euros. So there we have it, it took nearly 4 times as long to build as promised, and cost almost 3 times as much money as promised, and it has bankrupted Areva which has now been dissolved and absorbed by Electricité de France. But Electricité de France refused to accept Areva's debt load, which has been instead assumed by the French government (which in fact owned both Areva and Electricité de France).

Similarly, the bankruptcy of Westinghouse followed the collapse of another big project, four nuclear reactors down in the southern US, two in Georgia and two in South Carolina. Westinghouse had to file for bankruptcy in 2017 because of 9 billion dollars in losses from these reactor construction projects. South Carolina abandoned the project, the 2 reactors there, even though they had already spent billions of dollars on it. Georgia is still trying to finish their two reactors but it's a tough slog, and it's not clear whether they are going to be able to finish them.

Through all this, the US federal government gave 8.3 billion dollars in loan guarantees for the financing of these four reactors. Now these loan guarantees are needed because Wall Street and the big banks will not invest, and they do not advise their customers to invest, in nuclear projects. They are bad investments, according to them. So consequently, in order to get the money for any such project, the entrepreneurs have to go to the government and say: "Will you please guarantee the loan?" So what we have here is venture capital, or risk capital, but with no risk! Who holds the risk? Well, the risk is borne by taxpayers. It's not *their* money the government risks, it's *ours*.

That's what's happening with the small modular nuclear reactors too. The SMNRs are looking to governments for funding because they know that governments don't necessarily have to make a profit, and seldom do, on such ventures. So if they can just get the government to fork over *your* money, so that they can develop as they please, then they don't have to assume *any* financial risk.

The promise of a nuclear renaissance also led to a tremendous spike in uranium prices. You might remember when there was a lot of exploration for uranium mining here in New Brunswick and in many other jurisdictions. That's because the price of uranium went ridiculously high, and then collapsed right away again, because it soon became clear that the nuclear renaissance was simply not happening. That's just one other indicator of the fact that the nuclear industry is in the doldrums and shows no signs of getting out of the doldrums.



This graph only goes up to 2011, which is just before the Fukushima triple meltdown. After the Fukushima disaster, the price went down even lower – and it has now sunk down to about $9 a pound for uranium. That has forced Cameco, the great Canadian uranium giant, to close some of its richest mines in Saskatchewan and to lay off thousands of workers.

In November 2019, just a few months ago, the American Society of Mechanical Engineers wrote this in one of their journals: "**The state of affairs**: The International Atomic Energy Agency, looking ahead to 2050, sees the most optimistic global electricity market share for nuclear as only 5%, down from the 10% today."

So when we were talking a minute ago about nuclear's 10 percent share of electricity, that's ignoring the fact that most of these reactors are really old, and they're going to be shutting down – shutting down much faster than any new reactors can possibly be built. So that 10 percent is going to shrink to 5 percent, and in the US and Europe, it is already declining to between 3 and 5 percent of the market, constituting a potential for total market failure. In other words, this industry is in danger of being snuffed out. And that's why they are really desperate.

What we are seeing here, with SMNRs, is a desperate effort on the part of the nuclear industry to really push hard to get the government to pony up taxpayer's money to allow them to launch a second nuclear renaissance. The first one was a bust. I used to joke at the time that the reason they want a nuclear renaissance is because they realize they are still in the dark ages. So this sense of desperation has led them to a second try, and that second try is the small modular nuclear reactors. They said "If people won't buy the big ones, maybe they'll buy the small ones?"

Back in 2016, for example, the Hatch company was commissioned to do a study for the Ontario government. They looked at an initial list of 90 small modular nuclear reactor technologies. Imagine! 90 different technologies! Each one of these 90 different reactor types are competing with all the others. It's like a goldrush. It's like the Yukon goldrush, except instead of having prospectors you're having these little nuclear entrepreneurs putting forward their favourite dreams of a nuclear renaissance, on their own terms. They are all jostling for the same bag of money and the same bag of opportunities. Only 9 models were looked at by Hatch for this report, and they were the ones that were short-listed for more detailed assessment.

Ontario Ministry of Energy
SMR Deployment Feasibility Study

Feasibility of the Potential Deployment of Small Modular Reactors (SMRs) in Ontario

Key Findings

From an initial list of ninety small modular nuclear reactor (SMR) technologies, nine designs (less than 25 MWe) were selected and short listed for detailed assessment for potential deployment in off-grid remote mines, with specific emphasis placed on northern Ontario. The technical readiness, vendor readiness, technology compatibility and lifecycle power costs of these reactors have been examined in detail. The results are as follows:

What they are really talking about here, is off-grid remote mines. So the real motivation is not so much to solve the climate change problem, but to assist the extractive industries. They want to use SMNRs in the oil sands, to get the bitumen out of the ground. They want to use SMNRs in the Ring of Fire in Ontario, to get those mineral resources out; to accelerate resource extraction.

But the mining companies don't want this, even the oil sands don't want this; it's the nuclear industry that wants it, it's the government of Canada that wants it. Why? Because, firstly, the government of Canada created the nuclear industry. And secondly, they want to do it for political reasons, because they have so far been unsuccessful in trying to reduce carbon emissions quickly – the pipeline they bought, the oil sands still progressing, the bitumen flowing – and Doug Ford in Ontario has cancelled all signed renewable energy contracts, even at a penalty of $200 million.

So what can the government of Canada do to pretend to be solving the climate crisis? Well they're now saying "OK, we're going to bank on nuclear." But if you think about it, you realize that what they are really doing is kicking the can down the road – because they can't get these nuclear reactors online for 10 to 20 years! So they are really saying "we're not going to do anything for 10 to 20 years. But we're going to tell people we're doing something by throwing money at these new nuclear reactors."

Here's where the Ring of Fire is located, there's all kinds of mining opportunities there. And the nuclear industry is always looking for a rationale. It's a technology in search of a cause, and right now they are trying to hitch their cause to extractive industries and to the climate crisis.

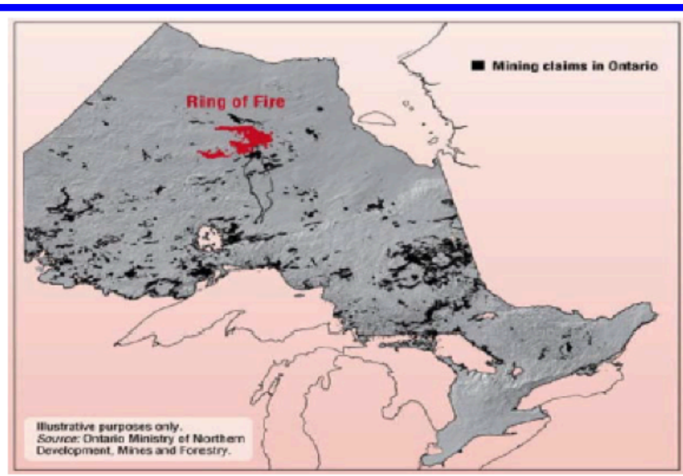


Figure 3-2 - Ring of Fire

Meanwhile, the Union of Indian Chiefs of Ontario – over 47 First Nations, represented by the Anishinabek Nation and the Iroquois Caucus – have joined together on the nuclear waste problem. They have passed a very strong resolution demanding that the nuclear industry abandon its plans to operate SMNRs in Ontario and elsewhere, and requesting the Government of Canada to cease funding and supporting the Small Modular Nuclear Reactor program.

But Natural Resources Canada is still pushing ahead with a Canadian "SMR Roadmap" which they first published in November of 2017. They are really hoping that they can create markets for Saskatchewan uranium, which is in the doldrums, and for nuclear reactor sales, which is also in the doldrums.

You may remember the failure of the CANDU industry. It was such a phenomenal success that SNC Lavalin bought the entire CANDU industry for $15 million – and immediately received $85 million in government grants to proceed to try and sell the darn things. The CANDU industry is pretty well dead in terms of opportunities. In fact, even senior executives of nuclear companies like Exelon are saying openly that there will never again be a large nuclear reactor built in North America. That's why they are going for these small reactors. It's really an act of desperation, to try to keep the nuclear industry alive.

One way of trying to facilitate this sales pitch is to stop using the word nuclear. Take it out. Just call them "small modular reactors", not "small *nuclear* reactors". "Let's try not to highlight the fact that this is nuclear energy. And do not talk about radioactive waste."

Because nuclear energy poses very specific problems. If it were not for the radioactive waste, a nuclear reactor would be not dangerous at all. Even if a reactor exploded sky-high, who would it hurt other than the workers on site? It would not hurt the public. It would just be an unfortunate incident.

The reason why nuclear reactors are dangerous is precisely because of the radioactive waste inside. That's why. If the reactor explodes or is damaged, for whatever reason, the radioactive waste can escape. And this highly dangerous material can contaminate large areas of land and affect the health of millions of people. That's why nuclear is problematic.

Also the nuclear waste contains plutonium, which is the ingredient needed for nuclear bombs. And so the radioactive waste is also the key to the so-called nuclear weapons proliferation problem.

These are the problems that make nuclear special, and these are the things that are not even mentioned in the promotional literature for SMNRs. They simply talk about an SMNR as if it were just another generating machine, sort of like a back-up diesel generator. "Let's put a small modular reactor close to a mine, and they can use the energy." "But what about the radioactive waste?" "Well, we just don't talk about that. We'll get around to that later."

There is another thing the government could do to help speed the process. Because the nuclear industry is saying: "Hey guys! You, government people! You better invest now, because this is a hot market. If you don't put your money in now, you're going to be behind the 8-ball. Because other governments are moving ahead on this. The UK is moving ahead on this. And the US is moving on this. And if you want to get in on the ground floor, you've really got to hurry up, you know? Get these things while they last, because they are not always going to be available to you."

And so what the government of Canada has done to speed things up is they have exempted almost all SMNRs from any environmental assessment. They passed a new environmental assessment act that creates an impact assessment agency, which is supposed to do all the environmental assessments that are to be done in Canada. By law, you're not allowed to do an environmental assessment, except through this agency. But the new agency has been given a list of projects which specifically excludes nuclear reactors below 200 megawatts of heat generation, if sited at a new location, or less than 900 megawatts of heat, if located at an existing reactor site.

But SMNRs are always, by definition, less than 900 megawatts of heat generation. So if they want to build SMNRs at Lepreau, no environmental assessment is required, even though they are completely new untested devices. I mentioned 90 different models earlier, there's actually more than 150 different models, all competing with each other, all vying for attention, all untested.

There are 3 nuclear reactors being discussed specifically in Canada, two in New Brunswick, that are completely different models. One uses molten salt as a coolant and liquid molten fuel. Another one uses liquid sodium metal as a coolant and is modeled after the fast breeder reactors that were built in the US fifty years ago. And in Chalk River, Ontario, they want to build another reactor that is cooled with helium gas. All these reactors are competitors with each other, they are all completely different in design. None of them can make money unless they can mass produce them. They have to sell them by the hundreds – maybe thousands – to lower the cost down to where it's even affordable. And what are the chances that any one of those models is going to corner the market enough to make a profit? Highly unlikely.

The elephant in the room is the radioactive waste, which is the root of all the problems with nuclear reactor technology, and which makes nuclear so expensive as well. It’s not discussed.

We know that uranium is the only element in nature that can be used to make an atomic bomb. There is no other element found in nature that can do this, and it's a particular type of uranium, uranium-235. Uranium is also the only naturally occurring element that can be used to produce industrial-scale energy by fuelling a nuclear reactor.

Now there is another element that can be used for both those purposes, both bombs and reactors, and that's plutonium. But plutonium was never found on earth before 1939. It has only existed since we started making it. And where does plutonium come from? Well actually, it's a derivative of uranium. So uranium is truly the key element of all nuclear fission technology.

And what is nuclear fission? Nuclear fission occurs when a neutron, a small sub-atomic projectile, strikes the uranium-235 atom, and the atom actually splits into two or more pieces, big chunks. Those chunks are called the fission products, and there are hundreds of different varieties. They all have different names, and you've heard some of these names: cesium-137, iodine-131, krypton-85, strontium-90 – these are all broken pieces of uranium atoms.

When the crippled Fukushima plant for example gives off radioactive materials into the environment, they are all basically broken pieces of uranium atoms that came from Saskatchewan, because Japan buys their uranium from Saskatchewan. So we send the uranium over there, and they send it back to us as radioactive fallout.

The strongest force in the universe is what holds the nucleus of an atom together, and so when you split the atom, you release some of that energy. But while the energy is being released, you also release more neutrons. That allows the possibility of multiplying the splitting process very rapidly, and that's the basis of the atomic bomb. It's also the basis for nuclear power, to be able to get a self-sustaining chain reaction, like a self-sustaining fire. You light it with a match, and from there you let oxygen and wood take over to get a good fire going. Well here you start it off with a neutron, and you let the multiplication of neutrons carry you forward to keep it going.

Meanwhile those extra neutrons create another category of radioactive materials called activation products, and we'll talk about that in a minute.

So what is radioactivity? Well, most atoms that we experience are stable, unchanging, eternal atoms. Each atom of hydrogen in a water molecule, for example, was around hundreds of millions of years ago, the very same atom. Nature simply recycles these atoms into different combinations, and that applies to most of the atoms that we deal with.

But a radioactive atom is unstable. Radioactive atoms explode, they disintegrate. And when they disintegrate, they damage nearby living cells because they throw off a kind of a sub-atomic shrapnel which is called atomic radiation. Atomic radiation breaks the DNA molecules and other molecules and causes things to grow incorrectly, not according to the original DNA plan but according to the randomly-modified damaged DNA plan – which sometimes leads to cancers, and sometimes leads to genetic damage to the eggs and sperm. That "genetic damage" can be transmitted to future generations.

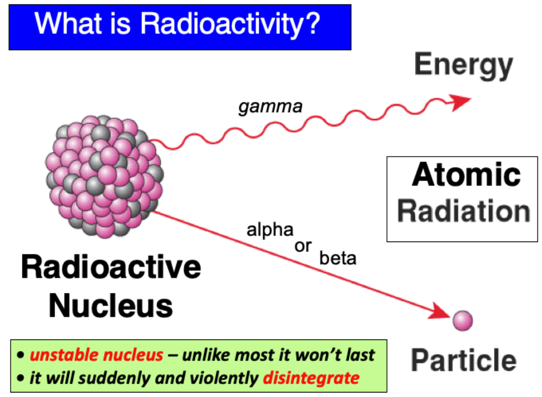
The half-life is the time it takes for half of the radioactive atoms to explode. There is a small handful of naturally occurring radioactive elements but there are many hundreds of human-made radioactive elements. And when the radioactive nucleus explodes, it gives off either a powerful photon of gamma energy, which is much more powerful than x-rays, very penetrating, or it may give off a particle, a charged particle travelling with great speed, but not having nearly the same penetrating power as a gamma ray.

A beta particle will go several centimetres in soft tissue, an alpha particle will go a much shorter distance, just a few millionths of a metre. These are called "particulate radiation", alpha particles and beta particles. They are very damaging inside the body. They are not so harmful outside the body. So we talk about radio-toxicity, to refer to the internal hazards. When you get radioactive materials inside your body, they irradiate you from the inside, and damage the cells from inside. That's where the alpha emitters and beta emitters are most damaging.

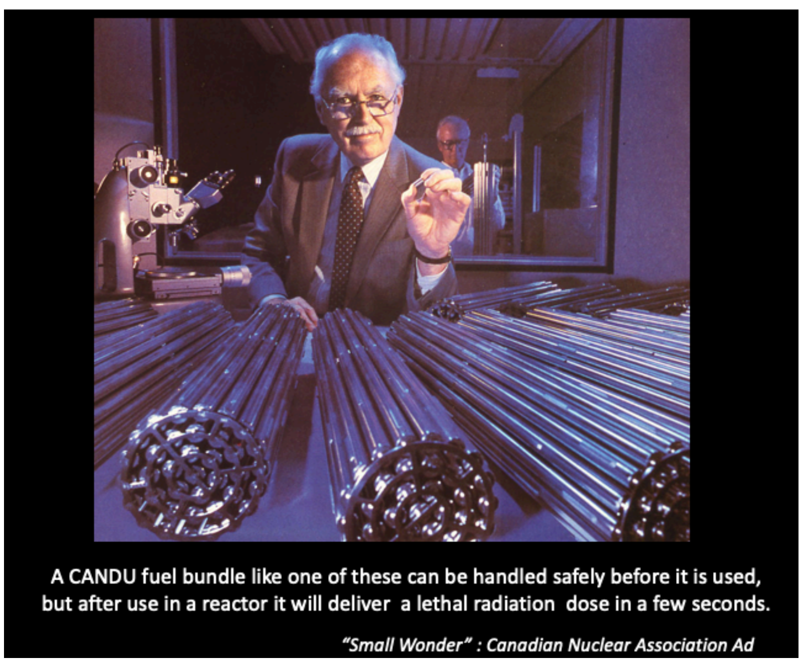
It's only the gamma that can create a lot of damage from the outside. The beta can create a certain amount of damage from outside, but the alpha is completely harmless outside the body. However alpha radiation is much more dangerous than the other types, once it gets inside.

So a gamma ray is like an x-ray but more powerful. A beta particle is like a ... well, I call it a sub-atomic bullet, which only goes a few centimetres. The other type, the alpha particle, is like a sub-atomic cannonball – it does tremendous damage but only within a very short radius, so it's slightly penetrating but highly damaging. And everybody says, even the CNSC and everybody else, that an alpha particle will cause at least 20 times as much damage as a beta particle or a gamma ray. That means it will create 20 times as much cancer, or 20 times as much other biological damage. So beta and alpha emitters are primarily internal hazards.

Radiation is invisible. You can only see these emissions in a special "cloud chamber". Here is a lump of uranium ore, and you can see the tracks made by all these particles and gamma rays that are constantly given off, but it's not detectable by our eyes, or by any of our senses. We can't see it, we can't smell it, we can't taste it. Without special equipment, you would never know that there is any radioactivity there at all. It just looks like a normal rock.



And in fact what the nuclear industry has done is it has created "analogues" of stable atoms that are non-stable. Non-radioactive cesium, for example, exists in nature. Before 1939, there was no radioactive cesium in nature, none at all. We created it. Strontium also exists in the soil – it's not radioactive. We created radioactive strontium. And the trouble with these radioactive analogues that are created is when the radioactive material is mixed with the non-radioactive material, they are chemically identical and so you can't separate them anymore. You can't separate the radioactive from the non-radioactive. That's why it's so important to keep the radioactive material isolated. That's why we have a radioactive waste problem.



Now a CANDU fuel bundle looks like this. You can hold a fuel bundle in your hands before it goes into the reactor. Why? Because although it's radioactive, it gives off mainly alpha radiation. Uranium is an alpha emitter, and consequently, that alpha radiation can't even go through a sheet of paper, let alone the metal coating of these fuel bundles. So you can safely handle it. You should have gloves on, and not stay there too long. Outside the body, alpha radiation is harmless.

But when that fuel bundle goes into the reactor, and comes out the other end, it will kill any human being in just 20 seconds at a distance of one metre, because of the intense blast of gamma radiation coming from the newly created fission products. Those broken pieces of uranium atoms are so radioactive, they will kill anybody that is unprotected by shielding.

And in fact, once that bundle has been used in the reactor, it's called used fuel, or irradiated fuel – and it's the most radioactive object on earth. It will never again be handled by human hands for at least the next 500 or 600 years, because it's too dangerous to do that. It also has to be cooled for about 10 years in a pool of water, and I'll talk more about that in a minute.

So there are three categories of radioactive waste materials. There are first of all the fission products which I've talked about – and there are hundreds of them. They are the broken bits of uranium atoms.

There's another category, very important, called the “transuranic” elements. These are heavier than uranium. The fission products are all lighter than uranium because they are broken pieces of uranium atoms. But the transuranics are heavier than uranium. And how they come about is this. Some uranium atoms absorb a neutron but do not split, so they become heavier, and they change into very toxic radioactive alpha-emitting materials, like plutonium, americium, and neptunium. There's about 36 of those that I could recite off-hand, taking into account that each one has several different isotopes – for example plutonium-239, plutonium-240, plutonium-241, plutonium-242 and so on. There are about 36 that are commonly listed.

And then there's a third category called the activation products. Remember those extra neutrons that are given off? Some of them go into the steel and into the concrete and they encounter non-radioactive atoms in the structural materials and make them radioactive. That's called activation. That happens when a non-radioactive atom like cobalt-59, in steel, will absorb a neutron and turn into cobalt-60, which is a very intense, powerful, gamma emitter, and that becomes very dangerous for the workers. Now because the cobalt-60 is right in the steel, you can never recycle that steel. So all that structural material has to be buried as radioactive waste. It's not recyclable.

Some people have called nuclear energy the ultimate example of the throw-away society, because it's the absolute opposite of recyclability. And that's why, even after you take the irradiated fuel out of the reactor, you still have a whole lot of radioactive waste left behind in the reactor, because the structures themselves have become radioactive.

And by the way, that radioactive waste (other than the used fuel) is not the responsibility of the federal government. The federal government has said they will look after the irradiated fuel, but “you guys” (i.e. the provinces) are responsible for all the other radioactive waste. So New Brunswick would be left with a legacy of radioactive waste from these SMNRs, if any were left behind in New Brunswick. And the same would apply in any other jurisdiction.

Now here's a list of 211 radioactive materials in the irradiated fuel. Almost all of them are human-made elements. There's a few of them that occur in nature to a very slight degree but we create them in mass quantities. There's 211 of them listed. I got this list from Atomic Energy of Canada Limited. They are all found in the irradiated nuclear fuel, and they all are very dangerous

to living things because of the atomic radiation. The list is by no means complete. They don't even know all of the radioactive materials that are created in a reactor. I've been told by nuclear engineers that there are over 1,000 of them, and they have only really studied a handful. Nobody knows what all these "radionuclides" do and how they all behave in the environment.
See http://www.ccnr.org/hlw_chart.html .

Here is a photo the face of a CANDU reactor, loaded with fresh unused fuel bundles. This man can stand safely in front of it because the reactor has never operated for a single day. But if this reactor had ever operated, and for him to stand there – he'd be dead as a doornail now, because there would be such a blast of gamma radiation coming off the fission product it would kill him in short order. See http://www.ccnr.org/candu.html .

The spent fuel is so radioactive that it generates heat and has to be cooled for 10 years in a pool of water. Now you might say "Well how can it be that hot?" Actually it's not that hot. The problem is not that it's hot, but that it *generates* heat. And unless you remove the heat as quickly as it's being generated, it will produce higher and higher temperatures. The heat drives the temperature upwards. If it's not cooled, the fuel will overhead, the metal cladding will melt or crack, and radioactive gasses – about 20 percent of the fission products are gasses – will be released into the atmosphere as radioactive material that is going to damage the cells in the bodies of the surrounding population and contaminate the vegetation and so on.

We have two main categories that people talk about in the irradiated fuel: the fission products, i.e. the broken pieces of uranium atoms, and the transuranic elements, the most famous of which is plutonium. Plutonium is also the key ingredient in modern nuclear weapons. Even the H-bombs require plutonium. When they talk about dismantling a nuclear weapon, what do they mean by that? Well what they mean is, they take the plutonium out of the weapon. If you take the plutonium out of the weapon it's no longer a nuclear weapon, it cannot be used as a nuclear weapon. So, it's the plutonium that really drives the whole nuclear weapons arsenals of the world.

And plutonium is created inside every reactor when a neutron strikes a uranium-238 atom. The uranium atom absorbs the neutron, and it becomes a little heavier, and turns into plutonium-239. And that's the stuff that bomb-makers love to use for their bombs.

Now, if that material (plutonium) gets into the hands of criminal organizations or terrorist groups, then we could be faced with a very terrible situation around the world. As somebody said once, in the Regan administration: "we could wake up tomorrow and find Washington DC gone and not have a clue who did it." Because you can make an atomic bomb the size of, or not much larger than, a soccer ball; you could put it in the trunk of a Volkswagen beetle and park it in a downtown city and explode it by remote control. And it would be more powerful than the Nagasaki bomb that was used in 1945.

So the idea that this stuff (plutonium) would become readily available is a kind of a nightmarish prospect, and it's one of the worst aspects of nuclear power. If we got to the point where plutonium is readily available, and is in wide circulation, this would be very, very bad news for planet Earth, because of humans. At the present time, this is not happening – for the most part.

Consider the fresh CANDU fuel that is used for Lepreau, for example. Nobody could make a bomb out of that stuff because it's not weapons-usable material. However if you were able to get the plutonium out of the irradiated CANDU fuel, out of the used fuel, then you could make a bomb from that – and that's where the danger is.

In Canada, we have decided not to access that plutonium but to bury the irradiated fuel with the plutonium inside – something that the nuclear industry hates to see, because they say: "what a shame, we could get that plutonium out and use it for peaceful purposes, for nuclear fuel."

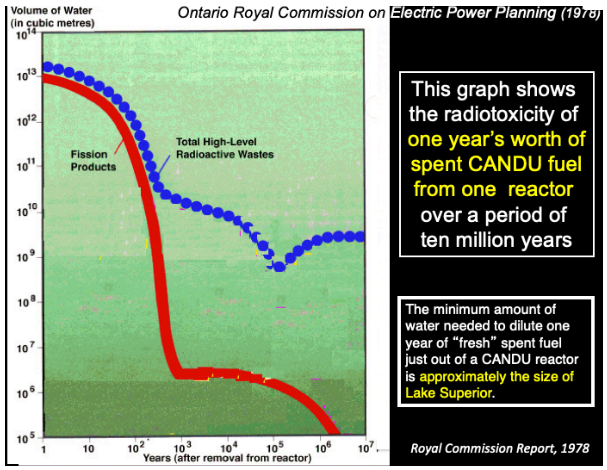
This photograph shows how much plutonium is needed to destroy a city. It is in fact a glass paperweight, which is custom-made to be exactly the same size and shape as the plutonium ball that was used in the Nagasaki bomb. It's only a few kilograms of plutonium, about six kilograms. Now they say with modern designs you can get the same degree of destruction with half as much plutonium, three kilograms, through a more efficient bomb design.


This glass paperweight is the exact size of the plutonium ball that was used as a nuclear explosive in the Nagasaki bomb.

Photo: Robert Del Tredici

In Canada, we talk about burying this waste, and all over the world they talk about burying this waste. Why? Because it's so bloody dangerous. This is a graph from a 1978 report, from the Royal Commission of Electric Power Planning in Ontario. The graph shows the radiotoxicity, that means the ingestion toxicity – if you were actually able to get this into your body, by eating contaminated food or drinking contaminated water, or inhaling contaminated air. The question is how toxic is it over a period of 10 million years?

The way they went about this, they said well let's look at just one CANDU reactor, and just one years' worth of spent fuel, one years' worth of irradiated fuel. So think of one year from Point Lepreau for example, the irradiated fuel produced in that time. The blue line represents the total toxicity. The way they did this, is they said “Well there's a legal limit on how much of this stuff you can put into drinking water. We have limits for every one of these radionuclides. How much is the maximum amount you're allowed to contaminate the drinking water? How much water would you need to dilute all this stuff to the maximum level of contamination permitted?



At the top of the graph on the left, the amount of water needed would be about equal to the volume of Lake Superior, in order to dissolve the radioactivity down to the maximum legal level of contamination. As you progress from left to right, the toxicity declines. After about 500 or 600 or maybe 1,000 years, the fission product – indicated by the red line – become less important than the transuranics (also called the "actinides"), and so the total toxicity remains much higher than the fission product toxicity after about 1,000 years. That's because the transuranics are much longer-lived and more toxic and so on.

Now in the case of these SMNRs they are planning for New Brunswick, they say that one advantage is that the SMNR can reduce the inventory of plutonium by "burning it up", and that will make the length of time needed to look after this high-level waste shorter. "It will reduce the radioactivity to hundreds of years instead of thousands of years" we are told.

It turns out that's not entirely true. In fact many of the things the nuclear industry says about such matters are not entirely true. One of the things that I found distressing as a scientist is that they don't seem to be able, or they can't afford, to tell the whole truth, and so they only tell part of the truth.

Because SMNRs are not clean. They produce radioactive waste of all kinds, and that means the irradiated nuclear fuel that we just talked about, as well as the activation products that are in the actual structural materials. So even after they take out the high-level waste, these machines are going to be radioactive themselves, and they're going to be constituting an additional source of radioactive waste – how are they going to handle that? They say not one word.

Radioactivity is a form of nuclear energy that cannot be shut off. That's why we have a nuclear waste problem. We don't know how to shut it off. And we don't know how to eliminate it. However, it's not true that by "burning up" the plutonium and the americium and the trans-uranics that you're going to eliminate the need for long, long, long, multi-thousands of years of storage. Because some of the fission products have half-lives of over 100,000 years, I've listed some of them here. Those things cannot be "burned up". As a matter of fact, by "burning up" the plutonium, we're actually increasing the amount of this stuff (i.e. the fission products, including the very long-lived ones). Because the only way you can "burn up" the plutonium is by splitting the plutonium atoms, which means you create *more* fission products.

Moreover, the fuel for the SMNRs has to be enriched fuel. Here in Canada, in our commercial reactors we use natural uranium which has less than 1% uranium-235. But these small reactors are going to have at least 5 percent uranium-235 or plutonium, and possibly as much as 20 percent, which means the irradiated fuel is going to be much, much more radioactive than the CANDU fuel because there's going to be a lot more fission products per kilogram. And add to that, the splitting of the plutonium atoms adds to the inventory, so you're going to have a much more serious problem with the small modular reactor fuel – transporting it, for example.

So, small modular reactor fuel is always enriched, unlike CANDU fuel. And when you have enriched fuel, and if the used fuel is then buried, it can cause a criticality accident underground. What does that mean? It means that when water comes in contact with enriched uranium, the uranium can spontaneously start splitting, undergoing a spontaneous nuclear chain reaction. That's called a criticality accident.

It turns out that's not possible with CANDU fuel because CANDU fuel is unenriched. The only way you can get a chain reaction going with CANDU fuel is to use a very special kind of water called heavy water. If you don't use heavy water, you will never get a chain reaction going. But with enriched fuel, ordinary water – the kind of water that we use all the time – will get a chain reaction going. So this poses special problems for burying it underground. It means you may have serious problems down there. Any underground repository will end up flooded.

In addition, the SMNR fuel that Moltex wants to use for the SSR (the "Stable Salt Reactor") is based on salt, which is very corrosive. By the way, the fuel is liquid, it's actually a liquid solution of salt with plutonium. If you put that stuff underground, then you have introduced a corrosive agent which shouldn't be there, because it's going to compromise the stability of the whole storage capacity. Other SMNR fuel can contain dangerous materials like sodium metal, because the ARC-100 reactor uses liquid sodium metal as a coolant. Now as anybody who has studied science knows, sodium reacts violently and ignites upon contact with air or water. And so having remnants of sodium down there (in an underground waste repository) is also very dangerous.

There's a paper called "Burning Waste or Playing with Fire" that raises these points in the Bulletin of the Atomic Scientists. I've given the reference there. Allison McFarlane, one of the authors, was the Chair of the US Nuclear Regulatory Commission (NRC). She's a geologist and she knows what she's talking about.

This is a drawing of the kind of facility they want to build to store high-level radioactive waste. Nobody knows whether it's really going to be successful or not because we have no way of testing it. We have no way of knowing whether the waste, when it's put down there, is going to stay there. We've had three geological disposal sites for radioactive waste which have failed in recent years. In Germany there were two of them, one being the Asse-2 Salt Mine. They're now taking the radioactive waste out of the Asse-2 Salt Mine at a cost of 3.7 billion euro, which is about $5.4 billion CDN. They're going to take the waste out because it's been leaking into the groundwater and into the surface waters and it cannot be left there. It's going to take 30 years to do it, and once they get the radioactive waste up on the surface again, they still don't know what they're going to do with it finally. And there's also been another one, the Morsleben radioactive waste facility in Germany, which has also failed.

In Carlsbad, New Mexico, they had a drum of plutonium-contaminated waste underground which exploded and turned into a flame thrower because of the organic kitty litter that was used as packing material. The plutonium dust went 750 metres vertically upwards, contaminated 22 workers, and drifted downwind to the city of Carlsbad. That was only a few years ago.

So these deep geological repositories, they sound great on paper but are they actually safe? We don't know. There has been not one approved for use anywhere in the world. Finland is the closest, they've actually built a repository called Onkalo, but it hasn't been licenced yet.

Here's another thing. Both the ARC-100 and the Moltex SSR – these are the two models they are planning for New Brunswick – they both plan to re-use the spent CANDU fuel. They brag about this. They say "we can burn up your waste." But the only way you can re-use irradiated fuel is by accessing the plutonium. That's the only way you can do it. And accessing the plutonium raises security risks worldwide. Because they want to – in order to be successful, they have to – sell these reactors in other countries. The domestic market is not in any way possible to be able to support such an industry. They have to be able to sell them in Africa, in Eastern Europe, in Asia, all over the world. If you have reprocessing (reprocessing is a way of accessing the plutonium in the irradiated fuel) this raises serious problems about the proliferation of nuclear weapons.

Who is going to inspect all these sites? Thousands of sites in remote communities, and mining sites, and so on? Is the International Atomic Energy Agency going to be able to send inspectors to keep an eye on all these things? Who is going to be watching the shop?

There's another article called "Reprocessing Revisited", from the Arms Control Today publication. They say that "proliferation-resistant reprocessing" – which is what the industry is calling it – is an oxymoron, because there's no such thing.

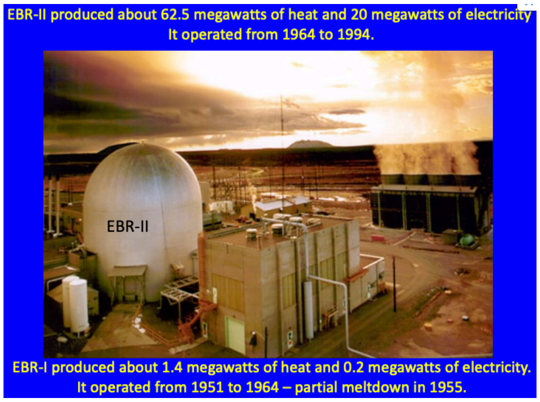
Reprocessing also requires more transport of spent nuclear fuel, and to transport even a small amount of spent fuel requires a shipping flask of at least 70 tons. And who says that in these remote communities that you can ship such heavy loads ... are the roads sufficient to be able to ship 70-ton, and 100-ton, and 200-ton flasks of irradiated nuclear fuel? Well, that's problematic.

Also the SMNRs are not that small, although they are called small. This is what the ARC-100 reactor design looks like according to the promoters. What they've done is put as much of the components as possible inside the reactor core, so that you have less possibility of things escaping by random leaks and random pipe breaks and so on. But when you put it all together, this is what they say it's modeled on. The ARC-100 is modeled after the EBR-2 (EBR stands for "Experimental Breeder Reactor"). The EBR-2 was conceived and built back in 1964.

So, 1964 – how's that for a new technology? Today's SMNR entrepreneurs are really reaching back into the past and dusting off old ideas and presenting them as if they are brand new breakthroughs, while in fact they are very old ideas that have all been tried with various degrees of success or failure in the past, and have been rejected for various reasons in the past.

Anyway the EBR-2 was the second Experimental Breeder Reactor. It was the successor of EBR-1 which is the first experimental breeder reactor. EBR-1 had a partial meltdown in 1955 and was retired in 1964 which is the year that EBR-2 started up. EBR-2 operated without a meltdown for 30 years, to be sure, but this was on a military site, with very heavy security and so on, it's not on some remote mining site or some remote Indigenous community or some remote exploration operation.

Below: Two "small" nuclear reactors (circa 1964) cooled by liquid sodium metal



EBR-2 Reactor, 62.5 megawatts of heat

Fermi-1 reactor, 200 megawatts of heat

They actually built a prototype commercial breeder reactor in the United States, it was called the Fermi-1 reactor, and it generated only 69 MW of electricity (200 megawatts of heat). These are (according to the current definition) "small" reactors. They don't look small, though, do they?

And they are not small in terms of their effects. There was a partial meltdown in this Fermi-1 reactor in 1966, as described in the book "We Almost Lost Detroit". All of these reactors I'm showing you, the EBR-1, the EBR-2, the Fermi-1 – and the NRX reactor in Canada which melted down in 1952 – these are all "small reactors". The NRX reactor that melted down in 1952 was only 10 MWth (thermal megawatts) – that's small! But it's big in terms of the consequences. The NRX reactor at Chalk River, Ontario, underwent a series of explosions and a partial meltdown in 1952, the first major nuclear reactor accident in the world.

Sodium leaks are also a problem, because sodium reacts violently with air or water – and all of the breeder reactors using liquid sodium coolant around the world have been problematic in that regard. Most of them have had sodium leaks and fires. The Clinch River Breeder Reactor was cancelled by President Carter because, if it underwent an accident, it could have contaminated three states. The "Superphénix" breeder reactor was cancelled by France – it's also a liquid sodium metal cooled reactor – because it would have contaminated almost the whole of France in case of a severe accident, and they just couldn't get it operating in a way that was sufficiently safe to be confident.

There are long-standing concerns as well with the plutonium economy and "breeders". The word "breeder" refers to a nuclear reactor that uses plutonium as a fuel and breeds even more plutonium. Technically, a breeder reactor is a reactor that uses plutonium as fuel and creates even more than it uses.

The Moltex stable salt reactor uses a concept that has also been tried before, and it is also problematic. It is not so small once you get it fully assembled. And SMNRs are not green, because they take too long to build. Climate action is needed now, not 10 or 20 years from now. The UK House of Lords reported in 2017 that they couldn't build a prototype SMNR before 2030. The same thing goes here in Canada, they've used 2030 in their literature. So what we are doing is bypassing energy efficiency and renewables, which are faster and cheaper alternatives, and we're putting money into these nuclear reactors that cannot do any good at all even at a prototype level for 10 years – and it'll be 20 years before you can get any degree of deployment.

So we're kicking the can down the road again. Now Germany, on the other hand, more than doubled its offshore wind power capacity in just one year. We're talking about 2,300 MW of offshore wind electricity. That would be the equivalent of two large American reactors or four Pickering reactors here in Canada. We couldn't do that in just one year with nuclear power, but you can do it with wind power.

SMNRs are not affordable, as I mentioned before, because you have to get hundreds or thousands of them sold, and so far they don't have any buyers. They have no customers on their books. They are trying to create a market. That's why they are running around the country talking to people. They want to get people interested in buying these things. Right now nobody wants them.

The trouble arises when you dismantle these small modular reactors. Putting an SMNR into a remote site is going to be relatively easy but taking it out is going to be damn hard, because it's so radioactive that it needs a great deal of shielding. That requires very heavy containers, and it's very, very dangerous. What's more, the building itself becomes radioactive. What they are now trying to do, the Canadian Nuclear Safety Commission (CNSC), is trying to suggest that we can just bury the radioactive leftovers on site.

But I have a list here of radioactive materials that are contained in the structural material. These are not in the irradiated fuel – these are in the steel, in the concrete, in the structural materials which are going to be left behind. And you'll notice that a whole lot of them have very long half-lives. In fact, of the 34 radionuclides indicated here, 22 of them have half-lives over a century, 18 of them have half-lives over 5,000 years, 14 have half-lives over 100,000 years, and so on. These are not short-term problems, these are very long-term problems. The defunct reactors are going to be leaking radioactivity into the environment for thousands of years if you just bury them onsite and leave them in those remote communities – if turn your back on them and say "OK, we're not even going to look at this anymore, it's not our problem anymore."

Longevity of Some Activation Products

Radionuclide	Half-Life	Ten Half-Lives
Nickel-59,	76,000 years	760 thousand years
Nickel-63,	101,000 years	1.01 million years
Niobium-94,	20,300 years	203 thousand years
Plutonium-239,	24,000 years	240 thousand years
Technetium-99,	120,000 years	1.2 million years
Iodine-129,	15,700,000 years	157 million years
Chlorine-36,	301,000 years	3.01 million years
Calcium-41,	102,000 years	1.02 million years

Draft EIS, in-situ decommissioning of the Whiteshell WR-1 Reactor

This the end of my talk. Thank you for your patience.

Questions and Answers

Question: *You said that SMNRs are exempt from an Environmental Assessment Review. Could you clarify if that is a fait accompli, or can it be challenged at this point?*

Gordon: It's a fait accompli. When the bill was passed, the First Nations in Ontario wrote a letter to the Senate saying "do not allow for SMNRs to be exempt from this". The First Nations have already passed a resolution opposing SMNRs in general.

http://ccnr.org/ AN_SMNR_Senate_Letter_2019
http://ccnr.org/ COO_resolution_SMRs_2018.pdf

But the idea that SMNRs would be exempted from environmental assessment is a fait accompli. It's not in the legislation, but they have a project list. The projects that are on that list indicate whether something is going to be subject to an environmental assessment or not. The law also says that if there is any environmental assessment done of any kind, it has to be done by the environmental assessment agency. But the project list says that nuclear reactors (1) that generate less than 200 megawatts of heat, anywhere in the country, or, (2) that generate less than 900 megawatts of heat, if they are on the site of an existing nuclear power station, will not need to undergo any environmental assessment whatsoever. *[Note: That excludes any SMNRs that are on the site of an existing nuclear plant, because – by definition – all SMNRs are designed to produce less than 900 megawatts of heat.]*

And in fact the CNSC (Canada's nuclear regulator) lobbied for this exemption to take place. They want these things off the "project list". They don't want them to be subject to environmental assessment. Part of this is just to speed up the process. But bear in mind that we have 150 different models. CNSC has already looked at about a dozen of them, and they've done "pre-licencing evaluations". But the designs are all different. They all pose very different technological problems, different environmental difficulties, and so on. Yet none of them will be subject to environmental assessment, unless they are more than 200 MW of thermal power AND away from an existing nuclear generating site, or more than 900 MW of thermal power on an existing nuclear generating site.

Question: *An environmental assessment was required for the large Lepreau reactor. The SMNRs are exempt because they are small?*

Gordon: Of course, that was a completely different piece of legislation, that was two EA Acts back. The 2012 Harper Environmental Assessment Act put the entire environmental assessment apparatus totally in the hands of the CNSC, a body which by the way has never once, in its entire history, ever refused to grant a licence to any major nuclear facility. CNSC is conducting the environmental assessment right now for certain nuclear waste dumps. But in the future, with the new law that the Trudeau administration has now put in place, these small reactors have been specifically exempted from environmental assessment depending on their power level.

Question: *Some people on this webinar are on the Peace and Friendship Coalition who would potentially be supporting Indigenous voices against these developments. What would you advise that could happen at this point?*

Gordon: I think it's very important to be really respectful of Indigenous people and not even begin to suggest that you're telling them what do or suggesting what they should do. I think the important thing one can do is to act as an honest broker, to explain to them as honestly as one can what is known about these things, what the advantages are, what the disadvantages are, and let them make up their own mind.

We had a recent victory from the environmental movement point of view, in Ontario, where the Saugeen Ojibway Nation voted against a deep geological repository right beside Lake Huron, less than one mile from the Lake, for all of the low and intermediate level waste – which is the other kind of stuff, by the way, that New Brunswick would be stuck with, because the federal government won't take that off your hands. They voted against that because it's on their traditional unceded territory. And the main reason they did that was because of the sacredness of the water, which is the lifeblood of the planet, and for which Indigenous people is associated with all kinds of ceremonies and prayers and dances and so on, and legends about the great importance of the water. And also the sacredness of the earth.

Indigenous people just need to be assisted in answering their questions honestly and letting them consider what they think should be done.

Question*: What is your proposition for baseload? Renewables are not dependable enough for a baseload, and we don't have the technology to store that kind of energy. How do you propose a baseload energy source?*

Gordon: There are many people who think we can possibly move to 100% renewable, which may or may not be possible. But anybody who looks at the economics even, and the speed of deployment, would see very clearly that energy efficiency is both a lot cheaper and a lot faster than any form of new source of energy. Renewables are also quickly deployable. They are more expensive than efficiency investments, but they are cheaper than nuclear, and their costs are coming down fast, whereas nuclear costs keep going up. The renewables keep coming down in cost, and the two “cost curves” have already crossed over.

So the thing is, you should go for the quickest and cheapest things that you have, that can more quickly and efficiently reduce greenhouse gasses, i.e. carbon emissions, and that's efficiency and the renewables. Now to the extent that we're successful in doing that, then we can talk about whether we can achieve 100% or 90% or 80% or 70% or whatever, but only then should we be talking about how to fill in the gap, because we know very well what is the best thing to do in the short term.

Now baseload is probably an antiquated idea. It's sort of like mainframe computers. Mainframe computers have been obsolete in the sense that portables and laptops can use mainframes as a kind of accessory but the power should be on the desktop. That's what the founder of Apple said a long time ago. In a similar way, baseload is based on old technology. If we use new technology with so-called smart grids, the renewables are dependable enough, at least we're working towards it. They are not yet there but they are getting there rapidly, and the breakthroughs in storage, such as in Australia – utilities like Pacific Gas and Electric are now using industrial scale Tesla batteries, instead of diesel backup for peaking, they are using these batteries instead. And that's the direction we should be going.

And if you talk about any form of energy storage – for example, nuclear proponents like to say: "Well, we could produce hydrogen from nuclear. Hydrogen is a storage system, hydrogen can be used as a fuel." But the point is that if you solve the storage problem, to whatever extent that you solve the storage problem, that will automatically favour the renewables rather than nuclear, because the only present disadvantage of renewables is the storage problem.

If we wanted to make hydrogen as a portable fuel, for example, it would make a whole lot more sense to use solar and wind to produce that hydrogen for vehicular use, rather than to use something like baseload electricity. So I think the baseload problem is resolving itself. The more we build nuclear, the more we lock ourselves into this antiquated paradigm of baseload electricity. Solar and wind, together with storage – and together with energy efficiency, which is number one – can go a long way toward reducing the need for this baseload concept.

Question: *Is it correct to suggest that there is probably no solution to the structural waste problem?*

Gordon: I would say absolutely there is no solution. Because they have worked very hard. They used zirconium as a fuel cladding material because it's a lot better than certain other metals. They use beryllium welds in making the fuel bundles because beryllium is basically invisible to neutrons. They have taken great lengths to find better structural materials as you say.

But the result is disappointing. You have some of the finest stainless steel in the world that has gone into building the core of the Point Lepreau reactor, and that stainless steel will never be able to be recycled and reused again. It's going to have to go into the ground or into permanent storage as radioactive waste, because the radioactivity is right inside the atomic structure of the steel. It's not a surface contamination only, it's an actual transmutation of non-radioactive elements into radioactive varieties.

So this is an unsolvable problem at the present time. It will also be a problem with fusion reactors. Although fusion reactors would not create high-level waste, which is a great big plus for fusion reactors, it will create probably even worse problems in terms of activation products – because the neutrons from fusion are much more powerful, 14 million electron volts, compared with 4 million electron volts with fission. It means you're going to have a lot more problems that way.

Question: *Do you think nuclear reactors should be shut down before their planned end of life, even if it means burning fossil fuels for power?*

Gordon: I wouldn't necessarily say so. It would have to be decided on a case-by-case basis. If it is possible to shut them down and replace them with renewables, then yes. For example, in Ontario right now, Premier Ford is paying $250 million in penalties for cancelling all the contracts that were already signed to build renewable energy facilities. And yet he's spending tens of billions of dollars to rebuild the cores of old nuclear reactors instead of buying surplus hydro power from Quebec, which is non-carbon-dioxide generating, and which is available at about half the price.

So there's a lot of bad choices being made here, because politics is politics, and politicians are often more interested in pleasing their supporters and in making political hay rather than doing what is the best thing for solving the problem, in this case the energy problem. In Ontario, the Pickering reactors are being run into the ground and the Darlington reactors are being refurbished and a lot of that cost could be saved. The Pickering reactors should have been shut down quite a few years ago, they are past their best-before date. They could have been shut down quite a while ago had they made a deal with Quebec to buy the surplus power at a cheaper rate.

Question*: Is it not possible to make up the energy requirements with both renewables and nuclear?*

Gordon: You hear a lot about this. It comes mostly from the nuclear proponents and people who have been persuaded by the nuclear proponents. But the point is that nuclear and renewables are largely incompatible, as we see with the example of Doug Ford. Investing in nuclear often means shutting down the renewables, because nuclear can't afford to have those competitors.

As a matter of fact, there's been negative pricing at certain times in Ontario because the demand for electricity has been diminishing for over 10 years now in Ontario. They at one point had to shut down the power from Niagara Falls in order to keep the nuclear reactors running, which is really insane – it's sort of like the mad hatter at the tea party – because it's more expensive to shut down the reactors and then have to start them up again than it is to just turn off the renewable flow of water form Niagara Falls. You can't turn off Niagara Falls, of course, but you can turn off the electrical generators. They have proven to be incompatible.

Interestingly enough, if you look at the Moltex literature – that's the Stable Salt Reactor supplier – they say in their literature that the Moltex SSR reactor is ideally designed to complement renewables because the renewables are intermittent, as we talked about, and it needs some certain amount of storage. The Moltex reactor has a way of storing very hot molten salt – we're talking about hundreds of degrees – in special containers, and we can use that energy to produce power to fill in the valleys caused by renewable energy production.

But if you took that logic literally, it would imply that the first thing you should do is build the renewables, because what's the point of having a backup for renewables when you don't have renewables? So in order to be a backup for renewables, you have to start with the renewables. And what we're doing is standing the priorities on their head. We're investing in the slowest and costliest option, which may or may not even be viable in the long run because none of these reactors have been built or tested so far. We do know that every one of the them is going to be economically more expensive per unit of energy, per unit of electricity, when they are built one at a time. There's no way that they can be cheaper. They are going to be more expensive, and consequently they are going to be an even less attractive option than the large reactors.

The only way they can overcome the difficulty of added expense because of the small size is to mass produce them, and that means they've got to have hundreds or thousands of customers, which they do not have. So, it's highly problematic whether any of these reactors are going to be successfully deployed, whereas with wind and solar and geothermal, we know it can be successfully deployed, there's no question about it. So we're bypassing the easy things, the low-hanging fruit, and we're concentrating on stuff that's pie in the sky.

I think it's no accident that this support for SMNRs comes from premiers who have traditionally wanted to kick the can down the road when it comes to combatting climate change.

Question*: Renewables are dependent on storage that is also not yet sufficient for present dependability needs and likewise hypothetical. How do you square one being a problem and the other not?*

Gordon: I'm not trying to solve all the problems of the universe, nor do I have all the answers. The point is to follow the experimental method: you try something and see what happens. It seems clear that renewables can contribute, that renewables have contributed. Renewables have been very successful in various places. The price has gone down fantastically, and as I showed in an earlier graph, the growth rate of renewables around the world surpasses the growth rate of any other energy source. So whatever the problems might be with renewables – there are problems with any energy technology no doubt – but we should try it and see. Usually you find when you start investing in something you create a market, and that's what happens with renewables. The price goes down. The more you buy them, the more the price goes down. With nuclear, the more you buy them, the more the price goes up. That should tell you something.

To the extent that we can get the storage technology going ... everybody's talking about electrifying the transportation sector. It's impossible to electrify the transportation sector without breakthroughs in storage. So the more you invest in electrification, and the more you invest in renewables, the more you you're going to stimulate the energy storage technology.

Storage has made great strides. They are not using diesel generators for backups in California anymore, they are using utility-sized Tesla batteries. And that's the way we should be going. Tesla batteries may not be the be-all and end-all, but we didn't even think Tesla batteries were possible until we started investing in them.

Question*: How do the mining and waste concerns related to lithium and cobalt for battery storage compare with concerns with nuclear waste?*

Gordon: Well that is a very good point. It is true that there are some various dangerous materials involved – the rare metals for example, the rare earths – involved in renewable technologies, and yes that is a serious problem and it does have to be dealt with.

However I'd like to point out that nuclear power is the only technology that actually creates new elements. It creates hundreds and hundreds of new elements which never existed on earth before 1939. These new elements become their own problem, over and above the natural elements that we already have. [The new elements that are created are all unstable, i.e. radioactive.]

Now lithium and cobalt are naturally occurring non-radioactive elements. It's true we're using them. But we did not create them. Nuclear industry is actually creating a whole galaxy of new problematic elements that have added dangers. Radioactive cobalt is a hell of a lot more dangerous than non-radioactive cobalt. Radioactive lithium is a hell of a lot more dangerous than non-radioactive lithium. These non-radioactive elements can be serious problems – and I'm not trying to minimize them, they do have to be looked at very carefully, and I think the disposal problem and storage problem for these elements is very important – but we did not create them and we cannot destroy them, we have to deal with them. Maybe we should stop creating new problems however, and that's what nuclear is doing.

Question*: A political question. There are huge political forces both federally and provincially pushing for SMNRs. What is a strategy to counteract that?*

Gordon: The push is really coming from the nuclear industry. The nuclear industry is the pusher. The governments are the target. If they can, they will convince government to pour public money into this for whatever reason, by misrepresenting its advantages and minimizing or even ignoring its disadvantages. The governments I think are being suckers. Because if Wall Street and the banks will not finance this, why should it be the role of the government to engage in venture capitalism of this kind?

Is the government in a position to realistically assess the business case for this whole situation? People who are in a position to actually analyze the business case are not impressed. Westinghouse dropped out of the SMR market saying that they did not see a business case for it. The president of Exelon has said that he is not enthusiastic about SMNRs for one simple reason: there are no customers. You can't have a viable business case with no customers.

The nuclear industry is desperately fighting to try and stay alive. They are going out. It's important to understand that background. Their nuclear renaissance was a flop. Now they are trying again. They are trying desperately to get governments to pour money into this, because that's the only place they can get the money.

The UK House of Lords in 2017 did a report on this and they expressed a lot of scepticism, and interest in the possibilities, but they said that 2030 would be the earliest that they could get even a prototype up and running. And during that period of time, during the interval, there would be absolutely zero contribution to climate change. There would be no reduction of GHG. In fact it would be adding to GHG because uranium enrichment plants use as much energy as a large city, and they give off a helluva lot of GHG just like the tar sands do.

So we're going to be – for all the 10 years leading up to the first prototype being produced – we're going to be adding to the climate change problem and doing nothing to reduce GHGs. That's not a strategy.

I believe our government is doing this because they are politically in hot water. They can't stop the petroleum industry. They have bought a pipeline. They're having difficulty getting that accepted by native people and others. They are not cutting down on GHGs like they said they were going to. They are going to be adding to it. The Government of Ontario is not going into renewables, they are going into refurbishing nuclear. So politically, it makes sense for the government to say, since we can't do a damn thing about actually fighting climate change, let's just say we're putting all our money behind nuclear reactors and that *they* are going to solve the problem.

So they're basically passing the ball to the nuclear industry, saying "OK, you haven't solved the problem in 80 years – neither the problem of radioactive waste or of climate change – let's see if you can solve it now!" They are really relinquishing their role as leaders and saying let's pass it over to the nuclear industry and let them lead.

One other thing I should mention. The uranium markets are dismal. The price of uranium is extremely low. Saskatchewan would love it if the uranium prices would rise even a little. But it's not going to rise unless you have more reactors.

There are other reasons why it's politically advantageous to push the nuclear envelope. And people are mystified by nuclear. it's a lack of leadership and a type of political opportunism to say "the nuclear people are going to solve all the problems." By the way, if you look at the mandate letter for Seamus O'Regan (Minister of Natural Resources) you will see there is not one word about nuclear. Not one word.

For more information, anyone can sign on to Gordon's mailing list.
His email address is ccnr@web.ca | Website: www.ccnr.org