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The title of this presentation is:
NUCLEAR MITIGATION OF CLIMATE CHANGE – (Part 1, Nuclear Fuel Issues)

Display title slide

Hello!

CO2 History
During the 1960s it was both theoretically and experimentally proven that the presence of a low concentration of CO2 and/or other greenhouse gases in a planet's atmosphere substantially increases the atmospheric temperature.

In early 1970 the results of 12 years of precision atmospheric CO2 concentration measurements at Mona Loa, Hawaii were published. These results showed a consistent annual increase in Earth's atmospheric CO2 concentration and that this increase is primarily caused by combustion of fossil fuels.

Display IR Emission Slide
Display Visible Light Photo of Earth

In late 1996 a US spacecraft, named Mars Global Surveyor, recorded the thermal emission spectrum of planet Earth from deep space. Note the average temperature of 270 degrees K of this IR emission.
A few degrees of atmospheric warming or cooling significantly changes Earth's ice cover and hence the planetary albedo.

Note the major IR notch caused by the 1996 atmospheric CO2 concentration.

This thermal emission spectrum, in combination with a visible light photograph of Earth from Apollo 17, shows that, due to progressive ice

melting, Earth's surface temperature will increase rapidly during the coming decades. If all the ice melts an average atmospheric temperature rise of 17 degrees C is possible, which would drive most large land animals into extinction.

A consequence of the present ongoing combustion of fossil fuels is that on dry land the dry bulb atmospheric temperature is rising causing wild fire and drought. The oceans are absorbing net radiant heat which is causing a delayed rise in wet bulb temperature and large scale human migration away from the tropics.

In much of Canada, due to the temperature driven change in average local albedo, the rate of rise of average dry bulb temperature is 3X that expected from just greenhouse gas effects.

Fossil fuels presently supply mankind about 20,000 GWt of average thermal power.
The law of conservation of energy indicates that even with 5000 GWt of average intermittent renewable power, stopping further average atmospheric temperature rise requires **ceasing all use of fossil fuels** and supply of at least **15,000 GWt of fuel sustainable dependable nuclear power.** In the electricity business this corresponds to about 5000 GWe of firm power. The Canadian portion of this is likely to be about 2% or 100 GWe.

To put these numbers in perspective, the total thermal output power from all of today's nuclear power reactors is about 1200 GWt, of which less than 10 GWt is fuel sustainable.

Hence, displacement of present fossil fuel consumption requires both maximum economic renewable power generation (5000 GWt) plus more than 12X the existing installed nuclear reactor thermal power capacity.

Most existing power reactors use thermal neutrons to fission the rare uranium isotope U-235. However, the limited economic natural uranium resource prevents thermal neutron reactors providing fuel sustainability

TRU are atoms with atomic numbers greater than 92 that result from neutron irradiation of U-238. Achieving fuel sustainability requires use of Fast Neutron Reactors (FNRs). A FNR relies on fission of TRU with fast neutrons, simultaneous formation of more TRU using surplus fission neutrons and periodic fuel reprocessing. The FNR process and fuel cycle is well known but deployment of FNRs has been politically opposed by our federal government under the influence of fossil fuel majors for over 30 years.

Deployment of a fleet of fuel sustainable FNRs at a rate sufficient to stop climate change also requires deployment of Intense Neutron Generators (INGs) to increase the initial TRU production rate.

The choice facing the young adults today is stark, either rapid large scale deployment of fuel sustainable FNRs or thermal extinction in the decades to come.

The minimum qualifications for rationally making the necessary FNR deployment decisions are a good understanding of astrophysics, electric power systems and fast neutron reactor physics.

Politicians who lack the necessary technical education must delegate long term energy production planning decisions to suitably qualified engineers.

If, due to political procrastination and intransigence, net radiant heat absorption by planet Earth is permitted to continue, the consequent rising temperatures will in decades, not centuries, exterminate all large land animal species, including humans. The natural processes that absorb excess CO2 from the atmosphere and oceans and convert it into fossil fuels and carbonate rock are at least 10X slower than the present rate of fossil CO2 production.

Relevant Nuclear History:
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After WWII Atomic Energy of Canada Ltd. (AECL) pursued peaceful uses of

nuclear energy.

By the early 1960s AECL had identified two different nuclear power generation technologies. One technology, known as CANDU reactors, relies on fission of the rare uranium isotope U-235 with thermal neutrons. The other technology, known as ING, uses the abundant uranium isotope U-238 to make both energy and supplementary TRU.

In 1965 the government of Canada forced AECL to cut costs. In response AECL shelved its entire ING (Intense Neutron Generator) program and terminated many of the program's skilled personnel. Some of these personnel emigrated to the USA where they joined the US Fast Neutron Reactor (FNR) Experimental Breeder Reactor (EBR) development program. These FNRs are also fueled by TRU and U-238.

Other AECL trained personnel accepted faculty positions at universities across Canada, where a few undergraduate physics students, such as myself, were the immediate beneficiaries.

After 1965 AECL and Ontario Hydro proceeded with deployment of CANDU reactors at Douglas Point, Pickering, Bruce and Darlington. During the same time frame light water based thermal neutron reactors were widely deployed in the USA.

In the spring of 1969 I attended a meeting at Chalk River, Ontario where I learned the rational for AECL's decision to shelve the ING work. The bottom line was that the cost per free neutron was then less for CANDU than for ING. At that time the world reactor fleet was small, natural uranium, the source of U-235, was readily available in Canada and several important FNR fuel tube issues had not yet been resolved.

In 1994, the US Clinton Administration, acting on corrupt advice from the fossil fuel sector, defunded the successful US FNR development program.

During the period 2010 to 2023 Peter Ottensmeyer and others developed the Ottensmeyer Plan for implementation of FNRs in Canada. Various aspects of this plan are available at www.xylenepower.com.

In November 2023 at COP 28, 22 industrialized countries recognized the need to triple their installed nuclear power capacity by 2050. However, if that plan is followed using thermal neutron (water cooled) reactors, by 2070 the economic U-235 resource will be exhausted and there will be no capacity to follow up with FNRs.

Today Canadians are faced with the following issues that can no longer be ignored:
a) A rising atmospheric CO2 concentration;
b) Falling ocean pH;
c) Rapidly rising average atmospheric and ocean temperatures with corresponding fire and flood damage;
d) A rapidly diminishing U-235 resource.

The only sustainable and dependable physical solution to all of these problems is rapid deployment of FNRs to displace fossil fuels. However, the total FNR thermal power output is limited by the TRU inventory in the FNR fuel.

TRU can be produced using CANDU reactors, FNRs and INGs.

Light Water Reactors (LWRs) produce TRU at about (1 / 4) the rate as do CANDU reactors. Used LWR fuel should be reused in CANDU reactors to produce both energy and more TRU. Doing this requires CANDU reactors that are configured for loading hot fuel.

However, sufficiently rapid production of TRU to stop climate change also requires TRU production via INGs.

I now come to the saddest part of this tale. In Canada production of energy is a provincial responsibility. Hence, construction and operation of the FNRs is

a provincial responsibility. Each province has its own electricity utility that subcontracts part of its work to private industry. However, construction of FNRs cannot be financed by either provinces or private industry unless there is a certain source of FNR fuel.

Recall that a key component of FNR fuel is TRU. At this time the only Canadian source of TRU is used CANDU fuel. However, the federal government has jurisdiction over used CANDU fuel. At this time the federal Nuclear Waste Management Organization (NWMO) still proposes to bury used CANDU fuel in an expensive Deep Geologic Repository (DGR) and as of June 2023 Natural Resources Canada still refused to even part fund TRU Concentration, which is the first step in harvesting TRU from used CANDU fuel for use in FNRs. That refusal makes no logical sense because, according to Corporate Knights, Natural Resources Canada still has $5 billion in unallocated funds for clean energy production.

Summary:

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In summary, the rate of net radiant heat accumulation by planet Earth is rapidly increasing. Stopping this heat accumulation requires stopping all combustion of fossil fuels and large scale deployment of FNRs

FNR deployment will remain impossible until there is a U turn in federal government policy relating to Fast Neutron Reactors (FNRs) and FNR fuel. It is unclear whether the present government problem is incompetence, fossil fuel corruption or both.

I see no solution other than to terminate the present federal government decision makers for cause. If that requires changing the federal government, or challenging the federal government authority over used nuclear fuel and nuclear safety, so be it. Continuation of present federal government policies will soon lead to human extinction.

In the second half of this presentation I will focus on the major FNR hardware and FNR deployment issues.

I invite your questions.