CO2, ENERGY AND POWER REALITIES – Last revised **November 18, 2021**
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EXECUTIVE SUMMARY:
This document has been prepared to inform persons in government and the media about myths and realities relating to CO2, energy and power. It is important to recognize that CO2, energy and power matters are governed by the laws of physics, not by political doctrine or public opinion. In establishing energy and power policy governments should be guided by the laws of physics and by engineers who are skilled in application of those laws to energy and power systems.

The energy used by mankind can be divided into two categories. Consumers presently obtain about 80% of their energy requirements directly from combustion of the fossil fuels: coal, petroleum and natural gas. The remaining 20% of their energy requirements is obtained from electricity, part of which also comes from fossil fuels. The non-fossil portion of this electricity is referred to as "clean energy" or "clean power" because it comes from electricity sources that do not emit CO2.

Today in Canada and the USA there are many politicians who are convinced that they know more about electricity systems than experienced electrical engineers. The costs of building and operating a clean electricity system are a function of the annual peak load reliably met, but politicians still insist on allocating electricity system costs to consumers in proportion to each consumer's electrical energy consumption. This poor cost allocation method prevents economic displacement of fossil fuels by intermittently available low marginal cost clean electricity that is surplus to the instantaneous dependable power requirement. In a fully clean electricity system the corresponding waste of intermittently available clean electrical energy is about 50% of the dependable electrical energy consumption. Efficient use of the intermittently available clean electricity requires a dependable electricity rate primarily based on the consumer's monthly peak dependable power use and an interruptible electricity rate based only on the consumer's interruptible energy consumption.

During the last 150 years combustion of fossil fuels resulted in about a 50% increase in the concentrations of CO2 in the atmosphere and in the oceans. Today the atmospheric CO2 concentration is increasing at about 0.6% per year and has many serious consequences including climate change and species extinctions. The continuing CO2 concentration increases are of concern to all of mankind. Persons who express concern about the increasing CO2 concentrations are collectively referred to as "environmentalists".

A related issue, which is particularly serious in Canada and the USA, is inadequate public core curriculum education in the physical sciences. As a consequence, although most North American voters recognize that there is a world wide CO2 problem, most of them have no understanding of the physical steps necessary to mitigate the problem.

The most fundamental law of physics is the Law of Conservation of Energy. A related law is Conservation of Power. Conservation of Power prevents displacement of power derived from fossil fuels with power supplied by clean energy sources unless sufficient clean power is available when and where needed. Adapting wind and solar electricity generation to provide the dependable clean power needed for fossil fuel displacement requires uneconomic amounts of energy storage and energy transmission.

No amount of legislation or environmental wishful thinking can alter the fundamental energy: supply, storage and transmission constraints. Major nations and sub-national states including Australia, Germany, Denmark, Texas and California have ignored their power engineers and have attempted to displace fossil fuel generated electricity with wind and solar energy, but have experimentally discovered that there are physical constraints which make impossible meeting more than about 20% of the average electricity grid load from unconstrained wind and solar electricity generation. The remaining 80% of grid supplied electricity must come from a mix of fossil fuel energy, nuclear energy and hydroelectricity. The reasons for the 20% limit on unconstrained wind and solar generation are not obvious to either politicians or the general public.

Many environmentalists have mistakenly promoted electricity conservation, whereas to reduce or eliminate CO2 emissions the Law of Conservation of Energy requires that clean electricity consumption must be increased, not decreased.

Another issue that many environmentalists have failed to grasp is that absent sufficient hydroelectricity it is physically impossible to sustainably fully displace fossil fuel based electricity generation without use of nuclear power and that economically meeting the winter comfort heating load with clean energy requires utilization of the low grade heat rejected by nuclear electricity generation.

Another poorly understood issue that is that Fast Neutron Reactors (FNRs) configured for fuel recycling realize about 100X as much energy from one kg of natural uranium as do existing CANDU power reactors while producing about 100 fold less short lived nuclear waste and 1000 fold less long lived nuclear waste. To achieve efficient fuel recycling these FNRs require substantial initial inventories of relatively rare fissile isotopes. The limited supplies of these rare fissile isotopes are presently being squandered in thermal neutron reactors instead of being used in fissile isotope conserving FNRs.

A major emerging political issue is that large FNRs are presently only being made in Russia and China and that these autocratic countries have more than a 30 year lead over North America in development and deployment of such reactors.

Another issue that uneducated environmentalists seldom understand is that sustainable displacement of fossil fuels requires production and constructive use of the artificial fissionable isotopes Pu-239 and U-233, not disposal of these isotopes in deep geologic repositories.

A deeply disturbing matter is the number of commercial parties that today are promoting unsustainable nuclear plans to western governments and electricity utilities. If a nuclear plan is not sustainable on the scale required for displacing fossil fuels, then there is no merit in allocating scarce public resources to develop and deploy of that plan. Public resources should be focused on sustainable displacement of fossil fuels, not on helping selected companies make a quick profit. In making capital equipment development and deployment decisions energy supply utilities should concern themselves not only with the present costs of nuclear fuel purchase and disposal, but with these costs in the future when nuclear fuel is in much higher demand for combating climate change. Similarly, there is merit in nuclear technologies that reliably reduce other future costs.

INTRODUCTION:
Present Canadian federal/provincial government policies relating to carbon dioxide (CO2) driven climate change, energy and dependable power have **little basis in physical fact**. Ignorance about power systems and the consequences of the ongoing accumulation of CO2 in the atmosphere and the oceans is rapidly guiding planet Earth toward an apocalypse, an extinction of major land animal and marine life forms comparable to previous global extinctions in Earth's geologic past. This extinction process is being rapidly accelerated by failure of mankind to conserve fissile isotopes.

SCOPE OF THE WORLD CO2 PROBLEM:
In Canada and the USA there is little public appreciation of the full scope of the world CO2 problem.

WORLD COAL PRODUCTION:
During the year 2019 the total world coal production, obtained by summing the productions from the major producers was;
8.13 billion tonnes
= .813 X 10^10 tonnes/year
The corresponding carbon mass that entered the atmosphere in 2019 was about:
0.8 X .813 X 10^10 tonnes / year = **.6504 X 10^10 tonnes carbon / year**.

The average thermal power liberated by world combustion of coal during 2019 was about:
.813 X 10^10 tonnes coal / year X 32,494 X 10^6 J / tonne coal X 1 year / 8766 hour X 1 hour / 3600 s
= **8.371 X 10^12 watts**

WORLD OIL PRODUCTION:
The world oil production in 2019 as obtained by summing producers outputs was about 35 billion barrels / year. The corresponding annual carbon output is:
35 X 10^9 barrels /year X .137 tonnes/barrel X .86 tonne carbon / tonne oil
= **0.412 X 10^10 tonne carbon / year**
Not all of this carbon immediately goes into the atmosphere because a small fraction of the carbon related to oil production is used to produce asphalt, which may take as much as 50 years to oxidize into CO2.

The thermal power liberated by world combustion of oil is about:
35 billion barrels / year X (5.8 X 10^6 BTU / barrel) X 1055.06 J / BTU X 1 year / 8766 hour x 1 hour / 3600 s
= **6.786 X 10^12 watts**

WORLD NATURAL GAS LIQUIDS PRODUCTION:
The world natural gas liquids production in 2004 as obtained by summing producers outputs was about 7,393,210 barrels per day. The corresponding annual carbon output is:
7,393,210 barrels / day X 365 days/year X .137 tonnes/barrel X .86 tonne carbon / tonne NG liquid
= **.03179 X 10^10 tonne carbon / year**
Not all of this carbon goes into the atmosphere because part of the carbon related to NG liquid production is used to produce resins. However, the non-atmospheric carbon amount is likely off set by unreported fossil fuel production, especially unreported coal.

The thermal power liberated by world combustion of natural gas liquids in 2004 is about:
7,393,210 barrels / day X 5.8 X 10^6 BTU / barrel X 1055.06 J / BTU X 1 day / 24 hour x 1 hour / 3600 s
= **0.5236 X 10^12 watts**

WORLD DRY NATURAL GAS PRODUCTION:
The world dry natural gas production during 2019, as obtained by summing the producers outputs was:
4100 billion m^3 / year.
The corresponding amount of carbon released to the atmosphere was:
4100 X 10^9 m^3 /year X 1000 lit / m^3 X 1 mole / 22.4 lit X 273/288 X 16 gm / mole X 1 tonne/10^6 gm X .75
= 4.1 X 10^15 lit / year X (1 mole / 22.4 lit) X (273/288) X 16 g / mole X 10^-6 tonne / gm X .75
= 2.082 X 10^9 tonnes carbon / year
=**0.2082 X 10^10 tonnes carbon / year**
Almost all of this carbon enters the atmosphere.

The average thermal power liberated by world combustion of natural gas in 2019 was:
4100 X 10^9 m^3 / year X 1000 ft^3 / 28.328 m^3 X 1000 BTU / ft^3 X 1055.06 J / BTU X 1 year / 8766 hour X 1 hour / 3600 s
= **4.839 X 10^12 Watts**

WORLD AVERAGE FOSSIL FUEL THERMAL POWER PRODUCTION IN 2019:
[8.371 + 6.786 + 0.5236 + 4.839] X 10^12 Wt
= 20.52 X 10^12 Wt
= **20.52 X 10^3 GWt**

To better understand the scope of this fossil fuel problem it is helpful to examine the ratio of:
(Present world average thermal power supplied by combustion of fossil fuels) / (Present world population)

= (20.52 X 10^12 Wt) / (7.8 X 10^9 persons)

= **2.63 kWt / person**

However, in Canada and the USA the comparable figure is about **9 kWt / person**.

The average thermal power per person is a good indication of the average standard of living.

About half of the present human population lives in tropical countries. Today the single most important issue in most tropical countries is the rise in ocean surface temperature caused by global warming. That rise in ocean surface temperature causes a comparable rise in average wet bulb temperature which reduces the ability of a human body to dissipate heat by evaporation of perspiration. With sufficient drinking water humans can live for significant periods of time in places where the daily dry bulb temperature exceeds 50 degrees C. However, when the wet bulb temperature exceeds 35 degrees C (95 degrees F) humans rapidly die due to inability to dissipate heat by evaporation of perspiration.

There are only two solutions to this rise in average wet bulb temperature, human migration away from tropical countries and mechanical air conditioning that also provides water desalination. Either solution will cause the world wide average per capita thermal power consumption to approximately double.

There is a further problem of a continuing world population increase. As the average standard of living increases the rate of world population growth will decrease, but the population is still projected to grow by at least a further 25% before it stabilizes.

Thus the world wide the average thermal power will grow to at least:
20.52 X 10^12 Wt X 2 X 1.25 = 51,300 GWt.

The challenge facing mankind today is to in a few decades build sufficient clean energy: generation, storage and transmission to fully displace about 51,300 GWt of fossil fuel supplied thermal power.

To put this **51,300 GWt** number in perspective provision of each GWt requires either one modest size nuclear power reactor or about 1000 commercial size wind turbines together with associated energy storage and electricity transmission facilities.

SCOPE OF THE ONTARIO CO2 PROBLEM:
The only practical way of efficiently transmitting clean energy over medium distances is via electricity. Today with fossil fuels on average an Ontario resident requires:

1.2 kWe from electricity + 9 kWt from fossil fuels.

If the energy required for displacement of fossil fuels is to be sourced outside major cities and is to be transmitted into the cities by electricity the average electricity generation in Ontario must increase by a factor of:
[1 + (9 kWt / 1.2 kWe)] = **8.5**

The only way of substantially reducing this factor is to site advanced nuclear reactors inside cities so that part of the waste heat from nuclear electricity generation can be used to meet the comfort heat load. If for every unit of electricity generation sited inside a city on average it is practical to recover one unit of useful heat, then the appropriate electricity generation expansion factor becomes:

8.5 / 2 = **4.25**

but all of the new generation must be both nuclear and urban sited.

In 2019 about 60% of the electricity consumed in Ontario came from nuclear power. Hence to meet the requirements of CO2 displacement the minimum increase in Ontario installed nuclear power generation capacity is a factor of:

4.25 / 0.60 = **7.08**

and all of this nuclear power generation capacity increase must be urban sited. If instead all of the electricity load is to be met by rural sited nuclear power plants the required increase in nuclear power plant capacity is a factor of:

8.5 / 0.60 = **14.17**

and in addition rural sited nuclear power plants require radial transmission lines into cities whereas urban sited nuclear power plants do not.

Thus mitigation of climate change requires major investments in new nuclear power capacity and to be economic most of that capacity must be urban sited. This requirement for urban nuclear power plant siting and for construction of of nuclear power plant capacity is a reality that the government of Canada, The Nuclear Waste Management Organization (NWMO), the Canadian Nuclear Safety Council (CNSC), the government of Ontario, Ontario Power Generation (OPG), major municipalities and most Ontario residents have yet to face.

PAN CANADIAN ISSUES:

If clean energy generation is rural sited there is opportunity for limited application of renewable energy generation. Of particular interest in certain parts of Canada is a combination of wind based electricity generation and hydro based energy storage. However, the costs of combining wind and hydro with the necessary connecting transmission to provide dependable power are often much higher than the cost of new nuclear power capacity. The extra costs are often only justifiable to the extent that that the available renewable power generation serves remote areas with low average population densities or coincides with seasonal power demand peaks.

Expansion of the dependable clean electricity system capacity requires power station sites, energy storage sites and energy transmission corridors. Elected politicians of all political stripes in Canada and the USA have been unwilling to face the realities of expropriation of the required power station sites, energy storage sites and energy transmission corridors. Politicians have also been unwilling to levy tax and /or electricity rate increases of sufficient magnitude to fund the required increase in dependable clean electricity generation capacity.

The situation has been further confused by corruption of governmental bodies by the fossil fuel industry. That corruption has led to large amounts of low marginal cost clean electrical energy being discarded instead of being provided to consumers for displacement of fossil fuels. The present political failure to adopt retail electricity rate structures that enable economic sale of all available zero marginal cost clean electricity for fossil fuel displacement is complete climate madness.

GROSS EFFECTS OF CO2:

Over hundreds of millions of years plant, animal and marine life forms on Earth evolved to exist in an atmosphere with a carbon dioxide (CO2) concentration in the range 220 ppmv (parts per million by volume) to 300 ppmv.

The atmospheric CO2 concentration regulates life form chemistry, ocean chemistry and temperature.

When the atmospheric CO2 concentration is significantly below 220 ppmv green plants, which rely on a sufficient atmospheric CO2 concentration for photosynthesis, cannot grow. When the atmospheric CO2 concentration is significantly above 400 ppmv (CO3)-- ions in ocean solution convert into (HCO3)- ions. Then marine life species at the bottom of the food chain, that rely on a sufficient ocean (CO3)-- ion concentration for formation of bone and shell material, cannot grow.

When the atmospheric CO2 concentration is below about 220 ppmv the thermal radiation flux emitted by planet Earth into outer space is significantly larger than the absorbed solar radiation flux, causing net heat loss, which over time results in an ice age and sea level fall. When the atmospheric CO2 concentration is above 350 ppmv the thermal radiation flux emitted by planet Earth into outer space is significantly smaller than the absorbed solar radiation flux, causing net heat gain, which over time melts the polar ice caps and causes sea level rise.

When the atmospheric CO2 concentration is below about 200 ppmv the lower atmosphere is cold which causes water molecules in clouds and on Earth's surface to form ice crystals that efficiently reflect solar radiation. Hence Earth further cools. When the atmospheric CO2 concentration is above 400 ppmv the lower atmosphere is warm which causes water molecules in clouds and on Earth's surface to form a liquid that efficiently absorbs solar radiation. Hence Earth further warms. At lower latitudes where the solar radiation is intense the water molecules can accumulate so much energy in the form of latent heat of vaporization that violent storms occur.

Note that the interaction between water and CO2 causes alternating prolonged ice ages and prolonged warm periods. If circumstances occur that cause the atmospheric CO2 concentration to be unusually high a prolonged warm period becomes a prolonged hot period during which the southern ice cap melts and there is a global extinction of large animals. Such global extinctions have occurred in the past at multi-million year intervals. A well known example is the Paleocene-Eocene Thermal Maximum (PETM) which occurred about 56 million years ago.

During the last 150 years there has been about a 50% increase in the atmospheric and ocean CO2 concentrations, almost entirely due to combustion of fossil fuels. Even if there is a maximum effort by mankind to reduce future fossil CO2 emissions, by the year 2100 the atmospheric CO2 concentration will likely exceed 560 ppmv, twice the pre-industrial atmospheric CO2 concentration of 280 ppmv. Due to the CO2 driven decline in ocean pH it is unlikely that wild ocean fish, which mankind has relied on for protein for at least 3 millennia, will survive beyond the year 2050. On land many large animal species are already becoming extinct due to loss of habitat.

If present trends continue the average temperature on Earth's surface in the year 2100 in the tropics will be about 3 degrees C warmer than in 1950 and in the circumpolar countries will be about 9 degrees C warmer than in 1950.

If present trends continue by the year 2100 the open ocean pH will likely drop from its present value of 8.05 down to about 7.85, which is lethal for a wide variety of marine life either directly or due to food deprivation.

There needs to be public realization that on a geologic time scale the rate of transfer of fossil carbon by mankind from Earth's crust to Earth's atmosphere and oceans is very fast whereas the natural processes that permanently remove excess CO2 from the atmosphere and the oceans are very slow. The CO2 concentrations in the atmosphere and oceans are in near equilibrium. Any additional fossil CO2 formed now will remain in the atmosphere and oceans for many tens of thousands of years into the future.

The more CO2 that accumulates in the atmosphere and oceans the more life adverse the environment on Earth will become. Reversing the CO2 accumulation would require significantly more energy than

fossil fuels have provided during all of the last 150 years. Hence, the concept of man kind inventing a technology that could reverse the fossil CO2 accumulation in the atmosphere and oceans violates the law of conservation of energy and has no basis in physical reality.

The so called “Carbon Capture and Storage” technologies are simply an excuse by the fossil fuel industry for yet more fossil fuel production. That increased fossil fuel production results in yet more fossil CO2 being injected into the atmosphere and oceans. Furthermore, over multi-century time scales compressed CO2 injected underground combines with ground water to form H+ and HCO3- ions which find their way back to the surface by ionic diffusion through ground water. When this water evaporates the contained CO2 is again released into the atmosphere.

Anaerobic breakdown of plant matter forms approximately equal amounts of CH4 and CO2. However, most subsurface accumulations of natural gas primarily consist of CH4. Over time the CO2 released by anaerobic breakdown has escaped to the atmosphere and oceans. Hence, in most rock formations, the concept of permanent storage of CO2 deep under ground is just a pipe dream.

To prevent the environment worsening it is necessary to halt all further extraction of fossil fuels. Unfortunately this simple concept seems to be beyond the comprehension of most elected politicians.

REMEDIAL TECHNOLOGY:

To prevent further fossil CO2 production it is necessary to provide consumers with sufficient sustainable, dependable and economic non-fossil power. Renewable energy does not provide dependable power. To meet consumer needs it is necessary to rapidly deploy advanced nuclear reactors with sustainable fuel cycles. There is no other clean energy technology capable of meeting human dependable power requirements. Conservation and renewable energy generation can at best meet only a fraction of mankind's energy requirements and cannot meet any of mankind's dependable power requirements.

Unlike in China, India and Russia, national governments in North America have failed to face the need for urgent development and deployment of advanced nuclear reactors. It is not a matter of just reducing fossil CO2 emissions sufficiently for compliance with the 2015 Paris Accord. To prevent further CO2 accumulation in the atmosphere and oceans it is necessary to halt all man made fossil CO2 and CH4 emissions. That halt means **leaving fossil fuels in the ground,** regardless of political consequences. This is an issue that Canadian and US politicians of all political stripes have refused to face and is a main point of both public and political denial. Wind and solar electricity generation are seasonal and intermittent and, in the absence of impossible amounts of efficient energy storage and energy transmission, cannot supply sufficient dependable power to displace fossil fuels.

Wind and solar generation also do not provide synchronous generation moment of inertia, which is required for electricity grid frequency stability. Frequency instability causes cascade grid blackouts. Recovery from a blackout requires black start capacity that wind and solar generation also do not provide.

Achievement of the required halt in fossil CO2 emissions requires the following:

a) Immediate ceasing of all new investment in fossil fuel infrastructure;

b) Prompt implementation of a fossil carbon tax of about $200 / CO2 tonne, sufficient to keep fossil

carbon in the ground;
c) Restructuring retail electricity rates and taxes to enable use of existing and future surplus intermittent clean electricity generation capacity to provide low cost interruptible electricity for partial displacement of fossil fuels, for production of electrolytic hydrogen and for charging of electric vehicles;
d) Supply of sufficient sustainable and dependable clean electrical and thermal power to completely displace fossil fuels by large scale deployment of advanced reactors that are primarily fueled by the abundant fertile isotopes U-238 and Th-232;
e) Political acceptance of the reality that these advanced reactors must contain significant ongoing core fuel fractions of the fissionable isotopes Pu-239 or U-233. It is necessary for all parties building, owning, operating or maintaining such power reactors to satisfy all other parties that fissionable isotopes produced in the power reactors will not be diverted to make nuclear weapons;
f) The advanced nuclear reactors will require closed cycle electrolytic fuel recycling for efficient fuel utilization and waste minimization. This fuel recycling method limits the solid fuel waste stream to short lived fission product isotopes that over a 300 year period naturally decay to a radio toxicity less than that of natural uranium;
g) Elimination of nuclear reactor decommissioning waste by surrounding a fast neutron reactor fuel assembly with a 3 m wide band of liquid sodium to fully absorb all neutrons that escape from the fuel assembly. When stable Na-23 absorbs a neutron it becomes Na-24 which decays with a 15 hour half life to become stable Mg-24;
h) The advanced reactors must be walk-away-safe and proliferation resistant;
i) In any credible prompt critical condition the advanced reactor fuel must safely disassemble;
j) The advanced reactors must be suitable for urban siting for economic district heating as well as for electricity generation. This constraint dictates use of a compact reactor that emits no noise and operates with a low pressure high temperature coolant such as a liquid metal or a molten salt;
k) The resulting electricity generation must be able to automatically compensate for uncontrolled changes in grid electricity load;
l) Each advanced nuclear power plant must be assembled from multiple standard replaceable modules that can be safely delivered and removed by truck via city streets. This requirement imposes weight and size restrictions on individual modules and on shielded fuel bundles;
m) Each advanced reactor must be sufficiently robust and surrounded by protective structures to safely withstand direct impact by a large passenger airplane loaded with fuel;
n) The advanced reactors must safely withstand extreme earthquakes;
o) Each advanced reactor must be sited so that damage by floodwater or a tsunami is not a credible risk for centuries into the future. Hence the reactor elevation must be high above large bodies of water and redundant on-site cooling towers sufficient for disposal of fission product decay heat are required;
p) The advanced reactors should be electrically network interconnected such that end use customers will not be impacted by individual reactor shutdowns for maintenance or refueling;
q) Reactors used for district heating must have hydrogen or natural gas emergency backup;
r) To minimize on-going costs the advanced reactors must be designed for autonomous operation;
s) The non-nuclear portion of a nuclear power plant must be designed so that routine maintenance can be safely conducted without a reactor shutdown;
t) To minimize system costs economic energy storage and energy conservation measures should be adopted;
u) Electrolytic hydrogen produced using surplus clean energy should be used to meet low load factor winter heat requirements, thus reducing the peak winter load on the electricity system and providing emergency winter heating backup;
v) Implementation of the necessary energy infrastructure will require extensive urban planning and

work force training and will likely take about half a century.
w) Every aspect of the nuclear power plant design, construction, operation and maintenance should be transparent to provide investor confidence, local public safety certainty and international confidence with respect to non-proliferation of nuclear weapons.

THE U-235 RESOURCE LIMIT

An important issue that persons not expert in nuclear matters fail to appreciate is that most present nuclear power reactors rely on fission of the relatively rare natural uranium isotope U-235 which has a limited global supply so that future nuclear reactors providing sustainable clean power must derive their energy from the much more abundant natural isotopes U-238 and Th-232. This issue is not opinion, it is blunt fact.

As of 1 January 2017, reasonably assured uranium resources (RAR), recoverable at < US $260 kg U amounted to 4,845,000 tU. Inferred resources (IR), recoverable at < US $260/kg U amounted to 3,173,000 tU.

Hence in 2017 the total projected U resource was (4,845,000 tU + 3,173,000 tU) = 8,018,000 tU
The U-235 content of this resource is .007 (8,018,000 tU) = 56,126 tU-235

The thermal energy potentially available from fission of this U-235 resource is:

56,126,000,000 gm X 1 mole / 235 gm X 6.023 X 10^23 atoms / mole X 200 MeV / atom
X 10^6 eV / MeV X 1.602 X 10^-19 J / eV X 1 Wt-s / J X 1 MWt / 10^6 Wt X 1 GWt / 1000 MWt
X 1 h / 3600 s X 1 y / 8766 h

= [5.6126 X10^10 X (6.023 / 235) X 10^23 X 2 X 10^8 X 1.602 X 10^-19 X 10^-9 X 10^-6] GWt - y
/ (3.6 X 8.766)

= 0.01460 X 10^8 GWt-y

= **1,460,000 GWt-y**

However, the ongoing thermal power requirement from fossil fuels over the coming decades just to bring world average per capita energy consumption up to half of the North American average per capita energy consumption is conservatively projected to be:
51,300 GWt
which means that if that thermal power requirement is met from fission of U-235 instead of from fossil fuels the maximum projected U-235 resource life is

1,460,000 GWt-y / 51,300 GWt = **28.5 years**.

Clearly nuclear reactors powered by fission of U-235 do not provide a sustainable source of clean energy sufficient for long term fossil fuel displacement. We must instead deploy a reactor fleet that obtains its energy from the abundant isotopes U-238 and/or Th-232. In fact the situation is several times worse than the above simple calculation suggests because reactors consuming U-238 and Th-232 require initial fissile start fuel inventories sufficient for about 20 years of full power output. Continuing

consumption of U-235 without breeding comparable amounts of either fissionable Pu-239 or U-233 will soon threaten the future existence of mankind.

The future of today's young people hinges on present governments promptly implementing energy related policy choices based on facts, not mistaken beliefs or short term political expediency. Political procrastination in large democratic countries has already put the younger generation in peril.

THE PRESENT CO2 TREND:

Today we are confronted with the physical reality of increasing and irreversible accumulations of CO2 in the atmosphere and oceans caused by ongoing large scale combustion of fossil fuels. This physical reality has many adverse and irreversible consequences including climate change, sea level rise and progressive extinction of numerous plant, animal and marine species. Moreover, most of man kind's efforts to address the CO2 problem have been futile due to politicians repeated failure to adequately take into account the law of conservation of energy.

Every day there is combustion of approximately 100 million barrels of oil as well as comparable amounts of coal and natural gas resulting in over 110 million tonnes of fossil CO2 / day injected into the atmosphere. Over time almost half of the excess fossil CO2 dissolves in the oceans. The natural chemical reactions that can permanently absorb excess CO2 from the atmosphere and oceans either by formation of fossil fuels or by formation of carbonate rock take over 100,000 years to operate. From the perspective of a human lifetime fossil CO2 production is irreversible.

A fossil carbon tax will be effective at causing CO2 emission reduction IF AND ONLY IF CONSUMERS HAVE AVAILABLE TO THEM A SUFFICIENT SOURCE OF DEPENDABLE AND ECONOMIC NON-FOSSIL POWER. Today in most provinces in Canada there are no sources of non-fossil power with sufficient capacity for displacing fossil fuels and there are no governmental plans to build non-fossil power sources having sufficient capacity. Even in jurisdictions where there is a surplus of zero marginal cost clean power the present retail electricity rate structures prevent that clean power being economically used by consumers for fossil fuel displacement.

For more than 30 years North American politicians have promised action on reduction of CO2 emissions but have failed to deliver. In part that failure is due to governmental corruption by fossil fuel interests that have lobbied for retail electricity rate structures that force consumers to use fossil fuels instead of available zero cost surplus non-fossil electricity. As recently as July 9, 2020 the Conservative government of Ontario rejected the OSPE (Ontario Society of Professional Engineers) proposal for use of zero cost surplus non-fossil electricity for displacement of fossil fuels.

On a per person basis Asian CO2 emissions are far below North American CO2 emissions. China, India and Russia are pursuing development and world wide deployment of nuclear reactors. From the perspective of young people in Asia the excessive per person fossil CO2 emissions from Australia and North America are totally unacceptable and intentional destruction of new North American and Australian fossil fuel infrastructure may soon be justifiable to force reductions in per person CO2 emissions. Political leaders around the world must get the message that further investment in fossil fuel infrastructure is unacceptable, especially in circumstances where there are reasonable nuclear and/or renewable power alternatives.

The fate of Canada's young people hinges on governments making immediate and appropriate energy policy changes based on facts, not on fossil fuel corporate interests or mistaken beliefs. Mankind is rapidly running out of time to stop fossil fuel use globally. Canada should be using its political influence to accelerate the transition away from fossil fuels, not expanding fossil fuel production. The various provinces with fossil fuel reserves will simply have to face the fact that fossil carbon must stay in the ground. Combustion of fossil fuels is damaging the oceans and other countries. Continuing fossil fuel extraction is morally indefensible and might eventually lead to a world war.

MYTHS & REALITIES RELATING TO POWER AND ENERGY SUPPLY:

1) There are people, including many voters in Alberta and Saskatchewan, who mistakenly believe that mankind can keep on burning fossil fuels without serious consequences. That belief has no foundation in fact. In addition to the well-known problems of climate change and sea level rise, CO2 driven ocean acidification is negatively affecting many fish species on which humans and other animal species rely for protein. As set out in Appendix I attached hereto the increasing atmospheric CO2 concentration causes a reduction in the ocean (CO3)-- ion concentration which in turn prevents simple micro-organisms from forming bone and shell material. These simple micro-organisms are critical food for herring which in turn are food for larger commercial fish such as salmon. Collapse of the ocean fishery is already occurring and and will likely cause massive near term human migration as countries that presently rely on fish for supply of human food protein can no longer do so.

2) Fossil fuel infrastructure investments and CO2 emission reduction are mutually exclusive. There are leading politicians in Canada who mistakenly think that spending $12 billion of federal taxpayers money on a new heavy oil pipeline expansion or $500 million on a natural gas pipeline will by some magic alleviate the increasing CO2 problem. That error diverts critical public resources at a time when those resources are urgently needed for investment in dependable non-fossil energy production.

3) The present grip of the fossil fuel industry on governmental decision making must be broken. The fossil fuel industry shareholders must be forced to fund remediation of the environmental mess that the fossil fuel industry has made (over $70 billion in Alberta alone) and must be persuaded to invest in non-fossil energy technologies, particularly advanced nuclear power and supporting electricity and heat transmission instead of in new fossil fuel infrastructure.

4) There is a myth that after humans stop burning fossil fuels the CO2 concentration in the atmosphere will spontaneously decrease due to excess CO2 in the atmosphere dissolving into ocean water. This myth is not true. After CO2 emissions have totally stopped, the atmospheric CO2 concentration will only drop to the level where it was about 16 years prior to the halt in combustion of fossil fuels. Thereafter the atmospheric CO2 concentration will remain nearly constant because the excess CO2 concentrations in the atmosphere and in the ocean will be in equilibrium.

5) There is almost no public appreciation of the persistence time of excess CO2 in the atmosphere and oceans. Natural processes will take over 100,000 years to remove excess CO2 by formation of fossil fuels and carbonate rock. On this time scale planting trees does almost nothing to mitigate the CO2 accumulation because within about a century almost all of the tree biomass decays back into CO2. In order to form fossil fuels the biomass must be buried deep underground where it will decompose by anaerobic digestion.

6) There is little public appreciation of the issue that even if we stop all CO2 production today planet Earth will continue to absorb heat for many more decades until the bulk ocean temperature rises to match the increase in dry land surface temperature. That thermal absorption will cause prolonged sea level rise.

7) A fossil carbon tax achieves very little CO2 emission reduction unless consumers also have available to them alternate dependable and economic sources of clean power. With a very large expenditure of resources additional heat conservation might result in a 20% reduction in fossil fuel consumption whereas meaningful reduction of CO2 emissions requires a 100% reduction in fossil fuel consumption.

8) There is economic merit in using the revenue from a fossil carbon tax to fund the construction of advanced nuclear power capacity. However, that revenue application will require political leadership that is presently lacking.

9) There is a mistaken belief by "environmentalists" that the CO2 problem can be solved by building sufficient solar and wind generation. The fundamental problem with that concept is that wind and solar electricity generation have uncontrolled variability and often collectively produce little or no power at times when electricity and heat are most needed.

10) The variability and seasonality of renewable electricity generation means that to make renewable power dependable renewable energy must be transmitted to an energy storage site, converted to a different form of energy, at a later time recovered from storage, converted back into electricity and then re-transmitted to the load. This energy transmission, storage, recovery and re-transmission process is highly inefficient, is real estate and resource intensive and is prohibitively expensive. In most jurisdictions the necessary geography for economic seasonal energy storage simply does not exist.

11) The practical experience in Ontario has been that only 30% of the electricity produced by wind and solar electricity generation can be sold under the present electricity rate structure. The remaining large amounts of non-fossil electricity are presently either discarded or are exported at a low market price of less than $0.02 / kWh.

12) There is opportunity for significant fossil fuel displacement simply by changing the retail electricity rate structure to permit economic use in Ontario of all available non-fossil kWh. In Ontario this opportunity has existed for almost two decades. However, instead of reducing fossil CO2 emissions the retail electricity rate has remained structured to provide a windfall financial benefit to the liquid fossil fuel industry of close to $1 billion / year. This retail electricity rate structure is indicative of deeply entrenched governmental incompetence and corruption.

13) Synchronous electricity generators (hydroelectric, nuclear, fossil) presently provide the dependable power capacity and rotating moment of inertia required for operating a stable electricity grid whereas intermittent renewable energy generators do not. Long term displacement of fossil fuels with non-fossil energy requires the use of sustainable and stable nuclear and hydroelectric technologies. Electricity system stability is required to limit the transient line frequency and line voltage changes caused by rapid changes in load. If these transients become too large safety devices trigger grid blackouts.

14) In the public electricity system surplus generation causes an increase in line frequency. Similarly a

deficiency of generation causes a decrease in line frequency. The deviation of the actual line frequency from the intended frequency (60 Hz) is used to control the amount of kinetic power fed to the major synchronous generators. The problem with unconstrained renewable energy is that it does not contribute to this control action. As the ratio of unconstrained renewable generation to synchronous generation increases the grid becomes less frequency stable and is less able to safely absorb normal step changes in load.

15) The annual minimum electricity grid load is typically about 40% of the annual peak electricity grid load. The average electricity grid load is about 70% of the annual peak grid load. The peak in unconstrained renewable generation is typically about 3X the average renewable generation. Hence if a random peak in unconstrained renewable generation occurs coincident with the grid load minimum then unconstrained renewable generation can force the synchronous generation to zero, so that there is nothing to control grid frequency. That condition can occur when the average renewable generation is only 13.3% of the peak load or about 19% of average generation. In order to make renewable generation a larger fraction of total generation it must be progressively constrained, which increases its cost per kWhe. Practical experience in ERCOT (Texas) has shown that even under the most favorable conditions, as the fraction of unconstrained renewable power exceeds about 20% of the average grid power, the electricity system becomes too unstable to operate. In theory application of sufficient energy storage would mitigate this problem, but the cost is prohibitive. Thus Green New Deal (GND) supporters who advocate much higher fractions of unconstrained renewable energy on the electricity grid generally do not know what they are talking about.

16) The only clean energy technology capable of sustained full displacement of fossil fuels is advanced nuclear power.

17) The present widely used water moderated nuclear power reactor technology is not sustainable. This technology is fueled by the relatively rare isotope U-235. There is simply not enough accessible U-235 to provide sustainable displacement of fossil fuels.

18) There are two sustainable nuclear fission fuel cycles, the U-238 – Pu-239/Pu-240 cycle and the Th-232 – U-233 cycle. U-238 is about 140X more abundant than U-235. Th-232 is about 600X more abundant than U-235. Russia has adopted the U-238 cycle and China and India have adopted the Th-232 cycle. The U-238 cycle has technical and waste disposal advantages but relies on a large reserve of uranium. The Th-232 cycle is being developed by China and India because those two countries have large reserves of thorium but relatively little uranium. However, the Th-232 cycle still requires some U-238 cycle support for sustainable operation and for permanent disposal of high atomic weight fuel waste.

19) Halting Canadian fossil CO2 production requires the government of Canada to fully embrace advanced nuclear reactor technology. Advanced nuclear reactors can be used in combination with district heating, heat pumps, electrolysis and renewable energy charged hydrogen storage to economically supply electricity, heat and hydrogen.

20) There is a mistaken belief by “environmentalists” that conserving non-fossil electrical energy will mitigate the CO2 problem. Conserving electricity reduces the amount of waste heat emitted by electrical appliances. However, waste heat from electrical appliances is an important component of winter space heating. Hence, electricity conservation presently causes more fossil fuel to be consumed

to maintain indoor comfort conditions in the winter. Reduction of fossil fuel consumption requires a dependable source of non-fossil heat, not a reduction of indoor electricity consumption.

21) There is a mistaken belief by "environmentalists" and electricity regulators that clean electricity should be priced proportional to the electrical kWh consumed whereas in reality the cost of clean electricity is proportional to the annual peak electricity demand. This mistaken belief causes incorrect electricity rate structures which lead to large amounts of available clean electricity being discarded or exported instead of being provided to consumers for fossil fuel displacement. To fix this problem the retail electricity rate structure must be changed to be primarily based on peak demand (kWe), not energy consumption (kWhe). The per kWhe portion of the electricity rate must be less than the per kWht rate of the competing fossil fuel.

22) Much of the Canadian public does not grasp that over 80% of energy consumption in Canada is for mobility (transportation) and production of heat. Meeting the entire heat load with electric resistance heating would be a very inefficient and very expensive way of addressing the CO2 problem. It is much more economic to use a combination of nuclear district heating and heat pumps supplemented by combustion of stored hydrogen during extremely cold weather. Bulk hydrogen can be generated using renewable energy and can be seasonally stored by chemically compounding the hydrogen with toluene or nitrogen. Those chemical reactions are reversible with suitable catalysts to enable hydrogen gas recovery.

23) There is a public misconception that used CANDU reactor fuel is highly toxic waste that has tremendous burial related disposal costs. The reality is that used CANDU reactor fuel contains 99% of its original potential energy and can be recycled into liquid sodium cooled Fast Neutron Reactor (FNR) fuel using a non-aqueous molten salt electrolytic process. Liquid sodium cooled FNRs can improve the energy recovery from natural uranium more than 100 fold and can reduce the formation of long lived nuclear fuel waste more than 1000 fold.

24) Unlike used CANDU fuel, which takes about 400,000 years to naturally decay to a safe level, spent liquid sodium cooled FNR fuel consists of 99.9% fission products that within about 300 years naturally decay to less than the radio toxicity of natural uranium.

25) There is a public misconception that the contemplated used CANDU fuel recycling system could be misused to make nuclear bombs. That is physically impossible. Used CANDU fuel and FNR fuel both contain too high a fraction of the isotope Pu-240 to allow effective fission bomb production. Separation of Pu-239 (bomb material) from Pu-240 is almost impossible. Fuel theft would be very difficult. Just moving one fuel bundle requires an 80 ton truck due to the weight of the required shielded shipping container.

26) The Canadian federal government is still adhering to a past Conservative government policy of burying used CANDU reactor fuel rather than recycling it into metallic FNR fuel. That policy must be changed forthwith.

27) The trust funds that have been accumulated by electricity utilities for burial of used CANDU fuel must instead be re-allocated to recycling of used CANDU fuel to make metallic FNR fuel. The automated facilities required for converting used CANDU fuel into metallic FNR fuel will require substantial investment. That investment will not be made until there are appropriate governmental

policy changes.

28) Private industry will not invest in FNRs until there is certainty with respect to metallic FNR fuel availability.

29) Educational institutions will not invest in FNR related training programs until there is certainty that private industry will need their graduates.

30) Present water moderated power reactors operate at high core coolant pressures and as a consequence require a surrounding public safety exclusion zone about 1 km wide. If due to a pipe failure the pressure drops the cooling water will instantly flash into high pressure steam. Making power reactors completely safe for urban siting with no exclusion zone requires use of atmospheric pressure pool type nuclear reactors that use liquid metal or molten salt instead of water for reactor core cooling.

31) Making nuclear power sustainable in terms of both fuel supply and long lived waste minimization requires that many of the new reactors be liquid sodium cooled FNRs. These FNRs can breed more fissile isotopes than they consume and can consume high level nuclear waste from other reactor types. FNR fuel waste naturally decays to a safe level suitable for use in other applications after about 300 years.

32) Enabling the nuclear technologies required for CO2 emission reduction is presently not sufficiently high on the Canadian government's agenda. There is presently almost no Canadian government support for proven FNR technology. The reactor technologies presently being pursued by CNL (Canadian Nuclear Laboratories) are not fissile fuel sustainable and produce difficult to manage nuclear fuel waste. The federal government should immediately adopt policies that encourage development and deployment of low pressure fuel breeding liquid sodium cooled FNRs that are walk-away-safe for installation at urban sites. These reactors should be configured for district heating as well as electricity generation.

33) In the Province of Alberta, the fossil fuel industry has effectively transferred its environmental protection responsibilities from bankrupt fossil fuel companies to taxpayers. The fossil fuel industry is still looking for federal taxpayer support, is putting BC residents at risk for a potential heavy oil spill and is contributing to the collapse of the BC fishing industry as well as the collapse of fish dependent mammals such as orcas and bears. This behavior is inconsistent with the environmental stewardship required to protect future generations. The federal government needs to force a change in the fossil fuel industry priorities.

34) Delivery of non-fossil heat in urban markets requires district heating systems. These systems require long term municipal road planning, suitable building codes, suitable easements, suitable property zoning, and suitable energy utility legislation.

35) In Ontario and most of North America the present law related to attachments to buildings makes it impractical for any party, other than the building owner, to finance the cost of the changes to a building's fossil fuel heating system necessary to connect it to a district heating system. The problem is that the first mortgage holder for a building generally has security primacy over all other creditors, including any creditor that finances changes to the building heating system. This issue is known as the

law of attachments. In a building insolvency the lead mortgage holder usually sells the building to a third party. That third party has no legal obligation to the creditor that financed the heating system changes. Fixing this problem requires a fundamental legislative change that places the security held by the party that finances the heating system changes (eg a local energy utility) ahead of the security held by the lead mortgage holder. This issue is a major legal obstacle to displacement of fossil fuels by non-fossil energy. Fixing this problem is opposed by North American banks and like financial institutions because it reduces their mortgage security. Governments must come to the realization that preventing climate change is more important than providing ultra high mortgage and line of credit security to banks and like financial institutions.

36) Both in North America and elsewhere public opposition to power producers and nuclear fuel processors maintaining large plutonium inventories in power reactor fuel must be suppressed. That plutonium is required to provide a sustainable nuclear fuel cycle.

HISTORICAL DENIAL OF REALITY:
The current CO2 situation is not the first instance of public denial of obvious reality by national governments.

From approximately 300 AD to almost 1700 AD the Roman Catholic church, in its quasi government role, proclaimed that Earth is the center if the universe around which other heavenly bodies revolve.

In the year 1512, Nicolas Copernicus used naked eye observations to conclude that Earth is a planet and, like other planets, Earth orbits around the sun and our moon orbits Earth. Copernicus did not widely circulate his findings until about 1530, shortly before his death, because he feared prosecution for heresy by church authorities who then held political power.

In the portion of Europe that remained under the control of the Roman Catholic church denial of reality with respect to the structure of the solar system continued for another 150 years. In 1630, Galileo was imprisoned for publishing telescope observations which confirmed that the planet Jupiter has its own moons.

During the early 1600s the English navy was able to defeat the Spanish navy, in large measure because English mariners, who were Protestants, were much better than the Spanish at celestial navigation. However, if English mariners were caught by the church run Spanish inquisition the English mariners faced death by torture for denial of Roman Catholic church doctrine.

The Roman Catholic church did not fully face reality with respect to the structure of the solar system until after 1680 when Newton's published work on the mathematics of planetary motion enabled both mariners and land explorers to accurately determine their positions on the surface of planet Earth from celestial observations.

In summary, in spite of obvious conflicts with physical reality, it took about 150 years and extensive maritime losses for people everywhere to accept that navigation should not be based on unsubstantiated church doctrine. Similarly in energy and power matters today's politicians should be guided by physical facts, not popular opinion, religious beliefs, fossil fuel industry propaganda or political party doctrine.

TODAY'S REALITY – LAW OF CONSERVATION OF ENERGY:
A principle which underlies all of physical science is the Law of Conservation of Energy. This law gives physicists and engineers certainty about many aspects of physical reality.

One only needs to understand the Law of Conservation of Energy to have certainty that global warming is occurring and is progressively getting worse. The atmospheric CO2 concentration is increasing. Observations from spacecraft have confirmed that CO2 in the atmosphere reduces the thermal radiation emitted by planet Earth. Glaciers and sea ice are melting which reduces local planetary solar reflectivity (albedo) causing increased solar radiation absorption. Hence Earth is absorbing more radiant energy than it emits which is causing global warming. The rate of average temperature rise is limited by the heat capacity of the oceans.

It does not matter whether a person making a claim contrary to the Law of Conservation of Energy is a king, a prime minister, a member of the judiciary, a bishop, an economist, a business tycoon or a famous celebrity. If the claim is contrary to the Law of Conservation of Energy the claim is wrong. Government decisions based on claims which are not consistent with physical reality do not benefit the public.

As recently as the 2019 federal election no Canadian political party leader was factual about Canada's energy options.

PRESENT DENIERS OF REALITY:
For decades senior Canadian and US politicians have made decisions which favored fossil fuel industry interests, that are inconsistent with environmental science and that do not protect the long-term public interest.

With respect to energy matters the Canadian federal government is presently focusing on expanding fossil fuel infrastructure rather than on transitioning from fossil fuel energy to non-fossil energy technologies of which the most important is advanced nuclear power.

North American politicians have become so dependent on the short term financial benefits of the fossil fuel industry that they are unwilling to act in the long term public interest. This short-term focus has severely affected the high school core curriculum. Many students graduating from high school have no understanding of major issues relating to sustainable power and CO2 emission reduction.

REALITY CHECKERS:
When politicians make assertions that are clearly contrary to physical laws persons who understand physics and engineering know that these politicians are wrong and will not protect their constituents.

However, physicists and engineers are not the only groups that understand the threat to mankind.

Other groups in Canada that are sensitive to environmental changes caused by the excess CO2 concentrations are the indigenous people. For thousands of years indigenous people relied on climate

stability and natural populations of fish, whales, seals, deer, bears, caribou and other species for survival. In these matters the indigenous people have a reliable oral history and a deep knowledge of the effect of local climate on animal species behavior. The indigenous people notice significant changes ice cover and in natural species populations long before these changes become the focus of government and academic studies.

During recent decades, these indigenous people have been heavily affected by climate change driven forest insect infestations, ocean water acidification and loss of ice roads. Climate change has destroyed forests, killed fish, driven to extinction all manner of other wild species dependent on fish and forests and has reduced winter road access to other sources of foodstuffs and supplies.

These indigenous people have also been at the mercy of senior government bureaucrats who have repeatedly failed to honor treaty commitments. The indigenous people are also subject to decisions of the fossil fuel and mining industries that have not respected indigenous people's rights and environmental needs. Government officials have repeatedly refused to accept scientific evidence that should have caused cancellation of major fossil fuel projects.

The indigenous peoples are using the only legal tools that they have to preserve their way of life, which means doing all necessary to stop further production of fossil fuels.

Today the claims propagated by governments and the fossil fuel industry, which effectively deny the serious consequences of increases in the CO2 concentrations in the atmosphere and oceans, are as false as the 16th century claims by the Roman Catholic church regarding an Earth centered universe.

THE CO2 REALITY:

Carbon dioxide has been extensively scientifically studied. Antarctic ice cores have shown that for the last 800,000 years, up until the industrial revolution, the atmospheric CO2 concentration oscillated between 180 ppmv (parts per million by volume) and 300 ppmv. Today the atmospheric CO2 concentration is nearly 420 ppmv (50% above the pre-industrial CO2 concentration of 280 ppmv) and is exponentially rising, currently at about 2.5 ppmv / year.

Scientists further know that the mass of excess CO2 dissolved in the oceans is nearly equal to the mass of excess CO2 in the atmosphere.

During the early 1960s the rate at which CO2 in the atmosphere comes to equilibrium with CO2 dissolved in the oceans was measured after atmospheric nuclear bomb tests. The exponential decay time constant for the C-14 concentration in the atmosphere was found to be about 16 years, which is three orders of magnitude less than the nuclear half life of C-14. Hence for times long compared to 16 years the concentrations of CO2 in the atmosphere and the oceans are in equilibrium and the amounts of CO2 in the atmosphere and CO2 dissolved in the ocean are nearly equal.

The rise in Earth's average atmospheric CO2 concentration due to combustion of fossil fuels has been accurately measured since 1957,

For over a century naval submarine personnel have known that too high an atmospheric CO2 concentration is toxic to humans. CO2 extraction is a critical function in: submarines, closed circuit

breathing apparatus, manned space craft and advanced air conditioning systems.

The toxicity to marine life of an increased concentration of dissolved CO2 in the oceans has been known for many decades. The ocean pH has been monitored by the Japanese since 1980 and by the Canadian government since 2014. A simple projection of Japanese open ocean pH data shows that if present trends continue many ocean species will become extinct by about the year 2040. Already in the BC inside passage, where the average dissolved CO2 concentration is higher than in the open Pacific ocean, populations of herring, salmon and orcas (killer whales) are in a precipitous decline. Bears are also affected as they rely on plentiful salmon to put on sufficient weight to enable their survival during winter hibernation.

The issue of the GHG (green house gas) effect of atmospheric CO2 became well known during the 1960s when US and Russian space vehicles measured the atmospheric composition and temperature of the planet Venus. The GHG effect on planet Earth was precisely measured in November1996 using the far infra-red spectrometer on board the spacecraft Mars Global Surveyor. This spectrometer also showed that most of the thermal radiation photons emitted from Earth into outer space originate from freezing of water droplets in the atmosphere.

The average solar reflectivity (albedo) of planet Earth was precisely determined in 1999-2000 by measuring Earth shine reflected from the dark face of the moon. Earth's average solar reflectivity steadily decreased during the period 2000 – 2020.

By 2012 it was clear that planet Earth is rapidly heading toward a large animal thermal extinction.

THE FALSEHOODS:
Fossil fuel interests have influenced political decisions, particularly in North America, in a manner that is contrary to the long-term interests of the human species.

Fossil fuel propaganda has convinced much of the voting public and many elected politicians that wind and solar electricity generation are solutions to climate change. Professional engineers knowledgeable in electricity matters know that is not the case. Wind and solar generation are intermittent and seasonal and collectively lack dependable capacity. At best wind and solar electricity generation could only meet about one third of the electric energy load and none of the dependable power and thermal load. In Canada the load presently met by fossil fuels is more than 4X larger than the average electricity load. The fossil fuel companies encourage wind and solar generation because in most power grids fossil fuels are used to balance wind and solar generation, and to provide wind and solar generation grid frequency stability, a practice that locks in a significant role for fossil fuels.

Biomass is not a solution for balancing intermittent wind and solar generation. There is not enough surplus sustainable biomass to make aircraft fuel, for which it is essential, let alone use biomass for other purposes.

For many years both the federal government and provincial governments have failed to meet their treaty obligations to indigenous people. Now the indigenous peoples are being told that if they want fair treatment they must accept fossil fuel projects on their traditional lands. The indigenous people know that these fossil fuel projects will adversely affect them and their descendants for centuries to

come. Often indigenous consent to fossil fuel projects has been obtained by various forms of extortion.

To comprehend the real motivation of the fossil fuel companies just look at Alberta where the cost of environmental remediation of abandoned oil/gas wells is reasonably estimated to be in the range $70 billion to $200 billion. Now after receiving huge tax payer funded subsidies the fossil fuel industry is attempting to transfer its environmental remediation obligations onto tax payers.

SUSTAINABLE AND DEPENDABLE PHYSICAL SOLUTIONS:

Any solution to CO2 induced climate change must provide complete and sustainable displacement of fossil fuel supplied energy and dependable power with non-fossil energy and dependable power. Between 1957 and 1994 advanced prototype U-238 and Th-232 nuclear reactor technologies were developed in the USA for the supply of sustainable, affordable and dependable non-fossil energy and power. However, when the existence of these new technologies was perceived by the fossil fuel industry to be a potential threat to its market share the fossil fuel industry used political corruption and financial support of anti-nuclear groups to prevent deployment of these advanced reactor technologies in North America.

However, over time detailed data relating to these advanced reactor technologies made its way to China, India and Russia. Now each of these Asian countries has a large scale advanced nuclear reactor development and deployment program. Russia has pursued uranium fueled liquid metal cooled breeder reactors and China and India are both pursuing liquid fuel molten salt thorium breeder reactors.

For technical reasons the uranium technology is easier to implement. Russia already has three large liquid sodium cooled power reactors in operation and is working on a fourth large unit. Russia is assisting China in construction of two more large liquid sodium cooled power rectors. As of early 2020 Russia is advancing its economic and foreign policy influence around the world with over $200 billion in foreign orders for 36 reactors, and with plans to underwrite the construction of more than 50 reactors in 19 countries.

China and India lack large uranium resources but they have large thorium deposits. China has a policy that all new passenger vehicles are to be electric. The Chinese are not constrained by price and market constraints. As of late 2019 China was building over 1 million battery electric vehicles per year and reasonably plans to convert its entire passenger automobile vehicle fleet to electric power by 2030. China is currently constructing four large power reactors abroad, with prospects for 16 more reactors across multiple countries, in addition to the 45 reactors built in China over the past 33 years, and the 12 reactors currently under construction in China. China is projecting completion of 6 to 8 large reactors per year until at least 2030, The Chinese are deploying the waste heat from some of their nuclear reactors for urban district heating.

In summary, the Chinese are building nuclear power capacity and electric vehicles faster than the entire rest of the world combined.

It is only in the imagination of North American fossil fuel promoters that there will be a continuing large demand for petroleum based automotive fuels. The present world demand for oil as a source of automotive transportation fuel will collapse. The surpluses of oil in Russia and the OPEC countries

mean that there will be almost no foreign demand for relatively high cost oil from Canada and the USA. Hence, there will be no oil export profits with which to pay for the Trans-Mountain pipeline expansion or the Keystone pipeline. These pipelines will become a stranded assets and mill stones around Canadian taxpayers necks. The Canadian federal government and the Alberta government should divest themselves of these pipelines at the earliest opportunity. In addition to capital costs to taxpayers of over 14 billion dollars the pipeline owners are at risk for about a $20 billion dollar marine accident claim in the Straights of Juan de Fuca through which all ships must pass to enter or leave Vancouver harbor.

If Alberta and Saskatchewan insist on these pipelines to meet their short term needs they should raise provincial sales taxes to pay for them. Within a decade sustained world oil price collapse will cause default on the pipeline related bonds. Taxpayers in other Canadian provinces should not be liable for stranded assets arising from foolish new investment in fossil fuel infrastructure or for the marine accident risk at a time when the world is trying to reduce fossil CO2 emissions.

In order to permit continuing present pipeline operation for oil export it is reasonable for the BC government to require that the pipeline owners carry $20 billion in liability insurance for all risks, including marine and dry land oil spills that may affect BC or its inhabitants.

CLEAN ENERGY SUPPLY IN CANADA:

Today the indigenous people of Canada are saying “no” to more new fossil fuel infrastructure and it is up to scientifically educated Canadians to stand with the indigenous people.

Ontario has used CANDU nuclear reactors for base load electricity generation for 50 years. The now obsolete CANDU reactors recover only about 1% of the energy potentially available from their fuel. There is now sufficient used CANDU nuclear fuel in storage in Ontario to power all of Canada for several centuries by recycling the fuel through liquid sodium cooled Fast Neutron Reactors (FNRs). However, the used CANDU fuel remains stuck in storage due to political decisions within both the federal and provincial governments. That used CANDU fuel should be recycled into FNR fuel. There is an existing $11 billion trust fund originally intended for disposal of used CANDU fuel by burial that should instead be redirected for this purpose. With matching private funds this money should be used for development and deployment of FNRs.

FNRs can be mass produced, sited close to load centers and used to supply both electricity and district heat in all of Canada's major urban centers.

A major issue limiting the rate of FNR deployment is education of the required work force, especially engineers. It typically takes at least 10 years of post-graduate training and experience to produce a competent nuclear engineer and 25 years to produce an engineer who can efficiently direct a major nuclear project. The last major new-build nuclear project in Canada was the Darlington Nuclear Power Plant which was built between 1975 and 1992. Most Canadians with relevant new-build nuclear reactor construction experience are now either retired or dead. Anyone in Canada who gained experience in advanced FNR technology during its development in the USA is also past retirement age.

Another major issue limiting the rate of full FNR deployment is design and implementation of urban district heating systems. While comfort heat can theoretically be delivered to urban loads via electricity,

that method very energy inefficient and very expensive. A much more energy efficient arrangement is to use waste heat from nuclear electricity generation to heat water for district heating and then to use terminal heat pumps at distant thermal loads to raise the temperature of the supplied heat from about 30 degrees C to about 60 degrees C. However, the required heating water pipes must be buried under city streets and the elevation of these pipes is important to limit the peak water pressure in the heat distribution system, which sets the required pipe wall thickness. Thus implementation of a nuclear district heating system requires many years of lead time for municipal planning and then for pipe burial at times when city streets must be dug up for other reasons.

An adequately funded FNR program sufficient to fully displace fossil fuels across Canada would likely take about 50 years to efficiently implement. During that period CO2 will continue to accumulate in the atmosphere and oceans. For the last 30 years politicians around the world have been aware of CO2 driven climate change but have failed to act to mitigate it.

THE FISSILE ISOTOPE DILEMA:

Mankind's use of fossil fuels is limited by the advance of global warming. However, there is another extremely serious energy supply threat. Within the lifetimes of younger persons now living much of the human population may be extinguished by mankind's failure to conserve the rare natural isotope U-235 and the man made isotopes Pu-239 and U-233. While there is enough energy potentially available from the fertile isotopes U-238 and Th-232 to support the present human population for over 6000 years, that energy resource can only be accessed by converting the fertile isotopes into fissile isotopes. That conversion process requires maintenance of large inventories of the fissile isotopes Pu-239, U-233 and U-235. At the present the supply of these fissile isotopes is being squandered in “burning” reactors, instead of being conserved in “breeding” reactors. At the projected rates of consumption of these rare fissile isotopes, their inventories will be depleted within a few decades. Then the energy contained in the fertile isotopes will be inaccessible for centuries and much of the human population will starve due to lack of energy supply. Outside of a small subset of nuclear engineers, few people are aware of this emerging threat. It is urgent that all new nuclear power reactors be of a “breeding” type, not a “burning” type so as to sustain and grow the fissile fuel inventory instead of further depleting it.

In this matter the public is in extreme danger because this matter is not addressed by existing government policy and any mention of this danger places an individuals employment at risk.

In Ontario executives of Ontario Power Generation (OPG) and Bruce Power are afraid to invest in “breeding” type reactors because they require multi-billion dollars in dedicated development and approval costs which should be federally rather than provincially funded. Meanwhile the Canadian federal government remains a pawn of the fossil fuel industry. The advanced reactor development capacity of Atomic Energy of Canada Limited (AECL) was destroyed by the previous Harper led Conservative government.

Unfortunately, understanding of the importance of conservation of fissile isotopes seems to be beyond the intellectual capacity of present elected politicians. Instead these politicians and their media lackeys seek to destroy fissile isotopes because these isotopes might potentially be used to make military weapons. These politicians and media representatives all lack the basic science education required to grasp that the lives of their children and grandchildren will completely depend on enlarging, not

reducing, the inventory of fissile isotopes.

Without sufficient fissile isotopes and without fossil carbon fuels the price of energy will become more than most consumers can afford. The present human population relies on abundant low cost energy to support production of fertilizers, automated planting, irrigation, weed and pest control, automated harvesting, environmentally controlled foodstuff storage, world wide shipping, conversion of grains into consumable foods and retail distribution. Absent abundant low cost energy this industrial scale food supply system will not be sustainable and starvation will wipe out much of the human population.

NUCLEAR EDUATION:

The single most urgent matter in addressing climate change and fissile isotope conservation is to make nuclear power engineering, construction, operation and maintenance desirable career options for today's young people. Without sufficient numbers of technically competent young people no amount of money or other resources will solve either the present CO2 problem or the emerging fissile isotope conservation problem.

Canadians must face the reality that due to prolonged government ignorance and intransigence with respect to nuclear power matters and related engineering education the number of suitably skilled people presently available is extremely limited and there will be a major cost and a significant time delay related to personnel training and supply chain development.

The concept that each such engineering student must fund his/her own education must be abandoned. Otherwise there will be insufficient trained persons. Canadian engineering, physics and chemistry student candidates must be selected based primarily on merit in math, physics and chemistry and on ability to communicate complex matters to others. Each such student needs to be fully publicly funded for at least 10 years of post secondary education.

Canada could enhance its position on the world stage by training not only its own work force but also engineering and science students from emerging countries. During the war in Vietnam in the late 1960s and early 1970s China sent its best students to Canada for engineering training at what was then Canada's foremost science and engineering training institution, the University of Toronto. From 1969 to 1975 this author had the privilege of teaching some of those brilliant young Chinese minds. Today some of these former students are captains of industry in China. In terms of wise expenditure of foreign aid dollars there is much to be said for providing sophisticated training to brilliant nationals from developing countries. If they choose to stay in Canada they will contribute to the Canadian economy. If they choose to go home they will provide critical technical guidance in their native country.

PUBLIC EDUCATION:

Mitigating the CO2 problem via deployment of advanced nuclear reactors will require a lot of public resources and will require voter support. In every province basic knowledge about CO2, the various non-fossil power technologies and their advantages and disadvantages should be part of the high school core curriculum. Students must become aware that 70 years of practical experience with nuclear power technology have shown that properly engineered and operated nuclear reactors are by far the safest, least expensive and least resource consuming and most dependable of all non-CO2 emitting

energy sources.

Canadian students should be proud of the unmatched safety record of the Canadian nuclear power industry. This record is the result of Canada's engineering safety culture.

APPENDIX I – OCEAN ACIDIFICATION:

1) When the atmospheric CO2 concentration is very low limestone (CaCO3) weakly dissolves in water in the form of Ca+ and (CO3)-- ions. Many aquatic organisms near the base of the food chain rely on the (CO3)-- ions to make bone and shell material.

2) As the atmospheric CO2 concentration increases part of the CO2 gas combines with pure water (H2O) molecules and produces carbonic acid (H2CO3) which exists as H+ and (HCO3)- ions.
   $CO2 + H2O = H2CO3 = H+ + (HCO3)--$
   This solution is essentially soda pop without sugar.

3) In ocean water that is subject to an increasing external CO2 pressure there is another important reaction:
   $CO2 + H2O + (CO3)-- = 2\ (HCO3)-$

As the atmospheric CO2 concentration increases this reaction reduces the (CO3)-- ion concentration in the ocean on which many aquatic species depend for making bone and shell material.

In summary raising the atmospheric CO2 concentration increases the amount of CO2 in water solution which reduces the (CO3)-- ion concentration which kills a wide range of micro-organisms near the base of the food chain upon which many fish depend for food.

Chemists monitor the progress of the aforementioned ocean acidification process by measuring a water solution parameter known as pH.

In the year 1960 the average ocean surface pH was about 8.20.
In the year 1980 the average ocean surface pH was about 8.15.
In the year 2000 the average ocean surface pH was about 8.10.
Today in the year 2020 the average ocean surface pH is about 8.05.

Note that due to the increasing atmospheric CO2 concentration the average ocean pH has decreased by about 0.05 every 20 years. Major ocean species extinctions will commence at a pH of about 8.00.

However, today there are patches of ocean, particularly nearly enclosed portions over continental shelves, where the ocean depth is less than average, which causes the dissolved CO2 concentration to be higher than average. In these patches the pH is already lower than the 8.00. In these patches many micro-organisms, near the base of the ocean food chain on which fish such as herring and salmon rely, have disappeared. One of these patches is the Salish Sea, which roughly speaking is the portion of the Pacific Ocean between Vancouver Island and the mainland. Typical pH values in the Salish Sea are in the range 7.50 to 7.90 with average values of about 7.70. As a result the herring and salmon populations are collapsing. Lack of salmon is causing the resident orca (killer whale) population to fall and is preventing bears putting on the weight that they need to survive winter hibernation.

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Additional information regarding Ocean Acidification is available at:
www.xylenepower.com/Ocean%20Acidification.htm

An engineering plan related to deployment of Fast Neutron Reactors for displacement of fossil fuels in Canada is available at: www.xylenepower.com/INZEM%20Energy.htm

Additional information related to Fast Neutron Reactors (FNRs) is available at:
www.fnrpower.com

Additional information related to Interruptible Electricity is available at:
www.interruptibleelectricity.com

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