

CO₂, ENERGY AND POWER REALITIES – March 9, 2020
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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 that both government and the media stop giving credibility to persons and organizations that deny reality. In establishing non-fossil energy and power policy government should obtain guidance from engineers who have relevant knowledge and experience.

INTRODUCTION:

Present Canadian federal/provincial government policies relating to carbon dioxide (CO₂) driven climate change, energy and dependable power have **almost no basis in physical fact**. Ignorance about power systems and the consequences of the ongoing accumulations of CO₂ in the atmosphere and the oceans is rapidly guiding planet Earth toward an apocalypse, an extinction of major life forms comparable to previous global extinctions in Earth's geologic past.

GROSS EFFECTS OF CO₂:

For hundreds of millions of years life forms on Earth evolved to exist in an atmosphere with a carbon dioxide (CO₂) concentration in the range 200 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 200 ppmv plants, that rely on a sufficient atmospheric CO₂ concentration for photosynthesis, cannot grow. When the atmospheric CO₂ concentration is significantly above 300 ppmv (CO₃)⁻ ions in ocean solution convert into (HCO₃)⁻ ions. Then marine life that relies on a sufficient (CO₃)⁻ ion concentration for formation of bone and shell material cannot grow.

When the atmospheric CO₂ concentration is below 200 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. When the atmospheric CO₂ concentration is above 300 ppmv the thermal radiation flux emitted 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 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 300 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 CO₂ concentration to be particularly 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 reach 540 ppmv, about 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.

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 has been very fast whereas the natural processes that can permanently remove excess CO₂ from the atmosphere and the oceans are very slow. Hence during the last 150 years fossil CO₂ has accumulated in the atmosphere and oceans. Any fossil CO₂ formed now will remain in the atmosphere and oceans for many thousands of years into the future.

The more CO₂ that accumulates in the atmosphere and oceans the more life adverse the environment will become. Reversing the CO₂ accumulation would require significantly more energy than fossil fuels have provided during all of the last 150 years. The concept of man kind inventing a technology that rapidly reverses the CO₂ accumulation violates the law of conservation of energy and hence has no basis in physical reality.

To prevent the environment worsening it is necessary to halt all further production of fossil CO₂. This simple concept seems to be beyond the comprehension of present political leaders in Australia, Canada and the USA.

REMEDIAL TECHNOLOGY:

To prevent further fossil CO₂ production it is necessary to provide consumers with sufficient sustainable, dependable and economic non-fossil power. In short it is necessary to rapidly deploy advanced modular nuclear reactors with sustainable fuel cycles. There is no other non-fossil energy supply technology capable of meeting human dependable power requirements. Conservation and renewable energy generation can meet a fraction of the energy requirements but cannot meet the dependable power requirements.

Unlike in China, India, Russia and France, 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

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 fossil CO₂ and fossil methane (CH₄) emissions. That halt means leaving fossil carbon in the ground, regardless of political consequences. This is an issue that Canadian 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 absent impossible amounts of energy storage, cannot supply sufficient dependable power to displace fossil fuels.

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

- a) Immediate cancellation of all investment in new fossil fuel infrastructure;
- b) Implementation of a fossil carbon tax sufficient to keep fossil carbon in the ground;
- c) Restructuring retail electricity rates and taxes to enable use of existing surplus non-fossil electricity generation capacity to provide low cost interruptible electricity for: displacement of fossil fuels, production of electrolytic hydrogen and charging of electric vehicles;
- d) Supply sufficient sustainable and dependable non-fossil electrical and thermal power to completely displace fossil fuels by large scale deployment of advanced nuclear reactors that are fueled by the abundant isotopes U-238 and Th-232;
- e) The advanced reactors will require closed cycle electrolytic fuel recycling for efficient fuel utilization and waste disposal. This fuel recycling method limits the solid fuel waste stream to short lived fission products that naturally rapidly decay;
- f) Elimination of nuclear reactor decommissioning waste by surrounding the reactor fuel assembly with a 3 m wide liquid coolant guard band;
- g) The advanced reactors must be walk-away-safe and proliferation resistant;
- h) The advanced reactors must be suitable for urban siting for economic district heating as well as electricity generation. This constraint dictates use of a compact reactor that emits no noise and operates with a low pressure high temperature core coolant such as a liquid metal or a molten salt;
- i) Each advanced reactor must be assembled from modules that can be safely delivered and removed by truck via city streets. This requirement imposes weight and size constraints on individual modules and on shielded fuel bundles;
- j) Each advanced reactor must be sufficiently surrounded by protective structures to safely withstand direct impact by a large passenger airplane;
- k) The advanced reactors must safely withstand severe earthquakes;
- l) Each advanced reactor must be sited so that damage by floodwater or a tsunami is not a credible risk;
- m) The advanced reactors must be interconnected such that the energy distribution system can accommodate two adjacent reactor shutdowns without impacting consumers;
- n) To minimize on-going costs the advanced reactors must be designed for autonomous operation;
- o) To minimize system costs economic energy storage and energy conservation measures should be adopted;
- p) Implementation of the necessary energy infrastructure will require extensive work force training and will likely take about half a century.

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. Energy systems are governed by natural physical laws, not wishful thinking, political doctrine or majority vote. Repeated political procrastination, particularly in North America and Australia, has already put the human species in peril.

THE PRESENT CO2 TREND:

Today we are confronted with the physical reality of increasing accumulations of CO2 in the atmosphere and oceans caused by 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.

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 CO2 / day injected into the atmosphere. Over time about half of the excess CO2 dissolves in the oceans. The natural chemical reactions that can permanently absorb excess CO2 either by formation of fossil fuels or by conversion of igneous rock into carbonate rock take over 100,000 years to operate. From the perspective of a human lifetime 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 all fossil fuels and there are no plans to build non-fossil power sources with sufficient capacity. Even where there is non-fossil power of sufficient capacity the present retail electricity rate structures prevent that power being economically used 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 corruption by fossil fuel interests that have lobbied for retail electricity rates that force consumers to use fossil fuels instead of available zero cost surplus non-fossil electricity.

On a per capita basis Asian CO2 emissions are far below North American CO2 emissions. China, India and Russia are all pursuing development and world wide deployment of nuclear reactors. From the perspective of young people in Asia the excessive per capita CO2 emissions from Australia and North America are totally unacceptable and intentional destruction of new fossil fuel infrastructure would be justifiable to force reductions in per capita CO2 emissions. Political leaders around the world must get the message that further investment in fossil fuel infrastructure is unacceptable if there is a reasonable nuclear power alternative.

The fate of Canada's young people hinges on governments making immediate and appropriate energy policy changes based on facts, not fossil fuel corporate interests or mistaken beliefs. We are 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 other countries and continuing fossil fuel extraction is morally indefensible and will eventually cause 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 occurring right now 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 will by some magic alleviate the increasing CO₂ problem. That error diverts critical 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 must be forced to fund remediation of the environmental mess that it has made (> \$70 billion in Alberta alone) and then must be persuaded to invest in non-fossil energy technologies such as nuclear power 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 sea water. This myth is only slightly true. After CO₂ emissions have totally stopped, for about a 16 year period the atmospheric CO₂ concentration will 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 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 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.

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.

7) A fossil carbon tax achieves very little CO₂ emission reduction unless consumers have available to them an alternate dependable and economic source of non-fossil 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. Achieving that 100% reduction in fossil fuel consumption is only possible if consumers can easily access a sufficient source of economic and dependable non-fossil electrical and thermal power.

8) There is economic merit in using the revenue from a fossil carbon tax to fund the construction of nuclear power capacity. However, that revenue application would likely 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 power at times when electricity is 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 storable 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 energy inefficient and is prohibitively expensive. In most jurisdictions the necessary geography for economic seasonal energy storage simply does not exist. Hence solar and wind electricity generation only have value as sources of interruptible power for: displacing fossil fuels, producing electrolytic hydrogen and charging energy storage.

11) The practical experience in Ontario has been that only 30% of the electricity produced by wind and solar electricity generation can be sold at present electricity rates. The remaining significant 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 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 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) Dispatchable generators (large hydroelectric, nuclear, fossil) presently provide the dependable power capacity required for operating an electricity system whereas intermittent renewable energy generators do not. Long term displacement of fossil fuels with non-fossil energy requires the use of sustainable nuclear and hydroelectric technologies.

14) The only non-fossil technology capable of fully displacing fossil fuels is nuclear power.

15) The present widely used water cooled nuclear power reactor technology is not sustainable. This technology is fueled by the relatively rare isotope U-235. There is simply not enough U-235 in Earth's crust to sustainably and economically displace fossil fuels.

16) There are two sustainable nuclear power fuel cycles with abundant fuel isotopes, the U-238 – Pu-239 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 supply of uranium. The Th-232 cycle has been adopted by China and India because those two countries have large reserves of thorium but little uranium.

17) Halting 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 hydrogen storage to economically supply electricity, heat and hydrogen.

18) 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. Fossil fuel consumption reduction requires a dependable source of non-fossil heat, not a reduction in electricity consumption,

19) There is a mistaken belief by “environmentalists” and electricity regulators that non-fossil electricity should be priced proportional to the electrical kWh consumed whereas in reality the cost of non-fossil electricity is proportional to the annual peak load demand. This mistaken belief causes incorrect electricity billing which leads to large amounts of available non-fossil electricity being discarded or exported instead of being delivered to consumers for fossil fuel displacement. To fix this problem retail electricity billing must be changed to be primarily based on peak demand (kW), not energy consumption (kWh).

20) 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.

21) 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 Fast Neutron Reactor (FNR) fuel using a non-aqueous molten salt electrolytic process. FNRs can improve the energy recovery from natural uranium 100 fold and can reduce the formation of long lived nuclear fuel waste 1000 fold.

22) Unlike used CANDU fuel, which takes about 400,000 years to naturally decay to a safe level, spent FNR fuel consists of 99.9% fission products that naturally decay to a safe level in about 300 years

23) There is a public misconception that the contemplated 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 fission bomb production. Separation of Pu-239 (bomb material) from Pu-240 is almost impossible.

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

25) Present water cooled power reactors operate at high core coolant pressures and as a consequence require a surrounding exclusion zone 1 km wide. Making reactors completely safe for urban siting with no exclusion zone requires use of modular low-pressure pool type nuclear reactors that use liquid sodium or molten salt for reactor core cooling.

26) Making nuclear power sustainable in terms of both fuel supply and long lived waste minimization requires that a reasonable fraction of the new reactors be liquid sodium cooled FNRs. These FNRs can

breed more fissile fuel 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 in about 300 years. 27) 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 federal government should immediately adopt policies which encourage development and deployment of low pressure fuel breeding liquid sodium cooled FNRs that are walk-away-safe for installation at urban sites and are configured for district heating as well as electricity generation.

28) The federal government should immediately adopt a policy to re-allocate trust funds originally intended for burial of used CANDU fuel to re-processing of used CANDU fuel into FNR fuel. This policy change is essential to enable private sector investment in FNR related technology. The private sector cannot invest until after the federal and provincial governments provide certainty with respect to future FNR fuel availability.

29) 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 species 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's priorities.

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 of 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 rightly feared prosecution for heresy by church authorities who then held political power.

In the portion of Europe which 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 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 today's politicians should be guided by energy and climate facts, not religious beliefs, fossil fuel industry propaganda and 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 planetary 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 false claims are not consistent with physical reality and 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 do not protect the long-term public interest. The fossil fuel industry has effectively convinced politicians that it is not responsible for providing consumers access to economic and dependable non-fossil energy.

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 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 even affected the high school core curriculum where long term effective methods of CO₂ emission reduction are not taught.

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 fail to protect their constituents.

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

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 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 understanding of local climate and animal species behavior. The indigenous people notice significant changes in climate and natural species populations long before these changes become the focus of 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, eliminated all manner of other wild species dependent on fish and forests and has cut off winter road access to other sources of foodstuffs and supplies.

These indigenous people have also been at the mercy of senior government bureaucrats and government policies that have repeatedly failed to honor treaty commitments. The indigenous people are also subject to decisions of the fossil fuel industry that have not respected indigenous people's 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.

At atmospheric CO₂ concentrations below about 200 ppmv various plant species start to die.

At atmospheric CO₂ concentrations above about 350 ppmv various ocean life forms start to die.

Scientists further know that the mass of excess CO₂ dissolved in the oceans is approximately 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 ratio of the CO₂ concentration in the atmosphere to the CO₂ concentration in the ocean is an approximate constant.

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. This issue has been carefully monitored via ocean pH measurements 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 the year 2040. Already in the BC inside passage, where the average dissolved CO₂ concentration is higher than in the open Pacific ocean, herring, salmon and orcas (killer whales) are in a precipitous decline. Many 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 greenhouse 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 greenhouse gas effect on planet Earth was precisely measured in November 1996 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 energy matters know that is not the case. Wind and solar generation are intermittent and seasonal and even collectively lack dependable capacity. At best wind and solar electricity generation can only meet

about one third of the electric energy load and none of the dependable power and thermal load. In Canada the thermal load is about 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, 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 sustainable biomass to make aircraft fuel, let alone use it for powering anything else.

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 subtle 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 and other fossil fuel facilities is estimated to exceed \$70 billion. After receiving huge tax payer funded subsidies the fossil fuel industry is attempting to transfer this environmental remediation obligation onto tax payers.

SUSTAINABLE AND DEPENDABLE PHYSICAL SOLUTIONS:

Any sustainable solution to CO₂ induced climate change must completely displace fossil fuel supplied energy and power with non-fossil energy and power. Between 1964 and 1994 advanced prototype uranium and thorium 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.

Over time detailed data relating to these advanced reactor technologies made its way to China, India and Russia. Now these Asian countries all have a large scale advanced nuclear reactor development and deployment programs. 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. However, 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. China is presently building over 1 million battery electric vehicles per year and reasonably plans to convert almost its entire passenger automobile vehicle fleet to electricity within a decade. The Chinese are building numerous new nuclear reactors to power their electric vehicle fleet. They are also deploying the waste heat from nuclear reactors for urban district heating.

In North America there are presently only a few persons fully engaged in molten salt nuclear reactor development work. In the UK there are perhaps a few dozen. In China in 2012 there were over 600. It is no surprise that the Chinese are building nuclear power capacity and electric vehicles faster than the entire rest of the world put together.

Russia already has three large liquid sodium cooled power reactors and is working on a fourth large unit.

Russia, China and India are collectively dominating nuclear power markets in developing countries where the plan is to build numerous nuclear reactors to power electric vehicles.

It is only in the imagination of North American fossil fuel promoters that there will be a continuing large market for petroleum based automotive fuels. The present world demand for oil as a source of automotive transportation fuel will collapse. There will be little demand for relatively high cost oil from Canada and the USA that may also be subject to a fossil carbon tax. There will be no oil export profits to pay for the Trans-Mountain pipeline. That pipeline will become a stranded asset long before it can be amortized. The Canadian federal government should divest itself of the Trans-Mountain pipeline as soon as possible.

If Alberta and Saskatchewan insist on building the Trans Mountain Pipeline expansion to meet their short term needs they should raise provincial sales taxes to pay for it. Within a decade the world price of oil will collapse causing default on pipeline related bonds. Taxpayers in other provinces should not be liable for stranded assets arising from foolish expansion of fossil fuel infrastructure at a time when the world is trying to reduce CO2 emissions.

In order to permit 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 or dry land oil spills that may affect BC or its inhabitants.

NON-FOSSIL ENERGY SUPPLY IN CANADA:

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

Ontario has used CANDU nuclear reactors for base load electricity generation for 50 years. CANDU reactors only consume about 1% of the energy potentially available from their fuel. There is sufficient potential energy in used CANDU nuclear fuel in storage in Ontario to power all of Canada for centuries using liquid sodium cooled Fast Neutron Reactors (FNRs). However, the used CANDU fuel remains 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 be redirected for this purpose. The money saved by not investing federal tax payer money in the Trans-Mountain pipeline should be used together with matching provincial and private funds, for development and deployment of FNRs.

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

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 of relevant experience 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 1980 and 1990. Most Canadians with

relevant new-build nuclear reactor construction experience are now retired or dead. Anyone in Canada who gained experience in advanced FNR technology during its development in the USA is also past retirement age.

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 single most urgent matter in addressing climate change is to immediately make nuclear power engineering, construction and operation desirable career options for today's undergraduate science and engineering students. Without sufficient numbers of technically competent people no amount of money will solve the CO₂ problem.

Canadians must face the reality that due to prolonged government 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.

Canada could enhance its position on the world stage by training not only its own work force but also engineering 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. Today these same persons 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 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 support in their country of origin.

PUBLIC EDUCATION:

Mitigating the CO₂ problem will require a lot of public resources and 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 technology have shown that properly engineered nuclear reactors are by far the safest, least expensive and least resource consuming of all non-fossil energy sources.

Canadian students should further be proud of the unmatched safety record of the Canadian nuclear power industry. This record is in part the result of the unique safety features embodied in CANDU nuclear reactors.

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. This water is known as hard water. 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 combines with pure water (H₂O) molecules and produces carbonic acid (H₂CO₃) which exists as H⁺ and (HCO₃)⁻ ions.
$$\text{CO}_2 + \text{H}_2\text{O} = \text{H}_2\text{CO}_3 = \text{H}^+ + (\text{HCO}_3)^{-}$$

This solution is essentially soda pop without sugar.

3) In ocean water that is subject to an external CO₂ pressure there is another important reaction:
$$\text{CO}_2 + \text{H}_2\text{O} + (\text{CO}_3)^{--} = 2 (\text{HCO}_3)^{-}$$

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 population to fall and is preventing bears putting on the weight that they need to survive winter hibernation.

ACKNOWLEDGEMENTS:

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

Additional information relating to deployment of Fast Neutron Reactors for displacement of fossil fuels in Canada is available at: www.xylenepower.com/INZEM%20Energy.htm

The author of this document gratefully acknowledges the assistance of the following persons, all of whom are expert in various aspects of energy, power and CO2 driven climate change:

Paul Acchione, P.Eng.,FCAE

Dr. Alex Canara

Dr. Alex Pavlak, P.Eng.

Dr. Tom Rehm, P.Eng.

Dr. Harry Windsor.