ENERGY REALITIES

The truth about sustainable non-fossil energy in Ontario

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1969 – 1974
- graduate studies, Dept. of Electrical Engineering, U of T

1975 - 2003
- u-processor control and monitoring of electrical and mechanical equipment,
- energy storage, temperature and power control in major buildings,
- utility cost saving performance contracts,
- commercial high efficiency boilers,
- commercial co-generation systems.
- represented UDI and FRPO at OEB,
- u controller RF access control

2004 – 2017
- astrophysical analysis of climate change,
- OPA IPSP intervention,
- development of sustainable nuclear power,
- theoretical derivation of Planck constant

SUSTAINABLE ENERGY PROBLEMS

1) Astrophysics shows that the CO2 related climate change problem is much more serious and much more urgent than has been indicated by governments and by the IPCC.

2) Seriousness arises from the size (~ 20 degrees C) of the projected future rapid planetary emission temperature rise known as thermal runaway. The geophysical isotope and fossil record shows that prolonged periods of such high temperatures have occurred in the past.

3) Urgency arises from the scale and scope of the industrial effort required to prevent thermal runaway from occurring and from the relatively small increase in planetary emission temperature (~ 2 degrees C) required to trigger thermal runaway.

The astrophysics relating to thermal runaway will require a dedicated presentation at a future date. For today I will simply state that it is essential to immediately do all necessary to keep fossil carbon in the ground. This is a non-negotiable issue if mankind is to survive.

4) Since 1981 Ontario government policy has encouraged electricity to natural gas fuel substitution. To prevent climate change Ontario must do a complete U turn and focus on fossil fuel displacement, energy storage and electricity peak demand reduction.

5) In Ontario the resources devoted to wind and solar generation have been almost completely wasted. In a non-fossil energy system wind and solar have little value without sufficient seasonal energy storage, which storage is nonexistent in Ontario.

6) The Ontario government has ignored engineering advice relating to individual metering and energy storage in major buildings.

7) The Ontario government has done nothing to enable use of available interruptible electricity to displace fossil fuel consumption in Ontario.

8) Prevention of future thermal runaway requires about a 10 fold increase in nuclear power capacity in Ontario, a major change in electricity rate structure and a fossil carbon tax sufficient to keep all forms of fossil carbon in the ground.

9) The change in electricity rate structure is required to financially enable energy storage and load control which are essential for mitigating nuclear power costs.

10) Existing water moderated nuclear reactor technologies such as CANDU are not sustainable for fossil fuel displacement and must be replaced by liquid sodium cooled fast neutron reactor (FNR) technology.

11) Experimental measurements of atmospheric C-14 concentration transients indicate that the world wide the total fossil carbon oxidation rate is about 1.9X larger than is indicated by governmental coal, oil and natural gas production reports. This ratio is supported by analysis of government data collection methodology and refinery practice.

12) In energy matters the governments of Ontario and Canada are technically incompetent and are dominated by fossil fuel industry influence. How else can anyone explain the recent approvals of tripling of Canada's heavy oil exports and construction of a new LNG port by a federal government that was elected on a platform of preventing CO2 related climate change? How else can anyone explain why the present Ontario electricity rate structure benefits fossil fuel producers at the expense of Ontario electricity ratepayers?

13) Implementation of the present plans of federal and provincial governments will neither prevent nor significantly delay onset of thermal runaway.

14) Intervention by audience members will likely be required to change the courses of present Ontario and Canadian governments.

WIND AND SOLAR

Intermittent combined wind and solar energy, without fossil fuel balancing, is today worth about $0.016 / kWh. Wind costs over $0.13 / kWh to generate and costs 3X as much as nuclear energy per kWh-km to transmit. To access balancing storage in Quebec from Ontario requires transmission distances which are more than 4X the average distance from nuclear generation to load centers resulting in a more than 3 X 4 = 12 fold increase in transmission costs.

Integrating wind and solar energy onto the grid without fossil fuels requires about 250 kWh of storage per kW of output capacity. Solar storage requirements are even more demanding due to low winter solar output and high daily cycling.

At a high penetration the combined costs of wind and solar energy transmission and storage are prohibitive.

REQUIRED NUCLEAR REACTOR CAPACITY

World wide the rate of fossil carbon oxidation is about 1.9X the rate of total fossil fuel production reported by governments.

Displacing fossil fuels, coke, asphalt, resins and refinery loads in Ontario will require about 10X the present installed nuclear power capacity.

Allowing for 30% population growth over 40 years implies 240 CANDU 6E capacity equivalent reactors by year 2057.

Provision should also be made for export electricity capacity for water desalination.

Some nuclear capacity reduction is possible if nuclear reactors can be located within urban centers to provide district heating/cooling.

NUCLEAR COST

Nuclear power is the only economic source of large scale new non-fossil energy in Ontario. Nuclear reactors are economic when the average load factor is high.

Presently Nuclear power costs ~ $60 / kW-month or $0.082 / kWh

New nuclear costs 2X to 3X as much depending on prevailing interest rate.

Some potential hydroelectric capacity in Northern Ontario might displace a few reactors at a comparable cost

CANDU REACTORS

CANDU reactors are very wasteful in terms of usage of natural uranium.

CANDU reactors produce large amounts of long lived nuclear waste with a disposal cost that rivals the original cost of the reactors.

CANDU reactors are not sustainable due to high uranium consumption and high spent fuel waste production per kWh of output.

We have the capacity to build more CANDU reactors with minimum notice.

We do not rely on other nations for supply of CANDU reactor fuel.

FAST NEUTRON REACTORS

The only economic and sustainable non-fossil energy source is liquid sodium cooled Fast Neutron Reactors (FNRs) fueled by U-238.

As compared to a CANDU on a per kWh basis a FNR requires 100 fold less uranium and produces 1000 fold less nuclear waste requiring long term isolated storage.

FNRs can dispose of the existing highly toxic CANDU spent fuel inventory.

FNRs lend themselves to automated production.

FNR physics was developed in Canada before 1966.

Canadians working in Idaho during the period 1966 to 1994 had a central role in development of the successful EBR-2 FNR

LOAD FACTOR

The costs of generation and transmission in a non-fossil electricity system depend on kW, not kWh.

LOAD FACTOR = LF = (average kW) / (peak kW)

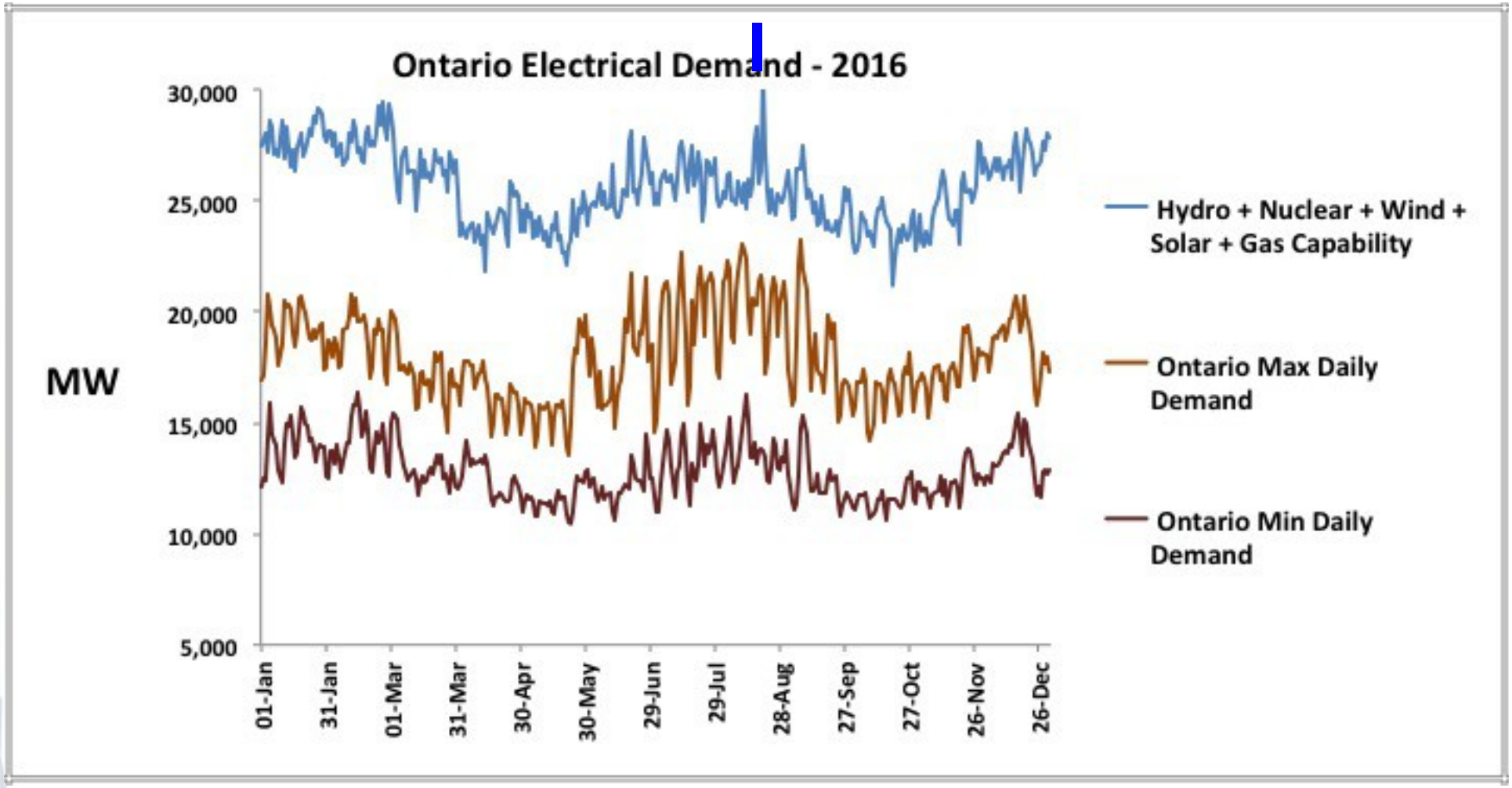
COST / kWh = (Cost / peak kW-month) (peak kW-month / kWh)

= (Cost / peak kW-month) (peak kW -month / average kW - month)

= (Cost / peak kW-month) (1 / LF)

Thus the blended cost of electricity to an end user is inversely proportional to that user's load factor.

Load factor improvement through proper use of behind the meter energy storage potentially reduces blended electricity costs by about 30% and is key to making nuclear power affordable.


Ontario Electrical Demand - 2016
MW
30,000
25,000
20,000
15,000
10,000
5,000
01-Jan
31-Jan
01-Mar
31-Mar
30-Apr
30-May
29-Jun
29-Jul
28-Aug
27-Sep
27-Oct
26-Nov
26-Dec
Hydro + Nuclear + Wind + Solar + Gas Capability
Ontario Max Daily Demand
Ontario Min Daily Demand

INTERRUPTIBLE ELECTRICITY

For reliability total available generation must be at least 15% greater than projected grid peak demand. Hence, even with high load factor firm customers there is always surplus generation capacity that can be sold at a discount as interruptible electricity. The non-fossil portion of interruptible electricity can be used for displacement of fossil fuels.

The fossil fueled portion of interruptible electricity can potentially be used by consumers that contract to reduce electricity usage during peak demand periods in exchange for a blended price discount.

All that is necessary to implement an interruptible electricity rate is an appropriate electricity meter and an radio or internet connection with the IESO.

Effective use of interruptible non-fossil electricity for fossil fuel displacement is a major opportunity that should be pursued forthwith.

BEHIND THE METER GENERATION

Today Ontario electricity rates are so high that some parties are burning natural gas to generate their own electricity and heat. The government of Ontario calls it “energy savings” because consumer owned generation reduces the average electricity grid load. I call it undue fossil fuel lobby influence because co-generation involves unnecessary long term commitments to fossil fuel usage.

Natural gas fueled consumer owned generation is a contributing factor to apparent low electricity grid load growth and increasing provincial fossil fuel consumption.

When the electricity rates are made more peak demand weighted this behind the meter generation will gradually become additional grid load, which will lower provincial CO2 emissions.

NEW ELECTRICITY RATE

The present energy (kWh) based Ontario retail electricity rate leads to waste of both electricity system and fossil fuel resources.

In order to financially enable behind the meter energy storage, which makes nuclear power economical, the retail electricity rate must be primarily peak kW demand based rather than energy (kWh) based. The peak demand charge must be sufficient to recover the energy system fixed costs. In order to allow displacement of natural gas the marginal electricity cost must be about $0.02 / kWh.

A suitable retail electricity rate is: ($70.00 / kW – month) + ($0.02 / kWh)

There can be no improvement in the load factor until this new rate structure is adopted which requires an act of the legislature to allocate the global adjustment to peak kW instead of kWh.

UNDUE FOSSIL FUEL LOBBY

Since the 1970s the fossil fuel lobby has exercised control over electricity generation in Ontario by influencing Ontario government policy.
A fossil fuel oriented electricity rate structure in a non-fossil electricity system causes unnecessary use of fossil fuels at times when there is plenty of zero marginal cost non-fossil electricity available.

The Pickering Nuclear Generating Station will close before any replacement can be built. Wind and solar generation can at most replace (1 / 3) of the Pickering reactor capacity.

The other (2 / 3) of Pickering capacity will have to be entirely replaced by natural gas fueled electricity generation running around the clock until replacement reactor capacity is built.
Every passing day adds to this required natural gas consumption and cost.

Why is it that for years surplus non-fossil electricity in Ontario has been exported at $0.01 / kWhe while rural consumers in Ontario were simultaneously paying $0.08 / kWht to $0.12 / kWht for oil and propane?

These are all ongoing SCAMs on the Ontario ratepayers!

ROLE OF THIS AUDIENCE

The governments of Ontario and Canada have been heavily influenced by fossil fuel interests since the 1960s and continue to be influenced to this day. Government claims about reducing CO2 emissions are pure nonsense when massive increases in fossil fuel exports are approved.

It is no accident that the fossil fuel industry has supported wind and solar generation. These intermittent generation types lock in about 6 kWht of fossil fuel consumption for every non-fossil kWhe generated. This deception will not materially reduce the atmospheric CO2 concentration.

Unless everyone in this audience does all necessary to change the present direction of both the Canadian and Ontario governments mankind is doomed.

On the bright side, if the governmental problems can be promptly solved then there will be major employment opportunity relating to application of Fast Neutron Reactors (FNRs) and supporting technology both in Canada and around the world.

STEADY STATE RADIATIVE ENERGY BALANCE

Earth's steady state radiative energy balance equation is:

$$I (1 - Fr) = 4 Ft Cb T^4$$

where:

I = solar irradiance ~ 1367 W / m^2

Fr = Earth's planetary Bond albedo

Ft = Earth's emissivity

Cb = (2 Pi^5 K^4) / (15 h^3 C^2) = 5.6697 X 10^-8 W m^-2 K^-4
= Stefan-Boltzmann constant

Pi = 3.14159

K = Boltzmann constant

h = Planck constant

C = speed of light

T = absolute emission temperature (degrees K)

Fr ~ 0.30 for T < 273.15 deg K, Fr ~ 0.10 for T > 273.15 deg K

Ft rapidly decreases as water transitions from liquid to gas

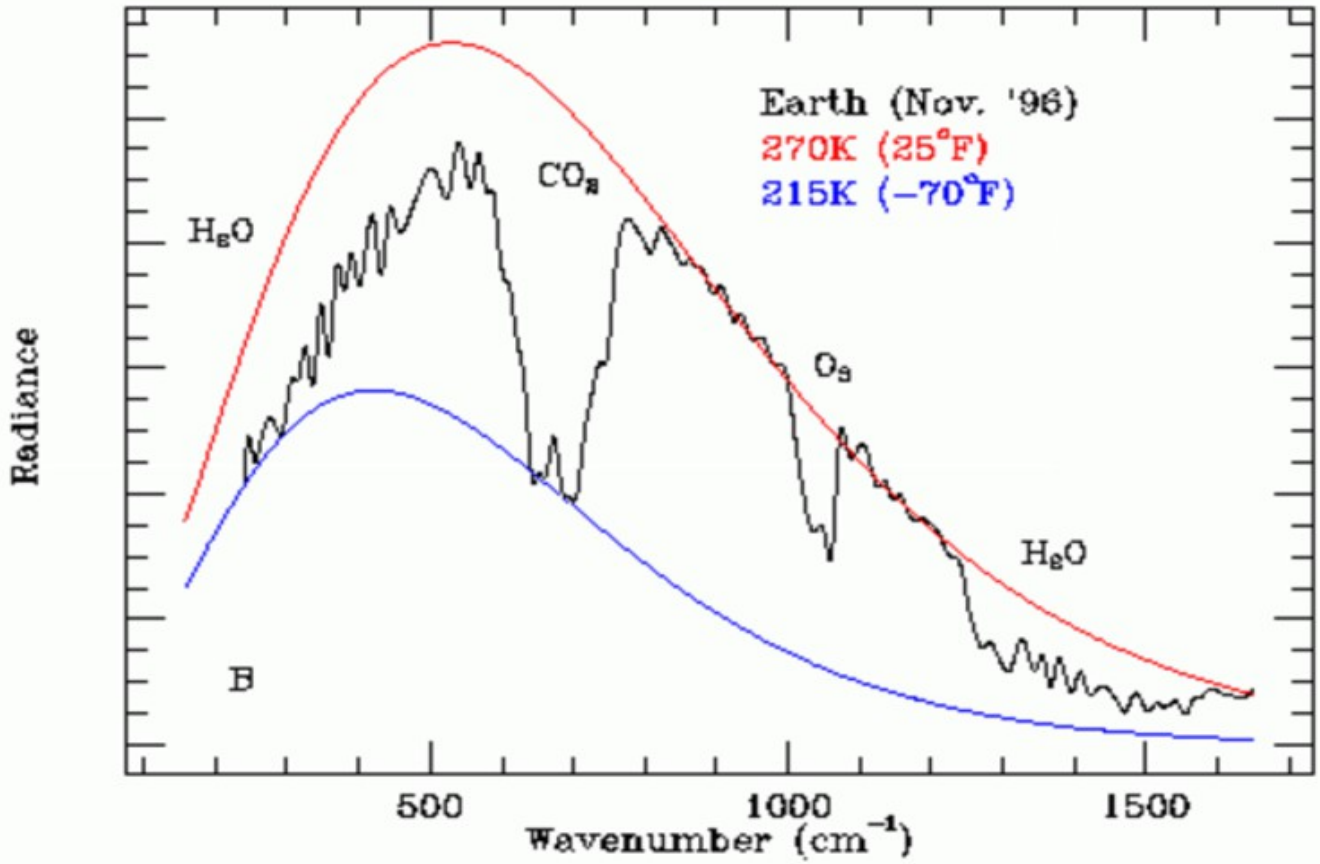
THERE ARE TWO REAL STABLE SOLUTIONS FOR T !

1972 Apollo 17 photo
Planetary Bond albedo = 0.30
Ocean: Fr = 0.035 Tropics: Fr = 0.10 Poles: Fr = 0.50

THERMAL RUNAWAY

A change in Earth's planetary Bond albedo (solar reflectivity) Fr due to melting of ice from the year 2000 value of Fr = 0.30 to a future Fr = 0.10 corresponding to no ice causes a 17.5 degree C increase in steady state emission temperature T without considering other emission temperature increasing factors such as the decrease in emissivity due to increasing CO2 and H2O concentrations in the upper atmosphere.

The “planetary emission temperature” T of Earth is the temperature measured using a thermal infrared spectrometer mounted in a spacecraft that is far from Earth.



In November 1996 the Mars Global Surveyor spacecraft measured Earth's planetary emission temperature as 270 degrees K.
Note the frequency bands of reduced emission due to CO2 and H2O in the upper atmosphere. Doubling the atmospheric CO2 concentration raises T over dry land by 3 degrees K. Increasing the atmospheric CO2 concentration causes net heat absorption by the oceans for many years.

If due to increasing CO2 concentration and and ice melting T increases by 3 degrees from its 1996 value of 270 degrees K then thermal runaway melting of ice will cause T to increase by a further ~ 14.5 degrees.

Earth's steady state radiative energy balance equation is:

$$I (1 - Fr) = 4 Ft Cb T^4$$

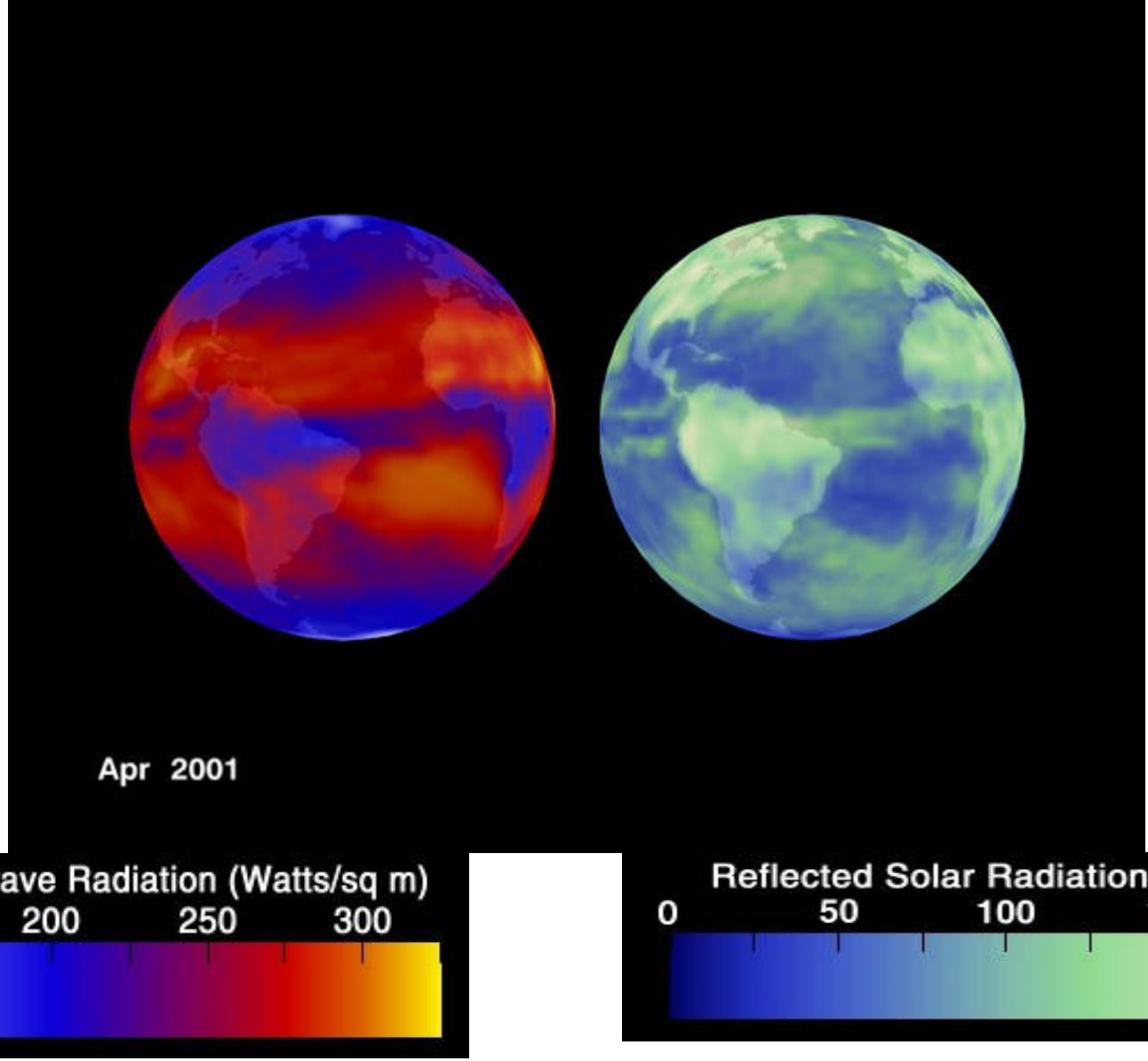
Due to the temperature dependence of Fr and Ft there are two real stable solutions for T.

In 1996 T lay in the range: 270 deg K < T < 270.8 deg K
This solution is stable only for T < 273.15 deg K.

For T > 273.15 K the stable solution is T ~ 288 deg K

Thus there are two stable solutions for T separated by about 18 deg K and today we are only 2 deg K away from the transition point between the low temperature stable solution and the high temperature stable solution. The ongoing decrease in Fr due to melting of polar ice and the ongoing decrease in Ft due to increasing atmospheric CO2 concentration are both driving T closer to 273.15 deg K.

At or near T = 273.15 degrees K spontaneous thermal runaway will occur.



Ceres satellite data showing 8 um to 12 um far IR emission by Earth on the left and 0.3 um to 7 um visible and near IR on the right.

Recall that thermal emission power per unit area P / A is given by:
$P / A = Ft\ Cb\ T^4$

The reduced IR emission from the polar regions is due to low temperature.

The reduced IR emission over the equator is due to the emitting water molecules being in their vapor phase instead of the liquid or solid phases prevailing at higher latitudes.

Thus the T = 270 degrees K is actually an average of higher and lower T values around 270 degrees K. Over the equator thermal runaway conditions are starting to occur but have not yet spread to higher latitudes. As the width of the equatorial band expands the rate of net heat absorption by the oceans increases.

Infrared data gathered by the Ceres satellites confirms that in 2001 Earth was already close to thermal runaway. Whether or not nuclear power capacity will actually be built fast enough to prevent eventual thermal runaway remains to be determined.

THERMAL RUNAWAY SUMMARY

Earth's steady state radiant energy balance equation has two real solutions.
In the “cool” state T < 273.15 degrees K
In the “warm state” T > 273.15 degrees K

In the “cool” state a sustained above equilibrium atmospheric CO2 concentration raises the emission temperature over dry land and causes net heat absorption by the oceans. The absorbed heat circulates and melts near polar ice which decreases the planetary Bond albedo (solar reflectivity).

The decrease in planetary Bond albedo causes yet more net solar energy absorption which further raises the emission temperature. For T > 273.15 K this process, known as thermal runaway, will run spontaneously until all the ice melts causing an ~ 20 degree C increase in planetary emission temperature.

Based on the recent rate of polar ice melting and rising temperatures in circumpolar communities the time to onset of spontaneous thermal runaway is likely at most a few decades.

PETM:

The geologic and fossil records show that 56 million years ago, during a period known as the PETM (Paleocene Eocene Thermal Maximum) there was a large injection of organic CO2 ito the atmosphere and Earth switched from its "cool" state to its "warm" state.

Earth remained in its "warm" state for about 200,000 years during which time large land animals ceased to exist. Due to the high ambient temperatures only small land animals could survive because their surface area to volume ratio was sufficient to allow heat dissipation.

That is mankind's own future if we do not immediately address the atmospheric CO2 problem.

SOLVING THE THERMAL RUNAWAY PROBLEM

Prevention of thermal runaway requires about a 10 fold increase in nuclear power capacity in Ontario, major changes in electricity rate structure and a fossil carbon tax sufficient to keep all forms of fossil carbon in the ground.

There can be no negotiation or compromise with respect to these three issues. In other industrialized countries the required nuclear capacity per person and the required electricity rate structure will be comparable.

Either everybody accepts these issues and works together to prevent thermal runaway or everybody dies.

I will not live to see these issues resolved. I can only point the way. I wish the young people in the audience every success in this endeavor.

BELIEFS

In order to solve the thermal runaway problem two beliefs must over ride all other religious and value concepts:

1) Belief in the basic laws of physics, particularly those relating to emission, absorption and conservation of radiant energy;

2) Belief in the merit of doing all necessary to provide for the welfare of succeeding human generations to ensure survival of the human species.