Good morning

Thank you for inviting me to this Seminar. I’m delighted to be part of a discussion which is extremely important to the future of Canada and indeed the future of planet Earth.

Before I go any further, I would like to make it clear that this presentation does not reflect official policy of the Liberal Party of Canada. Rather, it reflects my current thinking on the subject and is intended to stimulate discussion.

I consider myself to be an environmentalist but that was not always the case. Before my first spaceflight, I was not particularly well informed about the environment, but that changed when I headed for space aboard the Space Shuttle Challenger on mission STS-41G in 1984. Let me quickly tell you a little bit about that experience.

Having seen what I have seen, it is perfectly natural to become concerned about what we as humans are doing to our planet, however well intended those actions may be and I’ve only shown you a few examples.

Wanting to do something to address the problem is highly desirable but it must also be considered in a larger context. That larger context includes our need for energy. The world runs on energy. It is a surprisingly inelastic commodity.

The world’s population has almost tripled in my lifetime and will increase to a peak of about 9 billion by mid-century.

The central question is whether we can reconcile our need for energy with our desire to do something about the changes underway in our environment. We must ask some tough questions and if we don’t find any easy solutions, we must entertain more difficult ones. Otherwise, we won’t solve our problem and we will have to adapt to whatever happens.

Up until now, I believe that there has been insufficient critical examination of the realities with which we must deal. We want to clean up the environment but we have not necessarily worked out the mathematics to get there. We have assumed that conservation, greater energy efficiency, renewable forms of energy and the potential for technical solutions such as CO2 capture and sequestration will be enough to get our emissions down to an acceptable level without compromising our need for energy. At the opposite end of the spectrum are those who believe that we don't need to do anything and that it won't be that big a deal to adapt to whatever environmental changes are coming.

I view the challenge ahead of us as a global one. While different solutions may work for different countries, I am more concerned about a solution for the entire planet. The discussion for me is therefore not restricted to what Canada must do, but to what the World must do.

Energy creates wealth. At the present time however, it also creates carbon emissions because most energy comes from fossil fuels. In other words, income level and carbon emissions are both correlated to available energy. Energy demand will continue to rise because the great majority of humans are focused on raising their income levels. Bear in mind that the majority of the world does not enjoy anything close to our standard of living.

Let's look at the projected demand for all forms of energy in this century. The International Energy Agency predicts that under "business as usual" conditions, global energy demand will rise by more than 50% from 2005 to 2030. By the end of the century, it will increase by over 300% from the 2000 year level, mostly because of increasing demand from the developing world. And bear in mind that the global figure for the year 2100, assumes reasonable gains in energy efficiency.

According to Marc Jacquard in his book ***Sustainable Fossil Fuels***, fossil fuels accounted for 83% of energy production in 2000 and, based on current trends, will still account for 66% of all energy by the end of the century, much of it coming from coal by then.

And so let me frame the global challenge we face: **<u>we need to make more energy available while reducing the amount of greenhouse gases escaping into our atmosphere.</u>**

How can we get there?

One way to effectively make more energy available is to conserve and to be more energy efficient.

Energy conservation is a good thing and should be encouraged. It represents a conscious decision by individuals, organisations or even entire countries to reduce the amount of energy they consume. It also sends the right signals.

However, in order to conserve energy, you need to satisfy two conditions: to have a conservation mindset and to be currently using more than you really need. That's not the case for more than half the world. Certainly we Canadians can and should do much more to conserve but that's not an option for the people in many countries. The bottom line is that those who are in a position to conserve should conserve.

What about increased energy efficiency? The Intergovernmental Panel on Climate Change estimates that our energy efficiency, based on historical data, improves by roughly 1% per year. As I've mentioned before, current energy projections to the year 2100 make the same assumptions under a business as usual scenario, so unless we find much more efficient ways of producing energy or establish clear policies and standards focused on increasing efficiency, the bulk of the challenge will still be there.

The potential for greater energy efficiency is present in a number of areas: for example, in our building codes, in more efficient appliances, in greater use of cogeneration and in more fuel-efficient cars. Policies that are based on incentives and penalties can set the stage. Standards can establish the targets to be achieved. Again, I want to emphasize that like conservation, increased energy efficiency is something we should strive for but that it will only be part of the solution.

This brings us to renewable energy such as hydro, wind, solar, geothermal and biomass energy.

Hydro is an ideal renewable energy and a very efficient one. However, since the most obvious locations are already being exploited, there is limited potential for growth and hydro power will probably not account for more than about 5% of total global energy by 2100. Certainly, fortunate countries such as Canada can exploit hydro power to a greater extent, providing of course that First Nation concerns are addressed, but on a global basis, the growth potential for hydro is limited. Hydro projects also have environmental consequences such as flooding, rerouting of waterways and the destruction of ecosystems.

While geothermal energy has enormous potential given the fact that there is a great deal of heat below our feet, most of that heat will not be accessible in the near future due to engineering and environmental challenges involved in going deep below the surface of the Earth to extract it. Currently, geothermal energy is constrained to certain locations where that heat can be easily accessed. For example, it can play an important role in the energy mix of a country such as Iceland.

After hydro power, biomass is currently the second largest renewable energy and is primarily generated from waste from the lumber, pulp and paper and agricultural industries. Its growth potential is limited in my opinion since growing additional biomass to convert it to energy is both land intensive and energy inefficient and can have an inflationary effect on the cost of food. Not only that, where useful biomass growth does not take place naturally, it requires water and sometimes pesticides and fertilizers. It also raises concerns about endangering natural habitats.

Wind energy is certainly discussed a great deal and wind farms are sprouting everywhere. While wind energy can be connected usefully into an existing power grid to supplement it or be used in individual stand-alone operations that are equipped with an energy storage capability, its potential as a straight replacement for other forms of energy should not be overstated. As we all know, the wind does not blow constantly at the same speed. It is therefore not a reliable source of energy. Nevertheless, it is being developed quite aggressively including offshore. Its projected use could potentially reach about 8% of total energy supply by 2100.

Solar power, like wind power is suitable for small standalone applications where cost is not a factor. However, its large scale use is not practical unless there is a radical improvement in the efficiency of photovoltaic cells. Like wind power, it cannot always depend on the availability of its energy source. Consequently, its contribution to the overall supply of energy will remain small. And I have to add that the concept of large solar farms in space radiating their power to the ground as microwave energy, while interesting to imagine, is prohibitively expensive.

If we add up all of the renewable sources of energy that I've just discussed and include a few others such as tidal power, renewable energy might provide 25-30% of world energy by the end of the century. We should aggressively pursue renewable energy given current projections that two thirds of the world's energy will still come from fossil fuels.

What should be our goal in replacing fossil fuel energy with other forms of energy? The Kyoto targets applied to 1990. For the sake of simplicity, let's say that we don't want to go above the global emissions levels for the year 2000. According to Mark Jacquard, 83% of energy in 2000 was from fossil fuels or roughly 360 exajoules.

Given that energy consumption is projected to more than triple and that 66% of it will still come from fossil fuels, that would mean 920 exajoules of energy from fossil fuels in 2100. The difference is a staggering 560 exajoules which is more than the total energy we currently produce globally on an annual basis.

If we stick to that kind of a target for reducing greenhouse gases, and assume that renewable energy will account for about 25-30% of our energy, then unless we can capture and sequester massive amounts of CO2, we owe it to ourselves to critically re-assess the role of nuclear energy in helping us meet our challenge.

Before examining Carbon Capture and Sequestration, let's discuss the biggest challenge in reducing the use of fossil fuels: transportation.

Currently, transportation accounts for 20-25% of world energy consumption. The bulk of road, air and maritime traffic will require fossil fuels for some time to come.

On a positive note, there is great potential to power public transport in our cities using electricity if we are prepared to take three important steps: design or redesign our cities for public transport, make serious personal changes in our lifestyles and increase our electricity supply. That would certainly make the urban environment a much healthier one and I certainly hope we move in that direction over time.

Much has been said about the potential of electric vehicles. Certainly, electric vehicles are going to become more common, or perhaps a gasoline/electric hybrid but for major progress to occur will require dramatic developments in battery technology. Let’s hope that happens.

As for cars powered by hydrogen fuel cells, the challenge is more than building a reliable and rugged fuel cell and a safe storage system for the hydrogen itself. It is also the fact that most hydrogen has to be produced from other materials, primarily natural gas, which is a fossil fuel. Such a process not only requires energy but produces CO2 in the process. Alternatively, large scale production of hydrogen from water electrolysis requires considerable amounts of energy. In other words, because hydrogen does not exist in pure form, we need to use energy to produce that hydrogen in the first place. Like corn being used to produce ethanol, energy is needed to produce that clean fuel and incidentally, quite a bit of greenhouse gas. One has to weigh all of this carefully in deciding on the most intelligent approach.

And so, because oil supply will peak at some point, one might even want to make the case that we should begin to reserve our oil for certain transport applications and for the production of important products from the petrochemical industry and not use it where other forms of energy could be substituted.

If we continue to rely heavily on fossil fuels in this century, then we have to deal with the resulting greenhouse gases. Are we able to decarbonise or capture and sequester all those gases?

Decarbonisation involves removing some of the carbon before the fuel is used so that less is emitted when it is burned. An example is “clean coal”. There are processes to do this but they require energy and so there is a price to pay in terms of efficiency.

Capture and sequestration is another option for limiting greenhouse gases. Sequestration reservoirs include the oceans, trees, soils, depleted natural gas or oil fields, deep saline aquifers, coal seams and solid mineral carbonates. The challenge is to sequester the gases permanently so that they do not eventually re-emerge into the atmosphere.

Some sequestration takes place naturally, for example in our forests and oceans although not necessarily permanently. Sequestration in the ocean is also of concern because it acidifies the water, which affects certain species.

We know how to inject CO_2 into oil and gas fields for enhanced recovery of remaining fossil fuels although we still end up with that CO_2 back on the surface when the recovery is complete. We are also investigating coal bed methane production by preferential absorption of CO_2 but it's too early to tell whether this will become viable on a large scale.

We do have some experience capturing and compressing CO_2 exiting in power plant flue gases and then injecting it underground as a supercritical fluid, so some of the technology is known and some countries including Canada have pilot projects in place. A few countries including, Norway and Algeria, have actually built the necessary infrastructure to sequester CO_2 and are doing so at this time in modest amounts.

This type of sequestration obviously requires suitable underground storage sites. For example, the Alberta Energy council estimates that the Alberta basin offers the potential to store about 18 billion tons of CO_2 in deep saline aquifers, coal seams and depleted oil and gas reservoirs.

Although not all environmentalists support the concept of sequestration, I would like to strike an optimistic note about its potential. At the same time however, this optimistic note must be tempered by the fact that sequestration presents significant technical challenges and will not be inexpensive.

The National Roundtable on the Environment and the Economy recently predicted that we might be facing GHG prices of $190 to $240 per ton of CO_2 equivalent in 2003 dollars to achieve a reduction of 45% in Canadian GHG emissions predicted under a "business as usual" scenario by 2050 using Canadian actions only, i.e. without international emissions trading.

In addition, it is very unlikely that all the CO_2 from all the fixed installations in the world can be captured. Again, citing the National Roundtable report, their model assumes that by 2050, carbon capture and sequestration could handle roughly 45 % of the GHGs that would otherwise be produced in a "business as usual" scenario.

And so this brings us to nuclear energy and its potential in helping us meet our global challenge. That global challenge bears repeating: sufficient energy in a clean environment.

I do not think of nuclear fission as a permanent long term solution to our energy needs any more than I think of fossil fuels as a permanent solution to our energy needs. However, in the short term, we will have to make some decisions until we find that magic bullet.

As I have tried to explain, conservation, increased energy efficiency, renewable energy and massive carbon sequestration efforts will all help but will not, by themselves satisfy all of our energy requirements. The math does not add up.

Nuclear energy is one of the important energy options on the table because it emits virtually no greenhouse gases other than those resulting from mining the ore. If public concerns are addressed, it can make an important contribution in helping Canada and the world achieve environmental objectives over the coming decades.

First, let me mention nuclear fusion, one of the most promising long term solutions to our energy needs. Nuclear fusion has been a dream for decades and will remain so until at least the middle of the century. We must however continue to pursue that dream with programs such as the International Thermonuclear Experimental Reactor or ITER even though an operational commercial fusion reactor is still a long way off. In the meantime however, given the urgency of the situation, we also need to look at fission-based reactors.

Nuclear fission is something we all know. We have such reactors in this country and in others and nuclear reactors are powering ships and submarines on the high seas. Nuclear power is even used on planetary space probes. Currently, nuclear energy represents roughly 5% of the total energy used globally.

What are the concerns about nuclear energy?

1. The first is safe operation of the reactors themselves.
2. The second is the security of the waste products.

3. The third is the security of nuclear installations from military or terrorist attack.
4. The fourth is concern about the propagation of the technology to unstable countries.
5. The fifth is the safe long-term storage of the waste
6. The sixth is cost; and
7. The seventh is the continuing supply of the nuclear fuel itself, currently uranium.

With roughly 440 reactors currently operating in 30 countries throughout the world, I believe we can operate nuclear reactors safely with sufficient safeguards in place

With respect to a 9/11 type of terrorist attack, I believe we have the technical means to protect reactor facilities from such threats. Similarly, we can ensure the security from theft of the stored waste products.

With respect to safe long term storage of waste, we cannot state at this time that we can safely store the waste for 24,000 years (half life of plutonium 239). What we can state however, is that we can safely store it for the next 100 years and that in that time, we will find longer term solutions, including reprocessing a large part of that waste.

As for cost, indicators are clearly pointing in the direction of more expensive energy. The U.S. Energy Information Administration estimates that world oil production will peak by 2026 with a 5% probability, by 2037 with a 50% probability and by 2047 with a 95% probability. Whichever date is correct or even if it's a bit later, oil then becomes a dwindling commodity. As we approach this date, oil is certain to become even more expensive than it currently is. Notwithstanding an abundance of cheap coal, it too will cost a lot more if we commit ourselves to a cleaner environment. And so the nuclear option is becoming more attractive on a cost basis.

Having said that, there has been justified criticism about cost in Canada, due to sizeable cost overruns in the building and commissioning of certain nuclear facilities. As Generation 3 reactors begin to appear on the scene, with their promise of greater capacity, efficiency and security, many will be watching carefully to see whether cost overruns occur. Nothing creates more cynicism than a project that does not live up to its advertised cost.

As for the increased risk of propagation of the technology to unstable countries, we need to achieve a greater degree of international cooperation and oversight with respect to the secure use of nuclear power by a combination of measures such as:

- **Increased inspection authority for the United Nations International Atomic Energy Agency**
- **Strong treaty commitments by all countries for the secure operation of nuclear facilities,**
- **Safeguards and protocols, including the potential use of international teams in the operation of nuclear facilities.**

The last concern about nuclear power deals with the supply of the nuclear fuel itself. If that fuel is uranium and the entire current world energy needs were met by nuclear fission using current thermal reactors, we would run out of uranium in a matter of decades.

For that reason, and because the cost of uranium will continue to grow as it becomes scarcer and in greater demand, it would seem wise to accelerate the development of Generation 4 advanced fast breeder reactors. Because they are 50 to 100 times more efficient at burning nuclear fuel than conventional thermal reactors, they would eliminate concerns about the long term availability of the fuel. A major additional advantage is that we would be left with a less radioactive waste product with a much shorter half life and that we could also use some of the spent waste currently in storage as a fuel for this type of reactor.

Although two experimental fast breeder reactors are currently in use in France and Russia, and two more are under construction in Russia and India, we are still some way from building commercial fast breeder reactors. However, certain countries are now investing more in research into this type of reactor including China and Japan and, as I've mentioned, Russia, India and France. As we know, France is a major user of nuclear energy and has ambitious plans for an advanced fast breeder reactor prototype by about 2020 and a commercial reactor by 2040.

If I could summarize my presentation, I would say that our global challenge is to limit how much greenhouse gas we are putting into the atmosphere while at the same time satisfying our growing energy demands. The math suggests that in order to do this we need to make greater use of nuclear energy. Although no solution is perfect, given the need to make some pragmatic decisions, I think we need to bring nuclear energy back into the mix of available options and then move ahead.

As I end this presentation, I want to acknowledge the debt I owe to Douglas Lightfoot in the preparation of this speech. Douglas is with the Global Environmental and Climate Change Centre at McGill University. Douglas in fact would go as far as to say that it is energy that is the biggest challenge for the planet in this century. In his thinking, nuclear energy will allow us to meet our energy needs while also addressing both the environmental challenge and that other major global challenge, the shortage of fresh water, in this case through large scale desalination plants.

I mentioned at the beginning of my presentation that my perspective was a global one and not just a Canadian one. There may be a tendency if you are a Canadian to think that the situation isn't quite as urgent as I have portrayed it today. That probably comes from the fact that we are the most fortunate nation on this planet. Being the second largest country on Earth, with vast resources and a very small population, our future seems assured.

Complacency on our part would certainly be unfortunate. The planet is changing. We must do something about it. We face some tough decisions but there are solutions if we are prepared to invest in them. The problems we have unwittingly created can be corrected if collectively, we make the right decisions.

Thank you.