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Going the Distance
Nuclear Energy in the New Age

2007 World Energy: The Past and Possible Futures

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Good morning ladies and gentlemen, it is a pleasure to be here today. My presentation is not exactly on nuclear power and Dr. Garneau of course, said just about everything I had to say, so maybe repetition will serve to imply emphasis. You will see that much of what he had said really would more or less collaborate about what I am going to show here, to put some more numbers on things.

What I am going to present today, is work that was completed last December at CERI (Canadian Energy Research Institute) and it is really the title of my speech here, "World Energy: The Past and Possible Futures"

In March of 2005, we produced that same outlook. This is the second edition of this work that I will be presenting here today - A broad glimpse of that work, and obviously between 2005 and today, the world has changed quite a bit in energy. The speed of change has really been hard to track. Just one example - in March of 2005 when we finished that first outlook, oil prices were trading at $54.00 a barrel. Of course seeing what happened since then, in 2007 it averaged over $70.00 and not long ago, just crossed the hundred dollar barrier. Quite a bit of changes have happened in the last couple of years.

Fossil fuel based electricity generation is becoming increasingly more costly and the concerns over global warming and CO2 emissions, as we have just heard from our previous speaker, are gaining further momentum in the world appearing today. These have lead to a resurgence of interest and there will likely be more economical and cleaner electricity generation sources such as wind and nuclear power. You've heard many talk about the resources here - it is very much the beginning of that renaissance. What we're seeing here is that there are a lot of challenges that lie ahead; we'll see some of those that are required to be addresses for that resurgence to continue. What we have done is surveyed the work of many commentators on energy and environment and provided a summary of the relevant past and a way to look at the future. We have drawn liberally from previous works within CERI, adapted presentations of others, we have not attempted to provide a purely original interpretation of what is happening around us but rather synthesis and present a collected view of what is out there. So with that I would like to just begin my presentation and time permitting, I will go ahead and summarize what we have found and learned from all of this.

First who we are: Canadian Energy Research Institute. We are a not-for-profit research organization, established. We do economics, environment and energy research in Iran for about one third of a Century now. We are established and currently supported by industry, academia and government at the Provincial and National level. We conduct short courses and training on energy, two day courses for those who do not want to take a whole semester, term papers, exams and so on. We offer a much quicker way of educating about energy. We conduct four annual conferences a year; this week was our Natural Gas conference. In April we have our oil conference and June we have Petrol chemicals and in fall we have Electricity. You are all invited to come to all theses conferences; you'll find them very interesting. We put out monthly publications on oil and gas and due politics of energy available to all members and we conduct public education. So what I am going to do today is a quick introduction and background to the whole energy scene worldwide. What i'm trying to present to you here is quite an undertaking, so I will not do it justice no matter what I do, but I will give it my best. We will talk about

energy consumption first, the consumption side of the energy sector, then the supply side of the energy sector. We will then move on to the subject of the day and the decade and from here on, I believe, which is the energy and the environment. We will then talk about some alternative energy futures that have been laid out by others and by CERI. We will look at North America and its energy outlook and then time permitting, do some summary and conclusion.

This is a simple representation of the economy, technology, energy, labor and the interactions that take place among these different parts of the economy and its components. Now, until recently, that interaction was not constrained very much by the ability of the environment to support it. In other words environmental concerns were not very serious until very recently. In this picture here, we represent this constraint by there's a limited capacity for the environment to absorb waste that comes out of economic activity and energy. That ability of the environment to absorb waste from economic and energy activities is beginning to change the way we look at energy, the way we produce it, the way we use it, the way we conduct our lives as we see here. So over time and this will continue to be the case, energy consumption is driven by three broad factors. Of course, among these there are many other sub-factors and these factors themselves interact with one another. Growth of population, economic growth as Dr.Garneau mentioned wealth, is a driver for energy consumption and of course energy intensity, this is the measure of the overall efficiency in the economy. It is basically the amount of energy it takes to produce one unit of economic output - about a U.S dollars' worth of output. These three, the first two interact with energy consumption in a positive way. Meaning they are positively correlated with energy consumption. More growth in the economy and population draws more demand for energy. However, when energy intensity increases, it also increases the demand for energy. However, an improvement in energy intensity means that a decline in energy intensity will work to offset the effect of these first two factors. That has been the experience since the early 70's as we will see later. The general trend for energy intensity or efficiency has been a decline (that is an improvement in energy efficiency) driven by energy events and political factors that occurred in the early 70's.

So this is the first driver – population. Clearly, positively correlated with energy demands in million tons or equivalent over time, the rate of increase has been accelerating recently as you can see in the steepness of the curve going forward, mainly due to the recent growth in India and China and their demand for energy. This is a correlation between GDP (Gross Domestic Product) total and then it gains energy consumption, the trend is also positive.

This is the energy consumption correlated to per capita income. Now, the relationship here is not that smooth, you will see for example on the far left side the High Per Capita Income – you will see there is variation in these points of energy consumption. That reflects differences say between Canada and other countries. Canada happens to be the most energy intensive country in terms of per capita consumption. The other factors that enter into here are the size of the country, the climate, the population density and so on, that give variation in the amount of energy used, even though the per capita income may be similar.

Now with population growth comes urbanization. With urbanization, people moving from the countryside to cities, and particularly in developing countries, mean increased demand for energy. As they move to the cities they would be acquiring more appliances, transportation, autos and so on. China is the one that comes to mind here. What's happened in china? In 1975, the urbanization rate in china was 17.4%. That is the proportion of their population living in cities. Now today, China has 160 cities with one million or more population. In 2005, the urbanization rate in China increased to 40.5%. That's more than two and a half times. Today,

700-800 million Chinese live in the countryside. About half of those are expected to move to the cities within the next two decades. In all that read for more demand for energy as urbanization increases with the growth in the economy and wealth.

The third driver- energy intensity. See here the overall trend, at least in OECD counties (Organization of Economic Corporation Development) this is the rich country club. Although this graph does not go far enough, you can see the blue line the trend which started in 1973 with the oil embargo that occurred in that year by the Arab organization. Petroleum exporting countries drove people to look for alternatives to oil and fossil fuels and increase efficiency in consumption. The rate of improvement in energy intensity overall has been about 2% per year decline meaning improvement.

For the energy consumption side of the picture, this shows world electricity consumption rising over time. You can see again accelerating recently, reflecting the tremendous growth in the Asian economies, particularly India and China. The consumption over time of primary energy sources (these are oil, gas, coal, nuclear and hydro.) has grown mostly from nuclear and gas in recent years where nuclear was from almost nothing in the 1950's to about six and a half percent of total primary energy consumption in the world today. Gas is also rising in importance. Both of these are driven by environmental concerns about emissions and gas and nuclear, both offer advantages in that regard.

Moving on to energy consumption in different regions of the world- this is by type of primary energy. You see here that there's a reason with diverse energy picture in most regions. Exceptions – the Middle East. Not a surprise, they are almost completely dependent on oil and gas; 98%. The total energy consumption comes from oil and gas. Guess why? Well, it's abundance. In the early 70's in graduate school, we were studying Theory of International Trade for the Hecture Olean (after the two authors) that really explained factor endowments. That is the amount of factors of production a country is endowed with, explained what that country did and what it is specialized in .This is a good example of it here in the Middle East, completely dependant on oil and gas. As far as the highest of all these things, you can see that for nuclear, it's Europe and Asia, and Eurasia have the highest fraction of nuclear in their mix. For coal, it is Asia Pacific.

This is Energy Consumption by Region. What is important here is again all regions, despite the energy efficiency improvements, there's a point here. There is more demand for energy as we go forward even though the amount of energy we need per unit to become active is declining. Total consumption is rising due to the rise in wealth and rise in population. The point here as you can see, is that Asia and Oceania (now exceeding North America in electricity consumption), overtook North America a few years ago in total consumption of electricity.
So in summary, these have been the drivers for energy consumption and will continue to be so in the future.

For the energy mix in the future within transportation, needs will continue to be met by oil. Low emission concerns would lead to more interest in natural gas, it has, and in nuclear it also has, and renewable power. Renewables as Dr.Garneau was telling us before, they do have (I will show later on each one of those and what the issues associated with each is. If they are not addresses their contribution would be very limited in the future) but their penetration into the system will always depend on societies' willingness to pay the premium. They tend to be more expensive than other energy sources.

On the Energy Supply picture of course we move from biomass in the form of wood in pre-industrial age, and then coal during the Industrial Revolution (the fuel of the Industrial Revolution) internal combustion engine assured them oil as king of energy sources today. In 2006 this number (Dr. Garneau would see that it's higher than what he has quoted) Fossil fuels altogether account for almost 90% of the world primary energy supply today. That is a very high dependence.

Here is how these different primary industry sources grew over time the last 20 years or so: 1986 to 2006 - The average growth rate in the energy supplies has been about 2%. Nuclear and gas are the only two that grew above average during that time, as was shown earlier. Pooling all the reserves by region; Middle East dominates by far where oil is today in the world and this is conventional oil.

Before where we ask where the oils sands are, here they are. The amount of Alberta oils sands' resources are - I think the term to describe the amount of resource is simply staggering. The amount of resources shown here puts Canada second only to Saudi Arabia in the amount of oil resources proven recoverable. The Oil and Gas Journal in 2002 recognized 178 billion barrels of oil sands as economically recoverable with todays cost and technology. We produce about five million, so there are 173 remaining. However, the Bitumen resource in place is close to ten times that much. That is with the advances in technology, the right prices, there's quite a bit of oil in the ground assuming the environmental issues of extracting it can be resolved.

OPEC - Player in oil the market obviously, does not have the share in the world oil market it used to, but it still supplies 40% of the world oil market today. The decline you see in the share war of OPEC and world oil began about 1973 again the oil embargo where oil sales were stopped in U.S and its allies for particular reasons. It was not the first time that oil became a true political commodity as we'd see later but it was one prominent time. The former Soviet Union also came on the market producing oil and therefore eating away at OPEC's share during that period. Their share now seems to be stabilizing at 40%.

This is the history of oil production by different regions. Basically you can see that OPEC is about 40% and the rest of the world produces mainly 60% of oil today. Natural gas reserves are more, the thing will oil is, it exists where the deposits are, are not contiguous where the consumption is. The major consuming centers of the world are in the Western Hemisphere, but oil deposits are, as we have seen, in the Middle East. That creates as you will see a little bit later true political problems and security problems. Natural gas is more evenly distributed around the world; the Middle East still has very large reserves of natural gas, in particular in Iran and Kutar.

The production of gas over time in the last 36 years is very stable in North America, rising in the Middle East rising in Africa and rising in Asia Pacific. That is what the growth in natural gas production has been recently, stable everywhere else.

Coal – proven reserves. Again, this is more distributed than oil and closer to consumption as you will see in the next slide. The Middle East hardly has any coal and so for security reasons, coal now is being looked at _____ to liquid, how do we address environmental issues, create the oxymoron called "clean coal". But until then, if we can address all these issues, the deposits are really huge.

This is Production and Consumption of Coal in Different Regions. You can see the almost self-sufficiency in most regions here. This has to do mostly again, with the coal deposits being near the points of use and also difficulty with transporting coal as compared to oil necessitate its use near where it is produced.

Nuclear Energy is the topic of the day – the other primary energy source. Very modest beginnings as we said in the early 60's, a surge in the 80's driven again by the events of the early 70's of concern about oil and its security and its cost.

1973 - For those of you who are not old enough as I am to remember, oil went from what has quadrupled overnight by the organizations' role of turning exporting countries. It was increased 400%. That was the first big shock in oil, but six years later the Iranian Revolution came along and oil shot up to $40.00 a day. By the way, todays hundred dollar barrel of oil still near, not exactly more, than that peek in real terms when you account for inflation.

So, we can see the volatility here of this fuel and the procurians who are depending on it. The alternative such as nuclear, are driven really by the weakness of dependence on fossil fuel for security, reliability, emissions, and so on. So that resurgence in the 80's was driven by that slow stabilization of growth here. If we were to look beyond that as we will see later, we will see that resurgence will occur again.

This is the Number of Nuclear Reactors by country. In 2007 the U.S has the most, France is second, but in terms of percentage of generation these countries have more than 30% of their power generation coming from nuclear. France is always number one, almost 80% of their power generation today is from nuclear power, followed by Lithuania and so on. Notice that all these countries are European that have more than 30% of their power from nuclear. Europe is not very endowed in oil and gas resources and so nuclear is an option they went for. These other countries have less than 30% of total generation, and the construction today - there are quite a few reactors there being built but I have some statistics here to put that into context. There are quite a few being built here, but if you look back and compare this to the 1980's when the U.S built 47 reactors, France built 42 reactors, and Japan built 18 reactors. So this looks impressive but it's still really not quite here yet. The activity that nuclear experienced in the 80's is shown up here on this graph. The U.S is not constructing any presently, but there are more than twenty new third generation plants being proposed there.

The other primary energy resource is hydro. Hydro is small and large; usually 30 megawatts or less is considered small hydro, more than 30 megawatts is considered large hydro. The growth in hydro here, again, it's North America - you can see it has been stable, not really growing very much. There a lot of issues facing large hydro construction in North America. It has been happening though in other parts of the world, so it's been contributing more to world energy demand and again driven for its emission benefits compared to fossil fuel and energy security benefits as well.

A little bit about oil and due politics: World War I - That was the beginning of establishing oil as a strategic commodity and the World War II emphasized that even more. Army's that didn't have an adequate supply of oil had little chance of prevailing. The first large petrol chemical plants were built during World War II to manufacture synthetic rubber.

Here are some major events in old geopolitics: In 1951, the Iranian Prime-Minister Mosaddeq nationalizes the oil industry in Iran. He didn't last long after that, he was over-thrown. In 1956 – The Suez Crisis: Israel, France and Britain invade Egypt that had just now nationalized the Suez canal, caused disruption in oil transport and supply. In 1967 comes the Six-Day-War. All of this is happening in the Middle East, where most of the oil is found and is produced. 1973 - The Yum Kippur War. Another oil embargo that we mentioned here in 1973, by the Arab organization controlling exporting countries.

1979 - The Iran Revolution; There was also the Gulf War of 1990, the U.S invasion of Iraq today. The present day issues in the Middle East is where most of (not all) due political hotspots and issues are in the world today. When will the Iraqi production be fully restored to its pre-war level? These are issues…unknowns. Will civil unrest and terrorism disrupt oil production? When will Iran's nuclear issue be addressed? It seem like it's close to being resolved. Of course the core issue in the Middle East is really the old standard conflict that when it's resolved, I believe many of these political issues will come in place. There are issues with Russian supply, stability, reliability and also the Caspian Sea has resources, but it would be difficult to bring them to market.

This is why you thought the world was connected by the internet. It is, but it is also connected by the oil flows. This is one major reason why oil is such a true political commodity. Again, the producing/consuming regions are very far apart, there are problems with securing transportation routes. China - Most of its oil is passes through a very narrow strait called the Malacca Strait and can very easily be blocked and the Chinese are very concerned about that. The Suez Canal, and there's another one -the Strait of Hormuz, in the Gulf. All flows around the world, but has very weak spots that can easily be disrupted.

The unconventional oil resources in North America, we mentioned the oil sands – 173 billion barrels, proven. Corbid methane - This is an unconventional natural gas. It has been rising in Alberta, conventional gas has actually leveled off and began to decline and unconventional gas has just barely offsetting the decline in conventional gas today. So, the conventional gas production in the future in North America, aside from Alaskan _____ has been experiencing quite a bit of delays and we don't know when they will come on line, the outlook is not very promising.

In North America renewable power again, potential is largely untapped. Hydro electric - still great potential in Canada and Mexico, less in the United States, but these developments also, questionable.

Energy supply to 2050, what do we see? Crude oil will dominate the transportation still. For the middle of the Century we see that oil will still dominate transportation. Clear natural gas will be in demand in other sectors such as power generation. LNG trade will grow in scale or what it is today. Hydro Nuclear will see a resurgence of interest; some believe that nuclear resurgence is already here. Other renewables will take hold, but gradually, and environmental concerns will affect the mix of energy issues for the next 50 years.

You may be familiar with the entity IPCC. This is the Inter-governmental Panel on Climate Change. They have re-issued the report a couple of months ago I believe. It is only 2,600 pages if you want to read it! The IPCC is really a very large body of scientists from every country including Canada and what they do is review all available literature, analyze it, and synthesize it. Based on that, produce some conclusions. So their detailed review and analysis in that 2,600 page report declares that the scientific uncertainties of Global Warming are essentially resolved. I've been working in this field for a long time, and my history in California was looking at climate change issues 26 years ago. It was really believed that there was a Commons Conspiracy and we were just "nuts" to be working on things like that. But laws were passed then that actually required us to look at climate change and how it might affect California.

Today from that point to until a year or two ago, there was still the debate whether it was really happening or not and scientific controversy was still raging. This IPCC report puts to bed that debate, at least in the scientific issue. It says that there is clear evidence for a rising global temperature of .6 (clear evidence). They chose their words very carefully as all of these

countries have to agree on what they say and that is the first time they have said this. Clear evidence of global temperature rise of .6 degrees centigrade and 20 cm rise in the sea level in the 21st century. They could rise the reports say, by anywhere from 1.4 to 5.8 degrees centigrade and the sea level could rise anywhere between 20 and 88 cm by the end of the 21st century. This support has resulted in this issue again being taken more seriously and people are moving from talk to action.

Energy and the environment - As we had said before, the production of energy and economic activity produces toxic substances, greenhouse gasses (we just talked about) and particulates – particulate matter – dust for example.

This is the measurement of CO2 concentrations in the world from 1860 to today. You can see the slow rise up to1960 and then the sudden acceleration from 1960 to today. Before 1960, those measurements were taken from ice scores. That is where they drill holes in the ice sheets and look at the air bubbles trapped in the ice over years and determine what the ambient temperature must have been at that time. To the right, this is actual measurements from on top of Mauna Loa which is a big island in Hawaii; it's about a 12,000 foot mountain. There, the location is away from all pollutions and terrible incidents in air and so on and gives one of the best measurements of CO2 concentrations. Anywhere above 350 concentration of CO2 is believed where we have a problem that needs to be address so we clearly are past that point now. Increase of global mean temperatures if we double CO2 emissions, it could result in a 2 ½ degree centigrade rise in temperature. That could precipitate changing circulation, precipitation, volatility – unpredictable weather events.

Here are some of the energy sources that could be used to address some of these environmental issues; large hydro and small hydro. It is to be distributed around the world. Small hydro is really where most of the development will be taking place and that happens to be China today, where most of it is. This is _____of the river is less environmentally detrimental than large hydro. Contrary to belief large hydro does not have zero emissions of green house gasses. The decaying organic matter in reservoirs emits Methane, which is a much more powerful warming agent than CO2.

This is Environment Canada's estimate of the emissions of CO2 avoided by nuclear in Canada today. Coal emissions, you can see there, the emissions in the brown bar and avoided emissions due to Canadian nuclear generation are shown in the yellow bars - quite significant.

This is one of the issues that was raised recently about nuclear- that Uranium prices have risen to historical record. I believe that 292 in May 2007, was a record price for Uranium. The prices have dropped since then, but the thing to keep in mind here is if you double the price of Uranium, you raise the cost of electricity from Nuclear by about 5%. Because the fuel part of the total cost is a small fraction.

Gas generation on the other hand… if you double the price of gas, then gas-fired electricity would rise by 60%. So the sensitivity to fuel price quite different between these two sources. Dr. Garneau had talked about some of these issues: perceived issues of safety, proliferation, environmental aspects (aside from emissions), cost overruns and negative public perceptions relating to all of those. Its potential to address the issues are; low greenhouse gas emissions, high reliability (you have heard the availability factor of 90% or more in most of these plants), low operating cost, and of course medical applications. (We will be hearing from another speaker about that later). We have heard about biomass. 10% of the world primary energy supply comes from biomass. Biomass is many different things; it is direct combustion of wood and municipal solid waste, it is landfill gas (Methane gathered from landfills), it is digester gas (gas

emitted by bacteria digesting the waste). All of these forms are available and are being used today but most of the developing world still uses biomass 22% their primary energy source in the form of direct wood combustion, which has its own environmental implications.

Wind Power: Again, this is where I am duplicating Dr. Garneau here, but wind has grown really fast. It is the fastest growing renewable and has been growing about 30 or 40% per year during that last ten or fifteen years. Germany is the world leader now in wind power both onshore and offshore -some 20,000 megawatts are installed today. Technology has improved quite a bit and is cost effective today. It has issues with intermittency – wind blows when it wants, not when you need power. If these two things do not coincide you run into problems of storing that power until you need it. That is costly and technology is not quite here yet to do that. Wind resources happen to be in remote areas away from load points so therefore transmission availability and cost is also an issue to bring wind into market. Its ability to address some of these environmental issues because of that is limited.

Solar power in the form of affordable Pyex: Germany, Japan and California are the world leaders now in this technology. Part of the program that I ran was actually giving people half of the system cost, if they would put it up - what a good deal! California now has three and a half billion dollars they just earmarked to accelerate bringing this technology to market. The thing about affordable Pyex and some other renewables is it has a conative scale. That is the rationale anyway behind the program is that if you produce a large enough quantity, then the cost will drop. In the 1950's affordable Pyex was $100.00 a watt. Today, it is down to about $6.00. So we know the cost curve is declining and the question is how far can it go? It remains to be seen with all of these programs. It converts sunlight directly to electricity. No heat, silent, no moving parts, but it does require sunlight and therefore at night time there is no energy from there. Storage again, becomes important, just like in wind.

Geothermal: This exists in many parts of the world, very distributed and it does provide base load that is can run around the clock. Reliable power proven and happens to be sometimes in remote areas as well. Hydrogen is one mans' personal opinion about it from Shell Oil. It is the lightest element that exists with atomic weight of 1. Here is the U.S Department of Energy time-line and their review of developmental hydrogen, so the hydrogen economy will be here in about twenty-five or so years, beginning and then going on from there. The issues with hydrogen storage, transportation, as Dr.Garneau said, producing it requires quite a bit of energy and it can be produced either by steam reforming natural gas, of course that is going back to natural fuels again, but it can also produce it through electrolysis and as we mentioned, it is very expensive and very inefficient. First you convert fuel to electricity, then it converts electricity to Hydrogen, then you convert hydrogen to energy again and at each stage you lose something.

Some alternative energy futures. Here is a mix of primary energy supplies from 1980 to 2030 and how each form is in the view of IEA (International Energy Agency) would evolve over time.

Population growth – Between here and 2050, the world population could rise to 8 - 9 billion people from todays, and we have seen that that growth in population is a major driver of energy demand. Any way you look at it, energy demand is not going down in the future despite improvements in efficiency.

World marketed energy consumption – this is to remove energy sources that the Third World uses that do not go through market, such as wood gathering and so on.

If we do nothing, the "Business as usual" scenario for energy is that hydro carbons will continue to dominate, energy efficiency improves in the developed world, developing world uses cheap available hydro carbon fuels, accepting the resulting emissions, and continues for thirty to

fifty years despite increasing environmental consideration. This is if the "Business as usual" today continues on.

The International Energy Agency presents three interesting scenarios here for the future: The scenarios are not forecasts, the scenarios are stories about possible future and someone said, "Never forecast, especially about the future". You do not want to do that, you do scenarios and they are useful because they show trade-offs among different alternative futures. The first one they call the "Clean but Not Sparkling". This is where the environment is emphasized and because resources are scarce and limited, then the investment in R & D and technology development is slowed. So the environment is clean in the short run, but then suffers in the long run because technology development and alternatives lag behind.

The second one is called "Dynamic, but Cureless". It pursues technology without regard to the environment. Growth is accelerated, but the environment is stressed so much that it may cause irreversible damage.

"Bright Skies" is kind of the ideal scenario here, in the _____ concern about the environment and technological advance on the vertical axis. So what they call the "Bright Skies" scenario is one that combines the best of both worlds. It is sensitive to the environment but also advances technology. This is how these three scenarios affect these criteria in emission growth, security, emission transportation, technological change and so on.

Here are some technology scenarios developed by IEA; they call them Act Map. This is the reference scenario that they map the other scenarios against, and of interest here is the "Tech Plus", showing what each scenario entails for Renewables, Nuclear, Carbon Caption Sequestration, Hydrogen Fuel Cells, Advanced By-fuels and End Use Efficiency. The Tech Plus is the one that contains, "Cost Reductions for Nuclear", "Acceptance by the Public", and "Preparation of Renewable Power". These scenarios are showing the carbon emissions that will be resolved from these scenarios. The only scenario – the first bar is the baseline, 2003 emissions of carbon. The only scenario that brings carbon emissions in 2050 to below the baseline, is the last one in the previous slide called "Tech Plus" that basically emphasizes renewables and nuclear. All of the other scenarios, even though many of them were optimistic, still have carbon emissions increasing above the baseline.

And finally, some notes about the North American outlook. There is going to be growing demand and security issues of supply from North America. I was reading today in the Globe and Mail about Senator Obama and Senator Clinton promising to undue NAFTA, at least re-negotiate it. Well, geopolitics is not just across the world, it can be just across the border. This can have far-reaching implications for Canada and its exports of energy resources. We can expect it is just the nature of fossil fuel, especially oil and gas, high ____ energy prices and the challenge would be that we have to achieve sustainability. Did I mention sustainability here? Adequacy of reserves - I do not think that is a problem between here and at least to the end of 2050. But the other one is environmental ability to absorb the use of that available resource of fossil fuel - and there we have serious issues.

In the three countries; United States, Canada and Mexico, this is the mix of what they consume in oil, gas and the primary energy resources. So again Mexico of course has the highest consumption of oil- that is what they are endowed with. This is per capita income and per capita consumption. Canada is highest, obviously in per capita consumption. The two go hand in hand. Although the U.S has a higher per capita income, it does not have as high per capita consumption again reflecting unique characteristics of Canada as a country and economy. Basically, the yellow dots here – the farther out they are, the higher the growth rate of that thing is going to be.

So, for Canada, fox example, its GDP growth is between 2 and 3%, but for Mexico, this is to 2030, it's going to be about 4%. Canada is seen to have significant growth in nuclear, but not in Mexico, it's toward the origin, almost zero. You can see by how far out these yellow dots are as to how fast that source is going to grow. There are very different patterns between Mexico and Canada. This is U.S and North America- Very similar pattern. This is due to the dominance of the U.S economy in North America. North America mirrors what the U.S economy is going to do in various fuels and economic growth.

I think that brings me to the end of my time. I have written an eight page summary here… I'll save you from reading it and I thank you very much for listening. I hope you have found this information useful.

Questions

Guest: "I have a question about the total absence of prediction of tidal power. There is a reliability of tides in the vast coastline of Canada with the sea. I was just wondering whether there is any effort in trying to do some research about tidal power. We know wind turbines, we know hydro turbines can they combine some of these? I know there has been some research done for the Bay of Fundy for many years and there have been few tidal powers in the world, so what is Canada doing about it?

Marwan Masri: "I'm not sure I can answer what Canada is doing about it but in general, tidal power is the existence of the resource. There is no question the resource in Canada is substantial on both coasts and in the U.S and many other places, but so is solar power. A small fraction of what falls on the earth every day is enough to power the whole earth, yet it is not doing it, why? It's a question of cost, a question of commitment, what incentives are there to support that technology and whether the technology cost curve has flattened out or not. So, for tidal power it is not really any significant contribution today in any part of the world. Any other technology would be in the same place if it didn't have the support for R & D and so on. I am not sure of the extent of it in Canada today, so I am sorry I cannot really give you that answer."

Guest: "You had mentioned a 2,600 page report that you referred to and i'd like to look that up on the internet, is that published by the RPCC?"

Marwan Masri: "IPCC - International Panel on Common Change."

Guest: "I have a question actually following on the last one regarding the IPCC report. There was also a response by a few hundred meteorologists who pointed out a lot of the flawed, or a lot of the problems that they had against the methods of the modeling used for the IPCC consensus, and they said that the main problem with a lot of the climate and environmental problems was this lack of ability to develop the third world, or increase progress in energy to the third world because a lot of the cartelization of the economic situation. They also pointed out the current record-breaking temperatures in China. As we know there has been the coldest weather ever on record this winter. That made me also think about the rising water levels in the Great lakes of Canada. That has been occurring over the last 15 years too. So there are a lot of these anomalies. I was hoping to get some of your thoughts on this letter which anyone can find online too, or these similar types of things that refute the consensus of global warming."

Marwan Masri: "Well by no means is there a unanimous agreement but we look at a body like IPCC, it is just so widely dispersed across the world and broadly representative and it really does look at just about everything that has been published on the subject. The 2,600 pages is a "summary" of everything that has been done on the subject. So it tends to be balanced because of different points of view there. There are still views that think that climate change may not be happening.

Now there a lot of energy actions that can be under taken. We call them "no regret actions". These are actions that make economic sense on their own, such as energy efficiency. Maybe one source of energy of nuclear power, when you add carbon cost to coal, it's more competative. You do it anyway. The effect of that is also reducing carbon emissions. Now, if climate change

does not happen (it is not really the consensus that it won't happen, or is not happening already) then there's no extra cost for undertaking those measures. So the idea is if there is still uncertainty which most people think there isn't (at least after publication of their support), then they start with these low-cost or no-cost measures. They have net benefit and they keep doing that. The other measures that you need to undertake to address global warming that may have net cost, those depend on your perception whether global warming is happening or not and what the likely of that is going to be. That will then justify undertaking those costly measures or not."

Guest: "My question is about the business aspects of things. You know CANDU is recognized as being the finest reactor in the world. We tried to sell CANDU to France or Japan, or any of these markets that have protection as barriers. Has your institute looked at any of the opportunity costs posed by protection as barriers and Europe for instance, or in Asia to the procurement of for instance Canadian Technology? It's one thing to have fine technology but if you were prevented from selling because of National Policy, there is an opportunity cost to that. Has your institute looked at that?"

Marwan Masri: "We have not. Obviously yes, if any part of trade is restricted there is an opportunity cost for that. Namely the revenue it could generate from those sales. So we have not looked at it, this is not really what this report was trying to do, just lay out a very broad picture of the energy scene and what is happening. This particular question, we have not looked at."

Guest: "It's often said that nuclear power generation has almost no CO2 emissions and the caveat normally said it would be the extraction of uranium, but to construct a facility you know it takes years ranging from 4 to 10, and in that time, one would imagine that there would actually be a great deal of CO2 emitted from the various components of constructing a nuclear power generation facility. So have you or your institute come across any statistics about what those numbers would be in terms of emissions? Would it be negligible in your view, or would it be quite formidable, and if the latter, should that be added to the carbon cost when we are talking about emissions for power?"

Marwan Masri: "That is an excellent question. We have come across quite a few studies that actually looked at what you are talking about. It's called, "Lifecycle Assessment Emissions". So you look at not just the tail part emission in the case of a car, or power plant emissions, but all of the processes that were undertaken to produce that electricity such as mining of the oar, transporting it, building the containment vessels. The studies we have seen for the most part show that nuclear are on a lifecycle basis. It is really very close to wind or solar even when you account for all of the emissions from a lifecycle. We are currently undertaking our own study and we are not quite done with it to look at this very question of looking at lifecycle emissions for nuclear. We'd be happy to share those results when they are done".