<u>A NUCLEAR POWER FORUM AT UNB ON BEHALF OF SHAD VALLEY STUDENTS</u> (Revised, 2002-05-06) - John K. Sutherland.

`The best lack all conviction, while the worst are full of passionate intensity.'

W.B Yeats.

Shad Valley is a learning experience for several hundred bright high school students getting ready to enter university. They are divided into groups of about 50 students and they spend a summer month of intensive and challenging learning at universities across Canada. This subject occupies one morning of their stay at UNB (University of New Brunswick, Canada). They are encouraged to discuss the issues and to challenge the presenters (Prof. Lister and Dr. Sutherland), and are given the ammunition to do so by receiving this handout several days before (hopefully) the presentations. Some of the overheads to accompany this presentation are at the back.

<u>DID YOU KNOW THAT:-</u>

- *Life is a sexually transmitted condition that is inevitably fatal.*
- *The death rate will never be less than one per person. Death is inevitable. Prosperous societies have managed to push the point of death to close to 80 years by finding out what killed people prematurely at childbirth; in infancy; as young adults; and by combating those risks.*
- *A high cancer death rate in any western society, is indicative of a very healthy population surviving to die of the diseases of old age::- heart diseases and cancer. Low cancer-death rate societies are usually that way because they don't live long enough to die of cancer. They usually die of the diseases that are easily avoidable with technology, prosperity and education.*
- *Nothing is risk-free. But if you cannot identify what risks are influencing your life, or which are most likely to kill you and how, you will be unable to rationally change anything.*
- *The highest risks facing any society are those associated with poverty, illiteracy and deprivation. Others would try to persuade us through emotional arguments and by avoiding perspective and facts that they are technologically related. They are not; other than that technology reduces them.*
- *Spending of society's resources to reduce risk should be aimed at those risks which are defined as being the most significant. Such an assessment should be based upon observed related deaths and defined illness. We often spend the most money addressing the lesser risk and often spending it where it will do no good. Misspending in this way costs lives.*
- *The evolution of society has been achieved by substituting lesser risk activities for those of higher risk, with a few exceptions in the early stages of development.*
- *Risks are reduced by scientific advances in engineering and medicine.*
- *Wealth and education provide the bases for such advances, and without surplus energy, such advances cannot take place.*
- *Environmental issues require wealth, education, technology and energy to resolve them.*
- *More radiation is emitted from a coal burning power plant (about 20 microsieverts a year), than from a*

nuclear power plant like Point Lepreau (about 2 microsieverts a year)?

- *Natural background levels of radiation are about 2,000 to 10,000 microsieverts and larger per year.*
- *All fossil fuels and renewable energies exist because of nuclear energy? - the Sun is a fusion reactor. Wind and Solar energy, are both derived from the sun's incoming energy. Coal, oil, gas, tar sands, oil shales are stored solar energy built up over millions of years. Nuclear energy is the source of it all.*
- *The first known nuclear reactor on Earth was operating about 2 billion years ago at Oklo, Gabon, in Africa?*
- *Solar and Wind energy are - megawatt for megawatt - more dangerous than nuclear energy.*
- *The most damaging environmental problems today are **ignorance and poverty,** just as they have always been, and not the other widely publicized issues.*
- *Life expectancy today, in Canada, is about 75 to 80 years and life expectancy has been increased by at least 20 years by medical and scientific advances over the last 100 years, especially through the use of radiation in medical treatments? Many peoples in the world rarely live beyond 40.*
- *Just before the turn of the century it was widely believed that the human body could not possibly survive any speed greater than that of a galloping horse; iron ships could not float; craft heavier than air could not possibly fly; and the electric light would make us all blind and drive the birth rate down. The two wheeled velocipede (bicycle) could not possibly convey anyone as it would always fall over. Physics can be used to suggest that a bee cannot possibly fly.*
- *1995 was the **centenary** year of the discovery and widespread use of X-rays. We have been using radiation for more than 100 years - especially in medicine, to the very great benefit of humanity? We know more about radiation than about any other agent in the environment.*
- *Nuclear Waste, is an issue of great public concern, yet on any ranking of true risks in society, nuclear waste is as close to the bottom of the ranking as you could possibly find. It has killed or injured no-one, nor is ever likely to, yet we can be terrorized by it.*
- *Plutonium is widely publicized as being the most dangerous substance known to humanity and that one pound of it - if inhaled - could kill 8 million people (Nader and others). It has killed no-one; not even those workers highly exposed during the Manhattan project.*

Introduction.

We get a lot of our everyday information from the news media. The same news media regards good news as disastrous and vice versa. The public loves to be terrified. For subjects about which we know relatively little, our view of them is shaped by what is reported and how it is reported. How would you feel, for example, about a food that was reported in this way? (first overhead, page 24).

The statements are all true but are misleading and emotionally loaded - they could have been written by someone who had a pathological distaste for this item and wanted to rid the world of it regardless of its benefits (a common attitude in some `special interest' groups who oppose, for example, ALAR, food irradiation, genetic engineering, synthetic pesticides, growth hormones, GM food, etc.). The impression that you are likely to draw (concern and fear) was very carefully groomed by the way the statements were made. If we don't recognize this, we might obviously get concerned, anxious, angry, outraged and might press to have this common food removed from the shelves. The food is actually the common and garden carrot. Other, tongue-in-cheek 'truths' concern the dangers of di-hydrogen monoxide (water), responsible for thousands of deaths each year.

A lot of our news is presented in the same, deeply emotional, way. Only those with first-hand knowledge of a subject, or cynicism of some of the media agendas and techniques - especially those paraded on the television – are likely to recognize such dubious intent - to terrify an audience about an inconsequential issue; but they are not the ones whose knowledgeable views are sought by the media hounds. In fact, their views seem to be studiously avoided as they might bring a measure of rationality, perspective and facts.

This is especially true of the coverage granted to most of technology and especially of nuclear power as I hope you will be able to judge for yourselves to some degree after this forum.

Before I get into detail, let's take a look at another overhead. This is a table of Loss of Life Expectancy (LLE) for a few risks in U.S. society. It RANKS risks in terms of their impact upon society in general, by counting bodies. Risks with a large LLE should receive more attention and funding than those with a small LLE. The table was compiled by Prof. Bernard Cohen, a physicist at the University of Pittsburgh. What it points out, is that there are risks associated with **EVERYTHING** that we choose to do (or not to do), how we live, and what we are. In any rational society, every effort would be made to rank the everyday social risks, so that money could be allocated to those at the top of the list, while those at the bottom should be ignored. Do you think that resource allocation in our society is based on such objective assessments? Why not?

Not shown on this listing is the recently publicized but generally hidden fact, that the eighth ranked cause of death in most areas of the civilized world appears to be medical errors! Sceptical patients in hospitals have taken to writing on their bodies such things as 'My left kidney is the one that is diseased. Amputate the other leg, not this one. The tumour is here ('arrowed'), etc. You may laugh. But remember this, when YOU need to go under the knife.

There are serious risks to society, caused by spending scarce dollars on ill-defined environmental issues - especially upon most regulations and trying to meet the very poor science behind `zero tolerance', rather than on addressing significant health and environmental issues that actually **do** cost human lives (malaria and other diseases, ignorance and poverty) and that really do damage the environment (not treating sewage before discharging it to a body of water).

By the way, if you can interpret the meaning behind the risks with the largest LLEs you will be able to see that the most damaging and destructive social and environmental forces are **ignorance and poverty**, and not the numerous ill-defined and unscientific issues that clamour for our attention and dollars; glamour issues like Global Climate Change and so-called Ozone Depletion. The local disaster channel (the weather network) has now re-discovered that cancer-fighting vitamin D is sunlight related and that we all need some sun, after years of trying to terrify us that the sun was a great big cancer-causing orb and too keep it off us.

How do we counteract those real environmental problems for which we are truly responsible? With technology, education and wealth. There is no other way that is effective. Think about it!

They are all interesting figures, but a few of them are emphasized. If you work as a coal miner you face two unusual risks; being killed in a mine accident (the most feared and the most publicised) and suffering from black lung disease. They are both severe problems. Since 1900 there have been almost 90,000 coal miners killed in the U.S. alone and many thousands in Canada (26, a few years ago in the Westray mine accident and hundreds more each year in other parts of the world).

Ten percent of all rolling-stock in the U.S. is used for moving coal. Accidents with that, affect all of us.

Various studies of air pollution (M.I.T. study and others) suggest (but the science is not good) that between 50,000 and 100,000 members of the general public die because of air pollution each year in the U.S. mostly from pollution associated with fossil fuel use (electrical energy, heating and auto). This is reflected in the figure of about 80 days LLE for all of us, since air pollution affects us all.

Now, there is also the general recognition that the emission of toxic elements such as mercury from burning coal, is yet another serious environmental and human problem that we seem to have ignored until the present.

You may recall that in the present travail at Ontario Hydro, the nuclear genie was about to have its teeth pulled by mothballing about 4400 MW(e) of supply, until management issues were solved and worker training came up to par. This followed on from Maurice Strong (political hatchet-man) getting rid of 10,000 highly qualified workers. The underlying problem was more political than nuclear, and had nothing to do with the reactor design, but no-one wanted to know that. An interesting and very telling outcome of this proposed closure (spring, 1998), was that Greenpeace suddenly decided to go public with its concerns that about an extra 15 persons would die each month from the pollution associated with using fossil fuel, rather than nuclear, for electricity generation. After what they have previously said about the risks of nuclear energy, this concern should raise a few eyebrows about the real intent of Greenpeace and why they suddenly seemed to have inherited a concern for the public good that is generally not evident.

The lower part of the LLE table shows estimates of LLE if all electricity in the U.S. were generated by Nuclear Power. This is loss of life due to assumed core meltdowns - presumed to be the worst thing that can happen to the general public as well as to a nuclear power plant, but would actually be unlikely to kill anyone.

All other aspects of Nuclear Power impact on the public; mining wastes, power generation, radiation emissions, waste disposal and decommissioning are of much lesser concern apparently to the groups who did the evaluations. All of these are believed by much of the public and most of the media to be the most horrendous risks we - or our descendants - are likely to face. The figures are also **calculated, using pessimistic assumptions,** as there are no observed deaths that we can identify!

Bear in mind that there is only one issue with Nuclear Power that is used to frighten anyone, and that is danger of RADIATION and fear of cancer that is assumed to follow. This fear extends to consideration of the disposal of used nuclear fuel, with assumptions that unconscionable dangers extend out for hundreds of thousands or even millions of years. In reality, used fuel gets nowhere near the general public, so it is one of the least of public risks. In any case - after about 500 years - not thousands or millions, it is essentially no different from natural uranium, but in a man-made orebody, and could kill no-one. Additionally, it is immoral to assume that any of our present day risks will extend so far into the future. If they did, previous generations might have assumed that we would, by now, be neck deep in horse manure with all the horses that surely must be throughout society. Society has a knack of solving present day problems (diseases, general issues), so that they cannot be assumed to extend indefinitely into the far future.

Even the most pessimistic estimate of risks by the Union of Concerned Scientists (UCS) - who, like the Club of Rome and some other environmental organizations, used to be very outspokenly anti-nuclear (but now support it) - again because of this fear of radiation - suggest that it is in reality relatively harmless. This is probably the reason they could no longer maintain their anti-nuclear stance. Even the Vatican now supports nuclear energy - but without too much of a fanfare of publicity - along with almost every professional association in our society. Some few environmental groups, and their numerous supporters in the media, still vocally oppose it at every opportunity and try to persuade everyone that they are the moral majority. They are not. Their honesty and sincerity may not be questionable (except for the example immediately below), but their judgement and knowledge certainly are.

A most interesting and enlightening example of this occurred in Toronto in 1983. A group of several religious faiths (IPPANI - Interfaith Program for Public Awareness of Nuclear Issues) held an inquiry into nuclear energy, spread over three weeks. Briefs were presented from both sides of the issues. When the panels' unbiased reports were eventually prepared, based upon all of the facts to which they had been exposed, they showed overwhelming support for the nuclear industry. This had not been the intent of the original organisers, who remained anti-nuclear, and so the findings, the report and the entire IPPANI program was allowed to quietly die after a year of dithering and frustration (reference - Simms). The same sort of circus played out in the courts over nuclear liability, when the judge castigated various single issue groups (being anti-nuclear) for their dishonesty and cavalier approach to the truth - the media didn't report the outcome as it was too embarrassing for them, and exposed their single trick agendas. Most recently (2002), Club Sierra (sorry) had a court challenge thrown out in their attempts to block sales of reactors to foreign countries. Today, the ministers of the G8 countries have at last begun to use the word nuclear once more as the obvious and painless solution to the potential horrors of the current bete noire - the dreaded, but inevitable Global Climate Change. Well, at least they are right about ONE thing (nuclear) even if they know nothing about the other.

Basically, YOU are here today because of ENERGY. Without surplus energy you would still be working the land and labouring with horses; few of you would be able to engage in education; there would be little social wealth and little technology. Without education, wealth and technology, there would be no possibility of addressing, in any meaningful way, the various environmental problems that are a result of population pressure and population demand.

Wealth is Health AND Progress.

Let's be clear about this -- Wealth is Health. Poor nations cannot afford health care. To get back to LLE. One thing that LLE does not show directly, is that in the last 100 years, our life expectancy has almost doubled as our wealth and knowledge have increased, i.e. **risks and hazards in society have diminished.**

This is exactly the opposite to what is often publicized by those groups intent on terrifying us about selected issues that are really of minor risk or of truly little environmental impact. This improvement in health has come about because of wealth, which has funded research, medical advances, food preservation, education, and abundant energy; all of which diminish the risks that society used to face. Anything which needlessly robs us of wealth or wastes money, compromises our health. Air pollution because of energy use may cost us 80 days of LLE, but without adequate energy we would incur an LLE that would make even living in poverty seem quite healthy. There are a lot of tradeoffs like that.

When I am invited to talk about nuclear power, I usually say yes, but say that I intend to talk about energy, in general, first. The reason for this is simple. If you focus upon only one source of energy you do not get the perspective you should have about energy issues. After all, the intent should be to use the safest, cleanest and cheapest of those that are available to you and that make sense in your part of the world. The most sensible option may be hydro, tidal, solar, wind, coal, gas, oil or nuclear depending upon where you live, the latitude, how you live, the climate, distances, the standard of living you insist upon, your degree of industrialization, costs, and the resources available.

How do you know what is your most sensible option unless you can examine them all and compare them using the same frames of reference?

This is why the media and special interest groups have such fun with nuclear power. They block perspective as much as possible and then proceed to terrify people. They can scare people half to death with allegations of cancers, birth defects and mutations - even if these effects don't occur more than usual. They emotionally explore the minefield of misinformation about Chernobyl and even the rumours that still circulate, mostly without foundation, about the tragedy of Hiroshima and Nagasaki. They were indeed tragedies of accident, war and human suffering but the persistent rumours focus upon health effects that would mostly have occurred anyway, or do not exist at all.

For example, radiation related genetic effects in humans, though the stuff of Hollywood spectaculars (Mutant Ninja Turtles etc), have never been seen. Genetic defect fears sprang from the work of Muller on extremely high dose irradiation of fruit flies a few decades ago - but flies are not humans. All data on humans - especially in the last 50 years - show that fears of genetic defects because of radiation were ill founded. They don't occur. The doses that might cause obvious genetic defects are above the level at which the radiation is fatal - cold comfort.

Immediately following the Japanese bombings and over the next nine months, there was a very detailed study, by the Japanese Midwives Association, of all births in these areas. It is well known that infants in the womb (between weeks 8 and 15) are more sensitive than adults to radiation: this is why medical radiation exposures to pregnant women are usually carefully controlled. But not always!

The initial results suggested that there were horrendous birth defects from radiation and the study data were promptly publicized, blaming everything on the bombs.

Some time after this, comparable birth studies were made in similar detail on the Japanese population of Osaka - nowhere near the bombing areas. To the midwives' surprise, they discovered that the birth `problems' that had been seen in Hiroshima and Nagasaki were also present everywhere else. They had little or nothing to do with the bombs or radiation, but had not previously been noticed because no-one had ever studied births in such detail. Most news reports did not cover the subsequent findings to correct the first wave of hysterical misinterpretation, so we still hear these same stories from time to time.

Today, compared with a similar Japanese population, the 80,000 offspring of the survivors show the following arresting features compared with the control population: stillbirths are down by 85%, deaths from cancer were down by 20%, Down's syndrome was down by 50%, overall mortality was down by 30%, and infant mortality from all causes was down by 35% (Japanese Radiation Effects Research Foundation, (J.V. Neel - RERF) and the ABCC)!

These data were publicised in the recent court case over fathers' exposures, and supposed links to leukemia in their offspring, while they were working at Sellafield (UK). The court cases were dismissed based upon poor science and a lack of evidence. The media should be clamouring for more information on these sensational results on the offspring of the bomb survivors, but are not. If industry does not get a black eye, the media are not interested in the science.

We are now going through the same baseless agonies over rumours and allegations about the effects of Chernobyl.

To get back to perspective on energy. It is only reasonable and fair that when you consider Energy, you should look at all of our reasonable choices in the same frame of reference before you draw conclusions. When you talk about costs, safety, environmental impact, human health, long term effects etc, you should do the same for all of them. I will do some of this in a moment, but let's first look at where our energy use has come from over the last few hundred years.

The overhead shows evolution of energy use from primitive times to the advent of nuclear energy. The point is that they have evolved and changed with time, need and knowledge. What the graph does not show, is that not just primary energy, but electricity derived from it (starting about 1900), is now one of the most important driving forces of our society. Without abundant, affordable energy, (i.e., there should be no shortages and no uncertainties), our society would be in chaos. You would probably not be here, but labouring in what would probably be a subsistence economy just to survive from one year to the next. When (if) the electric (or fuel cell) car is in common use because of pollution concerns (electric vehicles have been around for almost 100 years and used to outnumber gasoline vehicles two to one), we can use oil for something else, and we will. What no-one seems to be asking, is where will we get the major quantities of electricity (hydrogen) to displace all of that oil? The fuel cell is only a conversion device for using either gas or hydrogen. You may have seen the advertisements for ethanol use in gasoline. The ethanol is produced from Corn. Farmers love the idea as it means that millions of acres will be put to a use other than for food (land clearing, habitat destruction) and there will be subsidies galore. The snag is that one gallon of ethanol has an energy value of only 77,000 BTU, while the energy used to produce that gallon of ethanol in all of the farming endeavour from beginning to end is about 131,000 BTU. Boy, are we some smart! Better not let the public find out about this political pork-fest.

California, undergoing energy agonies at the moment (2001) with energy prices rising (oil + 50%, gas up 300 - 400%, electricity spiking up to $1500/MW from a low of about $20), will face this question increasingly unless it adopts a hydrogen fuel. Then the question to ask is how it is to produce hydrogen fuel. Obviously, with electricity! It turns out that electricity is the key to societal development and advancement, so we had better understand our choices for producing electricity. This is something that Californians have neglected to do for the last few years, and still seem to be incapable of uttering the N word as an obvious solution - which it is.

The next overhead shows that at the present rate of use of fossil fuels, we will leave the fossil fuel age finally in about 100 to 200 years when we are theorized to eventually run out of coal and other fossil fuel resources (actually, reserves are greater today than they have ever been) unless we wean ourselves away from them earlier for other reasons. Unfortunately, using coal, oil or gas for energy use is a waste of valuable resources that could be better used for almost anything else, especially in the petrochemical industries. China (an emerging economy) is adding several million tons of coal burning capacity each year and is forging ahead with nuclear power.

As far as coal is concerned, it doesn't matter if it falls short of being clean, cheap or safe; it is still better than the alternative of not enough energy. China has little choice but coal, nuclear and whatever hydro resources (the Three Gorges project of about 18 gigawatts) it has, to meet its burgeoning energy needs. **We** are not running out of resources; in fact oil and gas reserves keep growing as we identify more - as the price keeps rising (Cato institute report). The Supply/Demand/Alternative juggernaut is amazing. We may stop using *conventional* oil and gas in the quantities we are using them, in about 50 years, more or less (maybe). What will we use then for energy and electricity?

What choices do we have? They are limited. They all have drawbacks, some of them have significant advantages. Whatever question you ask of one, you should ask the same question of the others. What are the pollutants? Costs? Availability? Reliability? Safety? Environmental impact? Human Impact? What are the alternatives? What about political intervention to tax energy, pollutants, or prohibit certain choices? Frightening stuff! The answers are very different in different countries, different climates, and different stages of development. Some people don't like either the questions or the answers.

Until uranium came along, we were saddled with dilute fuel sources needing large numbers of workers, massive transportation systems which all use energy, and have large environmental impact. Of all of our energy choices, uranium can provide the most energy per gram. Uranium is also of little use for anything except energy use, unlike coal, oil, gas or peat.

In a CANDU reactor, 1 ton of uranium (including plutonium, which also forms from the uranium-238, and provides about 30% or so of the total energy) is energy equivalent to about 20,000 tons of coal. In a breeder reactor, of which there are a few prototypes in the world, one ton of uranium (or thorium) is energy equivalent to 1.3 million tons of coal! The only significant `waste' product from this, is one ton of highly radioactive spent fuel which is relatively easily managed and is not even waste when you consider that about 98% of it could be recycled and re-used - when the economics allow it - which they do, now.

The same energy from coal (compared with 1 ton of uranium in a breeder reactor) would result in the problems of moving the **1.3 million tons of coal**, plus **sulphur dioxide (about 50 thousand tons)**, about **4 million tons of carbon dioxide**; nitrogen oxides, **tens of thousands of tons of toxic fly ash and bottom ash** to move and dispose of safely. Oh! and the emission of about the same amount of radiation or more (from natural radionuclides), than a typical nuclear power plant of today might also emit during ITS operation! That from the coal is ignored as being insignificant - which it is.

However, the lesser emissions from nuclear power plants give rise to allegations by the mendaciously mischievous, of Leukemia, Cancer clusters, animal deformities, Down's Syndrome, and many other health effects! I wonder why, and so should you, considering that 99.9% of our total radiation exposure is from everything else, and all of these awkward social problems are with us in just the same numbers whether we use nuclear power or not.

The existing uranium fuel cycle is based upon uranium-235 (fissile). Without it, there would be no nuclear power today. With breeder reactors, we multiply the uranium fuel resource by at least a factor of about 60 because of our ability to better use uranium-238 (by fast fission). We also open up the possibility of using thorium as a nuclear fuel (India is using thorium now) which would further increase the energy potential by another factor of about 100 or more from the same amount of fuel!

Energy Equivalence Numbers for 1 kilogram of fuel

Fuel	1 kilogram of fuel can produce this much electricity:	Fuel for 1000 MW for one Year (8,760,000 MWh)
Hardwood	1 kWh	8,760,000 tonnes
Coal	3 kWh	2,920,000 tonnes
Oil*	4 kWh	2,190,000 tonnes (15,330,000 barrels)
Natural Uranium	50,000 kWh	175 tonnes
Plutonium	6,000,000 kWh	1.5 tonnes

* 1 Litre of gasoline produces the energy equivalent of about 10 to 13 kWh of electricity, but is often inefficiently used in the automobile.

Costs

What is the cost of electricity from any source? Utilities make a best estimate before they build anything, based upon what they already know and assuming about a 30 year life, but the final, and accurate figure is known only when the facility generates its last kilowatt hour.

IF a 600 MW(electrical) facility cost $1 billion, and it generated only 1 kilowatt hour of electricity before it self destructed, then the cost would have been a whopping $1 billion for that kilowatt hour! Wow! If it operated for just one day at full power (14.4 million kilowatt hours), the costs drop to about $70 per kilowatt hour. If it operates for 1 week, 1 month, 1 year, or 1 decade, the theoretical costs are about $10, $2, $0.19 and $0.02 respectively (ignoring all other costs, such as interest charges, fuel costs, repair costs, labour costs etc, - all of which would increase the final electricity bill). But it still takes about 25 to 30 years to recover your investment, as you can't charge what it costs at the time you begin, or no-one would buy your electricity (it's not like a car, which you purchase outright) and you wouldn't have built the plant in the first place. Obviously, if you look at prematurely closing a facility, you will be faced with unacceptable and unplanned costs that you have never completely covered with consumers paying for electricity at a few cents for a kilowatt hour over the assumed longer life of a facility.

From an NEI report in late 1997 to 1998, according to McGraw Hill's Utility Data Institute, production costs at U.S. nuclear power plants averaged 1.91 cents/kWh in 1996, while production costs at coal plants averaged 1.83 cents/kWh; natural gas was 3.38 cents/kWh (they just took a hike of about 300 to 400% in the Spring of 2001 before dropping back); and oil was

4.14 cents/kWh (and that just took a big hike too). Oil and gas are really non-starters for electricity unless you have no other alternatives. One killer about oil and gas is their price. If there is a doubling of fuel cost, then electricity derived from them also doubles in price as their costs are almost entirely for fuel. If uranium doubles in price, then the price of electricity goes up about 6 to 10% as fuel costs are such a small part of total costs.

You all know that the *capital* cost of a nuclear power plant is more than the capital cost of a coal or oil or gas plant, as it is often publicized with great emphasis. Critics try to ensure that the debate ends there, as though that were the clincher. The last thing they want is for anyone to examine the lifetime costs or other constraints. What is rarely pointed out is that the cost of fuels for all of these, favours nuclear power most dramatically, with fuel costs that are about 10% of those of coal or oil or gas (and the fuel dollars stay in Canada where most uranium is produced!). What this means is that even after a high initial capital cost, running costs are so much less, that after a few years, 5 to 15 - depending upon interest rates and other costs - the baseloaded nuclear plant is a lot less expensive than coal, oil or gas. Today, the older nuclear plants are a gold mine for profits. There are now some proposed nuclear developments that have opponents of technology sputtering, fuming and foaming at the mouth and scrambling to block progress. First, and it has been happening anyway over the last decade or so, was the improvement in turbine efficiencies of up to 5 or 10% and more (all thermal plants benefit from this). Second is the threatened refurbishment of some of the older plants to give them another 20 or thirty years of life extension. This refurbishment provides (in theory) a brand new plant for about one third of the cost of a new one (a refurbished Point Lepreau for about 500 to 600 million dollars). Power gets a lot cheaper from that too. The third development will come when we begin to recycle some of our used fuel. Remember, in the first pass through a reactor only about 1 to 2% of the fuel is actually used. Using some of the remainder by reprocessing, or most of it in a Fast Reactor or Breeder cycle or mixed with plutonium as MOX fuel (a fourth possibility), brings fuel costs down even further. But for the political and environmentalist roadblocks, we really could be enjoying cheap and safe power, free of international price and other political manipulation and constant threat of war.

The overhead shows the figures for fuel equivalents; the cost of the Point Lepreau CANDU (a fuel bundle today is actually $2,000 not $3,000); and costs if it had been oil or coal instead (allow about $600 million to $1 billion for capital costs of these plants depending upon whether or not they have scrubbers). As you can see, the cost of oil alone, was more than the entire capital cost of the nuclear station AND the costs of uranium to fuel it for the first few years. Add in the cost of the plant to burn the oil and you get a clearer picture of costs. A similar story can be told for coal. Given the relevant information - without the usually associated emotional and political baggage - you don't need to be an accountant to see that over the medium haul, and especially the long haul, the costs generally favour nuclear power even with the burden of safeguards and regulations that the industry carries - many of them needless. Oh! and by the way, the costs for nuclear waste disposal and decommissioning costs, which some people focus upon as though it were a black hole for money; unknown and outrageous, actually adds only about 1% to the costs of electricity projected over the lifetime of the facility, and it is being collected from power bills even as I write this. The U.S public is now discovering, from practical experience, that the costs of decommissioning are much less than it had been led to believe. No wonder Mark Twain said that `a lie can race its way around the world while the truth is tying its shoelace'.

The cost of coal-fired electricity is sometimes cheaper than uranium-fired electricity, as a few of the International figures show - often because of the high costs of extreme over-regulation of nuclear energy, but also because some coal-fired generating stations are at the pit head (some have very low labour costs in some parts of the world) and avoid transportation costs and may be subsidized by government. They also do not pay for their pollution costs - whatever might be the cost. YET. It is also interesting to consider that there is more potential energy thrown away in the coal ash (uranium and thorium) than was derived from burning the coal in the first place.

Oil (conventional, as opposed to tar sands) does not enter this picture because of who controls most of the world's supply. And those of us who were around in the early 1970s, remember oil embargoes and oil shortages for heating and automobiles all too clearly.

If you wonder why I do not address wind or solar, it is because they generally cannot compete with electricity from the grid; even in Denmark (truly a bit player with less than 400 MW of installed capacity, yet providing 10% of their electricity (year 2001) AND very heavily subsidized - the subsidies are about to be dropped) or California where it provides about 1% of the electricity. Total generation of electricity from all of the world's wind facilities in one year, is about equivalent to the annual power output from a **couple of large size thermal plants!** Interesting news in 2002 was that Denmark was about to stop subsidizing their wind projects! And everyone had thought they were never subsidized to start with. In addition, the news from Denmark is that the unreliability of wind power, coupled with the legal obligation of the utilities to buy it in preference to other forms of electricity, plays havoc with their electrical reliability and costs, as the usual base-loaded plants (gas and coal) must be kept in spinning reserve all of the time to cut in when the wind drops - as it always does, and regularly. They have a lovely rosy glow about renewable energy while they tolerate unreliability and still pollute the environment. Having their cake and eating it too. But only until the day of reckoning, which is now here.

The real limitation however, is that they are both intermittent (no wind, no sun - no power!). They are also dilute, unreliable, far too expensive (up to about 30c/kWh) in most areas - except in rare areas (that the enviros say are typical when they are not), and cannot meet our growing energy needs. This is why the free market (you and me and industry) has tended to ignore them, except where the electrical grid does not reach, and necessity dictates usage regardless of cost.

There are only three energy sources that make sense to generate reliable electricity: nuclear, coal and hydro. Hydro is generally not available year-round (except in Quebec and BC and other favoured regions; and not even consistently true there considering the problems this last winter 2000-01, and the threatened water shortages next year), so utilities are often faced with the decision to build either coal plants or nuclear plants. If you have no coal and little hydro reserve (Ontario hydro) you have little choice other than nuclear, unless you are prepared to pay much more for electrical energy. Remember, that if energy gets too expensive, you begin to kill poor people who can't afford it - even in our society. When the choice is to eat or stay warm, people die of cold. I hear Marie Antoinette in the background. No bread? Let them eat cake! No wonder she got the chop.

Tidal power (the biggest tides in the world are in Fundy and have been studied for many decades) is also intermittent and its capital costs are about three times those of a nuclear power plant of the same capacity, with a major penalty because of unavailability at crucial times of the day. This is why tidal power is unlikely ever to be developed further than a few pilot projects, one of which (20 MW) is in Nova Scotia, with two major facilities in the world in France and the former USSR.

In fact, costs are only part of the picture. If you don't have a resource or access to it, then costs are immaterial. The philosophy in France behind their development of nuclear energy is: - No coal, no oil, no gas, no choice. Whereas there are some areas of the world fighting to keep the nuclear genie at bay (usually they don't need it anyway); in France, some communities fight to GET a nuclear facility.

Pollution

A recent survey (June 1997) in Canada suggested that about 75% of respondents thought that the concerns of the environment should be placed ahead of concerns about the economy. Talk about Cart before the Horse!

This is the spirit that pervaded the RIO summit in 1992. It sounds reasonable, responsible, moral and right, but it is none of them. Re-distribution of wealth because of RIO, would have plundered the poor of the wealthy nations to give to the wealthy kleptocracy (ruling by theft) of the poor nations. And made not one whit of change to the environment. Or third world poverty.

Environmental protection requires a healthy economy and wealth. Nations that are poor; practice subsistence farming; burn wood or dung; are mostly illiterate; die of simple diseases mostly to do with ignorance; are torn apart by war; and do not have the environment at the top of their list of issues. It may not even be ON their list. Wealthy nations are concerned about the environment, as they are at peace (usually), prosperous, well fed, educated, sheltered and can afford to address it and fund and tolerate the parasites that focus upon it while NOT living any kind of third world lifestyle. The economy comes first. If we do not recognize why, we are indeed in trouble, but so is the environment.

No-one deliberately pollutes the environment, but it is an inevitable part of life and nature. Technological development and dollars are the only sure way of reducing adverse environmental impact in any way that makes sense. The way that generally does NOT make sense, is to stop doing something essential or to try and regulate a new direction. Third world countries cannot afford to spend money upon environmental protection, as they told us at the Rio Summit and they have no alternative lifestyles either. Pollution from the major sources of energy is shown on the air pollution and waste overhead. It speaks for itself - especially if you are concerned about the Greenhouse effect and the possibility of Global Warming (or the next ice age - depending upon which school of thought you subscribe to).

Hydro is obviously the energy of choice in most places where it is available, except that some people strenuously object to its local effects - by pleading environmental destruction, even if there isn't - and do not want these projects in their backyards, though they (you, we) do expect all of the benefits that go with them (such as assured electricity).

Nuclear is also an obvious environmental choice because of lack of significant airborne pollutants, high energy density of fuel and minuscule volumes of waste, which is all carefully managed. However, the 40,000 tons of highly radioactive `waste' generated in the world each year (with all spaces removed, about 4,000 m^3 - the size of a large auditorium - 20 by 20 by 10 m) is not actually waste, but spent fuel with 98% of its energy potential still useable if it is reprocessed. It **is** reprocessed in some parts of the world, where enriched uranium has a very high value, but does not yet need to be in Canada, which uses cheap, natural, uranium.

The recycling ethic tends to go by the board when some environmentalists come across uranium and used fuel, though it is one of the very few recycling ideas that is worthwhile or economic. The fact that it might lower the long term costs of fuel even below the already small cost of about 0.2 cents/kWh has a few critics worried that it might become even more obviously cheap than it is now, and anything they can do to stall that unthinkable possibility is worth doing.

In addition, if refurbishing - at a cost of even $500 million dollars extending the life by 20 to 30 years, so that it may earn a further several billion dollars - can be blocked, then the industry opponents will do it.

However, back to used fuel. Used fuel is also carefully managed, totally unlike most of the other wastes from other energy sources. The oft repeated statement of it being dangerously radioactive for millions of years is not even true. What **is** true, is that it is dangerously radioactive for a few years after it comes out of the reactor, but becomes continuously less radioactive (i.e., safer) with time and eventually bottoms out at **less** than the original radioactivity of the starting uranium - as there is now less of it.

Although it would contravene regulations and good work practices, it could be handled without undue hazard after only about 50 years, just so long as the over-riding individual dose limits are not exceeded by those handling it. The small amount of long half-life plutonium (Pu-239, 24,000 years) in it, poses no radiation hazard, as the plutonium is of low radioactivity. The Queen was given a plastic bag of some to hold a few years ago, to feel how warm it was.

However, Ralph Nader still makes statements about the extreme toxicity of plutonium and that a pound of it could kill many millions of people! He is careful not to say how. In debating Ralph Nader on this, Ralph (another) Lapp (but someone who KNOWS about radiation) stated that if that were true, then it would be equally reasonable to point out that a pound of air could also kill several million people (a bubble of injected air is fatal). Then he did what Nader dare not do; he described how the right conditions could be achieved in both cases.

First, for plutonium to do its hypothetical stuff, it would need to be in a soluble form (it isn't), and in solution (it isn't) and an exact amount of it would need to be injected as an aerosol into the lungs of each human (it generally isn't, but was at one time about 60 years ago injected into the blood-streams of about 18 'terminally ill' test subjects who proceeded to live relatively long lives - some until fairly recently - and none of whom died of plutonium related causes) and then you wait for about 30 years to see who might die, and of what. From what we know from the 18 test subjects (and thousands of those who worked for many years with plutonium), it is unlikely that any of them would die in the way supposed, because of the outrageous presumptions we make about the dangers of low doses of radiation - and that's what they are - low doses.

Second, for air to do its thing, all you need to do is to inject a small bubble of it into the bloodstream of anyone, and within seconds or minutes they are dead from an embolism. Obviously, no-one deliberately injects anyone with air, nor with plutonium either, so both scenarios were manipulated to be scary. Now, who did it with the intent of terrorizing the public, and who did it to inform the public, and which was the unforgivable sin?

Back to used fuel and the silos. Those who wonder about the integrity of the re-enforced concrete silos after 50 years (they imagine it will crumble to dust, overnight, though they could easily survive for hundreds of years!) have forgotten about the longevity of the Egyptian pyramids (they were NOT built of concrete but of limestone and indicate the longevity of some engineered structures) and that Roman concrete is still around (after 2,000 years - even without re-bar) and that other major engineering projects - such as the Empire State building, the Toronto CN Tower and 100,000 others, should concern them more if they have such little faith in engineering and such little knowledge of concrete. They have never seen the process of building one either, with its steel liner, steel re-bar throughout, and its massive walls. They forget that the concrete does not become more radioactive from storing fuel and they also forget that it is a very easy process to empty one silo to another and demolish the first, if necessary. After even 50 years, with much lower radioactivity to contend with, this could be done at a fraction of the risk incurred by any worker - even the trained people doing the job - or watching and measuring it (me) - when the silos were originally filled. Go a few steps away from any of the freshly filled silos, and you would be hard-pressed to measure any radiation coming from them at all!

Used fuel becomes SAFER with time, not more dangerous. And it does not escape into the broader environment!

Used fuel after a year or so in a reactor is indeed highly radioactive, but it loses much of this radioactivity very quickly. Ninety nine percent of the radionuclides are very short lived and decay very quickly. These are the most dangerous ones, which is why this fuel is stored under water for six years to cool down (the water is also a highly efficient radiation shield) and to lose this short-lived radioactivity. After this, it goes into dry storage. Those who play mind games about solubilities, migration in groundwater, and subsequent health effects in a final repository, are deliberately playing games with our emotions in order to trigger a desired response. It is obvious that they usually know nothing of these subjects, and probably would never dare admit (if they knew it to start with), that we are soon looking at material that is not very different from natural background radioactivity. They also are unaware of just how much natural radiation - far in excess of regulatory guidelines - there already is in many unpolluted groundwaters that we use for drinking, and that most people are not at all concerned about because it is natural.

They also seem to assume that we will be helpless to apply simple engineering changes if we see anything happen (even those changes we are currently making to stop drainage from landfills). They assume we do not know about grouting, clay impermeable barriers and caps, ion exchange cleanup, chemical treatment, or filtration techniques and must stand back and watch the problems take over as we wring our hands and weep. The most potent weapon in any of our enemies' hands, is our own ignorance, stupidity and fear - as Nader, so well knows. As two-time Nobel prize winner Madame Curie said, `nothing is to be feared, it is to be understood.' The social luddites, have turned that on its head 'Keep the public in the dark, and they will fear almost anything you choose to misinform them about, even out to ten thousand years into the future.' The poor saps!

Even after just six years out of the reactor, used fuel is even **LESS** radioactive than the tens of thousands of medical radiation sources which are transported across the world each day (18 million shipments per year) safely, and safely managed when they are exchanged for others - nuclear power critics ignore this aspect of radiation management, use and benefit. The longer the half life, the less hazardous is the material. Those who say and repeat that there is no solution to the nuclear waste issue are clearly attempting to emotionally manipulate an audience; are obviously unaware of just how little of it there is; what is currently being done with it (dry storage or reprocessing) or what long term storage plans are (encapsulation, vitrification, deep storage etc.); or the safeguards associated with them. Native Americans in Canada and the US may eventually begin to recognize the financial bonanza that is being dangled in front of them with minimal effort or risk on their part (once they get passed the emotional issues, the fear and the mountain of hype). If they can overcome misinformation, fear and the emotional objections of critics and detractors, their future could be very different from their past. I know if I controlled a few thousand or more acres, I would break my neck to become a used fuel respository. It probably would be the only endeavour I would ever encounter where I could be paid millions of dollars to safely store billions of dollars of valuable material. And I would demand that I be given title to it, and have those who put it there take the responsibility of monitoring, insuring and looking after it in perpetuity. Money for jam! And then my descendents can turn around and sell it as an ore-body at some point in the future. More money for jam!

Health Risks

When you compare health risks, air pollution, transportation accidents, general accidents of all kinds, waste disposal, groundwater pollution of all major energy sources it is obvious which ones have the biggest adverse effects. Unfortunately, there are those who believe that accidents only happen with nuclear power plants and that all others are absolutely safe. None of them is absolutely safe, but nuclear energy is among the safest. Until recently there has been too little data on the use of natural gas, but that is now changing. There have been several explosions demolishing city blocks in Mexico and Korea and houses in Halifax, Nova Scotia. One disturbing feature of the earthquakes at California and Kobe was that the natural gas fires from numerous ruptured gas lines burned for a long time (water pipes were broken too) and resulted in major loss of life. Natural gas has severe safety drawbacks that are only now becoming obvious!

Those who assume that risks from nuclear power (again, there is only ONE significant hazard and that is radiation) to future generations or even to those of us here today, are unacceptable, are again labouring under a lack of information. We do know that there is a danger from very high doses of radiation, but not at low doses. Low doses are still about 100 times larger than natural background and are also many thousands of times larger than routine radiation emission from a nuclear plant. The health effects from even most high radiation exposures are slight and hard to prove, even knowing what we do after Hiroshima, Nagasaki, Windscale, Three Mile Island and Chernobyl.

The data from Hiroshima and Nagasaki (acute, high doses) are mostly used to assess the risks of radiation, even down to almost zero dose. We assume that the dose-response relationship is linear, without any threshold. We now know that this is incorrect and causes us to over-estimate the risks of low dose and low dose-rate radiation exposures. Unfortunately this over-estimation contributes to the public fear of radiation and stimulates even more onerous regulations. The assumption of risk down to very low doses also causes many people to assume that they can calculate the effects on entire populations of low dose radiation and can calculate future health effects. Neither assumption is true.

The overwhelming weakness of the assumption of linearity through zero (i.e., with no threshold) is that it does not allow for the obvious and major effects of fractionation repair of chronic doses; does not allow for the fact that the intensity of an effect is dose rate dependent; and does not allow for a threshold. Hiroshima Nagasaki data from acute high exposures, apply only to the survivors of Hiroshima and Nagasaki and should no longer be misapplied to low doses and low dose rates - which are the real world. These features can be exemplified by the following simple analogy.

We know that 100 aspirin will almost immediately kill any individual who takes them at one time. This is the high dose response (i.e., a dose of 100 person-aspirin) indicating that aspirin is dangerous to such a degree that 100 of them cause one obvious death. By assuming linearity of response in exactly the way we do for the risk from radiation, we then should believe that if 100 people each take one aspirin (100 person-aspirin) one of the 100 people will die prematurely as a result. Similarly, if one person consumes one aspirin each day for 100 days, death is assumed to be likely!

Though the data are obvious and convincing when one person takes 100 aspirin, the assumed extension and application to ever lower doses in linear fashion is unscientific, unreasonable, nonsensical, and unjustified, just as it is with low-dose and chronic radiation.

A similar, and perhaps more easily understood example of our selective paranoia about radiation was given by Theodore Rockwell (with Hyman Rickover in the US nuclear submarine program at its beginning, and who saw the first commercial reactor (a Sub. Reactor) established at Shippingport Penn.). I have taken the liberty of modifying it slightly. He likened the position of those who fear low doses of radiation to having a swimming pool containing a thousand gallons of water and you are swimming happily in it (this is equivalent to background radiation). You then add two more gallons to it (equivalent to the radiation from nuclear and industrial processes), and by doing so, the suggestion following from our assumptions of risk, is that this excess will now cause the swimmer to suffer an increased risk of drowning, and it must be taken out of the pool immediately for safety's sake.

In terms of radiation, we believe that an acute dose of 1 sievert carries a risk of developing a fatal cancer of about 4%. For a population dose of 100 person sieverts - 100 persons each receiving 1 sievert - we predict about 4 premature deaths. Unfortunately, because of our assumption of direct linearity of effect, as with the aspirin analogy, we assume that if 1 million people each get 100 **microsieverts** of dose (population dose of 100 person sieverts) that four of them will die prematurely of cancer (above the 250,000 that will die of cancer anyway), because of the radiation. We do not allow for fractionation repair effects stemming from whether the dose is delivered acutely or over the entire year, nor allow for any other protective mechanism, of which there are several. In this way one can **calculate** detriment from any dose, no matter how small or how protracted, even though that dose may be a small fraction of the natural radiation dose that we are exposed to each and every year. However, the calculations are always gross ever-estimates of harm; are mostly meaningless and are **always misused** to suggest harm across large populations to arouse public anxiety and outrage, even when no harm exists. Greenpeace has used this tactic when it suggested that the data of ICRP, BEIR and UNSCEAR (prestigious groups of international (usually medical) radiation experts) showed that deaths could be confidently calculated from BNFL (British Nuclear Fuels) discharges at low levels into the Irish Sea (letter in Atom, 1988). **Confidently calculated?** This was a gross misuse of scientific data and is tantamount to calculating deaths from taking aspirin and terrifying the public over the exercise. But then what can one expect of an organization whose founders were recorded in the following revealing observations:

> "*The secret to David McTaggart's* [early officer in Greenpeace] *success is the secret to Greenpeace's success: It doesn't matter what is true ... it only matters what people believe is true ... You are what the media define you to be.* [Greenpeace] *became a myth, and a myth-generating machine.*" - Paul Watson, co-founder of Greenpeace and founder Sea Shepard Conservation Society.
>
> "*If you don't know an answer, a fact, a statistic, then .... make it up on the spot ... for the mass-media today ... the truth is irrelevant.*" -- Paul Watson in *Earthforce: An Earth Warrior's Guide to Strategy.*

It is this mistaken assumption of our ability to calculate harm from low doses, that allows anyone of mischievous intent to suggest that background radiation may cause as many as 600,000 deaths in the world each year and similarly that medical uses of radiation may cause as many as 150,000 deaths per year, or that radon in the US causes up to 20,000 lung cancer deaths per year (EPA). All three of these assumptions are without substance or validity, but follow from our inflexible assumptions about the linear risk of radiation, no matter how low the total dose or the dose rate. Cohen's data (HP Feb, 1995) on radon show that higher doses of radon are associated with **lower** lung cancer rates.

He studied 90% of the US population, in more than 1,000 counties and allowed for 54 confounding factors including smoking. **The difference between his data and the linear dose response theory, was more than 20 standard deviations!** And he ***observed*** his data, he didn't theorize them!

As physicist Richard Feynman said `If it disagrees with experiment it is wrong.' The empirical (observed) data certainly do disagree with the hypothetical expectations from the linear dose response model at low doses and low dose rates, therefore the linear dose response model - the hypothesis - is wrong.

For these reasons, the assumption of being able to define harm from low radiation doses using the Hiroshima Nagasaki risk data is wrong, and the calculation of future population detriment from collective doses from low dose exposures is totally unsupported by the growing body of empirical data. It is clear that the Hiroshima Nagasaki data apply only to the H/N survivors and to no-one else, and even more of THEM are alive and living longer than expected - as Time magazine recently noted with surprise, though it pains me to give credit to this magazine for anything worthwhile.

We know that 10,000 millisieverts (mSv) (10 sieverts) of acute radiation dose will kill almost 100% of those exposed. We also know that even 100,000 mSv of chronic dose will not. Outside of nature and medicine, doses of greater than even 10 mSv in a year are very rare.

As the International Commission on Radiological Protection (ICRP) itself and other recommendatory bodies reluctantly admit, low doses of radiation, including those considerably higher than natural background, may carry zero risk and certainly no health effects are visible below about 200 mSv of dose. This dose is a factor of 20 billion higher than the entirely trivial annual chronic dose likely to be received by any individual from a managed High Level Waste (HLW) repository after closure, at any time over the next 10,000 years, which might give someone a dose equivalent to about 1 second's worth of natural background encountered in a year! Guess what the publicity, misinformation and fear, focus upon - the emotions of course, and not the facts.

Radiation from nuclear power (even including accidents) is a very small fraction (about 0.01%) of the radiation we are exposed to from nature (about 75%) and medicine (about 25%) and from former bomb tests. **It is also a remarkably weak carcinogen** or else we would never use it in hospitals and medicine to the extent that we do. More is known about radiation and its associated risks than about any other agent in the environment. We are also a whisker away from significant cancer cures. If we can remove the risk of cancer from radiation exposures - the most major - and to some, the only concern - would opposition to nuclear power cease? It should, but I doubt that it would. Recent research reports a vaccine (BB-2516) that shrinks some tumours in mice and eliminates them in others. Human trials were said to be likely in 1996! I still breathlessly await the outcome, and it is 2002.

In addition, if we show that hormesis is a valid human benefit from even moderate doses of radiation (and we can; most spa visitors seem to believe it AND show it), why are we so fearful about low doses of radiation everywhere else?

The next few overheads show what the first Loss of Life Expectancy figures showed and that you may have already forgotten - that ALL risks from nuclear power are small - and even less than those from wind, solar, oil, coal, etc for the same power output.

Economy of scale and concentrated energy allow for **lower overall risks** than the misleading notion that `small is beautiful' using dilute energy! Small power plants also use relatively much more materials in their construction than large ones built on `economy of scale' principles.

One of the biggest causes of injury in our society is falls. Cleaning and maintaining small plants, such as solar collectors or (bird blending) windmills, subjects an army of workers to falls and other gravitational injuries.

In relation to environmental radiation (75% of our total annual dose on average) and medical radiation (25% on average, which saves lives, diagnoses diseases, avoids the much greater risk of surgery, and kills cancers) nuclear power contributes about 0.1%, or less, of all of the radiation we are exposed to. Some critics, attempt to blame many of mankind's diseases upon this 0.1%. It seems that they either don't know about natural and medical sources of radiation, or hope that you don't find out. There are also thousands of uses of radiation in society that contribute directly to our continued good health.

A typical and unavoidable background radiation dose from nature is about 2,000 to 5,000 microsieverts (2 to 5 millisieverts) a year; perhaps a lot higher if you live in a radon rich area (they are common). Medical exposures might be zero (if you are **unfortunate** enough to live in a society that can't afford medicine) up to about a few thousand microsieverts (perhaps up to 100,000,000 microsieverts (100 sieverts) to kill a cancer but not the patient).

Each and every day, there are patients discharged from many Canadian hospitals after receiving I-131 for thryoid treatment. Each of these patients emits more iodine-131 in the next few days than a normally operating reactor emits in the entire year! Such use of iodine-131 in the major hospitals in Montreal, and eliminated by patients, is readily detected down the St Lawrence river in Quebec City - only about 150 miles downriver! Despite the undeniable benefits of medical radiation, there are some people who are terrified of even medical uses and will tolerate the much greater risks of being undiagnosed or untreated if it might involve radiation. Dental exposures give about 2,000 microsieverts to the neck and head.

Around the Point Lepreau nuclear power plant, the general public is exposed to less than 2 microsieverts each year from all emissions. We know this because we monitor all emissions and calculate the dose (I did this for 17 years). We have to calculate it, because it is far too small to measure in the large background 'noise'. This is comparable with or even less than the radiation dose that people get from emissions from many coal burning facilities (about 20 microsieverts per year). It is also less than the dose you get because of cosmic radiation when you take a trans-atlantic flight or get a chest X-ray (about 70 microsieverts). If you take a holiday in a `health' spa anywhere, or on the beaches of some countries - say Brazil - your radiation dose could be about 2,000 microsieverts - every week - from good old mother nature! People in these areas do not tend to show signs of ill health because of radiation, but there are signs of unusually good health and longevity.

Around Pickering, radiation dose to the general public gets as high as **20 microsieverts a year** from routine emissions (almost half the dose you get from a single transatlantic flight!). This has caused fears and accusations of all manner of diseases, despite the people in the area getting at least 100 times higher doses all of the time from nature and medicine (and higher still if some natural radon rich homes are taken into account). It is not surprising that such health-effect accusations by those intent on terrifying a gullible public, when investigated in detail as they have been by independent university researchers funded by the AECB (now the CNSC), turn up nothing unusual.

Even the workers at Nuclear power plants turn out to be healthier than the general working population. With occupational doses that are about the same, or less, than natural background - and are about 1000 or more times those to the public from Nuclear Power, one would expect to see about double the health effects in the workers, rather than in the public, if there were an effect to see. These studies also show no obvious health effect other than unusually good health.

People DO die of cancer. The normal lifetime risk of cancer in a healthy society is about 33% incidence and about 20% death. Cancer rates in third world countries are much lower than ours generally because they don't live long enough to get it - cancer is mostly a disease of old age - except for smokers and those exposed to them. Our life expectancy is now pushing 80 years. We are the healthiest hypochondriacs in the world and believe that we are being killed by technology, herbicides, pesticides, chemicals and science, even when it is obvious that it cannot be true, or we would not live so long on average. By the way, are you aware that *Studies have shown that most people suffering from lung cancer carry matches in their pockets. Clearly match-carrying should be avoided at all costs!*

Health effects studies of many worker groups have now been published. These cover large groups of nuclear workers in Canada, Britain, France, and the US. The studies in the US - the Hanford study, the Oak ridge study, the National Cancer Institute study, the Shipyard workers study and several public studies. For example, a study of people around the Three Mile Island accident site, was conducted by Columbia University and Audubon! (the public didn't feel they could trust anyone else!). The results showed they were as healthy as anyone else, though some of the people who hired the researchers to study them, were outraged at the results. A U.S. federal court recently threw out the cases of 2,100 people claiming injury after the TMI accident in 1979. The court decided that scientific consensus agreed that any doses less than 100 mSv could not be shown to produce any injury. Since no one had received any dose anywhere near this, their efforts were too obviously aimed at the deep pockets of industry and the manipulable emotions of jurors. **All** of these industry and population studies show the same thing - nuclear workers are a healthy bunch and are not dying of any effect that can be related to radiation even after thirty years of work, and there is no definable health effect on any of the general public.

You should remember that the risks of radiation are, in theory, considerably higher to workers at these plants than to any member of the general public outside of them, yet the health effects focus, and publicity, is always upon the general public, who are more easily panicked and can be misled. Just like the weak minded and empty headed politicians! Similar studies have been done in Canada at AECL, Ontario Hydro, and around processing and mining areas. Generally there is an absence of radiation-related health effects. Atomic Radiation Workers (ARWs) are a healthy bunch!

Public studies all over the world show something even more interesting. Those who live in areas with higher levels of background radiation seem to have fewer cancers at the ends of their long lives than those who live in low background radiation areas (data from two groups of 70,000 people in China; the study of lung cancer mortality in every state in the US; radon studies, etc.)!

We have been working with radiation since 1895 when Roentgen discovered X-rays, though researchers had been exposed to man-made radiation since about 1850 and the first vacuum tubes. The first radiographers up to about 1920 (about 340 documented premature deaths), and other users of radiation, (for example users of radium therapy) encountered health problems from extremely high cumulative exposures. Some medical uses of radiation in the 1920s to 1950s, at heroic dose levels, are now also known to have caused health effects in some of those exposed. At low doses (less than 200 millisieverts total) and those spread out over time, there are very few data to suggest any health effect at all.

Surprisingly, some 1,000 published studies show a **beneficial** aspect of low doses of radiation other than its obvious benefit in medical useage. It is well known that a small dose of radiation before a larger one, gives a measure of short-term protection by stimulating the immune system (called adaptive response), just like vaccination does. Also experiments on rats and salmon and insects show that relatively high doses of chronic radiation produce healthier animals which live up to 30% longer and produce healthier offspring. This effect is called hormesis. We ignore it when we engage in radiation protection, and assume that all radiation is dangerous. We may be harming people as a result of being over-protective!

We use radiation in thousands of ways that benefit our lives directly, especially in medicine, (when used on people) and to sterilize medical materials, but also in industry generally, agriculture, biology, chemistry and physics. At the same time we are exposed to radiation from nature and from man's activities. We get paranoid about the latter exposures even when they are extremely small. One should not be afraid of radiation, but cautious. It is a tool. Like any other tool it can cause injury if it is used unwisely or if we are exposed to too much of it, just like medical drugs or vitamins.

The biggest environmental and social problems we face in the world today are ignorance and poverty, and not technology, progress or industry. The biggest problems for future generations will be magnified if we try to curtail their technological ability to deal with them; deny them adequate energy; or squander limited funds on imaginative environmental issues that harm almost no-one - and certainly do not cause environmental harm to the degree that is publicized.

Wealthy nations, solve environmental problems. Poor ones, can't. Studies show that until a nation gets to a per caput income of about $5,000, it is a significant net polluter. As that income is exceeded, the pollution begins to fall - they can now afford to address it - and as it continues to rise, they choose to spend more money, research, and effort into finding alternative ways of doing things that actually start to protect their longer term lifestyle and to do things cleaner, cheaper, and more efficiently. Now that was OBVIOUS wasn't it? But not at all what the activists want you to think.

Point Lepreau Generating Station (680 MW)

Mactaquac Hydro Station (660 MW)

Suggested Reading:

Cohen, B. 1983. Before Its Too Late. A scientists case for Nuclear Power. Plenum.

Cohen, B. 1990. The Nuclear Energy Option. An Alternative for the 90s. Plenum.

Living with Risk. 1987. The British Medical Association Guide. Wiley.

Whelan, E. 1985. Toxic Terror. Jameson.

Luckey, T.D. 1991. Radiation Hormesis. CRC Press.

Ray, Dixie Lee and Guzzo, Lou. 1990. Trashing the Planet. Regnery Gateway.

Lehr, Jay, H. (Ed.) 1992. Rational Readings on Environmental Concerns. Van Nostrand Reinhold.

Inhaber, H. 1984. Energy Risk Assessment. Gordon and Breach.

Simms, Gordon. 1990. The Anti-Nuclear Game. University of Ottawa Press.

A Few Key Web Sites.

nci.org (provides links to dozens of nuclear and anti-nuclear sites. The anti's never do this).

Junkscience.com (A daily review of technology news - good and bad).

SEPP: Cato: Rand: Reason: Hudson: DOE: bp.com: etc.

Jeremy Whitlock's Web page at www.ncf.carleton.ca

<u>Carrots Will Kill You! The Facts</u>.

- Nearly all sick people have eaten carrots.
- An estimated 99.9% of all people who die from cancer have eaten carrots.
- Another 99.9% of people involved in auto accidents, ate carrots within 60 days before the accident.
- Some 93.1% of juvenile delinquents come from homes where carrots are served often.
- Among people born in 1839, who later dined on carrots, there has been 100% mortality.
- All carrot eaters born between 1900 and 1910 have wrinkled skin, have lost most of their teeth and have brittle bones and failing eyesight.

(taken from the Miner Institute, N.Y.)

LOSS OF LIFE EXPECTANCY (COHEN 1990)

(* average over total US population. The rest are those exposed)

Activity or risk		**LLE (days)**
Living in Poverty		3500
Being Male (vs female)		2800
Cigarettes (male)		2300
Heart Disease	*	2100
Being unmarried		2000
Being black (vs white)		2000
Socio-economic status		1500
Working as a coal miner		**1100**
Cancer	*	980
30 lb. overweight		900
Grade school dropout		800
Sub-optimal medical care	*	550
Stroke	*	520
15 lb. overweight		450
All accidents	*	400
Vietnam army service		400
Living in southeast US		350
Mining construction		320
Alcohol	*	230
Motor vehicle accidents		180
Pneumonia, influenza	*	130
Drug abuse	*	100
Suicide	*	95
Homicide	*	90
Air pollution	*	**80**
Married to smoker		50
Speed limit 65 mph vs 55 mph.	*	40
Falls	*	39
Poison + suffocation + asphyxia	*	37
Radon in homes	*	**35**
Fire, burns	*	27
Coffee (2.5 cups/d)		26
Radiation worker (age 18 to 65)		**25**
Firearms	*	11
Birth control pills		5
All electricity - Nuclear (UCS)	*	**1.5**
Peanut butter (1 Tbsp/d)		1.1
Hurricanes, tornadoes	*	1
Airline crashes	*	1
Dam failures	*	1
Living near Nuclear power plant		**0.4**
All electricity - Nuclear (NRC)	*	**0.04**

<u>LEADING CAUSES OF DEATH FOR DIFFERENT AGE GROUPS</u>
(ACSH publication)

Age	Top 5 Causes of death	Top 5 causes of Hospitalization
0 to 12 months	1. SIDS 2. Congenital anomalies 3. Preventable injuries 4. Pneumonia/influenza 5. Septicemia	
1 to 4 years	1. Unintentional injuries 2. Congenital anomalies 3. Cancer 4. Homicide 5. Congenital heart disease	1. respiratory diseases 2. digestive diseases 3. nervous system disorders 4. infectious diseases 5. injuries
5 to 9 years	1. Unintentional injuries 2. Cancer 3. Congenital anomalies 4. Homicide 5. Congenital heart disease	1. respiratory diseases 2. injuries 3. digestive diseases 4. nervous system disorders 5. infectious diseases
10 to 14 years	1. Unintentional injuries 2. Cancer 3. Homicide 4. Suicide 5. Congenital anomalies	1. respiratory diseases 2. injuries 3. mental disorders 4. Diseases of the blood/ endocrine, nutritional and metabolic diseases and immunity disorders.
15 to 19 years	1. Unintentional injuries 2. Homicide 3. Suicide 4. Cancer 5. Congenital anomalies	1. pregnancy/childbirth 2. injuries 3. mental disorders 4. digestive disorders 5. respiratory diseases.

Source: National Association of Children's Hospitals and Related Institutions, Alexandria, VA.

SOME MILESTONES IN THE USE OF ENERGY

The first few million years of life on earth.	Passive solar energy, furs. Volcanic and geothermal heat. Fire - using wood; coal from surface outcrops; and tars and oil from surface seeps.
A few thousand years BC	Animal power. Wind energy.
A few hundred years AD	Mechanical energy from water.
1700 to 1800	Coal exploitation, better steam engines, Industrial Revolution. Mechanization of work, Oil Shales.
1800s	Conventional oil; flaring of gas. Massive growth in energy demand and use of coal, oil and water.
Late 1800s	Commercial electricity. Hydro-electricity development. Thermal Electricity. Automobile.
1900s	Air transport. Strong growth of electricity. Development of commercial nuclear energy.

WHERE ARE WE TODAY IN TERMS OF FOSSIL FUEL USE?

Epoch of Fossil Fuel Exploitation (After M.K. Hubbert)

```
    300--



    200--              *
1E12                  **
kWh/y                 **
                      **
    100--             ***
                     ****
                     ****
                    ******
    0-------------------------------------------------------------------------------
    •  -4   -3   -2   -1   0   +1   +2   +3   +4
```

TIME BEFORE AND AFTER PRESENT, 1E3 y.

SOUTH ASIA AND PACIFIC RIM COUNTRY STATISTICS

Country	Population millions	Access to Electricity %	Installed Capacity GW	Electricity Consumption kWh/cap/a	GDP/Cap $ Can	Growth Rate in GDP %
China	1150	66	138	525	436	13.9
Hong Kong	6	100	8	4358	20042	5.0
India	867	80	67	227	440	5.8
Indonesia	181	24	9	246	809	6.3
Laos PDR	4	12	0.16	43	288	5.1
Malaysia	18	82	6	1075	3574	10.4
Myanmar	42	6	0.81	45	599	1.9
Nepal	19	9	0.25	28	240	4.5
Pakistan	116	37	8	223	533	5.1
Philippines	63	61	6.2	331	990	0
Singapore	3	100	3.6	5218	16316	10.3
South Korea	43	100	21	2259	8195	3.4
Sri Lanka	17	29	1.3	154	667	10.6
Taiwan	20	100	17	3870	11987	6.8
Thailand	57	71	3	656	1808	7.2
Vietnam	67	?	2	87	347	?
Canada	30	100	109	17607	25372	2.9
Japan	124	100	196	6734	35699	2.3
USA	253	100	780	12767	23559	2.9

Electricity Today, September 1994.

SOURCES OF ENERGY IN SOCIETY

Transportable	Intermittent	Local
Coal	Solar	Wood
Petroleum	Waves	Water
Natural gas	Wind	Geothermal
Uranium	Tides	Biomass
(Tar sands)		Ocean thermal
(Oil shale)		Peat
Hydrogen		

ENERGY EQUIVALENTS FOR VARIOUS ENERGY SOURCES

Energy Source	Tons of coal needed to replace 1 ton of fuel
Breeder Reactor (U)	1,300,000
CANDU reactor (U)	20,000
Light Water Reactor (U)	16,000
Oil	1.5
Coal	1
Peat	0.25
Oil Shale	0.15
Geothermal Steam	0.1

RELATIVE COSTS OF FUELS ($Can)

To produce the same energy.

	Uranium 1 fuel bundle	**Coal** 400 tons	**Oil** 1800 barrels
1988	$3,055	$27,000	$33,000
1994	$2,000	$16,000	$22,000

COAL, OIL, NUCLEAR - RELATIVE COSTS TO 1989.

- Point Lepreau GS, cost about $1.4 billion to build, after a period of inflation that added to the costs of all projects at the time.

- More than 37 billion kilowatt hours of power have been generated to the end of 1989, and about a billion dollars was brought into the provincial economy by exports of electricity from PLGS to the US.

- Uranium fuel cost for this power was $ 90 million.

- Oil for this power would have cost $1.5 billion.
  (57 million barrels of oil). Capital cost of a plant to burn it would have been about an additional $600 million.

- Coal for this power would have cost $750 million.
  (13 million tons of coal). Capital cost of the plant to burn it would have been about $600 million.

Assuming a thirty year lifetime for thermal power plants and a 90% lifetime capacity factor, the electricity generated from a 680 MW plant will be 1.6E11 kWh - 160 billion kilowatt hours.

At 6 cents per kWh this translates to earnings of close to 10 billion dollars.

About 1% of these earnings (**about 100 million dollars) may be the cost of decommissioning**. For this reason about 1% of the cost of electricity is earmarked for such end costs.

Fuel costs over this lifetime are very approximately estimated to be:

for coal	-	$2.9E9 (2.9 billion dollars!)
for oil	-	$4E9 (4 billion dollars!)
for uranium	-	$0.36E9 (0.4 billion dollars)

Differences: 2,500 million dollars between coal and uranium and
3,600 million dollars between oil and uranium (assuming 1994 prices).

Re-tubing of a reactor may cost about 500 million dollars or less, but then its life is extended by several decades, so the highly-publicized cost is more than recovered.

ELECTRICITY AND NUCLEAR ELECTRICITY IN THE WORLD (1992) Atom 1993, July/August

Country	Generation, TWh, 1992 (actual)			Installed Capacity, GWe, 1992 (actual)		
	Total	Nuclear	%	Total	Nuclear	%
Australia	138.6	0.0	0.0	34.5	0.0	0.0
Austria	49.6	0.0	0.0	16.9	0.0	0.0
Belgium	68.2	40.9	60.0	14.1	5.5	39.0
Canada	**526.3**	**75.5**	**14.3**	**104.5**	**13.8**	**13.2**
Denmark	28.6	0.0	0.0	10.1	0.0	0.0
Finland	54.7	18.2	33.3	12.6	2.3	18.3
France	441.4	321.7	72.9	105.7	57.7	54.6
Germany	**498.2**	**150.0**	**30.1**	**117.2**	**22.5**	**19.2**
Greece	33.4	0.0	0.0	8.8	0.0	0.0
Iceland	4.0	0.0	0.0	1.0	0.0	0.0
Ireland	14.6	0.0	0.0	3.9	0.0	0.0
Italy	**213.9**	**0.0**	**0.0**	**61.9**	**0.0**	**0.0**
Japan	767.1	206.2	26.9	177.8	33.9	19.1
Luxembourg	0.6	0.0	0.0	1.2	0.0	0.0
Netherlands	73.6	3.5	4.8	17.4	0.5	2.9
New Zealand	**31.7**	**0.0**	**0.0**	**7.1**	**0.0**	**0.0**
Norway	117.6	0.0	0.0	26.9	0.0	0.0
Portugal	29.4	0.0	0.0	8.0	0.0	0.0
Spain	153.0	53.0	34.6	44.1	7.0	15.9
Sweden	**141.0**	**60.8**	**43.1**	**33.7**	**10.0**	**29.7**
Switzerland	55.9	22.1	39.5	15.5	3.0	19.4
Turkey	67.3	0.0	0.0	18.7	0.0	0.0
United Kingdom	302.0	66.3	22.0	74.5	12.0	16.0
United States	**3122.0**	**610.0**	**19.5**	**742.0**	**99.0**	**13.3**

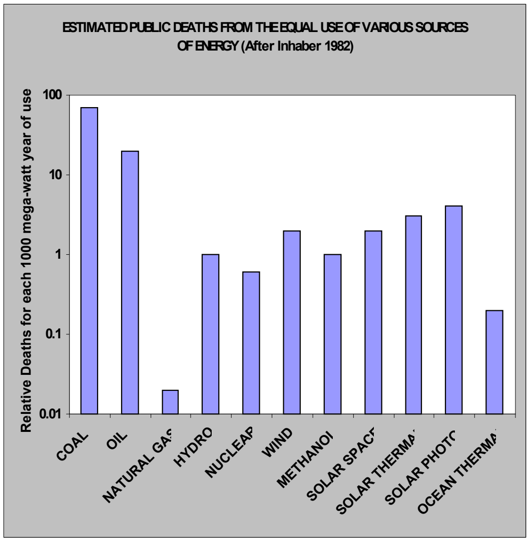
The 1984 data in the table below comparing the costs of coal and nuclear power are from an IAEA document, Nuclear Power: Status and Trends - 1987.

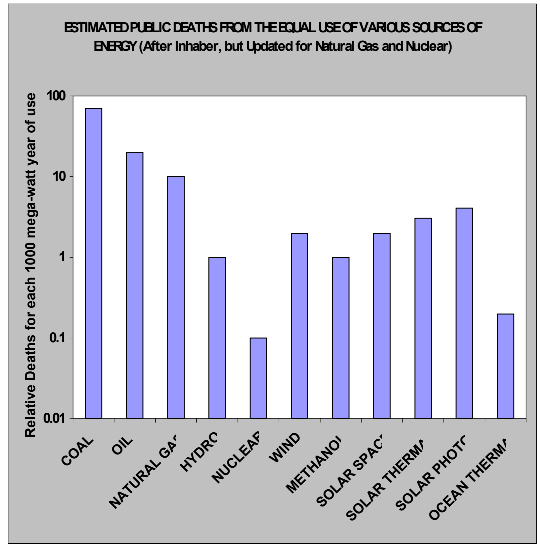
COMPARING ENERGY COSTS

Country	**Ratio of costs, Coal/Nuclear.** 1984	**
Belgium	1.62	1.79
Brazil		1.17
Canada: Central	1.44	1.33
West	0.66	0.82
China		1.30
Finland	1.3	1.20
France	1.80	1.45
FR Germany	1.68	1.42
India		1.42
Indonesia		1.20
Italy	1.41	?
Japan	1.37	1.28
Netherlands	1.31	0.95
South Korea		1.20
Spain	1.19	0.97
Turkey		1.05
UK: Sizewell B	1.40	1.06
Repeat Station		1.71
USA: Eastern	1.08	1.07
Rocky Mountain	0.77	0.81

** projected costs 1995 to 2000, assuming 30 year life, 72% capacity factor, and the price for coal at $60 for 26GJ/tonne, i.e. an average of $2.3/GJ, range $1.7 to $3.1

ATMOSPHERIC POLLUTION AND SOLID WASTE FROM WORLD ENERGY USE (Millions of tons produced in 1988)						
Sources	**Sulphur Dioxide**	**Nitrogen Oxides**	**Particulates**	**Carbon Monoxide**	**Carbon Dioxide**	**Solid Waste**
Coal	100	10	500	3	9000	200
Gas	<0.5	2	<0.5	5	4000	minor
Oil	40	10	2	200	9000	15
Wood	0.2	3	100	200	5000	50
Nuclear	0	0	0	0	0	0.04
Hydro	0	0	0	0	0	0
These are very approximate estimates. The use of gasoline in automobiles produces about 200 million tons of carbon monoxide each year, worldwide. In total contrast to that from fossil fuels, the entire solid waste product from nuclear power operations is managed and controlled.						





The graph on the left above shows Inhaber's 1982 extremely detailed Energy Risk Assessment data. When this study was first published there was a considerable outcry from those who fervently believed that the renewable technologies were risk free and relatively benign, and they objected to such comparisons being made. However, any honest evaluation of significant or highly publicized and widely promoted energy choices must include them all and examine the same issues.
When the book was first published, Natural Gas was relatively little used, and there were few data to show its risks to the General Public. All uses and risks then from gas use were assumed to be in electricity production rather than in its use for home heating. Today, Natural Gas is widely used in the public sector. Accidents in its transportation and public use are now better defined, with gas pipeline breaks, fires and explosions from the ignition of leaking gas in many cities where houses and even entire blocks have been destroyed by gas explosions and fires. Major accidents with large loss of life follow earthquakes when gas-lines rupture and major gas fires destroy damaged areas as in Kobe (1995) and Los Angeles (1994). Such accidents are likely to become more frequent as there are about 70 to 80 major earthquakes each year in the World, many of them in highly populated areas where natural gas is increasingly being used. An estimate of the broader risks from natural gas use (by me) is contained in the graph on the right.
The risks of Nuclear energy include those that are assumed for **chronic** radiation exposures that are typically much less than about 0.1% of those we get from natural radiation. The assumed linear relationship between acute and large doses and risk, and chronic low dose radiation and risk is scientifically unsupported. This relationship was derived from very large **acute** (instantaneous) doses and by extrapolating the effects down to zero dose. It does not allow for cellular repair mechanisms, adaptive response of cells, apoptosis (cell suicide), or hormesis (beneficial effects); all of which are significant. This is recognized as grossly overstating the risk of low dose exposures where there may actually be zero harm. Reduction of this calculated and much overstated risk of low dose radiation (as there are no observed effects), based upon the last six decades of scientific data, health studies, and medical research, is shown in the graph on the right.

Surprising <u>PERCEPTIONS (about 1993)</u>

<u>What US opinion leaders think:</u>

Practically speaking, how important a role do you think nuclear energy should play in meeting America's future energy needs?	**Very Important**	**32%**
	Quite important	**40%**
	Not too important	15%
	Not important	12%
	Don't know	1%

<u>What US opinion leaders THINK the US public thinks:</u>

What about the American public: Do you think the majority of Americans would say that nuclear energy should play an important role in meeting America's future energy needs, or do you think that the majority would say that nuclear energy should not play an important role?	**Important role**	**25%**
	Not important role	63%
	Don't know	12%

<u>What the US public REALLY thinks:</u>

Practically speaking, how important a role do you think nuclear energy should play in meeting America's future energy needs?	**Very important**	**35%**
	Quite important	**38%**
	Not too important	10%
	Not important	12%
	Don't know	5%

Atom 1993, July/August.

Hello! Hello! Is there anybody home?

Recent opinion polls (early 2001) show that about 70% of Americans favour nuclear power as a significant part of their energy; pretty well in line with the above.

FACTS ABOUT PLUTONIUM

1. Plutonium is NOT the most toxic material known to man. There are hundreds of compounds and many natural radio-nuclides more harmful: one of which, polonium-210, is common in cigarettes.
2. Plutonium has killed no-one in the last 55 years even though some workers have been significantly exposed to it.
3. Re-processed plutonium, shipped under international safeguards, is of little value for weapons and is thus of no interest to terrorists other than those who engage in terrorism through misinformation (Greenpeace and others).
4. It is not an external radiation hazard and can be safely handled. It is harmful if eaten in large quantities - like anything else.
5. It is less environmentally damaging than almost anything else moved by sea (e.g. oil).
6. An accident at sea with plutonium, could cause neither environmental catastrophe nor harm to life as it is relatively insoluble and not particularly toxic by ingestion. The plutonium is of high value and would undoubtedly be recovered, but could also be safely ignored.
7. Plutonium - reprocessed, recovered and recycled - is a very significant source of commercial energy with minimal pollution and little waste.
8. In a breeder reactor it can provide about 60 times more energy than is contained in uranium-235, used to produce energy in the present generation of nuclear reactors.
9. Weapons-grade plutonium, made by the military and kept in military stockpiles, is now being reduced. These weapons can be safely and responsibly eliminated in the energy cycle of commercial reactors.

TOTAL RISK PER UNIT NET ENERGY OUTPUT

(for 1 megawatt year)(Wyatt)

Energy Source	Total Person Days Lost (maximum estimate)
Coal	2,000
Oil	1,800
Wind	800
Solar Space Heating	150
Solar Thermal Heating	650
Solar Photovoltaics	700
Methanol	1,100
Nuclear	10 (too high, considering the inapplicability of the linear dose response hypothesis).
Natural Gas	7 (too low, considering the California and Kobe earthquake fires)
Ocean Thermal	30

Radiation risk data, assembled and assessed by scientific committees of medical radiation specialists - BEIR, UNSCEAR and ICRP - are based upon high, usually acute, radiation exposures, some of which are listed below. Most are from medical exposures.

Hiroshima, Nagasaki survivors (1945) **
Tuberculosis patients
Ankylosing spondylitis patients
Radium dial painters (osteosarcoma)
Thorotrast patients (liver tumours)
Cervical cancer patients
Tinea capitis patients
Uranium and iron ore miners

Others which are now recognized as important or potentially important for future assessment are:

Bomb test fallout exposures (Utah, Nevada, USSR)
Radiotherapy patients (second tumours)
Chernobyl (statistically not very robust)
Ionising radiation and sunlight exposures (skin tumours)

- Radon in homes
- Health Spas
- Occupational studies
- High background area studies

** **Acute, high dose exposures**, and statistically the best study for the effects of high dose acute radiation. The rest of the studies are chronic exposures and often of much lesser dose.

- These studies show what is possibly a hormetic (beneficial) effect rather than injury!

One fact which is not well known or publicized is that a comparison between bomb test fallout and radiation released from Chernobyl, indicates that about 100 times as much radiation has been released from bomb tests than was spread around from Chernobyl. Except for the firefighters (about 29 of the 31 dead), who represent the only fatalities to date that can be safely attributed to this accident, exposures from this accident are chronic. Using Hiroshima/Nagasaki risk data there may be about 20 extra leukemias in this population (Brucer). However, the Hiroshima, Nagasaki statistics based upon acute exposures, do NOT apply. The major concern at this time is the 800 childhood thyroid cancers that were unexpected, leading to three deaths. It is not at all certain, that these cancers are in any way related to Chernobyl, as the statistical data base for these areas was remarkably deficient at this time, and the natural rate of thyroid cancers seems to have been reported as being much lower than occurs in the West. When any correction is made, the paper increase seems to get blamed on Chernobyl - the nearest target. Thyroid cancer is easily treated in the West, but probably not in Russia at this time.

<u>Average Population Equivalent Dose From Natural And Man-Made Sources</u> (microsieverts per year).

Natural Background (about 75% of dose)	Cosmic Rays Radon Daughters External Terrestrial Internal Sources	330 600 440 200	1570
Medical exposure (about 25% on average)	Diagnostic X-Rays Radiotherapy Nuclear Medicine	300 50 5	355
Fall-out (0.6%)	Weapons Testing	10	10
Occupational doses (non-nuclear) (about 0.45%)	Medical Dental Research and Education Industry (non-nuclear)	2 0.5 0.5 0.3	3
Miscellaneous sources (about 0.5%)	Colour TV, Air Travel, etc.	3	3
Nuclear Power Generation (projected)* (about 0.1%)	Uranium Mining Reactor Operation Other Fuel Processes Transportation Accidents	1 15 3 0.01 0.5	20

- Assuming that every Canadian province generated 50% of its electricity from Nuclear Power.

SOME TYPICAL NUMBERS

Natural radiation impacting upon or within the human body in one hour.

(At a background radiation dose of about 2,000 microsieverts/year)

IN 1 HOUR:

500,000 Cosmic rays pass through our bodies.

15,000,000 Potassium atoms decay inside us.

30,000 Radon atoms decay in our lungs.

200,000,000 Gamma rays from soil, pass through us.

RADIATION DOSES IN VARIOUS PARTS OF THE WORLD. (from Luckey, HP Newsletter, June 1995).

	millisieverts/year
US average	2.6
Nile Delta	3.5
Exposed Workers (a)	3.6
Chernobyl Limit (b)	5
Hormesis allowance - proposed.	5
Kerala, India	4 - 13
Guarapari, Brazil	10 - 18
Meaipi, Brazil	22
Gerais, Brazil	23
Kerala Beach	23
Hormesis allowance - workers - proposed.	26
Araxi, Brazil	35
Optimum? Hormesis.	100
Ramasari, Iran	243
Guarapari Beach	263

a) This estimate includes natural plus industrial exposures.

b) The limit used to displace 200,000 persons from the Chernobyl area!!

TOTAL CANCER MORTALITY IN NUCLEAR WORKERS.

(Luckey. Radiation Protection Management. 1995)

Plant	SHIPYARD (US)	WEAPONS (US) *	WEAPONS (UK)	ENERGY (OH)
Author	Matanoski	Gilbert	Kendall	Abbatt

NUMBER OF WORKERS

Controls	111,757	20,619	58,945	21,000
Exposed	40,774	15,318	36,272	4,000

YEARS OBSERVED

Total	16	33	30	20
Mean	8	17	15	10

LIFETIME WORKING EXPOSURE

Man Sv	1095	1140	3,066	280
mSv/Worker	27	74	85	70
mSv/y	3.4	4.3	5.7	7.0

CANCER MORTALITY

Control Dead	3,086	718	584	463
Control Rate	27.6	34.8	9.9	22
Exposed Dead	968	318	96	8
Exposed Rate	23.7	20.8	2.6	2
Ratio	**0.84**	**0.60**	**0.27**	**0.09**
p Value	<0.001	<0.001	<0.001	<0.001

The controls, are all taken from within the working population at each location.

* Hanford, Oak Ridge and Rocky Flats.

A LOG-SCALE OF RADIATION DOSES (14 decades!)

millisieverts	
100,000	Typical acute dose to the thyroid - radiation therapy.
	Largest annual radon dose - tin mine in Cornwall.
	Dose to Chernobyl firefighters who died.
10,000	Hospital Leukemia treatment - 50% successful.
	Largest annual radon dose in a UK home.
	Astronaut doses in space from cosmic radiation.
1,000	
	No obvious effects below 200 mSv acute dose.
	Annual radon dose, Health Spa workers (200 mSv).
	Annual natural radiation dose in parts of the world.
100	
	Annual dose to a pack-a-day smoker (80 mSv) from natural polonium-210 in tobacco.
	Annual dose limit to Radiation Workers (20 mSv).
10	Approx. annual dose to commercial flight crews.
	Estimated acute CAT scan dose.
	Typical natural background annual dose (2 mSv).
	Average annual dose to workers at Point Lepreau.
1	New annual dose limit for the general public.
	Typical acute chest X-ray dose (less than 0.2 mSv).
0.1	Annual dose from fallout from past bomb tests.
	Dose from one return flight - NB to BC (40 uSv).
0.01	Annual dose from luminous signs, TV, smoke detectors.
0.001	**Annual dose to local residents from Point Lepreau emissions (1 uSv).** (Some environmental groups try to terrify people by implying health effects here.)

0.000,000,01	For all times up to 10,000 years, the estimated mean annual dose to an individual of the critical group from nuclear fuel waste disposal is less than this dose! Also used to terrify people!

A FEW RADIATION USES IN SOCIETY

Medical Uses:

Diagnostic Radiology
Radio-therapy
Nuclear Medicine
Radio-Immuno-Assay (RIA)
Production of isotopes
Sterilization of supplies

Industrial and other Uses:

Food Irradiation

Radiography
Sterilization of garbage and sewage
Sterilization of packages
Airport Security
Water Purification
Thickness Measurements
Curing Plastics, varnishes
Anti-static devices
Smoke detectors
Bore-hole logging
Satellite Energy systems

Screw Fly eradication (SIT)

Biological Tracers
Groundwater flow measurements
Energy for remote lighthouses and buoys
Wood Treatments
Archaeology
Art work - identifying forgeries
Agricultural uses
Permanent press creases
etc.