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Subject: Biscane Bay Nuclear Expansion Program: Written Submission
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Dear Sir/Madam,

It is my understanding that the NRC is accepting written submissions regarding its proposal to build a nuclear power plant on Biscayne Bay. Accordingly I attach a written submission, and should be most grateful if you would acknowledge receipt by return e-mail.

Sincerely,
Professor Simon Glynn, Ph.D.

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THE THREE FALACIES OF PANDORA: THE ACHILLES HEEL OF NUCLEAR POWER.

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Abstract.

At a time when global warming due to greenhouse gas emissions poses a clear and present threat to the environment, the Nuclear Power Industry is gearing up to provide a solution to this problem. And while 40% or 2 in every 5 of those people currently alive in the US (where cancer rates have doubled in the last 25 years) are expected to get cancers, of which between 80% and 90% are environmentally caused, the nuclear power industry trades upon the following fallacies to argue that it neither makes, nor will in future make, any *significant* contribution to these or other radiation linked diseases:

1. That there is a safe level of exposure to radiation, below which it does no harm.

2. That in any event the radiation emanating from nuclear power production is only a small proportion of the total level of radiation, from all sources, to which we are exposed, and thus produces a similarly small proportion of the health effects resulting therefrom.

3. That so long as we monitor radiation levels to insure they do not exceed permitted maximums, expansion of the industry may proceed without producing intolerable health costs.

The paper exposes these fallacies and argues, to the contrary, that even should the industry be able to avoid all accidents, routine radioactive emissions to the environment during power production, and most especially, fuel reprocessing, threaten to destroy all human life on the planet!

Key Words: Nuclear, Environmental Pollution, Radiation Accumulation, Cancer, Lead and Lag Times

THE THREE FALACIES OF PANDORA: THE ACHILLES HEEL OF NUCLEAR POWER.

With the active engagement of Coalition forces in Afghanistan and their continued deployment in Iraq being motivated in no small part by geo-strategic concerns that we protect “our” oil supplies, and confronting global warming due to greenhouse gas emissions which threaten to turn the blue planet into a brown cinder, it is perhaps unsurprising that the Nuclear Energy Industry, largely mothballed since the 1980’s, is being resuscitated.

However, just 5 kg of plutonium from a reactor, the core of which contains tonnes of radioactive material, constitutes a critical mass able to produce a nuclear explosion, capable of destroying, for instance, much of NewYork, and of contaminating the remainder of the city and well beyond, at levels that would produce unacceptably high health costs, for almost a quarter of a million years.[1] While unsurprisingly the proliferation of nuclear power technologies may lead, as the examples of India, Pakistan, North Korea and Israel demonstrate, and Iran may yet demonstrate, to nuclear *weapons* proliferation also. And the treat of nuclear *accidents*, such as occurred at Chernobyl, Three Miles Island and Fukushima, also increases with the expansion of the nuclear industry.

Yet T.S. Eliot insisted, perhaps prophetically, that “…the world ends not with a bang, but a whimper”, which is perhaps to say, not with nuclear war or accident, but with the rapidly escalating level of cancers, leukemias, genetic mutations, physical and mental deformities, retardations and still births etc. caused by the *routine* emissions of “low level” radioactive wastes into the atmosphere, the waterways and the oceans; releases which are an entirely planned part of the *normal everyday* operation of the nuclear fuel “cycle”[2] (Figure I). Indeed support for the nuclear energy industry has been largely predicated upon the following three fallacies:

1. That there is a safe level of exposure to radiation, below which it does no harm.
2. That in any event the radiation emanating from nuclear power production is only a small proportion of the total level of radiation, from all sources, to

which we are exposed, and thus produces a similarly small proportion of the health effects resulting therefrom.

3. That so long as we monitor radiation levels to insure they do not exceed permitted maximums, expansion of the industry may proceed without producing intolerable health costs.

However, nothing could be further from the truth.

Fallacy 1: Low Levels of Radiation Exposure are Safe.

Beginning then with the euphemistically labeled "low level" emissions, aqueous and airborne "radioactive emissions are about 100 times greater at the reprocessing stage than at the power production stage,"[3] (Figure 2) Strontium-90 (half-life[4] 28 years), Caesium-137 (half-life 27 years), Tritium (half-life 12 years), Krypton-85 (half-life 11 years) and Plutonium-239 (half-life 24,400 years) being just a few of the more than 200 radioactive substances routinely emitted into the environment.[5] Once there they are re-concentrated, by physical and biological processes and organisms, and passed up food chains and other "environmental pathways" to humans, to irradiate their unwilling hosts for well in excess of 10 times their half-lives.[6] Nor are the quantities involved trivial. For instance aqueous discharges from reprocessing facilities not unusually top half a million liters per day,[7] while, to take but one of the many atmospheric discharges, emissions of Krypton-85 often top 1 million Curies per year.[8]

As to the safety of such discharged, one Curie is enough to kill a person.[9] Indeed more generally, as two leading nuclear scientists, Lawrence Livermore Laboratory's Dr. John Gofman and Stanford University Senior Research Associate Professor Arthur Tamplin, have noted, "Nuclear electricity generation has been developed under the false illusion that there exists some safe level of radiation", yet "…even the smallest quantities of ionizing radiation produce harm, both to this generation of humans and future generations."[10] Sir Kenneth Mallenby confirms "Each exposure, even the least intense, does some damage…"[11]

This does not mean that everybody exposed to radiation, as we all are, contracts cancer or leukemia, or genetic mutations that may be passed on to future generations. However "…as the radiation dose goes up, the risk of future cancer development (and other radiation induced diseases and mutations etc.) goes up in direct proportion."[12] Thus, double an individual's radiation exposure and you double the risk that he or she will get cancer or receive some other harmful, perhaps fatal, mutation. Halve the exposure and you halve the risk. But note two things. Firstly, that no matter how much you reduce an individual's exposure, so long as there is *any* exposure to radiation whatsoever, the risk of cancers or other harmful mutation remains, *the effect of radiation being directly proportional to the dose down to the lowest does and dose rate.*[13] (Figure 3) And secondly, that what to an individual is a *risk* is, to a population at large, an inevitable *cost*. Thus, for example, a risk of 1 in 100 per year of contracting cancer, for a population of 100, translates into a cost of 1 new cancer per year, or 20 over a 20 year period, and for a population of 1,000, it is a cost of 10 new cancers per year, or, for a population of 1 million, 10,000 new cancers a year, year in and year out!

And yet while 40% or 2 in every 5 citizens currently alive in many of the advanced industrial countries (including the US where cancer rates have doubled over the last 25 years) are expected to get cancers, of which 80%-90% are environmentally caused,[14] the nuclear power industry continues to maintain that it makes no *significant* contribution to these and other radiation linked diseases!

Fallacy II: The Nuclear Industry's Relatively Small Contribution to Environmental Radiation Levels has a Correspondingly Small Impact on Health.

Specifically the industry argues that radiation levels emanating from nuclear power production are a small proportion of the total radiation levels to which we are exposed, thus inviting the *wholly incorrect* inference that it contributes a similarly small proportion of the health effects resulting from radiation exposure.

Incorrect because while the health costs of radiation are, as we have seen, directly proportionate to the radiation *dose,* that dose is related not only to the *intensity* of the source, but its *proximity* also. (Here the inverse square law applies. *viz*. Halve the distance from the source and the dose goes up 2^2 or 4 fold. Quarter the distance and the dose goes up 4^2 or 16 fold etc. etc.) While unlike the naturally occurring background radiation, emanating either from geological formations, which are usually relatively *stable* and thus *static* and at some *distance* from our immediate habitat, or from cosmic rays, which are wholly *removed* therefrom, or medical X-rays, TVs and the like, which are *contained*, *intermittent* and *terminable* at will, emissions from the nuclear industry tend to be highly environmentally *mobile.* Furthermore, due to their physical and/or biological properties, they concentrated to high localized levels in various "environmental pockets" or "ecological niches." From there they may be transported up various "environmental pathways", including food chains, not only to close *proximity* with, but also *into the bodies* of, humans, thus delivering (as per the inverse square rule) proportionately greater radiation doses, year in year out, which is to say *continuously,* for what, in the case of those many radionuclides with half-lives of more than a few years, are functionally *interminable* periods, well beyond the subject's lifespan. (Figure 4)

For example, Plutonium-239, upon being released at "low levels" to be diluted by the sea, being dense, sinks to the bottom where it is thus physically re-concentrated to higher levels before being absorbed by bottom feeding organisms which biologically re-concentrate it further[15] and pass it up to human, via both fish, or even by cows grazing on reclaimed land,[16] which also re-concentrated it before passing it back, via milk and beef. Similarly airborne emissions of radioactive Strontium-90 and Iodine-131, falling on land, are also physically and biologically re-concentrated and passed up to humans.[17] (Figure 4)

Furthermore, just as the physical and biological properties of nuclear wastes influence their distribution in the environment, similarly they influence their distribution in the human body, where they may be further re-concentrated to yet higher levels in particular "target organs"[18] to which they deliver a concomitantly higher radiation dose, resulting in a concomitantly higher risk of radiation induced cancer. For instance radioactive Caesium –137, though often much diluted in the sea, may be concentrated by as much as 1000 fold by fish, before being passed back to humans to be re-concentrated still further in the gastro-intestinal tract, which it then irradiates at close quarters, causing stomach cancers. Nor are such radioactive contaminates necessarily passed through us. Thus just as we biologically concentrate low levels of calcium in our diets to higher levels constitutive of teeth and bones, Strontium-90 being bio-chemically similar to calcium is, once absorbed, also concentrated and incorporated into our bone structure, from where it, affectively interminably, irradiates the marrow, at the closest quarters, causing bone marrow cancers and leukemia, while Iodine is concentrated in the thyroid, and the breast, and therefore, if it happens to be radioactive Iodine-131 delivers high radiation doses, causing thyroid and breast cancers. Caesium-134 concentrates in the heart, and Ruthanium-106 concentrates in the gastro-intestinal tract and the bowls. Similarly Plutonium-239 concentrates both on bone surfaces and in the liver, and, as a respiratory aerosol, on the lungs,[19] thus delivering higher doses to these organs, and therefore producing proportionately high numbers of liver and lung cancers.(See Figure 5)

These then are just a few of the more than 200 radioactive elements routinely emitted from the nuclear power industry,[20] often to be re-concentrated and passed up food chains and other environmental pathways to their unwilling hosts, where, once absorbed into the body, they may further concentrate in specific sites or organs, to which, consequently, they often deliver radiation doses that are many times higher than they would if there were uniform distribution of radioactive waste over the whole environment or even the whole body. Consequently the practice of averaging radiation doses over the whole environment, or indeed even over the whole body, results in the most extreme underestimation of health costs. A problem which is further exacerbated by the fact that not all the sights and organs where such concentration takes place have been identified, while even some of those that have been identified have not been officially designated as target organs. As the Royal Commission on

Environmental Pollution (R.C.O.E.P.) 6th Report, *Nuclear Power and the Environment,* acknowledged, for example, "Plutonium forms chemically organic complexes and finds its way into a number of organisms, not all of which are yet generally recognized as specific target organs."[21]

Moreover, in addition to concentrating in specific organs, radioactive material often further concentrates within a particular area of an organ.[22] For example Plutonium-239 is thought to concentrate on the periphery of the lungs. Yet in an absolute and potentially fatal reversal of the "precautionary principle,"[23] -- a reversal unfortunately all too often characteristic of nuclear watchdogs -- it has been the practice of the International Commission on Radiological Protection (ICRP) to average the radiation dose received over the whole organ "unless there is clear evidence that this assumption is not conservative".[24] Furthermore, as if this were not sufficient cause for concern there is also considerable debate as to whether so called Alpha-emitters,[25] of which Plutonium-239 is one, may not be several times more carcinogenic than previously suspected,[26] while some highly respected scientists have suggested that they may even be up to 1,000 times more carcinogenic.[27] A claim which, if true, it has been officially recognized, might well preclude the use of Nuclear Power altogether.[28] However, here again in absolute contradiction of the precautionary principle, it is simply assumed that that there is no additional danger! A *modus operandi* which, in effectively shifting the burden of proof to nuclear critics, who, unfunded by the industry, often have inadequate resources and time at their disposal, invites disaster; the more so if the rapid expansion of the nuclear industry presently being planned, comes to fruition.

Fallacy III: So long as we Monitor Radiation Levels and Health Effects closely, the Industry can Proceed Without Exceeding Acceptable Limits.

In response to all such objections proponents of nuclear expansion argue that so long as we monitor radiation levels and health effects we may continue emitting radioactive discharges into the environment until such time as they approach accepted limits, confident that if and when such practices begin to impose unacceptable health risks/costs upon the population, we may then limit, or even curtail, such operations, as necessary.

However, such an approach supposes that we know much more than we do, and that we have a greater consensus among scientists than we in fact have, concerning the health risks/costs accruing to an extensive range of levels and number of forms that "low level" radiation may take; knowledge that would entail, at a minimum, that we were confident that we had identified *all the major pathways*, as well *as all the key mechanisms of radioactive re-concentration operative both in the environment and in our bodies*, and *the significance of each*, which, as already indicated, we most certainly have not. Moreover such an approach also, most importantly, and potentially fatally as we shall now see, fails to take adequate account both of *the lead time, between the release of radioactive wastes etc. and the initial detection of the first significant increase in manifest cancers resulting therefrom*, and of *the lag time, between the cessation of emissions and the eventual cessation of all the cancers resulting from them.*

Leads, Lags, and Latencies

Thus to begin with *lead times*, let us take the case where 2 observers, noting that an individual who has jumped off a 10 story building remaining unharmed as s/he falls past the 9th floor, concludes such behavior is safe and immediately follows suit, to be followed in turn by 3 others, and so on and on, until, by the end of the *lead time,* between the first person jumping and the danger of their behavior being signaled by their hitting the ground, there are many people above him/her falling, each of whom will, in turn, meet his/her demise in similar fashion (Figure 6). Similarly, to move from the hypothetical to the actual, doctors continued to prescribe the drug Thalidomide, to prevent morning sickness, to increasingly large *new* cohorts of women entering the 3rd month of pregnancy, for at least 7 months, between the first cohort taking the drug, and the severely deformed babies to which they subsequently gave birth signaling its dangers. Consequently, even the immediate cessation of Thalidomide prescription at the end of this 7 month *lead time* (between the drug being prescribed to the first cohort and their giving birth to deformed babies) was too late to prevent the other cohorts of women who had been prescribed the drug during that *lead time,* from giving birth, over a corresponding *lag time* of 7 months, to other deformed babies; the magnitude of the tragedy being exacerbated by the fact that, due to the increasing popularity of this drug, each cohort was, in and of itself, larger than the previous one.

Latency Leads

But while with Thalidomide the *lead time* during which mutations remain *latent* is a matter of a few months, in contrast "there is usually a delay of some years, or even decades, between irradiation and the appearance of cancer."[29] Indeed the *latency period,* which is to say "The period between radiation injury and obvious cancer is quite long in the human. Leukemia … takes at least 4 or 5 years. Other cancers may take as long as 20 years, the intervening period is silent, the person does not realize it is going on."[30] And even if the initial detection of the *first significant cohort* of cancers traceable to nuclear emissions resulted in the immediate and completely cessation of such emissions, it would already be too late to prevent the additional cohorts of cancers, *already* caused by these emissions over the (up to 20 year) period that the first cohort remained latent, appearing over a corresponding *lag time.* Nor, most unfortunately, would this be an end to it, for, as we shall detail later, these same emissions will, of course, remain in the environment, and continue to irradiate it and those in it at significant levels, for at least 10 times their half-lives, which in many cases is well after further emission of radioactive wastes may have ceased.

And as if all of this did not provide sufficient cause for concern, the problem is further exacerbated by the fact that unlike the aforementioned birth defects, which were traced almost immediately to Thalidomide, the prescription of which was promptly discontinued, cancers, (the rate of which has increased by approximately 3% a year cumulative, over the last 25 years) leukemias, and genetic mutations etc. clearly have a number of different causes, the relative contribution of nuclear waste emissions to such health costs being subject to much dispute; a circumstance which further militates against timely identification and regulation of this source. Moreover, unlike Thalidomide, which was, of course, taken by only a small fraction of pregnant women, who at any one time are themselves only a small faction of the population at large, the entire population is, to a greater or lesser extent, exposed to radiation from nuclear emissions, thus making the potential dangers it poses, greater by several orders of magnitude!

Transportation Leads

Important as the impediment to timely identification of these dangers and regulation of their source may be however, there are a number of other, potentially even more significant impediments to timely action. For example, unlike Thalidomide, which is immediately ingested, nuclear waste may, and indeed often does, have a relatively circuitous route and concomitantly long *transportation lead time,* between its initial emission, and its arrival in environmental proximity to, and/or ingestion by, humans; a *transportation lead time* which clearly must be added to the *latency lead time* in order to calculate the *total lead time*, between emission of radioactive wastes and the manifestation of the first cancers resulting therefrom.

Regarding such transportation lead times then, as, for example, the Royal Commission on Environmental Pollution noted with regard to emissions from the UK nuclear reprocessing plant at Windscale, or Sellafield as it is now called:

> "Nearly all the Plutonium that is currently discharged to sea at Windscale ends up as bottom sediments, some of these move into the Ravensglass estuary…it is known that the estuary contours are changing with time because of the net landward movement of sediment…sediments that are above high tide level and are no longer wetted may blow about in the dry windy weather and possibly form repertory aerosols.[31] A smaller hazard could arise

> from grasses grown on newly reclaimed land which may support cattle as happens now."[32]

In light of such examples we should not be surprised to discover that this *transportation lead* between the emission of radioactive wastes, and their proximate irradiation of humans, which in some cases may be almost instantaneous, and in others less than *1 year*, may in yet other cases be well over *20 years* (depending on the particular environmental pathway the radionuclide takes) which when added to the *latency period* (as previously indicated not atypically somewhere between *4 or 5years*, and *20 years*, depending on the form of leukemia or cancer etc.) results, not atypically in a *total lead time* (comprised of the transportation lead + the latency lead) of, for example, somewhere between (say 1+4 =) *5 years* and (20+20 =) *40 years* between the *emission* of nuclear wastes and the *manifestation* of significant numbers of leukemias or cancers arising therefrom. A *total lead time* during which we may remain oblivious of such adverse effects of radioactive emissions, which we may therefore continue to discharge to the environment.

<u>Lags and Dose Delivery Spans</u>

Furthermore even in the extremely unlikely event that immediately following this *total lead time* (of, as per our example, between 5 and 40 years, depending upon the environmental pathway, and the leukemia or cancer etc. involved) the first cancers etc. emanating from radioactive wastes were immediately detected, and their source immediately identified and completely shut down, not only would the arrival, in proximity to the population, of the last wastes emitted immediately prior to the shutdown *lag* this shutdown or cessation of emissions for the transportation *lead*, not atypically of 10 years, but as already hinted, all emissions would, of course, continue to irradiate the environment and those in it, at significant levels, year in, year out, for 10 times their half-lives; a *dose delivery span,* as we shall call it, during which they would continue to make significant contributions to the *incidence* of new cancers etc.! Which, of course means that *the total lag time between the emission of nuclear wastes and the cessation of cancers etc. caused by them* will in many cases be hundreds, or, in the case of Plutonium-239, hundreds of thousands, of years.

Summation

To sum up so far then, in addition to the problems posed by our limited knowledge of the different mechanisms and pathways etc. by which nuclear wastes physically and biologically re-concentrate in the environment, and, up environmental pathways, in humans, the difficulties of identifying and regulating the health risks/costs resulting from the emissions of nuclear wastes are further, greatly, exacerbated **by i) the *transportation lead*, between the *release* of such radioactive waste and its *arrival*, *via* the various environmental pathways, to the population, ii) the *latency period* between the *genesis* and the initial *manifestation* of diseases eventually identifiable as emanating from such wastes etc. and iii) the *dose delivery span* between the *start* of irradiation of the population by such materials, and its *cessation* due to their half-life decay. These collectively result in *a total lag, between the emissions of any particular batch of nuclear wastes and the cessation of all cancers emanating therefrom, which can be of the order of a quarter of a million years! Indeed in consequence*** *of these leads, spans and associated lags,* ***the first statistically significant incidents of disease emanating from such nuclear sources will, even if nuclear power production and its associated emissions are immediately identified as the source and ended, inevitably constitute an extremely small "tip"@ of a huge "iceberg".***

Growth of Nuclear Power: Electricity and Other Energy

And these intractable difficulties, both of detecting health costs and efficaciously regulating their source, caused by such leads, spans and lags, are further exacerbated by the fact that, in order for nuclear power to make any notable contribution, either to filling the growing "energy gap" arising from the increasing demand for, and dwindling supply of, fossil fuels, and/or to reducing the emission of globally warming greenhouse gases, it would have to greatly, and fairly rapidly, increase its contribution to our total energy supply, and consequently the *rate* of emission of radioactive wastes.

Thus, the nuclear industry's *gross* annual energy production currently amounts to approximately 20% of annual US *electrical* energy production; while electrical energy currently accounts for approximately 40% of *total* annual US energy production, to which nuclear energy's *gross* contribution is therefore something of the order of 8%. This compared with "green" energy's (hydro, geothermal, wind, solar etc.) approximately 7% contribution, Oil's approximately 40%, Coal's 22% and Natural Gas' 23% contributions to *total* US energy production.[33] However, in light of the energy investment needed to build and decommission reactors, to operate the nuclear fuel cycle, and most significantly, the uninterrupted source of energy required to stir and cool high level wastes,[34] which must be managed and contained for periods in excess of 10 times their half-lives (for Plutonium-239 for instance, a period approaching a quarter of a million years!) -- a task at which the nuclear industry has so far demonstrated itself to be spectacularly incompetent[35]-- it is not entirely clear whether, *in the long run*, the nuclear power industry will prove to be a *net* producer or a net consumer of energy!

Nevertheless even if we were to make the charitable (though wholly unsupportable) assumption that nuclear energy's 8% contribution to US total energy production is *net,* the first point is that nuclear energy could only be a portable source of power for transportation if we were to build a reactor into each vehicle (as currently with nuclear *powered* submarines and aircraft carriers for example) which would seem environmentally, if not economically, infeasible. Nuclear power therefore in fact being largely restricted to supplying electrical energy, it follows that only if a large percentage of that sizable proportion of transportation, heating, manufacturing and other industrial, commercial and residential demand currently supplied by non-electrical sources, were to switch to electricity, would nuclear energy be in a position to make any truly significant contribution to reducing our dependence on highly polluting and/or rapidly diminishing oil, coal and gas resources**.** Let us therefore assume such a switch to electrical energy.

Now in light of the fact that even a modest 3% exponential or cumulative annual increase in economic output -- necessary merely to keep apace of population growth and increased urbanization – would imply a slightly more than doubling of energy demand in the 25 years[36] which would seem to be the minimum time it would take alternative "green" energy and conservation technologies to *begin* rendering us substantially independent of unclean and finite energy resources, it would seem not unreasonable to conclude that nothing less than a 10 fold increase in nuclear energy generation over, say, the next 10 years, would come anywhere near to making any substantial contribution to our resource depletion and greenhouse gas problems. Let us assume then -- as an illustrative (though revisable) example – just such a 10 fold increase in nuclear power generation over the next 10 years, and that, for ease of calculation, it is linear, and that having reached this point where it can supply a truly significant amount of our total energy, nuclear power then continues, steady state, to produce approximately the same amount of energy per year, at least until the time, just guesstimated as at least 25 years from now, as "green" energy technologies begin making a substantial contribution to the replacement of unclean and finite sources.

Under such a set of illustrative assumptions then whatever number of kilowatts of electricity, let us say K, that the nuclear energy industry produces in the 1st year, it will generate twice as many, or 2K, in the 2nd, three times as many, or 3K, in the 3rd year….and 10K in the 10th and final, year of expansion, and would then continue to operate at approximately the same, 10K per year, level for some time thereafter (Figure 7)**.**

Accumulation of Nuclear Pollution, Radiation Dose and Health Costs

Annual and Accumulated Nuclear Emissions (Figure 8)

Now whatever the quantity of "low level" *radioactive emissions* it produces in the 1st year, let us say X, the *annual discharges of radioactive waste* may reasonably be expected to be proportionate to, and therefore to increase in direct proportion to increases in, the energy output. In which case, consistent with the assumptions of our illustrative model, we might expect such ***annual** emissions* to be 2X in the 2nd year, 3X in the third year …reaching 10X at the end of the 10th or final year of expansion, and to proceed, steady state, at 10X per year thereafter. This being so then the *emissions **accumulated*** by any given year, derived by adding up the emissions over the preceding years, will be 1X in the 1st year, 1X+2X= 3X in the second year, 1X+2X+3X=6X in the 3rd year …. up to 55 X by the end of the final, 10th year, of expansion, and will continue to accumulate at 10X per year, thereafter (Figure 8).

*Accumulated Emissions and **Annual Radiation Dose*** (Figure 9)

Assuming that on average and in general radioactive emissions distribute themselves in the environment and those in it, in a relatively similar manner year in year out, then, other things being equal, the ***annual** radiation dose* in the 1st year, let us say Y, which the population *will* receive from such emissions, once, following the *transportation lead* -- which, as already noted is not atypically somewhere between less than 1 year and 20 years or more, and which we shall unscientifically but not unreasonably take, for illustrative purposes, to be *median* times of 10 years -- they become proximate to the population, *will*, of course, *be proportionate,* (not to the emissions discharged in the year in question, but rather) *to the accumulated emissions;* which is to say 1Y in the 1st year, 1Y+2Y= 3Y in the 2nd year, 1Y+2Y+3Y=6Y in the 3rd year… reaching, under our illustrative assumptions, 55Y (gross, minus a relatively small allowance for half-life decay[37] to derive a *net* figure) at the end of the 10th year *after arrival in proximity to the population*; these *annual* radiation doses continuing to increase, proportionately to increases in accumulated emissions, by 10Y per year thereafter .

***Accumulated Radiation Dose** and Health Costs* (Figure 10)

Now, as we noted earlier, the *health costs*, which is to say those cancers, leukemias, genetic mutations, physical and mental deformities and still births etc., caused by radiation, go up in direct proportion to radiation dose, while, **most significantly**, as the International Atomic Energy Agency notes "…the noxious effects of ionizing radiation are cumulative."[38] Thus ***the health costs*** (let us express them in units Z) which will begin to manifest themselves once the *latency period* -- which as already noted is not atypically anywhere between 4 years and 20 years, and which we shall unscientifically but not unreasonably take, for illustrative purposes, to be a *median* time of 15 years -- has passed, ***ARE PROPORTIONATE NOT TO THE ANNUAL, BUT TO THE ACCUMULATED, RADIATION DOSE.*** And just as in order to calculate the *accumulated* radioactive emissions present in the environment by the end of any given year we must add that year's radioactive emissions to those of all preceding years, in order to calculate the *accumulated radiation dose, and* thus *the health costs accumulated proportionate thereto,* by the end of any given year, we must add the radiation dose received in that year, to that received in each of the preceding years (see Figure 10). While ***it is***, of course, as we have seen**, *not until the end of the total lead time* --** which is to say the *transportation lead* which (being as already noted, not atypically between less than a 1 year and 20 years or more) we shall for illustrative purposes, not unreasonably take to be a median *of 10 years,* plus the *latency period,* taken above to be a median time *of 15 years,* for a total median lead time -- ***of*** **(say** 10 years+15 years=) ***25 years***, ***that the cancers, leukemias and other health costs, resulting from the 1st year's emissions*****, *will begin to manifest themselves in significant numbers.***

Leads, Lags and Overshoot

This being so, then by the time significant health costs emanating from the 1st year's emissions manifested themselves (following the 25th year after their emission) *the radioactive emissions already accumulated in the environment would,* as per our example (see Figure 10), *be 205 times greater than those, emitted in the 1st year, responsible for these first manifest health costs. And* ***the accumulated radiation dose, and as yet latent health costs proportionate thereto, would be*** *of the order of -- 645 (gross)* (see Figure 10) minus a, say

20%, allowance for half-life decay of the most significant radionuclides,[39] which is to say significantly **more than -- *500 fold (net), or 50,000% greater than those (resulting from the 1st year,*** *and) manifesting themselves following the 25th year.* Furthermore, due to the transportation lead, a large proportion of radioactive wastes, emitted over the 10 years immediately prior to the 25th year termination of the program, would not yet have arrived in close enough proximity to the population to irradiate it at significant levels. However by the end of this further 10 year transportation lead time, which is to say at the end of the 35th year, **the accumulated radiation dose, together therefore with the incidence of cancers, leukemias, genetic deformities, still births, heart and other diseases proportionate thereto, *manifest and latent*, would have increased --** 2245 fold (gross) (see Figure 10) minus say 30% allowance for the half-life decay of the most significant radionuclides, which is to say -- **well in excess of 1,500 fold (net) or 150,000%.**

Nor, of course, would this be an end to it, for having finally arrived in proximity to the population, and maximized the dose *rate,* these wastes would continue irradiating the environment and those in it at significant levels, thereby adding to the overall health costs, for the dose delivery span of at least 10 times their half-lives,[40] (which is to say, in the case of some emissions, for almost quarter of a million years) all but doubling the aforementioned (2245 gross, 1,500 fold net) increase in accumulated radiation dose and health costs over the *next* 15 years (up to the 50th year) for example.

<u>Of Sailors, Dinosaurs, and Chickens Coming Home to Roost</u>

Let us then, for the sake of argument, assume that the first manifestation of significant numbers of cancers emanating from nuclear emissions, appearing immediately after the total (transport and latency) lead time, at the end of the 25th year, constituted, say, 1 in 1,000 or 0.1% of all the cancers, deriving from all sources, first manifesting themselves in that year. Let us further make the **extremely optimistic, not to say entirely unrealistic, assumptions** that a) such a miniscule percentage increase in the overall cancer rate was immediately detected, and b) their source was immediately identified, and c) shut down, resulting in the complete cessation of nuclear emissions at the end of this 25th year. Now, as we have just seen, we would, as per our illustrative example, still expect the number of cancers, and other health costs, *manifest and latent*, to have emanated from this source by the **35th year** to be over 1,500 fold greater than the 0.1% increase in the overall cancer rate *manifesting* itself at the end of this 25th year (see Figure 10). This would therefore imply a (0.1% x 1,500 =) 1.5 fold increase in the overall cancer rate, although, of course, not all of these cancers would become manifest until the end of the 15 year latency period, which is to say in the 50th year (again see Figure 10). While in view of the previously noted fact that, even before the effects of the projected expansion of the nuclear program are factored in, 40% of the current US population are expected to contract cancer, this would therefore imply a (40% + (40% x 1.5) =) 100% overall cancer rate. Put otherwise, ***even if we assume that, following the 25 year median total lead time into the proposed (illustrative) program, we could immediately detect an increase in the annual rate of cancers, emanating from all sources, as miniscule as 0.1%*** (which overall manifest cancer rate is, incidentally, currently increasing by around 3% per year) ***and that we could immediately identify its source as nuclear, and completely shut it down, then under the not unreasonable assumptions of our illustrative example, the entire population would have contracted cancers by the end of the next ten years*** *(which is to say the end of the 35th year)* ***and would have manifested them, following the fifteen year latency period, by the 50th year!***

Nor would this be an end to it, for the radioactive emissions accumulated up to the cessation of the program would, of course, continue to irradiate the environment and those in it for 10 times their half-lives; the accumulated radiation dose, and *manifest and latent* cancers proportionate thereto *potentially* all but doubling during the aforementioned fifteen year period between the 35th and 50th year (see Figure 10). So that even if the illustrative example has assumed greater increases in the rate and ultimate scale of the expansion of nuclear power generation than is in fact likely, and concomitantly we revise our illustrative assumptions downward in favor of a substantially smaller increase in nuclear generating capacity, and even were we to cut the lead and lag times, or some combination thereof, considerably, and adopt entirely unrealistically optimistic assumptions regarding the early detection of such health costs along with early identification and prompt termination of their source, the proposed continuation of, not to say increases in, nuclear power generation, would probably still risk human extinction, and clearly risk truly enormous health costs.

Concomitantly the presumption, under which the nuclear industry has been tolerated, that it is comparatively safe for us to continue, and even to expand, nuclear generating capacity so long as the controlling authorities continually monitor health data, and remain prepared to shut down the industry as soon as significant adverse health effects are detected, is clearly a recipe for disaster. **The analogy of an ocean liner, the forward momentum of which outpaces its captain's capacity to detect obstacles ahead sufficiently early to steer clear of them, comes to mind. Indeed perhaps, like the Dinosaur, we are already dead in our front brain, only our back brain does not know it yet!**

An Alternative Energy Policy

In light of such considerations then, it should be obvious that even a comparatively short term increase in and reliance upon nuclear power as a stop gap measure until such time, say in 25 years, as it could be expected that increased R&D in alternative energy sources might enable these alternative sources to outpace increases in total energy demand sufficiently to begin to substitute for nuclear power also, would pose unacceptable health costs. This being so, it seems clear that a much more prudent approach would be to begin immediately to switch current and projected investment in nuclear power to R&D in Wind, Solar, Wave, Geothermal, Hydro, Biomass etc. and the energy transmission and storage technologies which will enhance their viability, and to already proven technologies, such as Fluidized Bed Combustion, Magnetohydrodynamic Suspension,[41] Combined Heat and Power, Electrostatic

Precipitation etc., as well as potentially fruitful ones such as Integrated Gas Combined Cycle, and Carbon Sequestration (capture and storage) all of which, by increasing the efficiency or/and reducing or/and controlling the emissions of oil and coal etc. can provide a medium term solution to our energy, resource and pollution problems, until such time as alternative “green” sources are able to completely replace them.

Figure 1

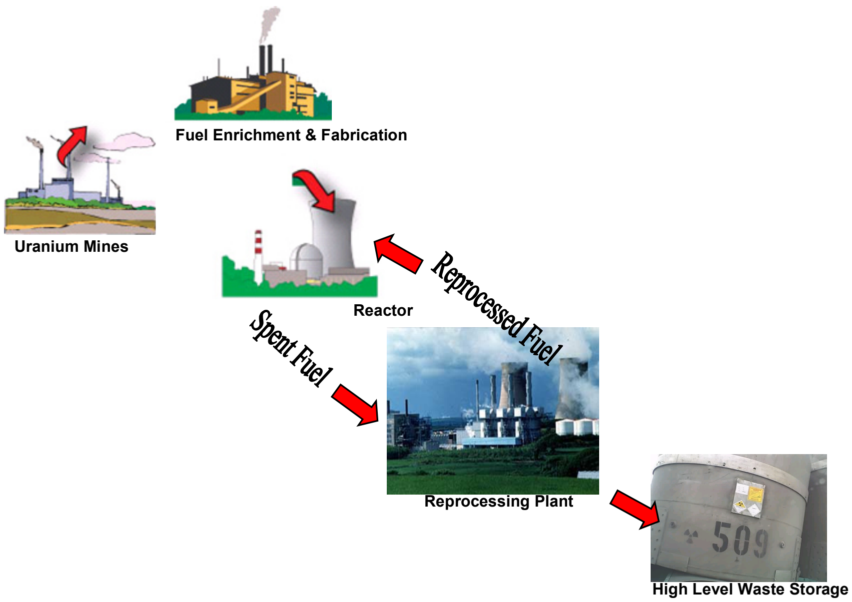


Figure 2

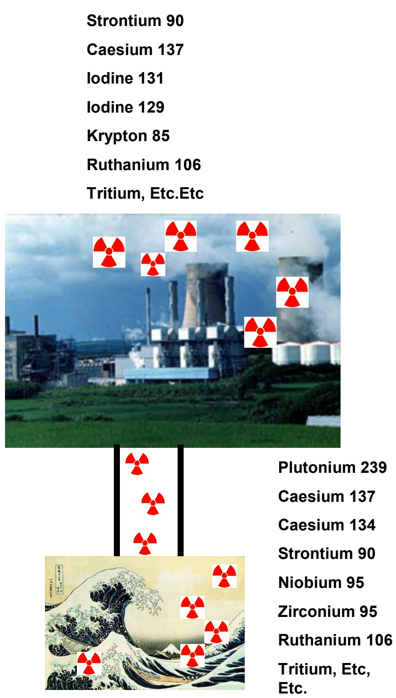


Figure 3

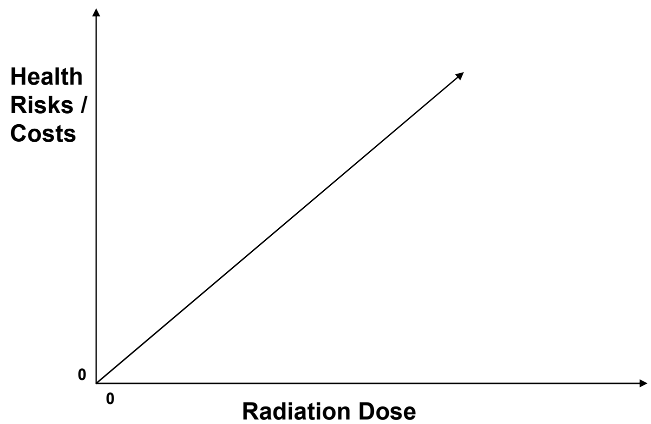


Figure 4

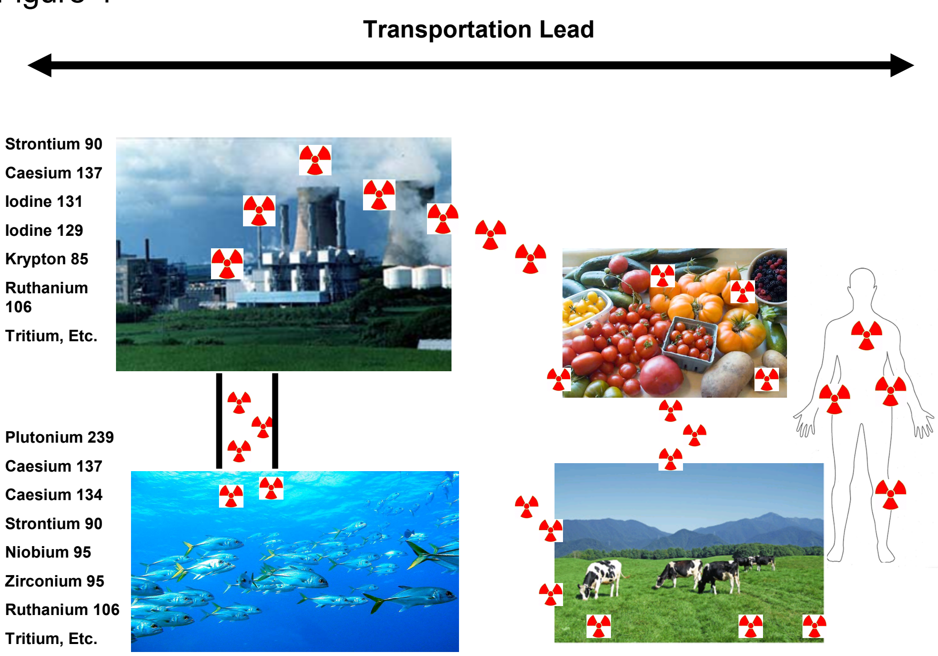


Figure 5

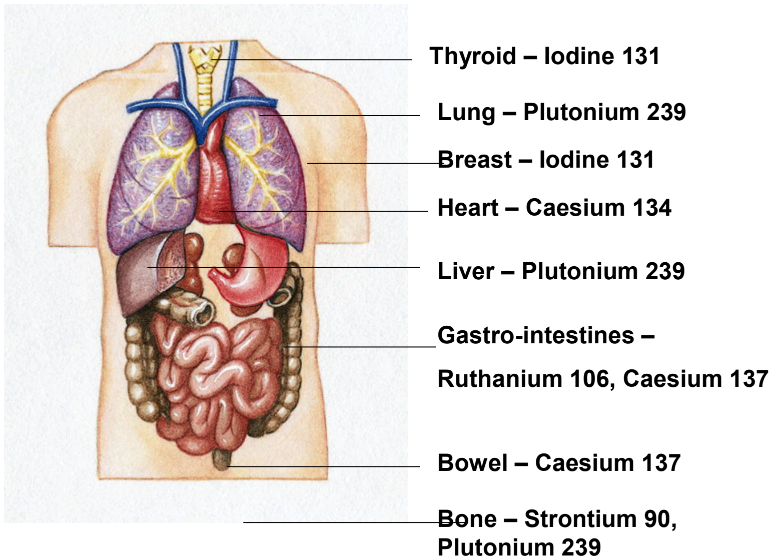


Figure 6

Figure 7

Yr	Annual Energy
1	K
2	2K
3	3K
4	4K
5	5K
6	6K
7	7K
8	8K
9	9K
10	10K
11	10K
12	10K
13	10K
14	10K
15	10K

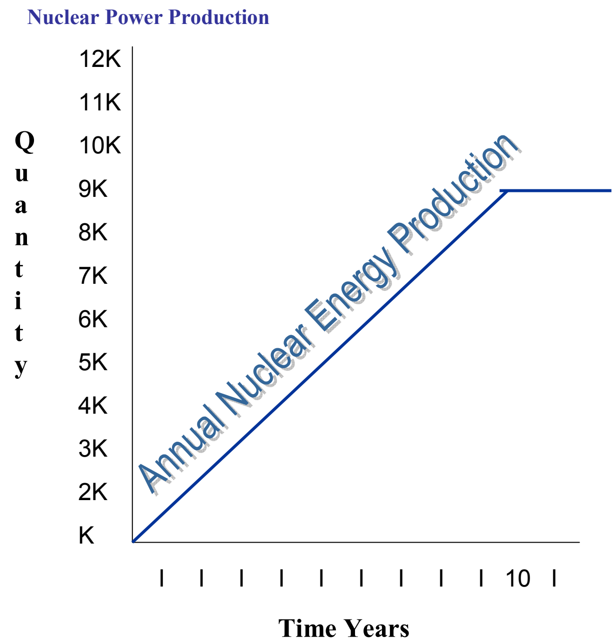


Figure 8

Year	Annual Emissions	Gross Accumulated Emissions
1	x	x
2	2x	3x
3	3x	6x
4	4x	10x
5	5x	15x
6	6x	21x
7	7x	28x
8	8x	36x
9	9x	45x
10	10x	55x
11	10x	65x
12	10x	75x
13	10x	85x
Etc	etc	etc

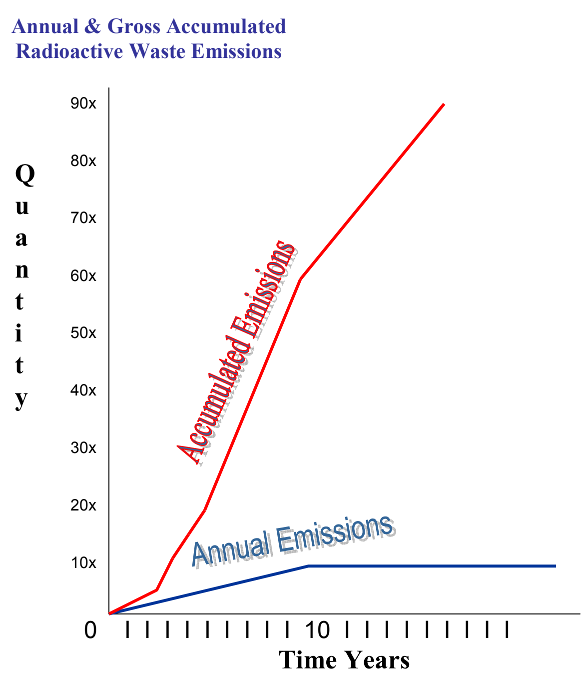


Figure 9

Yr	Gross Accumulated Emissions	Gross Annual Radiation Dose
1	1x	Transport Lead
2	3x	
3	6x	
4	10x	
5	15x	
6	21x	
7	28x	
8	36x	
9	45x	
10	55x	
11	65x	1y
12	75x	3y
13	85x	6y
14	95x	10y
15	105x	15y
16	115x	21y
17	125x	28y
18	135x	36y
19	145x	45y
20	155x	55y
21	165x	65y
22	175x	75y
23	185x	85y
24	195x	95y
25	205x	105y
26	215x	115y
27	215x	125y
28	215x	135y

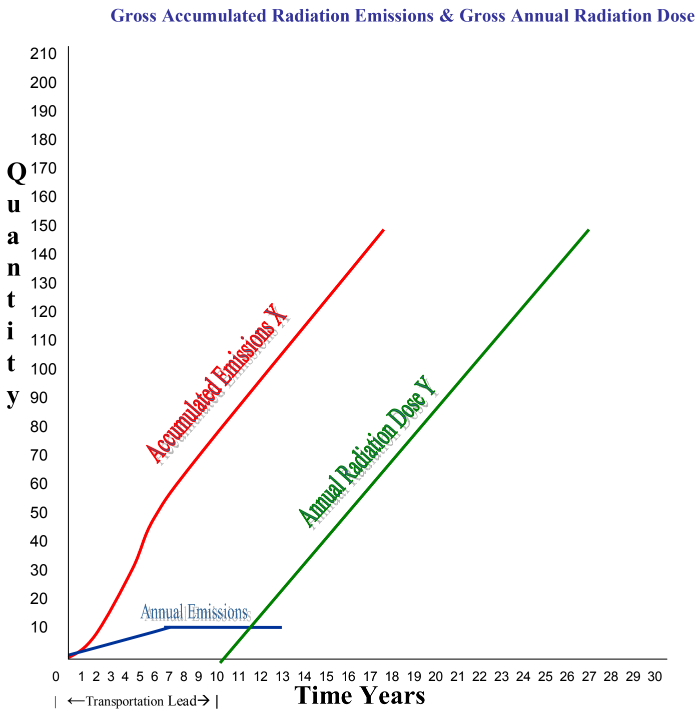
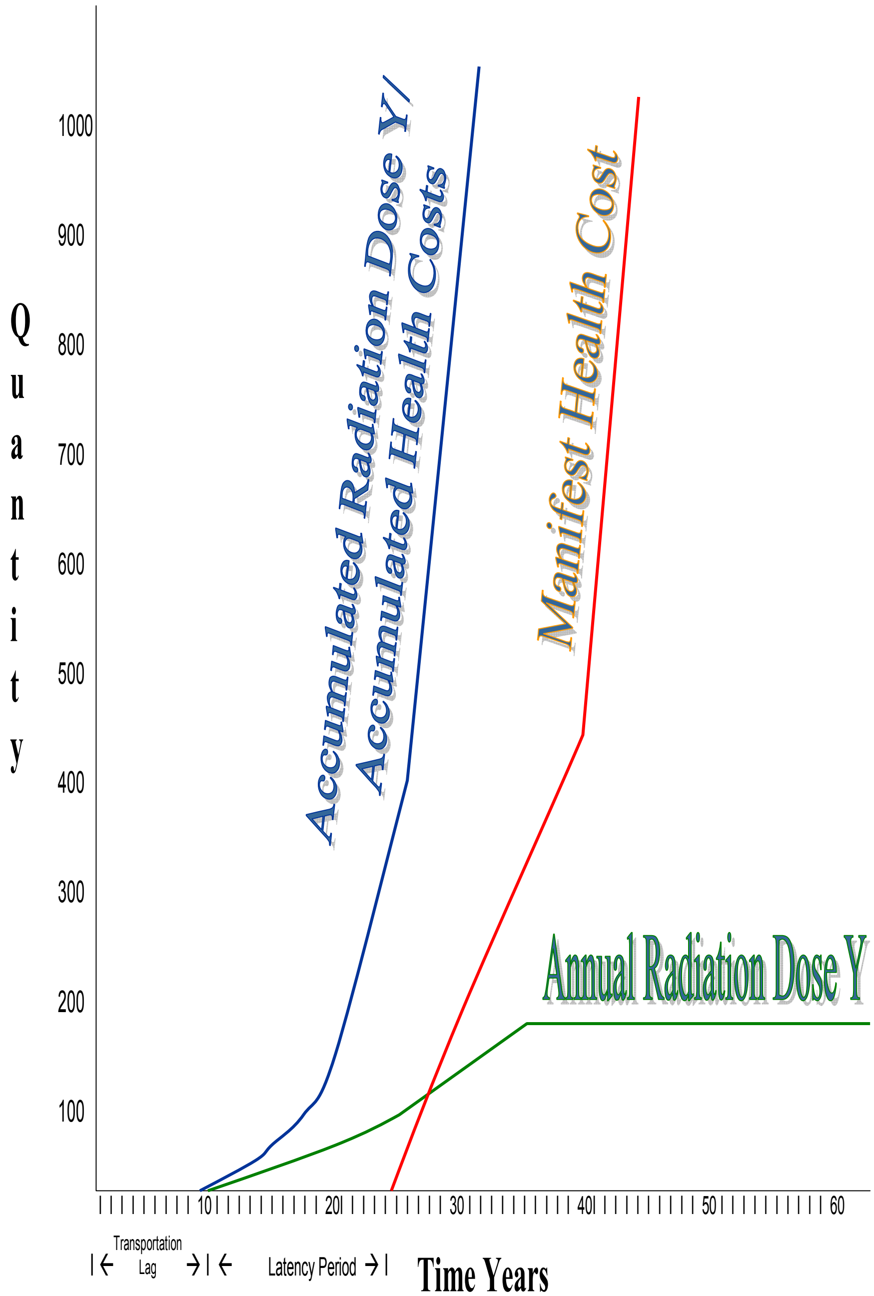


Figure 10
Accumulated Radiation Dose and Health Costs (Gross)

Yr	*Annual Energy Output/ Emissions*	*Accumulated Emissions (Gross)*	*Annual Radiation Dose (Gross)*	*Accumulated Radiation Dose/ Health Costs (Gross)*	*Manifest Health Costs (Gross)*
1	1K/X	1X	Transport Lead	Transport Lead	Latency Period
2	2K/ X	3X			
3	3K/X	6X			
4	4K/ X	10X			
5	5K/ X	15X			
6	6K/X	21X			
7	7K/X	28X			
8	8K/X	36X			
9	9K/X	48X			
10	10K/X	55X			
11	10K/X	65X	1y	1y/z	
12	10K/X	75X	3y	4y/z	
13	10K/X	85X	6y	10y/z	
14	10K/X	95X	10y	20y/z	
15	10K/X	105X	15y	35y/z	
16	10K/X	115X	21y	56y/z	
17	10K/X	125X	28y	84y/z	
18	10K/X	135X	36y	120y/z	

19	10K/X	145X	45y	165y/z	
20	10K/X	155X	55y	220y/z	
21	10K/X	165X	65y	285y/z	
22	10K/X	175X	75y	360y/z	
23	10K/X	185X	85y	445y/z	
24	10K/X	195X	95y	540y/z	
25	10K/X	205X	105y	645y/z	
26	0K/X	205X	115y	760y/z	1z
27	0K/X	205X	125y	885y/z	4z
28	0K/X	205X	135y	1020y/z	10z
29	0K/X	205X	145y	1165y/z	20z
30	0K/X	205X	155y	1320y/z	35z
31	0K/X	205X	165y	1485y/z	56z
32	0K/X	205X	175y	1660y/z	84z
33	0K/X	205X	185y	1845y/z	120z
34	0K/X	205X	195y	2040y/z	165z
35	0K/X	205X	205y	2245y/z	220z
36	0K/X	205X	205y	2450y/z	285z
37	0K/X	205X	205y	2655y/z	360z
38	0K/X	205X	205y	2860y/z	445z
39	0K/X	205X	205y	30655y/z	540z
40	0K/X	205X	205y	3270y/z	645z
41	0K/X	205X	205y	3475y/z	760z
42	0K/X	205X	205y	3680y/z	885z
43	0K/X	205X	205y	3885y/z	1020z
44	0K/X	205X	205y	4090y/z	1165z
45	0K/X	205X	205y	4295y/z	1320z
46	0K/X	205X	205y	4500y/z	1485z
47	0K/X	205X	205y	4705y/z	1660z
48	0K/X	205X	205y	4910y/z	1845z
49	0K/X	205X	205y	5115y/z	2040z
50	0K/X	205X	205y	5320y/z	2245z
51	0K/X	205X	205y	5525y/z	2450z
52	0K/X	205X	205y	5730y/z	2655z
53	0K/X	205X	205y	5935y/z	2860z
54	0K/X	205X	205y	6140y/z	3065z
55	0K/X	205X	205y	6345y/z	3270z
	Etc	Etc	Etc	Etc	Etc



Quantity
1000
900
800
700
600
500
400
300
200
100
Accumulated Radiation Dose Y/
Accumulated Health Costs
Manifest Health Cost
Annual Radiation Dose Y
10
20
30
40
50
60
Transportation Lag
Latency Period
Time Years

ENDNOTES

[1] The half-life (or time it takes to become half as radioactive) of Plutonium-239 is almost 24,400 years, while radioactive substances continue to pose significant health hazards for 10 times their half-lives.
[2] Taken to include not just re-cycling from power plant to reprocessing plant, and back, but uranium mining, fuel enrichment and storage and management of long term high level wastes.
[3] Tyler-Miller, G, *Energy & Environment: Four Energy Crises* (California: Wadsworth Publishing Co., 1975) p. 74. See also, Cook, E, Energy for Millennium Three, in *Technological Review*, December 1972, pp. 16-21.
[4] See endnote 1 above.
[5] Ehrlich, P. R., *Population Resources & Environment* (San Francisco: W. Freeman & Co., 1970), p.132.
[6] The half-life of a radioactive isotope is the time that must elapse before naturally occurring radioactive decay reduces the radioactivity of the isotope by half. Such radioisotopes are a significant health hazard for between 10 and 20 times these half lives (thus with a half-life of 28 years, Strontium-90 for e.g. released today will represent a health hazard for at least 280 years, while Plutonium-239, with a half life of over 24,000 years, will continue to irradiate the environment and those in it, at significant levels, for nearly a quarter of a million years).
[7] Tyler-Miller, G., *op. cit.,* p.74.
[8] See for example *The Royal Commission on Environmental Pollution (Sixth Report)* Chaired by Sir Brian Flowers (Hereinafter *R.C.O.E.P.*) "Nuclear Power and the Environment" (London: HSMO, 1976) p. 142.),
[9]Wilson, R. and Jones, W. J., *Energy, Ecology and Environment* (London: Academic Press Inc., 1974) p.245.
[10] Gofman, J. and Tamplin, A., *Poisoned Power* (Emmas PA 18049, Rodale Press, 1971) pp. 93 & 92-3.
[11] Mallenby, K., *The Biology of Pollution* (London: Edward Arnold, 1972) p. 2.
[12] Gofman and Tamplin, op.cit. p. 73.
[13] For support of this "No Threshold Linear Relation" see, for example: a) Stewart, A. & Kneale, G.W., "Production of Cancer and Leukemia in Children while in Utero" (*Lancet*, 5th June 1970) p. 1185, b) Jablon, S. and Belsky, J.L., "Production of Leukemia in Japanese Survivors of the Atomic Bombing of Hiroshima and Nagasaki" Paper presented to the 10th Annual Cancer Congress (Houston, Texas: May 1970), c) Hempleman, L., "Production of Thyroid Cancer in Children Irradiated by X-Rays" (*Science* 188, 160: 1968) pp. 158-163, d) Russell, W.C., Nucleonics 23, No. 1, 1965, pp. 53-62, e) L.V. Shelesborger et al "Production of Breast Cancer in Rats by X-Rays and Gamma Rays" – Radiation Induced Cancers (Vienna: International Atomic Energy Agency 1969) p. 161, f) Frinkley et al "Production of Cancer in time by Radiation" in Ibid. p. 369, g) Upton, A.C., "Production of Lymph Cancer in time by Gamma Rays" in Ibid. p. 425.
[14] See for e.g. Epstein, S., *The Politics of Cancer Revisited* (USA: East Ridge Press, 1998).

[15] Noshkin, V.E., *Health Physics* 22, 1972, p.537.
[16] *R.C.O.E.P.*, *op.cit.,* p.135, para. 352.
[17] See for example,Wilson, R. and Jones, W.J., *Energy, Ecology and Environment* (London: Academic Press Inc., 1974) p.251.
[18] See for example *R.C.O.E.P.*, p. 20, paras. 54-6.
[19] *R.C.O.E.P.* p.20.
[20] Ehrlich, P.R., *op. cit.,* p.132.
[21] See for example, *R.C.O.E.P*, p.24, para. 67.
[22] *Ibid,* p.24, para. 68.
[23] The precautionary principle is, of course, the principle that, should we feel there to be any significant chance of a risk/cost of one sort or another we err on the side of caution, and assume that there is indeed such a risk/cost unless and until it is proved otherwise. As with "Pascal's Wager," and indeed insurance generally, the justification for adopting such a principle is that the potential cost of imprudence is infinitely more than the cost of prudence.
[24] *R.C.O.E. P.* p. 24, para. 68.
[25] Radioactive sources may be Alpha, Beta, Gamma or Neutron emitters.
[26]. While so called Alpha particles are not terribly penetrating, as they dissipate so much of their energy over such a short path, for this very same reason they are thought, once absorbed by the body, to be much more carcinogenic than other particles. See, for example, J. W. Gofman & A. R. Tamplin*, Poisoned Power,* pp. 60-61.
[27] See for instance,Gofman, J.W., and Cochran, T.B., *Radiological Standards for Hot Particles,* (Washington: Natural Resources Defense Council, 1974), Lovins, A.B. and Patterson, W.C., *Plutonium Particles: Some Like Them Hot, in Nature,* Vol. 254, March 1975, pp. 276-80, and Tamplin, A.R., in *New Scientist,* March 20th, 1975.
[28] *R.C.O.E.P.* p.24, para.69.
[29] *R.C.O.E.P.,* p. 18.
[30] Goffman and Tamplin, *op. cit.,* p.67.
[31] A prospect that is particularly concerning when we remember that the official U.S. tolerance level for inhaled Plutonium is two billionths of a gram (1/150,000,000,000 of an ounce), and that some highly respected scientists have indicated that even this level may, in some circumstances, be 150,000-300,000 times too high! (See Gofman, J.W., and Cochran, T.B., *op. cit.*)
[32] *R.C.O.E.P.*, p.135.
[33] U.S. Government Official Energy Statistics, Annual Energy Review @ http://www.eia.doe.gov/aer/pecss_diagram.html
[34] Such wastes often take the form of extremely radioactive contaminates mixed with nitric and other acids used during reprocessing, which have to be stored in thick walled steel tanks, and which, as a result of absorbing their own intense radioactivity often boil and build up pressure, and consequence have to be constantly cooled and stirred to prevent eruptions that may, and often do breach containment, leaking 10's of 1000's of Curies of their waste into the surrounding environment. We get some idea of the scale of the problem when we consider

that that over 100 million gallons, and 100's of Billions of Curies of high level waste, are already currently being stored in the US alone and that "one year of operating of a single large nuclear plant generates as much of long-persisting radioactive poisons as one thousand Hiroshima atomic bombs" (Gofman, J.W. and Tamplin, A.R., *IEEE Transactions on Nuclear Science*, 1970 , Vol. N5-17, No.1, p. 22) .

[35] See for example Wilson, R., and Jones, W., *Energy Ecology and the Environment* (London: Academic Press Inc., 1974) p.326, The US, AEC, "Nuclear Fuel Supply" and Speth, J.G., *et al* "Plutonium Recycling: The Fateful Step*"* in *Bulletin of the Atomic Scientists,* Nov. 1974, p.21, which catalogue just a few hundred thousand gallons of such waste that have escaped into the environment!

[36] Note, as a rule of thumb, in order to calculate doubling times for relatively small exponential or cumulative growth we divide the % growth rate (in our example 3) into 72.

[37] Thus while, as previously indicated, due to the radioactive decay the *radiation* emitted by these discharges will becoming relatively insignificant after the elapse of 10 half-lives, most of the radionuclides of particular concern to us have relatively long half-lives. (Plutonium-239 for instance, with a half-life of 24,400 years will continue to irradiate the environment, and those in it, at significant levels, for almost quarter of a million years, while Strontium-90, with a half-life of 28 years, will be a significant health hazard for only 280 years, Caesium-137 for 270 years, Iodine-129 for 160 years etc.). This, together with the fact that, in order to meet increasing demand for energy against a background of diminishing traditional sources, to which we have added concerns over greenhouse gas emissions, the nuclear industry would, absent major increasing inputs from renewable energy sources, have, as our hypothetical example assumes, to embark upon a rapidly expanding program, and that **consequently by far the largest volumes of radioactive waste will be discharged in later years**, means that it will be many years before half-life decay will have any *major* effect on the radioactivity of *accumulated* discharges.

[38] International Atomic Energy Agency, *Nuclear Power and the Environment*, (Vienna, I.A.E.A.,1973) p. 71.

[39] See 36 above.

[40] See 36 above.

[41] See for example, Hammond, A., Metz, W. & Maugh, T*., Energy and the Future,* (Washington D.C.: American Association for the Advancement of Science, 1973) pp. 11-28.