# Review of the report

# "Exposure to Radiation and Health Outcomes" June 2009
**By Dr. Mark Lemstra;**
**A Report Commissioned by the Canadian Centre for Policy Alternatives (Saskatchewan office) and the Saskatchewan Union of Nurses**

**Prepared for:**

**The Canadian Nuclear Association**


**By Dr. Douglas Chambers**

**SENES Consultants Limited**
121 Granton Drive, Unit 12
Richmond Hill, Ontario
L4B 3N4


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**Executive Summary**

The following is an overview summary of our review of the Lemstra report ("Exposure to Radiation and Health Outcomes"). More detailed comments and references are provided in the attached Appendix.

In brief, our overall opinion is that Lemstra's review is both incomplete and misleading. We agree that it is well established that there are risks from exposure to ionizing radiation. However, the potential effects of exposure are in direct proportion to the dose from that exposure. Lemstra purports to provide an objective review of "*evidence-based epidemiology*", while in effect providing a superficial review of the literature he selects for review.

Of particular concern is Lemstra's misrepresentation of excess relative risks (ERR) from his review of the epidemiology. In his section A, Lemstra reports ERR for exposure to ionizing radiation as "%" but fails to mention that these are ERR projection factors for a dose of 1 Sievert (Sv[1]) and not the ERR for the doses actually received which are much lower than 1 Sv. This is an incorrect interpretation of the epidemiology, as the ERR of a group would be determined by combining the ERR projection risk factor with the dose received by the group. Doses of interest today are orders of magnitude smaller than the 1 Sv used in the projection factors; therefore, the ERR to populations of interest are orders of magnitude smaller than the ERR projection factors that Lemstra presents.

Lemstra has very limited discussion of doses received; therefore it is impossible for him to estimate the ERR to populations within his document. Further, he tends to ignore that radiation is received from many other sources besides nuclear power reactors. Natural ubiquitous radiation and medical treatments each constitute about 3 mSv/y on average to U.S. populations which are likely similar to Canadian populations such that lifetime doses from medical sources would be on the order of 500 mSv[2] (6 mSv/y times 80 y) or 0.5 Sv. Average doses to members of the public radiation from nuclear power production in the U.S. are about 0.0005 mSv/y which are more than 1,000 times lower than the average dose received during medical treatments of 3 mSv/y. Average nuclear power reactor worker doses are 1.9 mSv/y and these are within the range of medical workers and aviation pilots which are 0.8 mSv/y and 3.1 mSv/y, respectively for the U.S. It can be seen that average doses to members of the public from nuclear power reactors are a small fraction of the average dose from medical treatments and that nuclear power reactor workers have doses similar to those received in other occupations.

[1] Both gray (Gy) and Sievert (Sv) are measures of radiation dose. For present purposes, 1 Gy is assumed equivalent to 1 Sv.
[2] 1 Sv = 1000 mSv.

For illustrative purposes of ERR that follow, we estimate the typical lifetime dose for nuclear power reactor workers to be about 40 mSv which is 20 years at the average exposure of 1.9 mSv/y and for members of the public from nuclear reactors to be about 0.04 mSv (i.e., 80 years times 0.0005 mSv/y).

In section A, Lemstra should specifically note that risks he presents are ERR projection factors which apply to all radiation, including medical exposures, and note that the ERR for most people are much smaller than these levels. For example, using the ERR risk projection factor of 43% and 81% per Sv for males and females, the ERR for the average nuclear power worker with a lifetime dose of 40 mSv would be 2 and 3%, respectively. The ERR for an average member of the public would be 0.002 and 0.003%. The actual ERRs are much lower than the ERR projection factors.

Lemstra also suggests in Section A that there is a relation between low doses of radiation and cardiovascular disease or other non-cancer effects. However, according to his own reference (Annex B of UNSCEAR 2006), there is an increased risk of circulatory diseases in cases where the heart receives a <u>high</u> radiation dose and there is <u>insufficient evidence</u> to show a causal relationship between radiation doses less than 1-2 Gy (1-2 Sv). In other words, there is no evidence of risk other than cancer at doses of interest today, of the order of a few (10's) of mSv or below for nuclear power workers.

In discussing risks to nuclear power workers in Section B, Lemstra cites a 15 country study of nuclear power workers and suggests that these workers are subject to an ERR of all types of cancer of 97% and as before, he fails to note that it is an ERR projection factor per Sv. The average dose to nuclear workers from the same study was actually 19.4 mSv (0.0194 Sv); in this case, the ERR would be 2%. This is important since the relative risks Lemstra incorrectly suggests and the risks to an average worker in the 15 country study are very different. Most people would recognize, and think differently, about a 97% increase compared to a 2% increase.

Lemstra suggests that the risks to a nuclear power worker from a dose of <100 mSv, the current 5 year dose limit, would be 151%. This is incorrect since he used the ERR projection factor and not the actual dose for these workers to express the ERR. The credibility of his comment that current dose limits are too high is influenced by this error.

Lemstra also notes the large influence of Canadian data within the 15 country study on the risks of all cancers other than leukaemia. Although the current Canadian data represent about 4% of the total mortality, exclusion of the current Canadian data results in a 40% lower ERR projection factor of 58% relative to 97%. The ERR projection factor, excluding Canada, is similar to the Japan A-bomb and UNSCEAR reports but is not statistically-significantly different due in part to the relatively low doses to nuclear power workers. This issue has been clearly recognized and raised concerns about the validity of the Canadian study in the 15 country IARC study. The Canadian study is currently being reviewed to determine the nature of the anomaly, in particular, the dosimetric issues.

Lemstra also refers briefly to the experience of workers at the Mayak facility. However, he fails to mention that this facility was not a nuclear power facility but rather was a facility to produce plutonium weapons, something very different. Doses were high, on average about 0.5 Gy (0.5 Sv) (Wakeford 2009) of external radiation but also many workers would have received large internal doses. In brief, this reference is irrelevant for discussion of risks from nuclear power.

Section C focuses on ERR to members of the public. The studies of the effect of exposure to radiation on communities mentioned by Lemstra discuss primarily accidental releases such as Chernobyl, Techa River releases (not a nuclear power plant) and Three Mile Island. The Chernobyl and Techa River studies are not representative of normal nuclear power operation and these releases of radioactivity are simply not applicable to the normal operation of a nuclear power plant in Saskatchewan. A Chernobyl accident would not occur with a modern nuclear reactor and the Techa River is not a nuclear power plant hence these studies are irrelevant. It is of note that no excess risk was found in the Three Mile Island follow-up. Lemstra selectively refers to the study of leukemia in children at two reactors in Germany and England but fails to note this result has not been duplicated in many other studies surrounding nuclear power reactors. A recent review (Laurier *et al.* 2008) indicates that some clusters of childhood leukaemia cases exist locally but conclude that "results based on multi-site studies around nuclear installations do not indicate an increased risk globally."

We agree with Lemstra Section D that nuclear power production is preferred to other power generation approaches with respect to public health and greenhouse gas releases. The Lemstra report indicates that nuclear is preferred for both lower deaths and serious injuries and the contribution to $CO_2$ and the potential health impacts from global warming. In terms of greenhouse gas production, nuclear is about equivalent to solar and wind and is in any event better suited for baseload power production. It is noted that nuclear energy has a "perceived risk" compared to clear health impacts of coal and gas generation of electricity. It is important to note that Lemstra acknowledges that the health impacts are "perceived". The promotion of alternate energy sources such as solar appears to be out of context with the overall review of health.

Lemstra discusses that cost overruns might impact health care in Section E. Selection of a nuclear power plant to generate electrical power is a compromise between cost effectiveness (cost of power) including the potential cost over-runs and the non-monetary goals at present such as reducing greenhouse gas emissions. These attributes should be evaluated for other technologies as well (e.g. the price for power from solar technology is much higher than for nuclear power production (NPP)). A careful accounting is required for selection of NPP and according to Lemstra's Electricity Generation and Health section that NPP improves health over other options. This discussion of cost overruns is largely a scare technique with limited applicability to health outcomes.

The nurse's survey has a high potential for bias for two reasons. ERRs are expressed as projection factors from UNSCEAR and the multi-nations studies, and these dramatically overestimate the ERR for doses actually received from nuclear power generation to workers and members of the public. For example, the ERR for the 15 country study of nuclear power workers should be reported as 2% for the dose received rather than the risk factor of 97% using the average exposure of 19.4 mSv. It is very possible that the survey responders may have replied differently if the actual risks were presented and a fair unbiased context provided. Secondly, the survey had only two questions and is susceptible to bias in completion by those interested in the health effects of radiation.

In summary:

- In discussing the exposure to radiation and impact on health outcomes; the ERRs are incorrectly represented by projection factors and do not reflect the risks based on dose received. This misleads the reader to consider that radiation is more hazardous than expected. The non-cancer effects, although observable for high doses received during medical treatments, is likely not present at the doses most people receive.
- The Canadian experience in the 15 country study is currently under review as it appears anomalous relative to the other countries.
- Two studies mentioned in respect of exposure to radiation and impact on community residents, Chernobyl and Techa River, are irrelevant to nuclear power generation in Saskatchewan since the Chernobyl accident would not occur in modern reactors and the Techa River was not a nuclear power plant.
- Although Lemstra cites a study showing an increase risk of childhood leukaemia near the nuclear power stations, the consensus on increased leukaemia risk near nuclear reactors when all such studies are considered is that there is "no increased risk globally". There is no evidence of increased risk to members of the public.
- The section on electricity generation and health suggests that nuclear power has health effect and greenhouse gas advantages over other electricity generation methods. The purpose of this section is unclear and was apparently considered not important enough to be part of the report's executive summary. Its role in a report on exposure to radiation and health outcomes is unclear.

- The section on implications of nuclear power cost over-runs to population health was not considered important enough to be included in the executive summary. The implications of cost over-runs on health care are unclear and a true comparison should include the overall net cost of delivering electricity when comparing between options.
- The section on consultation with registered nurses and registered psychiatric was not considered important enough to be included in the executive summary. There was potential for high bias since the ERR projection factors were presented rather than an estimate of the ERR for the doses that might be received from a modern nuclear reactor and this resulted in a dramatic overestimation of the risk. Further, there were only two questions in the survey which would likely promote preferential response by persons interested in the health due to doses from nuclear power reactors.

The combination of incorrectly presenting ERR projection factors as ERR, the lack of considering actual doses, the inclusion of irrelevant materials and the incorrect representation of the scientific materials result in a misleading report that overstates the risk from nuclear power generation. Other sources of radiation exposure to the public, including that from natural background, are much higher than that from nuclear power generation.

## APPENDIX: DETAILED COMMENTS

A very important point related to ERR, is that the ERR depends on the amount of radiation dose received by the individual but the Lemstra report does not consider this. Doses from other sources are much higher than those received from nuclear power reactors. To facilitate discussion of actual ERR, we have "estimated" what we consider to be "reasonable" exposures.

*Perspective on Annual Dose Rates*

Nuclear power plants are not the only source of radiation doses to workers and members of the public. Ubiquitous background radiation from naturally occurring radioactive materials and cosmic radiation range average about 3 mSv/y in the US (NCRP 160, 2009) with an average of about 3 mSv/y from medical treatment for a total mean exposure of 6 mSv/y (NCRP 2009). The dose of U.S. members of the public from industrial (including nuclear power generation), nuclear medicine, and research is 0.003 mSv/y. The average dose from nuclear power generation is 15% of this small total dose with exposure from nuclear medicine patients and medical activities that are more than 5 times larger at 84%. The average dose to members of the U.S. public from nuclear power reactors of 0.00045 mSv/y (15% of 0.003) is far lower, about 1/10,000$^{th}$, than the ubiquitous background radiation or the doses associated with medical treatments[3].

It must be noted that there are variations in the doses to individuals. There is substantial variation between individuals with background ranging from 0.5 to more than 20 mSv/y, and individual computed tomography (CT) scans for abdomen and pelvis or heart angiography reaching 10 to 20 mSv per treatment. The NCRP reports average doses to members of the public from nuclear power reactors of about 0.00045 mSv/y with both lower and higher (up to perhaps 0.01 mSv/y) to individuals.

Mean occupational exposures to workers include 3.1 mSv/y to aviation workers, 0.8 mSv/y for medical workers and 1.9 mSv/y for commercial nuclear power workers (Table 8.1 of NCRP 2009). These doses also vary by individuals within these occupations.

Radiation limits have been established by the Canadian Nuclear Radiation Commission (CNSC) to protect workers and members of the public with upper limits of 20 mSv/y and 1 mSv/y, respectively (Canada Gazette 2000). Most of the individuals exposures are well within these limits (e.g. the average of 1.88 mSv/y for nuclear reactor operation workers and 3.26 mSv/y for nuclear reactor industrial radiographers, Health Canada 2008)) for nuclear power workers

[3] We are not aware of similar data for Canada and have assumed that the U.S. experience is reasonably comparable.

compared to the 20 mSv/y limit. Worker exposures for nuclear power reactors are in the realm of exposures to medical personnel and aviation workers.

*Lifetime Dose*

In simple terms ERR depends on the dose coefficient and the total dose. Few people get the same dose from occupational and member of the public doses for their entire life. Few workers would be expected to receive the 1 Sv as this would require working for 50 years at the maximum allowable dose each year. Most workers are much below the 20 mSv/y each year. In Canada, a reasonable estimate of lifetime exposure to nuclear workers is in the 10's of mSv.

## COMMENTS BY SECTION

In carrying out our review, we have not attempted to examine every statement in Dr. Lemstra's paper. Rather, we have attempted to identify what we consider to be key issues and to comment on those where we disagree with Dr. Lemstra's interpretation of original references and/or conclusions which he draws from those references. Notwithstanding, we do wish to point out that Lemstra's paper contains numerous minor scientific discrepancies that don't affect our overall key comments. In addition, where we thought it helpful to illustrate or to clarify a point, we have cited additional scientific materials.

The comments given below follow the same section headings and order used in Lemtra's paper.

### Search Strategy

We agree with Dr. Lemstra that peer review publications of the United Nations family, the UNSCEAR[4] reports for example, are of very high quality. Moreover, given the UNSCEAR review process, we suggest that UNSCEAR documents represent the most comprehensive reviews of "quality" scientific literature that are available.

Lemstra indicates that he identified 73 articles relevant to the subject matter and "*after conducting a check for scientific quality*" arrived at the 22 papers identified in his bibliography. Unfortunately, he does not provide a description of how he assessed the quality of the 73 relevant articles.

[4] United Nations Scientific Committee on the Effects of Atomic Radiation – UNSCEAR

**A. Exposure to radiation and impact on health outcomes**

Page 7 last para. - Lemstra indicates that the risk of solid cancers to the Japanese atomic bomb survivors was about 5% (479 cases). In this respect, it is worth noting that a great deal of effort has gone into the development of dose-response relationships, as for example, described in Section IV of UNSCEAR 2006 Annex A (Lemstra's *reference #2*). This statement indicates that exposures have to be very high for a population to indicate elevated risks. These exposures, on average, are much higher than those received by nuclear power workers or members of the public.

Page 8 Para 1 – the author describes the excess relative risk of cancer using the values in the Table 1 and Table 2 without noting that these are projection factors for a dose of 1 Sv rather the ERR for actual doses received by individuals which are much lower than 1 Sv. A Sv is a very large dose: for example, average nuclear power worker doses (average for all workers of 1.8 mSv/y to the maximum of 4.33 mSv/y for nuclear fuel handlers) (Health Canada 2008) would require 500 to 200 years of constant exposure to get a 1 Sv dose. The number of years to get 1 Sv dose for members of the public from nuclear power reactors, of the order of 10 µSv/y (maximum) or less would be more than 100,000 years. Obviously, it is unlikely for anyone to receive a 1 Sv dose from normal nuclear power operations. The ERR would be much lower then the ERR projection factor. The text, by not mentioning that the ERR cited by Lemstra are projection factors per Sv is highly misleading because it doesn't consider the doses received and thereby overestimates the ERR to the population.

With the foregoing in mind, we suggest that Lemstra's discussion is misleading and requires context, for example

- Page 8 para 2 - Lemstra refers to an ERR of 43% for males and 81% for females; however, he neglects to mention that these (statistical) risks would only apply for a dose of 1 Sv. For a more relevant dose of say 20 mSv for a nuclear power reactor worker, the corresponding excess relative risks would be 0.86% for males and 1.62 % for females and lower still at doses typically received by nuclear power workers. The ERR for a member of the public from nuclear power reactors would be very much smaller.
- Lemstra's Table 1 (cancer incidence) and Table 2 (cancer mortality) are incorrect in reporting 95% confidence intervals; the actual confidence intervals are for 90% (e.g., see Table 19, UNSCEAR 2006 Annex A).
- Lemstra's Table 3 is incomplete and has misleading, and in some cases incorrect representation of the cancer incidence data for the lifespan study (see Tables 20 – 43 of UNSCEAR 2006 Annex A, which provides cancer-specific incidence and mortality

data). No explanation of the basis for selecting the cancer types shown in Table 3 is provided.

- Tables 4 and 5 (page 10) refer to incidence and mortality, from leukaemia respectively. Table 65 of UNSCEAR 2006 Annex A provides lifetime leukaemia risk estimates for a variety of risk projection models for several doses, - 0.01 Sv, 0.1 Sv and 1 Sv. In general terms, the lifetime risks of leukaemia (per Sv) at low doses (0.01 Sv, or 10 mSv) are about a factor of 2 lower than at a dose of 1 Sv.
- Page 10 – the author notes that there is a "small causal relationship between low doses of ionizing radiation and cardiovascular and other non-cancer disease". He fails however to provide a context in terms of the doses at which such effects are observed. UNSCEAR 2006 Annex B examined epidemiological studies relating the risks of cardiovascular diseases and other non-cancer diseases from radiation exposure. Circulatory diseases were looked at in depth, as they are the leading cause of death in adults worldwide and they are more frequently reported in epidemiological studies. As the survivors of the atomic bombings in Japan are being followed, associations have begun to appear between non-cancer diseases and high doses of radiation. Historically, cancer patients treated with high doses of radiation over extended fields (e.g. – Hodgkin's Lymphoma and breast cancer patients) have shown long term risks of myocardial infarction; however, modern radiation therapies utilize new equipment and techniques to reduce doses to non-cancerous tissues.

According to Annex B of UNSCEAR 2006, patients who received lower radiation doses (primarily on the order of a few Gy) from various diagnostic and therapeutic exams show more diverse results, with some studies showing an increase in cardiovascular disease mortalities and others not. Overall, Annex B of UNSCEAR 2006 concluded that, although there is an increased risk of circulatory diseases in cases where the heart receives a high radiation dose, there is insufficient evidence to show a causal relationship between radiation doses less than 1-2 Gy for cardiovascular diseases. In other words, there is no evidence of risk other than cancer at doses of interest today, of the order of a few (10's) of mSv.

**B. Exposure to radiation and impact on health outcomes to nuclear power workers**

Lemstra notes the large influence of Canadian data within the IARC (Cardis *et al.* 2007) 15 country study on the risks of all cancers other than leukaemia. The IARC study reports an increase in mortality from all cancers (ERR of 0.97 per Sv and 90% confidence interval of 0.28 to 1.77). If Canadian data are excluded the ERR is estimated at 0.58 per Sv, 90% confidence interval -0.10 to 1.39). The current Canadian data represent about 4% of the total mortality and exclusion of the current Canadian data results in a 40% risk lower risk factor. The ERR projection factor using the remaining studies is not statistically-significantly different from zero. This issue has been clearly recognized and raised concerns about the validity of the 15 country IARC study. The Canadian study is currently being reviewed to determine the nature of the anomaly, in particular, dosimetric issues.

The following comments provide an expanded, albeit limited, sampling of references on risks to nuclear workers.

The main basis for estimating radiation risk to workers is the same as that for other potentially exposed populations: the more than 50-year follow-up of the survivors of Hiroshima and Nagasaki (Preston 2003). The survivors were exposed to a range of doses and the results of studies of atomic bomb survivors formed the primary basis for estimates of risk from radiation. The experience of the Japanese atomic bomb survivors is consistent with a linear dose-response for the risk of most cancers combined, and with a linear-quadratic dose response for leukemia.

Although many studies of workers in individual facilities or small groups of facilities have been published (e.g., Gilbert *et al.* 1989; Wing *et al.* 1991; Kendall *et al.* 1992; Gilbert *et al.* 1993; Carpenter *et al.* 1994; Cardis *et al.* 1995; Frome *et al.* 1997; Muirhead *et al.* 1999; Shilnikova *et al*. 2003), in general these studies are too limited to yield consistent statistically-significant ERR projection factors. In 1988, the International Agency for Research on Cancer (IARC) initiated a large multi-national study of nuclear workers worldwide with an expected statistical power nearly half that of the bomb survivor study. Its first report covering facilities in only three countries demonstrated a statistically-significant increase only for leukemia, but with large margins of error on all of the results (Cardis *et al*. 1995). Within these statistical error limits, the risks to the nuclear workers were not different from those estimated for the bomb survivors.

The 2007 paper by Cardis *et al.* provides radiation risk estimates from a 15 country collaborative study of nuclear workers. The study found a statistically significant association between radiation dose and all-cause mortality, primarily due to a dose-related increase in cancer mortality. The increased risk of mortality from cancer with increasing radiation dose was somewhat higher when the Canadian population was included but statistically compatible with estimates derived from the adult male atomic bomb survivors. Cardis *et al (2007)* also report that the risk estimate for leukemia is raised but is not significantly so.

Subsequent papers (e.g., Vrijheid *et al.* 2007a, b and Vrijheid *et al.* 2008) provide additional information on this cohort. Vrijheid *et al.* (2007a) elaborates on epidemiological methods and results of descriptive analysis of the 15-country study. Vrijheid *et al.* 2007b reports on diseases other than cancer and concludes that the 15 country study provides little evidence of a relationship between radiation dose and diseases other than cancer. Vrijheid *et al*. 2008, reporting on the risk of chronic lymphocyticleukemia (CLL), concludes that the 15 country study provides little evidence of an association between low doses of external radiation and CLL mortality.

Largely because of Canada's comprehensive National Dose Registry (NDR) and its national cancer registry, a number of epidemiological studies of radiation risks specific to Canadian workers have been published, though with necessarily lower statistical power than the IARC study. In 1993, Gribbin *et al.* reported a study of cancer mortality in Atomic Energy of Canada Limited (AECL) workers. This study found no statistically-significant increases in cancer deaths, but the uncertainties on the risk estimates did not exclude the risks estimated from the bomb survivors. Ashmore *et al.* (1998) and Sont *et al.* (2001) reported on the risks of cancer mortality and incidence (and other diseases), respectively, in the large cohort of radiation workers registered with the NDR. This registry includes many more workers than are employed in the nuclear industry, and the average radiation doses are low, making these studies more susceptible to bias. Both studies found significantly-elevated risks of cancer, greater than those reported, for example, by Cardis *et al.* (1995) and for the bomb survivors. Gilbert (2001) has commented on possible explanations for these discrepancies. In contrast, Zablotska *et al.* (2004) analyzed mortality among Canadian nuclear power workers using the same data and found, in contrast to the IARC (Cardis *et al.* 2007) results, only marginally significant excesses of solid cancers and leukemias, with risks not different from those derived from the bomb survivors. Follow-up investigations are currently underway under the auspices of the CNSC to better understand the reasons for the difference.

Risks other than personal cancer have been studied for Canadian nuclear workers to a limited degree. McLaughlin *et al.* (1993a) studied the occupational exposure of fathers to ionizing radiation and the risk of leukemia in their offspring. In contrast to an earlier report from the UK (Gardner *et al.* 1990), these authors found no evidence of such a risk in Canadian workers. Green *et al.* (1997) reported on the risk of congenital anomalies in children of Ontario Hydro workers occupationally exposed to ionizing radiation. No association was found between this risk and the exposure of the parents (mainly fathers) before conception, although as the authors note, the ability to detect such a risk is very limited in such a small sample population.

Wakeford (2009) has summarized many of these studies. They are necessarily limited in their ability to detect differences from background cancer rates, but their results are broadly consistent with those from the bomb survivor population, and support the risk basis for occupational radiation protection proscribed by the CNSC.

In summary, the exposure of Canadian nuclear workers to ionizing radiation may result in a nominal risk of excess cancers that increases with dose, based mainly on the results of a detailed follow-up of the survivors of the atomic bombings in 1945. For most workers, however, this risk is small, comparable to other risks in safe industries.

## C. Exposure to radiation and impact on community residents.

The accident at Chernobyl, and past-practices (not applicable to current examples) of Techa River are described. These scenarios while interesting are simply not relevant to a NPP in Saskatchewan and any potentially associated heath effects.

As indicated by Lemstra, the Three Mile Island study shows no increases in risk due to the partial meltdown and follow-up for 20 years.

Lemstra refers to two studies that show a correlation with distance and excess leukemia rates in children. The authors of the German study indicate the relationship was unexpected given the low doses received (i.e. less than 1/1000 to 1/10,000 of background exposures (Katsch *et al.*, 2008). It is not clear whether the correlation is due in part to confounding factors or chance alone. Other studies, notably a recent review of childhood leukaemias in children living around nuclear facilities indicates that some clusters of childhood leukaemia cases exist locally but conclude that "results based on multi-site studies around nuclear installations do not indicate an increased risk globally." (Laurier *et al.* 2008)

## D. Electricity Generation and Health

The information provided by Lemstra in this section actually shows the advantages of nuclear power relative to health effects than gas or coal generation and lower greenhouse gas releases than any technology. This would suggest that there are less health effects from NPP than there is for the other options of generating power. Unfortunately, the analysis does not include the cost for energy produced to allow for a true comparison of the "best" method by balancing cost, health effects and green house gas considerations.

This discussion serves as a distraction from the health effects of nuclear power and should not be included in this paper.

**E. Cost Overruns**

The association between health effects and cost overruns is not clear. While cost overruns may affect government budgets, the nuclear power option will reduce the health effects from other approaches as shown in Section D by Lemstra. Depending on the circumstances, there may be a reduction in health costs even with some cost overruns that could be larger than the reduction in health services due to cost overruns.

**F. Consultation with Registered Nurses and Registered Psychiatric Nurses**

The nurse's survey was provided with misleading information since the metric for excess relative risk was not described. The ERR are likely projection factors per 1 Sv and do not reflect typical exposures. The average exposure for chronic low dose exposures who received 19.4 mSv dose (according to Lemstra Table 9). This would suggest an estimate of 2% ERR for these workers (e.g. 97% x 19.4/1000). Lemstra has overestimated the ERR by about a factor of 50 for this group.

The leukemia risk is presented without consideration of the large number of studies that did not show a relationship and the overall consensus that leukaemia risk "is not globally elevated". These findings are based on a relatively low number of cancer cases compared to most studies.

There could be a large response bias in this survey since there are only two questions provided and response would be strongly determined by the bias of the respondents (822 respondents of 3043). The survey could be preferentially answered based on opinions on these two questions. There would have been less bias if these questions were included in a survey with more questions.

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