Rebuild of the Libby (FEC) to Troy section of BPA's Libby to Bonners Ferry 115-kV Transmission Line Rebuild Project

APPENDIX J:

ASSESSMENT OF RESEARCH REGARDING EMF AND HEALTH AND ENVIRONMENTAL EFFECTS

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1 Introduction

Over the last 25 years, research has been conducted in the United States (U.S.) and around the world to examine whether exposures to electric and magnetic fields (EMF) at 50/60 Hertz (Hz) have health or environmental effects. EMF is produced by both natural and man-made sources that surround us in our daily lives. They are found throughout nature and in our own bodies. The earth itself produces a static (0 Hz) magnetic field – this is the field that is used for compass navigation. Electricity provided to homes and offices produces EMF that changes direction and intensity 60 times per second - a frequency of 60 Hertz (Hz). Fields at this frequency are quite different from higher frequency electromagnetic fields such as radio and television signals, microwaves from ovens, cellular phones, and radar (which can have frequencies up to billions of Hz). Man-made EMF is found wherever electricity is generated, delivered, or used. Power lines, wiring in homes, workplace equipment, electrical appliances, and motors produce EMF.

One of the most important characteristics of electric and magnetic fields is that their strength diminishes as you move away from the source. This is similar to the way that the heat from a candle or campfire will diminish as you move away. Although ordinary objects do not block magnetic fields, they can be shielded by using special materials and techniques. In contrast, intervening objects, especially those that can conduct electricity, can reduce electric fields. For example, a typical house may block up to 90% of the electric field from outside sources. Scientific research on people has focused on magnetic fields since objects such as trees, walls, etc. easily shield electric fields.

Epidemiology studies have largely addressed many issues that have been raised about EMF and health. There is an overwhelming consensus in the scientific community, as expressed in multidisciplinary reviews, that the epidemiologic evidence is insufficient to demonstrate a causal relationship between extremely low frequency (ELF) -EMF and any health effect (NIEHS, 1998; NIEHS, 1999; HCN, 2001; NRPB, 2001; IARC, 2002; HCN, 2004; NRPB, 2004). Laboratory studies have not shown a biological mechanism for the development of cancer, including leukemia.

The Bonneville Power Administration (BPA) requested Exponent to update BPA on scientific research conducted on EMF and health and environmental effects in relation to exposures that might occur near the Libby (FEC) to Troy Transmission Line Rebuild Project. This update concentrates on recent major research studies to explain how they contribute to the assessment of effects of EMF on health (Section 2). The focus is on both epidemiologic and laboratory research, because these research approaches provide different and complementary information for determining whether an environmental exposure can affect human health. Section 3, Ecological Research, reviews studies of potential effects of EMF on plants and animals in the natural environment. This update includes studies of experimental, residential or environmental exposures to EMF that became available through June 2005.

2 Health

2.1 The NIEHS Report and Research Program

In 1998, the National Institute of Environmental Health Sciences (NIEHS) completed a comprehensive review of the scientific research on health effects of EMF. The NIEHS directed a research program that Congress funded in 1992 in response to questions regarding exposure to EMF from power sources. The program was known as the EMF RAPID Program (Research and Public Information Dissemination Program). The NIEHS convened a panel of scientists (the “Working Group”) to review and evaluate the

RAPID Program research and other research. Their report, *Assessment of Health Effects from Exposure to Power-Line Frequency Electric and Magnetic Fields,* was completed in July 1998 (NIEHS, 1998).

In June 1999, the director of the NIEHS prepared a health risk assessment of EMF and submitted it to Congress (NIEHS, 1999). Experts at NIEHS, who had considered a previous Working Group report, reports from four technical workshops, and research that became available after June 1998, concluded as follows:

> The scientific evidence suggesting that ELF-EMF [extremely low frequency-electric and magnetic field] exposures pose any health risk is weak. The strongest evidence for health effects comes from associations observed in human populations with two forms of cancer: childhood leukemia and chronic lymphocytic leukemia in occupationally exposed adults. . . . In contrast, the mechanistic studies and animal toxicology literature fail to demonstrate any consistent pattern. . . . No indication of increased leukemias in experimental animals has been observed. . . . The lack of consistent, positive findings in animal or mechanistic studies weakens the belief that this association is actually due to ELF-EMF, but it cannot completely discount the epidemiology findings. . . . The NIEHS does not believe that other cancers or other non-cancer health outcomes provide sufficient evidence of a risk to currently warrant concern (NIEHS, 1999: 9-10). (N.B. full quote in Table 1.)

Although the results of the RAPID research are described in some detail in the 1998 report, some of the studies had not been published in the peer-reviewed literature. Recognizing the need to have these results reviewed and considered for publication, the NIEHS arranged for this research to be published in a peer reviewed special edition of the journal *Radiation Research* (e.g., Balcer-Kubiczek et al., 2000; Boorman et al., 2000a; Boorman et al., 2000b; Loberg et al., 2000; Ryan et al., 2000).

2.2 Research Related to Cancer

To assess the potential health effects from any exposure, data from several types of studies, including non-experimental, epidemiologic observations of people, and experimental studies on animals, humans, and tissues in laboratory settings, must be critically evaluated.

Epidemiology is the study of diseases and their causes in the human population. Epidemiology studies are observational in that they examine and analyze people in their normal daily life. Such studies are designed to quantify and evaluate the associations between exposures to environmental factors (e.g., vegetables in the diet) and health outcomes (e.g., coronary artery disease). Epidemiologic studies can help suggest risk factors that may contribute to a disease risk, but they usually cannot be used as the sole basis for drawing inferences about cause-and-effect relationships, and they usually only provide information on a limited range of exposures.

In contrast to epidemiology studies, laboratory or experimental studies are conducted under controlled laboratory conditions. Experimental studies designed to test specific hypotheses under controlled conditions are generally required to establish cause-and-effect relationships. Conversely, the results of experimental studies, particularly of isolated tissues or cells, by themselves may not always be directly extrapolated to human populations. It is therefore both necessary and desirable that biological responses to agents that could present a potential health threat be explored by epidemiologic methods in human populations, as well as by experimental studies in the research laboratory.

Toxicology is an important part of laboratory research designed to evaluate the potential beneficial or harmful effects of an agent (e.g., a chemical or a magnetic field). The goal of toxicology studies is to identify the nature of effects that result from exposure and the dose of the agent in the target tissue that

elicits that effect. A most critical distinction, therefore, must be made between harmless biological responses or effects, and those that are truly adverse or deleterious. Many agents produce biological responses in organisms—like the response of the eye to light or the influence of food and water on growth and cellular metabolism—at quite low concentrations or intensities. Hence, the mere demonstration of a biological response or effect does not indicate that an exposure to an agent is hazardous *per se*. Rather, it is imperative to ascertain whether biological responses are deleterious or innocuous, and to establish what, if any, exposure concentrations may be toxic and under what conditions.

2.2.1 Epidemiology Studies of Children

Research on EMF in residential settings and health was prompted by an epidemiology study of children exposed to EMF, mostly from neighborhood distribution lines in the U.S. (Wertheimer and Leeper, 1979). Because the source of the fields was low voltage distribution lines, not high voltage transmission lines the assumption has been that the relevant exposure associated with power lines is the magnetic field, rather than the electric field. This assumption rests on the fact that electric fields are shielded from the interior of homes (where people spend the vast majority of their time) by walls and vegetation, while magnetic fields are not. Subsequent studies have largely addressed almost all issues that have been raised about EMF and health. Summaries of two of the largest and most comprehensive studies of EMF and childhood leukemia are provided below. Both groups of investigators concluded that their data provided little evidence for an association of magnetic fields with leukemia in children.

Epidemiologic studies report results in the form of statistical associations. The term "statistical association" is used to describe the tendency of two things to be linked or to vary in the same way, such as level of exposure and occurrence of disease. However, statistical associations are not automatically an indication of *cause and effect*, because the interpretation of numerical information depends on the context, including (for example) the nature of what is being studied, the source of the data, how the data were collected, and the size of the study. The larger studies and more powerful studies of EMF have not reported convincing statistical associations between power lines and childhood leukemia (e.g., Linet et al., 1997; McBride et al., 1999; UKCCS, 1999; UKCCS, 2000). However, despite the larger sample size, these studies had a limited number of cases exposed over 4 milligauss (mG).

The National Cancer Institute (NCI) — The NCI completed a large and comprehensive study of childhood leukemia in the US in 1997. This study compared exposure to magnetic fields in children who did not have cancer to the exposure of those who had acute lymphocytic leukemia (ALL), the most common form of leukemia in children (Linet et al., 1997). The major advantage of this study was the short time between exposure assessment and diagnosis compared to previous studies, and the assessment of exposure by a variety of methods. In addition, the investigators obtained magnetic field measurements from multiple rooms in each child's home, which included magnetic field exposures from household appliances. No association was found between ALL and the wiring configuration code at the residences occupied by the children before they had cancer. The researchers observed a statistical association between leukemia and magnetic field levels in the category 4.0 – 4.99 mG, but not for time weighted average (TWA) exposures less than 4 mG or for exposures greater than or equal to 5 mG, the highest exposure category. There was no overall trend for a stronger association with increased exposure. Further analyses indicated that distance from high-voltage lines and other exposure indexes were not related to risk for ALL (Kleinerman et al., 2000).

United Kingdom Childhood Cancer Study (UKCCS) — The largest childhood cancer study of magnetic fields to date was completed in the United Kingdom (UK) in 2000. The UKCCS investigators reported on magnetic field measurements on a portion of the cases and controls evaluated in a previous study (UKCCS, 1999). To obtain additional information, they used a method to assess exposure to magnetic fields without entering homes (UKCCS, 2000) and were able to analyze 50% more subjects (a total of 1,331 ALL cases). For all these children, they measured distances to power lines and substations.

This information, combined with data on historical current flow, was used to calculate the magnetic field from these external field sources, based on power line characteristics related to production of magnetic fields. The results of the second UKCCS study showed no evidence for an association with leukemia for magnetic fields calculated to be between 1 mG – 2 mG, 2 mG – 4 mG, or 4 mG or greater at the residence, which is consistent with the results of the earlier report in which magnetic field exposure was estimated by measurement (UKCCS, 1999). Children with leukemia were not more likely to live near distribution, high-voltage power lines or substations than control children. A more recent study of distance from transmission lines reported a weak association with childhood leukemia but not tumors of other tissues (central nervous system/brain, other) but the association was present at distances where no magnetic field would be measured (Draper et al, 2005).

Researchers have proposed that the associations that are sometimes reported between childhood leukemia and power lines might be due to other factors that can confound the analysis (other risk factors for disease that may distort the analysis). One example is heavy traffic, which may occur near power lines and can increase the levels of potentially carcinogenic chemicals in the area. Earlier studies had reported associations between traffic density and childhood cancer (Savitz et al., 1988). If power lines were more common in areas that had higher traffic density, then the increased air pollution might explain an association between power lines and childhood cancer. A recent study by Knox et al. (2005) reported stronger associations between exposures to sources of benzene, 1,3 butadiene, benzo(a)pyrene, and dioxins and childhood leukemia. These exposures should be included in future epidemiology studies of childhood leukemia (Steffen et al., 2004; Knox et al., 2005).

Meta-analyses of Studies of Leukemia

In 2000, researchers reanalyzed the data from previous epidemiology studies of magnetic fields and childhood leukemia that met specified criteria (Ahlbom et al., 2000; Greenland et al., 2000). In each of these analyses, the researchers pooled the data on individuals from each of the studies, creating a study with a much larger number of subjects and therefore greater statistical power than any single study. These meta-analyses focused on studies that assessed exposure to magnetic fields using 24-hour measurements or calculations based on the characteristics of the power lines and current load. Ahlbom et al. combined 9 studies; Greenland et al. used 12 studies, 8 of which were the same as used by Ahlbom. Both studies included ALL as well as other forms of leukemia. Neither Greenland et al. nor Ahlbom et al. included data from the recent, very large study from the UK (UKCCS, 2000), Greenland also did not include results from UKCCS (1999). The statistical results of these analyses can be summarized as follows:

- The pooled analyses provided no indication that wire codes[1] are more strongly associated with leukemia than measured magnetic fields.

- Pooling these data corroborates an absence of an association between childhood leukemia and magnetic fields for exposures below 3 mG.

- Pooling these data results in a statistical association with leukemia for exposures greater than 3-4 mG.

[1] Wire Codes are a surrogate for magnetic field exposure, based on the diameter or thickness of the wire and its distance from the residence.

It is important to note that the information from these pooled analyses is not new because, for many years, epidemiologic studies and reviews have suggested an association between magnetic fields and childhood leukemia. Previous reviews based on fewer studies had suggested an association of magnetic fields with childhood leukemia at time-weighted average exposure levels as low as 2 mG; however, an association is *not* present for exposures below about 3 to 4 mG. Average magnetic fields above 3 mG in residences are estimated to be rather rare, about 3% in the US (Zaffanella, 1993). The authors are appropriately cautious in the interpretation of their analyses and they clearly identify the limitations in their evaluation of the original studies (e.g., small sample size, uncertainty related to pooling estimates of exposure obtained by different methods from studies of diverse design).

Wartenberg (2001) published a different type of meta-analysis of data from epidemiologic studies of childhood leukemia studies. He used 19 studies overall, including the UKCCS (1999) study. This meta-analysis did not have the advantage of obtaining and pooling the data on all of the individuals in the studies, unlike those published before it (Ahlbom et al., 2000; Greenland et al., 2000). Rather than using individual data from each of the individual studies, Wartenberg used an approach based on the results from several published studies, which were reported as grouped data. No statistically consistent results in this meta-analysis were found. He reported a weak association for a) "proximity to electrical facilities" based on wire codes or distance, and b) magnetic-field level over 2 mG, based on either calculations from wiring and loading characteristics (if available) or on spot magnetic-field measurements. There are several limitations of the Wartenberg meta-analysis. The author concludes that the analysis supports an association, however, few scientifically significant odds ratios were found, and as he notes, "limitations due to design, confounding, and other biases may suggest alternative interpretations" (p 100).

2.2.2 Epidemiology Studies of Adults

Studies of occupational exposure have been conducted because these populations are presumed to have high exposure to EMF. Occupational studies have varied greatly in the methods used to estimate exposure (e.g., type of industry, exposure based only on job titles, direct electric and magnetic field measurements), study design (e.g., retrospective cohort studies based on death records, case-control studies with direct magnetic field measurements) and source of exposure to EMF (e.g., specific occupations i.e., railway workers, electricity generation and transmission industry or multiple industries). Recent studies have greatly improved estimates of EMF exposures. Occupational studies published through 2002 are described in the International Agency for Research on Cancer (IARC) monographs (IARC, 2002). No consistent relationship between residential and occupational exposures to magnetic or electric fields has been found for any type of cancer in adults, including leukemia, and types of cancer affecting the brain and breast (Gammon et al., 1988; Kheifets et al., 1999; Wrensch et al., 1999; Laden et al., 2000; Zheng et al., 2000; Davis et al., 2002; London et al., 2003; Schoenfeld et al., 2003; Forssen et al., 2005).

2.2.3 Laboratory Studies of EMF

Laboratory studies complement epidemiologic studies of people because the effects of heredity, diet, and other health-related exposures of animals can be better controlled or eliminated. The assessment of EMF and health, as for any other exposure, includes chronic, long-term studies in animals (*in vivo* studies) and studies of changes in genes or other cellular processes observed in isolated cells and tissues in the laboratory (*in vitro*).

Although the results of the RAPID Program were described in some detail in the NIEHS reports (NIEHS, 1998), many of the studies had not been published in the peer-reviewed literature. The RAPID research program included studies of four biological effects, each of which had previously been observed in only one laboratory. These effects are as follows: effects on gene expression, increased intracellular calcium in a human cell line, proliferation of cell colonies on agar, and increased activity of the enzyme ornithine

decarboylase (ODC). Some scientists have suggested that these biological responses are signs of possible adverse health effects of EMF. It is standard scientific procedure to attempt to replicate results in other laboratories, because artifacts and investigator error can occur in scientific investigations. Replications, often using more experiments or more rigorous protocols, help to ensure objectivity and validity. Attempts at replication can substantiate and strengthen an observation, or they may discover the underlying reason for the observed response.

Studies in the RAPID program reported no consistent biological effects of EMF exposure on gene expression, intracellular calcium concentration, growth of cell colonies on agar, or ODC activity (Boorman et al., 2000b). For example, Balcer-Kubiczek et al. (2000) and Loberg et al. (2000) studied the expression of hundreds of cancer-related genes in human mammary or leukemia cell lines. They found no increase in gene expression with increased intensity of magnetic fields. To test the experimental procedure, they used X-rays and treatments known to affect the genes (chemical and hyperthermia). These are known as positive controls and, as expected, caused gene expression in exposed cells.

Scientists have concluded that the combined animal bioassay results provide no evidence that magnetic fields cause, enhance, or promote the development of cancer including leukemia and lymphoma, or mammary cancer (e.g., Boorman et al., 1999; McCormick et al., 1999; Boorman et al., 2000a,b; Anderson et al., 2001; IARC, 2002; NRPB 2001; McLean et al., 2003; Sommer and Lerchl, 2004).

2.2.4 Summary Regarding Cancer

Epidemiology studies do not support the hypothesis that EMF from power lines increase the risk of cancers in adults. The latest epidemiologic studies of childhood cancer, considered in the context of laboratory data, provide no persuasive evidence that leukemia in children is causally associated with magnetic fields measured at the home, calculated magnetic fields based on distance and current loading, or wire codes. Recent meta-analyses reported no association between childhood cancer and magnetic fields below 2 or 3 mG. Although some association was reported for fields above this level, fields at most residences are likely to be below 3 or 4 mG. The authors of each of these analyses list several biases and problems that render the data inconclusive and prevent resolution of the inconsistencies in the epidemiologic data. For this reason, laboratory studies can provide important complementary information. Large, well-conducted animal studies and studies of initiation and promotion, provide no basis to conclude that EMF increases leukemia, lymphoma, breast, brain, or any other type of cancer.

2.3 Research Related to Reproduction

Several epidemiology studies have examined effects of exposures to magnetic fields on pregnancy, including miscarriages (spontaneous abortion). They reported no association with birth weight, birth defects, or fetal growth retardation after exposure to sources of relatively strong magnetic fields such as electric blankets, or sources of typically weaker magnetic fields such as power lines (Bracken et al., 1995; Belanger et al., 1998; Lee et al., 2000; Blaasaas et al., 2002; Blaasaas et al., 2003; Blaasaas et al., 2004).

Two studies of EMF and miscarriage reported a positive association between miscarriage and exposure to high maximum, or instantaneous, peak magnetic fields (Li et al., 2002; Lee et al., 2002). However, no reliable associations were found with higher average magnetic field levels during the day, the typical way of assessing exposure. Neither study found that miscarriage was associated with residential wiring codes, another method presumed to identify higher magnetic fields from power lines. There are several possible issues to be considered in assessing whether these statistical associations with the maximum magnetic field exposure during the day are possibly causal in nature (Feychting et al., 2005; Mezei et al., 2005). First, the studies include possible biases. For example, each of the studies had a low response rate, which means that the study groups may not be comparable because those who participated in the studies may have differed from those who declined (selection bias). Second, these studies found no reliable

association with higher daily average exposure, that is, the average of the measurements recorded throughout the day. Third, despite years of research, there is no biological basis to indicate that EMF increases the risk of miscarriage.

In summary, the recent evidence from epidemiology and laboratory studies do not support that exposure to power-frequency EMF has an adverse effect on reproduction, pregnancy, or growth and development of the embryo. The results of these recent studies are not sufficiently persuasive to change the conclusions of the NIEHS.

2.4 Implanted Medical Devices and EMF

Advances in technology have led to the development of more medical devices that can be implanted to maintain or enhance organ function. Of these devices, most concern has focused on potential interference to cardiac pacemakers and defibrillators. A cardiac pacemaker monitors the electrical activity of the heart. If the heart fails to beat, the pacemaker administers a small stimulus to trigger the 'missing' beats. An implanted cardiac defibrillator (ICD) similarly monitors the electrical activity of the heart but is designed to block disorganized contractions of the heart (arrhythmias) by administering a strong electrical shock to restore normal heart rhythms. Exposure to electric and magnetic fields could affect the function of these devices if induced signals on sensing leads are interpreted as natural cardiac activity (Griffin, 1986; CCOHS, 1988; Barold et al., 1991). However, the opportunities for exposure and interference from power lines are lower than for contact with ordinary household appliances.

Although scientific studies report that exposure to power frequency electric and magnetic fields have not resulted in adverse responses to patients with pacemakers, the possibility cannot be completely ruled out. In order to reduce potential effects of environmental exposure to electrical and magnetic fields, the Center for Devices and Radiological Health of the U.S. Food and Drug Administration (FDA) has developed guidelines for both the development of pacemakers and the design of new electrical devices to minimize susceptibility to electrical interference from any source. Pacemakers today are designed to filter out electrical stimuli from sources other than the heart, e.g., muscles of the chest, currents encountered from touching household appliances, or currents induced by electric or magnetic fields. Used in both temporary and permanent pacemakers, these electrical filters increase the pacemaker's ability to distinguish extraneous signals from legitimate cardiac signals (Toivonen et al., 1991). Most circuitry of pacemakers is encapsulated by titanium metal, which insulates the device by shielding the pacemaker's pulse generator from electric fields. Some may also be programmed to automatically pace the heart if interference from electric and magnetic fields is detected. This supports cardiac function and allows the subject to feel the pacing and move away from the source.

Due to recent design improvements, many pacemakers in use would not be particularly susceptible to low intensity electrical fields. There remains a very small possibility that some pacemakers, particularly those of older designs, and with single-lead electrodes, may sense potentials induced on the electrodes and leads of the pacemaker and provide unnecessary stimulation to the heart. In persons wearing some types or brands of implanted cardiac pacemakers, the pacing of the heart might be affected by electric fields at field intensities above about 2 kV/m. The sensitivity of ICD's to external 60-Hz fields has not been studied but might be expected to be somewhat lower than for pacemakers. The ACGIH (American Conference of Governmental Industrial Hygienists, 2001) recommends that routine occupational exposure of persons with cardiac pacemaker and similar medical electronic devices should not exceed 1 kV/m and 1000 mG (0.1 mT).

2.5 Weight-of-the-Evidence Conclusions by Multidisciplinary Groups

Numerous organizations responsible for health decisions, including national and international organizations have convened groups of scientists to review the body of EMF research. These expert

groups, including the NIEHS, the IARC, the National Radiological Protection Board of Great Britain (NRPB), and the Health Council of the Netherlands (HCN), have included dozens of scientists with diverse skills that reflect the different research approaches required to answer questions about health.

2.5.1 The IARC Working Group

Based upon the review of the epidemiologic and laboratory animal studies and consideration of other supplementary data, the IARC Working Group concluded that the epidemiologic studies do not provide support for an association between childhood leukemia and residential magnetic fields at intensities less than 4 mG. The IARC Working Group concluded that the EMF data do not merit the category "carcinogenic to humans" or the category "probably carcinogenic to humans," nor did it find that "the agent is probably not carcinogenic to humans." The latter classification has been applied to only a single chemical among more than 895 exposures evaluated by IARC. Overall, magnetic fields were evaluated as "possibly carcinogenic to humans" (Group 2B), based solely upon "limited evidence" for a statistical association of higher-level residential magnetic fields with childhood leukemia. The Working Group also evaluated the animal data and concluded that they were "inadequate" to support a risk for cancer.

In the rating system used by IARC, the recognition of an association between exposure and cancer in epidemiology studies is considered "limited evidence" of carcinogenicity. A rating of "limited evidence" for epidemiology studies, even without any evidence from experimental studies that an exposure might pose a cancer risk, requires that the exposure be categorized as a "possible carcinogen" even though chance, bias and confounding cannot be ruled out as the explanation with reasonable confidence (IARC, 2002).

The evidence for EMF was insufficient to establish a causal relationship between magnetic fields and childhood leukemia because there was neither sufficient evidence from epidemiology studies that magnetic fields caused cancer in humans, nor sufficient evidence that magnetic fields caused cancer in experimental studies of animals. In addition, no strong evidence is available to suggest a biological mechanism for the development of cancer. IARC noted that many hypotheses have been suggested to explain possible carcinogenic effects of electric or magnetic fields; however, no scientific explanation for the potential carcinogenicity of these fields has been established (IARC, 2002).

2.5.2 Conclusions of Other Multidisciplinary Review Panels

The conclusions from several other national and international organizations including the NIEHS (NIEHS, 1998; NIEHS, 1999), the National Academy of Sciences (NAS, 1999), the NRPB (NRPB, 2001; NRPB, 2004), and the HCN (HCN, 2001; HCN, 2004) are listed in Table 1. These organizations assembled large (7-31 members) multidisciplinary teams of scientists to review the literature.

The assessments by IARC, the NIEHS, the NAS, the NRPB, and the HCN agree that there is little evidence suggesting that EMF is associated with adverse health effects, including most forms of adult and childhood cancer, heart disease, Alzheimer's disease, depression, and reproductive effects. However, all of the assessments concluded that epidemiology studies *in total* suggest an association between magnetic fields at higher time-weighted average exposure levels (greater than 4 mG) and childhood leukemia. All agree that the experimental laboratory data do not support a causal link between EMF and any adverse health effect, including leukemia, and have not concluded that EMF is, in fact, the cause of any disease.

Table 1. Conclusions of Large Multidisciplinary Review Groups Assembled by Health Agencies and Scientific Organizations

Agency or Scientific Organization	Conclusions
National Institute of Environmental Health Sciences (NIEHS, 1999)	"The scientific evidence suggesting that ELF-EMF exposures pose any health risk is weak. The strongest evidence for health effects comes from associations observed in human populations with two forms of cancer: childhood leukemia and chronic Lymphocytic leukemia in occupationally exposed adults. While the support from individual studies is weak, the epidemiological studies demonstrate, for some methods of measuring exposure, a fairly consistent pattern of a small, increased risk with increasing exposure that is somewhat weaker for chronic lymphocytic leukemia than for childhood leukemia. In contrast, the mechanistic studies and the animal toxicology literature fail to demonstrate any consistent pattern across studies although sporadic findings of biological effects have been reported. No indication of increased leukemias in experimental animals has been observed. The lack of connection between the human data and the experimental data (animal and mechanistic) severely complicates the interpretation of these results. The human data are in the "right" species, are tied to "real life" exposures and show some consistency that is difficult to ignore. This assessment is tempered by the observation that given the weak magnitude of these increased risks, some other factor or common source of error could explain these findings. However, no consistent explanation other than exposure to ELF-EMF has been identified. Epidemiological studies have serious limitations in their ability to demonstrate a cause and effect relationship whereas laboratory studies, by design, can clearly show that cause and effect are possible. Virtually all of the laboratory evidence in animals and humans and most of the mechanistic work done in cells fail to support a causal relationship between exposure to ELF-EMF at environmental levels and changes in biological function or disease status. The lack of consistent, positive findings in animal or mechanistic studies weakens the belief that this association is actually due to ELF-EMF, but it cannot completely discount the epidemiological findings. The NIEHS concludes that ELF-EMF exposure cannot be recognized at this time as entirely safe because of weak scientific evidence that exposure may pose a leukemia hazard. In my opinion, the conclusion of this report is insufficient to warrant aggressive regulatory concern. However, because virtually everyone in the United States uses electricity and therefore is routinely exposed to ELF-EMF, passive regulatory action is warranted such as a continued emphasis on educating both the public and the regulated community on means aimed at reducing exposures. The NIEHS does not believe that other cancers or noncancer health outcomes provide sufficient evidence of a risk to currently warrant concern."
National Academy of Sciences NAS, 1999	"An earlier Research Council assessment of the available body of information on biologic effects of power-frequency magnetic fields (NRC 1997) led to the conclusion 'that the current body of evidence does not show that exposure to these fields presents a human health hazard. Specifically, no conclusive and consistent evidence shows that exposures to residential electric and magnetic fields produces cancer, adverse neurobehavioral effects, or reproductive and developmental effects'. The new, largely unpublished contributions of the EMF-RAPID program are consistent with that conclusion. We conclude that no finding from the EMF-RAPID program alters the conclusions of the previous NRC review on the Possible Effects of Electromagnetic Fields on Biologic Systems (NRC 1997). In view of the negative outcomes of EMF-RAPID replication studies, it now appears even less likely that MFs [magnetic fields] in the normal domestic or occupational environment produce important health effects, including cancer."

Agency or Scientific Organization	Conclusions
National Radiological Protection Board of Great Britain (NRPB, 2001)	"Laboratory experiments have provided no good evidence that extremely low frequency [ELF] electromagnetic fields are capable of producing cancer, nor do human epidemiological studies suggests that they cause cancer in general. There is, however, some epidemiological evidence that prolonged exposure to higher levels of power frequency magnetic fields is associated with a small risk of leukemia in children. In practice, such levels of exposure are seldom encountered by the general public in the UK [or in the US]."
(NRPB, 2004)	Because of the uncertainty… and in absence of a 'dose-response' relationship, NRPB has concluded that the data concerning childhood leukemia cannot be used to derive quantitative guidance on restricting exposure."
Health Council of the Netherlands (HCN, 2001)	"Because the association is only weak and without a reasonable biological explanation, it is not unlikely that it [an association between ELF exposure and childhood leukemia] could also be explained by chance… The committee therefore sees no reason to modify its earlier conclusion that the association is not likely to be indicative of a causal relationship."
(HCN, 2004)	"The Committee, like the IARC itself, points out that there is no evidence to support the existence of a causal relationship here. Nor has research yet uncovered any evidence that a causal relationship might exist."
International Agency for Research on Cancer (IARC, 2002)	"Studies in experimental animals have not shown a consistent carcinogenic or co-carcinogenic effects of exposures to ELF [extremely low frequency] magnetic fields, and no scientific explanation has been established for the observed association of increased childhood leukaemia risk with increasing residential ELF magnetic field exposure." IARC categorized EMF as a "possible carcinogen" for exposures at high levels, based on the meta-analysis of studies of statistical links with childhood leukemia at levels above 3-4 mG.

2.6 Standards and Guidelines

There are no state or federal standards for limiting exposure to power frequency (60 hertz) magnetic fields based on health effects. However, two states, Florida and New York, have enacted standards to limit magnetic fields at the edge of rights-of-way from transmission lines (150 mG and 200 mG, respectively) (NYPSC, 1978; FDER, 1989; NYPSC, 1990; FDEP, 1996). The basis for limiting magnetic fields from transmission lines was to maintain the "status quo" so that fields from new transmission lines would be no higher than those produced by existing transmission lines.

Additionally, several scientific organizations have published guidelines for public exposure to these fields. The limit published by the International Committee on Electromagnetic Safety (ICES) is 0.904 millitesla (9,040 mG) (ICES, 2002); the value published by the International Commission on Non-ionizing Radiation (ICNIRP) is 0.083 millitesla (830 mG) (ICNIRP, 1998).

2.7 Other EMF Perspectives

Several other organizations have provided perspectives on EMF and health. These include a report from the California EMF Program and two more recent publications from the World Health Organization (WHO) and the NIEHS.

2.7.1 California EMF Program

In response to a request from the California Public Utilities Commission, three scientists from the California EMF program (two epidemiologists and a physicist) reviewed and evaluated the scientific research regarding EMF and health (Neutra et al., 2002). The scientists evaluated over a dozen health conditions and the degree that they believe these diseases are caused by exposure to EMF and completed their fourth and final draft in June 2002.

The scientists used two different approaches to conduct their evaluation. One was characterized as following the IARC approach, described above, in which reviewers summarize the "quality of evidence." However, unlike IARC, which weighs both epidemiology and experimental data, the scientists gave little weight to the experimental data. The other approach was a set of guidelines developed by the California EMF Program, which calls for each scientist to express a degree of confidence in their belief that a disease may be caused by high EMF exposures.

The scientists evaluated data regarding approximately a dozen health conditions and concluded that the epidemiologic data provided little support for an association of EMF with nine of the conditions. For the rest, they expressed the belief "that EMFs can cause some degree of increased risk of childhood leukemia, adult brain cancer, Lou Gehrig's disease, and miscarriage." Their median "confidence ratings" for these conditions, however, were not high enough to indicate any strong certainty or "high probability" that EMF was a cause of these conditions. As noted previously, they state, "there is a chance that EMFs have no effect at all" (Neutra et al., 2001). For all other health effects, including breast cancer, heart disease, Alzheimer's disease, depression, increased risk of suicide, and adult leukemia, Neutra et al. do not believe that there is evidence that exposures to EMF increases the risk of developing any of these illnesses. They agree that EMF is not a universal carcinogen (Neutra et al., 2002). The California Department of Health Services has not changed its fact sheets to the public based on this assessment (CDHS, 1999; CDHS, 2000).

2.7.2 World Health Organization

In 2002, the WHO published a handbook for risk communication on EMF. The document entitled "Establishing a Dialogue on Risks from Electromagnetic Fields" was developed because of public concern over EMF and possible health effects. It is intended for persons who need to communicate possible risks from exposure to EMF to others, and to teach the reader about risk perception and risk management. In regard to the hypothesized cause-and-effect relationship between EMF and health, the WHO states "while the classification of ELF magnetic fields as possibly carcinogenic to humans has been made by IARC, it remains possible that there are other explanations for the observed association between exposure to ELF magnetic fields and childhood leukaemia" (WHO, 2002).

2.7.3 National Institute of Environmental Health Sciences

Since the conclusions of the California EMF Program have become available, the NIEHS published a brochure on questions and answers on EMF and health (NIEHS, 2002). The status of EMF and health is summarized by NIEHS as:

> Electricity is a beneficial part of our daily lives, but whenever electricity is generated, transmitted, or used, electric and magnetic fields are created. Over the past 25 years, research has addressed the question of whether exposure to power-frequency EMF might adversely affect human health. For most health outcomes, there is no evidence that EMF exposures have adverse effects. There is some evidence from epidemiology studies that exposure to power-frequency EMF is associated with an increased risk for childhood

> leukemia. This association is difficult to interpret in the absence of reproducible laboratory evidence or a scientific explanation that links magnetic fields with childhood leukemia.
>
> EMF exposures are complex and come from multiple sources in the home and workplace in addition to power lines. Although scientists are still debating whether EMF is a hazard to health, the NIEHS recommends continued education on ways of reducing exposures. This booklet has identified some EMF sources and some simple steps you can take to limit your exposure. For your own safety, it is important that any steps you take to reduce your exposures do not increase other obvious hazards such as those from electrocution or fire. At the current time in the United States, there are no federal standards for occupational or residential exposure to 60-Hz EMF (NIEHS, 2002).

2.8 Summary of EMF and Health Research

By far, the greatest interest in EMF and health has focused on childhood leukemia and estimated long-term exposures to higher magnetic field levels. Childhood leukemia is a rare disease and the evidence for causality between EMF and leukemia is lacking (Linet et al., 2003). The larger and more rigorous epidemiology studies (e.g., NCI, UKCCS) have not found evidence to support a causal relationship between exposure to magnetic fields and childhood leukemia, nor did they find a dose response relationship with exposure to higher magnetic field levels. Laboratory studies do not provide a biological mechanism for the development of any form of cancer, including leukemia. The consensus of scientists who have reviewed the literature for scientific and regulatory organizations including the IARC, the NIEHS the HCN, and the NRPB of Great Britain is that no cause-and-effect relationship between EMF from any source and ill health has been established at the levels generally found in residential environments.

The WHO provides insight as to why the reviews by these organizations are so important to weighing 30 years of literature on a single topic and states:

> Science is a powerful tool and has earned its credibility by being predictive. However, its usefulness depends on the quality of the data, which is related to the quality and credibility of the scientists. It is important to verify the knowledge and integrity of so called “experts,” who may look and sound extremely convincing but hold unorthodox views that the media feel justified in airing “in the interests of balance.” In fact giving weight to these unorthodox views can disproportionately influence public opinion. For the public, often the best sources of information are from panels of independent experts who periodically provide summaries of the current state of knowledge (WHO, 2002).

3 Ecological Research

Scientists have studied the effects of high-voltage transmission lines on many plant and animal species in the natural environment. This section briefly reviews the research on the effects of EMF on ecological systems to assess the likelihood of adverse impacts. In addition to the comprehensive review of research on this topic by wildlife biologists at BPA (Lee et al., 1996), a search of the published scientific literature for more recent studies published between 1995 and June 2005 was conducted.

3.1 Fauna

The habitat on the transmission-line right-of-way and surrounding area shields most wildlife from electric fields. Vegetation in the form of grasses, shrubs, and small trees largely shields small ground-dwelling species such as mice, rabbits, foxes, and snakes from electric fields. Species that live underground, such as moles, woodchucks, and worms, are further shielded from electric fields by the soil; aquatic species are shielded from electric fields by water. Hence, large species such as deer and domestic livestock (e.g., sheep and cattle) have greater potential exposures to electric fields since they can stand taller than surrounding vegetation. However, the duration of exposure for deer and other large animals is likely to be limited to foraging bouts or the time it takes them to cross under the line. Furthermore, all species would be exposed to higher magnetic fields under or near a transmission line than elsewhere, as the vegetation and soil do not provide shielding from this aspect of the transmission-line electrical environment.

Field studies have been performed in which the behavior of large mammals in the vicinity of high-voltage transmission lines was monitored. No effects of electric or magnetic fields were evident in two studies from the northern U.S. on big game species, such as deer and elk, exposed to a 500-kilovolt (kV) transmission line (Goodwin 1975; Picton et al., 1985). In such studies, a possible confounding factor is audible noise. Audible noise associated with high-voltage power transmission lines (with voltages greater than 110 kV) is due to corona. Audible noise generated by transmission lines reaches its highest levels in inclement weather (rain or snow).

Much larger populations of animals that might spend time near a transmission line are livestock that graze under or near transmission lines. To provide a more sensitive and reliable test for adverse effects than informal observation, scientists have studied animals continuously exposed to fields from the lines in relatively controlled conditions. For example, grazing animals such as cows and sheep have been exposed to high-voltage transmission lines and their reproductive performance examined (Lee et al., 1996). No adverse effects were found among cattle exposed to a 500-kV direct-current overhead transmission line over one or more successive breedings (Angell et al., 1990). Compared to unexposed animals in a similar environment, the exposure to 50-Hz fields did not affect reproductive functions or pregnancy of cows (Algers and Hennichs, 1985; Algers and Hultgren, 1987).

A group of investigators from Oregon State University, Portland State University, and other academic centers evaluated the effects of long-term exposure to EMF from a 500-kV transmission line operated by BPA on various cellular aspects of immune response, including the production of proteins by leukocytes (IL-1 and IL-2) of sheep. In previous unpublished reports, the researchers found differences in IL-1 activity between exposed and control groups. However, in their most recent replication, the authors found no evidence of differences in these measures of immune function. The sheep were exposed to 27 months of continuous exposure to EMF, a period of exposure much greater than the short, intermittent exposures that sheep would incur grazing under transmission lines. Mean exposures of EMF were 35-38 mG and 5.2-5.8 kV/m, respectively (Hefeneider et al., 2001).

Scientists from the Illinois Institute of Technology (IIT) monitored the possible effects of electric and magnetic fields on fauna and flora in Michigan and Wisconsin from 1969 – 1997 to evaluate the effects of an aboveground, military-communications antenna operating at 76 Hz. The antenna produces EMF at a frequency close to that of high-voltage transmission lines, but of much lower intensity. This study, which included embryonic development, fertility, postnatal growth, maturation, aerobic metabolism, and homing behavior, showed no adverse impacts of ELF electric and magnetic fields on the animals. The fish community examined in this study showed no significant differences in species diversity, biomass or condition when compared to the control site. The results of the other studies also demonstrated no convincing evidence for effects of EMF on any of the organisms or ecosystems they examined (NRC, 1997).

Another part of the IIT study examined the effect of the antenna system fields on the growth, development, and homing behavior of birds. Studies of embryonic development (Beaver et al., 1993), fertility, postnatal growth, maturation, aerobic metabolism, and homing behavior showed no adverse impacts of ELF electric and magnetic fields on the animals (NRC, 1997). Fernie and colleagues studied the effects of continuous EMF exposure of raptors to an electric field of 10 kV/m in a controlled, laboratory setting. The exposure was designed to mimic exposure to a 765-kV transmission line. Continuous EMF exposure was reported to reduce hatching success and increase egg size, fledging success, and embryonic development (Fernie et al., 2000). In a study of the effects on body mass and food intake of reproducing falcons, the authors found that EMF lengthened the photoperiod as a result of altered melatonin levels in the male species, yet concluded that "EMF effects on adult birds may only occur after continuous, extended exposure," which is not likely to occur from resting on power lines (Fernie and Bird, 1999:620). Fernie and Reynolds (2005) conducted a review of EMF from power lines on avian species and concluded that EMF can have an effect on birds, however these results are not seen consistently or in the same direction.

The hormone melatonin, secreted at night by the pineal gland, plays a role in animals that are seasonal breeders. Studies in laboratory mice and rats have suggested that exposure to electric and/or magnetic fields might affect levels of the hormone melatonin, but results have not been consistent (Wilson et al., 1981; Holmberg, 1995; Kroeker et al., 1996; Vollrath et al., 1997; Huuskonen et al., 2001). However, when researchers examined sheep and cattle exposed to EMF from transmission lines exceeding 500-kV, they found no effect on the levels of the hormone melatonin in blood, weight gain, onset of puberty, or behavior in sheep and cattle (Stormshak et al., 1992; Lee et al., 1993; Lee et al., 1995; Thompson et al., 1995; Burchard et al., 1998; Burchard et al., 2004)

Several avian species are reported to use the earth's static magnetic field as one of the cues for navigation. It has been proposed that deposits of magnetite in specialized cells in the head are the mechanism by which the birds can detect variations in the inclination and intensity of this direct-current (dc) magnetic field (Kirschvink and Gould, 1981; Walcott et al., 1988). In early studies of transmission lines, it was reported that the migratory patterns of birds appeared to be altered near transmission lines (Southern, 1975; Larkin and Sutherland, 1977). However, these studies were of crude design, and Lee et al. (1996) concluded that, "During migration, birds must routinely fly over probably hundreds (or thousands) of electrical transmission and distribution lines. We are not aware of any evidence to suggest that such lines are disrupting migratory flights" (Lee et al., 1996:4-59). No further studies on this topic have been identified in the literature (through June 2005).

Bees, like birds, are able to detect the earth's dc magnetic fields. They are known to use magnetite particles, which are contained in an abdominal organ, as a compass (Kirschvink and Gould, 1981). In the laboratory, they are able to discriminate between a localized magnetic anomaly and a uniform background dc magnetic field (Walker et al., 1982; Kirschvink et al., 1992).

Greenberg et al. (1981) studied honeybee colonies placed near 765-kV transmission lines. They found that hives exposed to ac electric fields of 7 kV/m had decreased hive weight, abnormal amounts of propolis (a resinous material) at hive entrances, increased mortality and irritability, loss of the queen in some hives, and a decrease in the hive's overall survival compared to hives that were not exposed. Exposure to electric fields of 7-12 kV/m may induce a current or heat the interior of the hive; however, placing the hive farther from the line, shielding the hive, or using hives without metallic parts eliminates this problem. ITT studied the effects of EMF on bees exposed to the 76-Hz antenna system at lower intensities and concluded that these behavioral effects of "ELF-EMF impacts are absent or at most minimal" (NRC, 1997:102).

Crystals of magnetite have also been found in Pacific salmon (Mann et al., 1988; Walker et al., 1988). These magnetite crystals are believed to serve as a compass that orients to the earth's magnetic field.

However, other studies have not found magnetite in sockeye salmon (*Oncorhynchus nerka*) fry (Quinn et al., 1981). While salmon can apparently detect the geomagnetic field, their behavior is governed by multiple stimuli as demonstrated by the ineffectiveness of magnetic field stimuli in the daytime (Quinn et al., 1982) and the inability of strong magnetic fields from permanent magnets attached to sockeye salmon to alter their migration behavior (Ueda et al., 1998). There are no data on the effects of ac EMF on salmon navigation, but based on a study with honeybees, it appears that organisms that use magnetite crystals to orient to the earth's magnetic field would be affected only when the field levels are very much greater than the levels expected from the transmission line. Given this evidence and the salmon's ability to navigate using multiple sensory cues, the proposed transmission line is unlikely to have an adverse impact on these species of concern and the aquatic ecosystems.

Reptiles and amphibians contribute to the overall functioning of the forest ecosystems. However, little research has been performed on the effects of EMF on reptiles and amphibians in their natural habitat.

3.2 Flora

Numerous studies have been carried out to assess the effect of exposure of plants to transmission-line electric and magnetic fields. These studies have involved both forest species and agriculture crops. Researchers have found no adverse effects on plant responses, including seed germination, seedling emergence, seedling growth, leaf area per plant, flowering, seed production, germination of the seeds, longevity, and biomass production (Lee et al., 1996).

The only confirmed adverse effect of transmission lines on plants was reported for transmission lines with voltages above 1200 kV. For example, Douglas fir trees planted within 15 meters (m) of the conductors were shorter than trees planted away from the line. Shorter trees are believed to result from corona-induced damage to the branch tips. Trees between 15 and 30 m away from the line suffered needle burns, but those 30 m and beyond were not affected (Rogers et al., 1984). These effects would not occur at the lower field intensities expected of the proposed 230-kV transmission line.

3.3 Summary of Ecological Research

The habitat on the transmission-line rights-of-way and surrounding areas shields smaller animals from electric fields produced by high-voltage transmission lines; thus, vegetation easily shields small animals from electric fields. The greatest potential for larger animals to be exposed to EMF occurs when they are passing beneath the lines. Studies of animal reproductive performance, behavior, melatonin production, immune function, and navigation have found minimal or no effects of EMF. Past studies have found little effect of EMF on plants; no recent studies of plants growing near transmission lines have been performed. In summary, the literature published to date has shown little evidence of adverse effects of EMF from high-voltage transmission lines on wildlife and plants. At the field intensities associated with the proposed 115 or 230-kV transmission line rebuild, no adverse effects on wildlife or plants are expected.

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Comment on *BioInitiative: A Rationale for a Biologically-based Exposure Standard for Electromagnetic Radiation*

Background

Scientific agencies develop exposure standards to protect the population against known health effects. The major purpose of a health risk assessment is to identify the lowest exposure level below which no health hazards have been substantiated (i.e., a threshold). Exposure limits are then set well below the threshold level to account for any individual variability or sensitivities that may exist.

Numerous scientific agencies have considered the cumulative body of research on extremely low frequency (ELF) electric and magnetic fields (EMF), and no scientific agency has concluded that ELF-EMF are the cause of any long-term health effects, including childhood leukemia. Therefore, no standards limiting exposure to ELF magnetic fields at the levels typically found in residential environments have been recommended or instituted. The only standards that exist to date protect against acute effects that are known to occur at high electric and magnetic field levels.[1] These international standards were published by scientific agencies with the authority and charge to develop ELF-EMF exposure standards and were developed following a review process that considered thermal and non-thermal (as well as acute and chronic) effects.

In August 2007, an *ad hoc* group of 14 scientists and public health and policy "experts" published a report to "assess scientific evidence on health impacts from electromagnetic radiation below current public exposure limits and evaluate what changes in these limits are warranted now to reduce possible public health risks in the future" (p. 4). The individuals who comprised this group did not represent any well-established regulatory agency, nor were they convened by a recognized scientific authority. The report (hereafter referred to as the BioInitiative report) is a collection of 17 sections on various topics each authored by one to three persons from the working group. The research on both ELF and radio frequency (RF) EMF was addressed, with major portions of the report focused largely or entirely on RF research. With regard to ELF-EMF, the epidemiologic literature related to childhood cancers, Alzheimer's disease and breast cancer was discussed, as well as the experimental data for a number of mechanistic hypotheses.

Conclusions and comments

The authors of the BioInitiative Report contended that the standard procedure for developing exposure guidelines – i.e., to set guidelines where adverse health effects have been established by using a weight-of-evidence approach – is not appropriate and should be replaced by a process that sets guidelines at exposure levels where biological effects

[1] The International Commission on Non-Ionizing Radiation Protection (ICNIRP) recommends a residential exposure limit to magnetic fields of 833 milligauss (mG) (ICNIRP, 1998), and the International Committee on Electromagnetic Safety (ICES) recommends a residential exposure limit to magnetic fields of 9,040 mG (ICES, 2002).

have been reported in some studies, but not substantiated in a rigorous review of the science or linked to adverse health effects.

Based on this argument, the main conclusion of the BioInitiative report was that existing standards for exposure to ELF-EMF are insufficient because "effects are now widely reported to occur at exposure levels significantly below most current national and international limits" (Table 1-1). Specifically, the authors concluded that there was strong evidence to suggest that magnetic fields were a cause of childhood leukemia based on epidemiologic findings. The report recommended the following:

> ELF limits should be set below those exposure levels that have been linked in childhood leukemia studies to increased risk of disease, plus an additional safety factor … While new ELF limits are being developed and implemented, a reasonable approach would be a 1 mG (0.1 µT) planning limit for habitable space adjacent to all new or upgraded power lines and a 2 mG (0.2 µT) limit for all other new construction. It is also recommended that a 1 mG (0.1 µT) limit be established for existing habitable space for children and/or women who are pregnant. (p. 22)

The recommendations made in the BioInitiative report are not based on appropriate scientific methods and, therefore, do not warrant any changes to the conclusions from the numerous scientific agencies that have already considered this issue. These organizations are consistent in their conclusions that the research does not support the setting of exposure standards at these low levels of magnetic field exposure.

The World Health Organization (WHO) published the most recent weight-of-evidence review in June 2007 and concluded the following:

> Everyday, low-intensity ELF magnetic field exposure poses a possible increased risk of childhood leukaemia, but the evidence is not strong enough to be considered causal and therefore ELF magnetic fields remain classified as possibly carcinogenic. (p. 357)

The report continued:

> Given the weakness of the evidence for a link between exposure to ELF magnetic fields and childhood leukaemia and the limited potential impact on public health, the benefits of exposure reduction on health are unclear and thus the cost of reducing exposure should be very low. (p. 372)

The WHO made no recommendations for exposure standards at the magnetic field levels where an association has been reported in some epidemiologic studies of childhood leukemia. In a fact sheet created for the general public and published on their website, the WHO stated,

> When constructing new facilities and designing new equipment, including appliances, low-cost ways of reducing exposures may be explored…However, policies based on the adoption of arbitrary low exposure limits are not warranted.[2]

The conclusions in the BioInitiative report deviate substantially from those of reputable scientific organizations because they were not based on standard, scientific methods. Valid scientific conclusions are based on weight-of-evidence reviews, which entail a systematic evaluation of the entire body of scientific evidence in three areas of research (i.e., epidemiology, *in vivo* research and *in vitro* research) by a panel of experts in these relevant disciplines. The report by the BioInitiative working group does not represent a valid weight-of-evidence review for the following key reasons:

1. **Review panels should consist of a multidisciplinary team of experts that reach consensus statements by collaboratively contributing to and reviewing the final work product.** This process ensures that overall conclusions represent a valid and balanced view of each relevant area of research. The document released by the BioInitiative working group was a compilation of sections, with each authored by one to three members of the group. It does not appear that the report was developed collaboratively or reviewed in its entirety by each member.

2. **Valid conclusions about causality are based on systematic evaluations of three lines of evidence - epidemiology, *in vivo* research and *in vitro* research.** The conclusions in the BioInitiative report are not based on this multidisciplinary approach. In particular, little attention is provided to the results from whole animal *in vivo* studies on cancer and disproportionate weight is given to the results of *in vitro* studies reporting biological effects.

3. **The entire body of evidence to date should be considered when drawing conclusions regarding the strength of evidence in support of a hypothesis.** The BioInitiative report is not a comprehensive review of the cumulative evidence. Rather, results from specific studies are cited, but no rationale is provided for their inclusion relative to the many other relevant, published studies.

4. **The evidence from each study must be critically evaluated to determine its validity and the degree to which it is relevant and able to support or refute the hypothesis under question.** The significance of the results reported in any study depend on the validity of the methods used in that study, so weight-of-evidence reviews must include an evaluation of the strengths and limitations of each study. In some discussions, the report claimed to use a weight-of-evidence approach, but the individual sections of the report provide little evidence that the strengths and limitations of individual studies (e.g., the quality of exposure assessment, sample size, biases, and confounding factors) were systematically evaluated.

[2] http://www.who.int/mediacentre/factsheets/fs322/en/index.html

5. **Support for a causal relationship is based on consistent findings from methodologically sound epidemiologic studies that are coherent with the results reported from *in vivo* and *in vitro* studies**. The BioInitiative group often arrived at conclusions about causality by considering only a few studies from one discipline, with no consideration of the significance and validity of the study's results.

In summary, the authors of this report largely ignored basic scientific methods that should be followed in the review and evaluation of scientific evidence. These methods are fundamental to scientific inquiry and are not, as the BioInitiative report states, "unreasonably high."

The policy responses proposed in the report are cast as consistent with the precautionary principle, i.e., taking action in situations of scientific uncertainty before there is strong proof of harm. A central tenet of the precautionary principle is that precautionary recommendations are proportional to the perceived level of risk and that this perception is founded largely on the weight of the available scientific evidence. The BioInitiative report recommends precautionary measures on the basis of argument, rather than sound peer-reviewed scientific evidence.

Unlike the BioInitiative report, the WHO report was the product of a multidisciplinary scientific panel assembled by an established public health agency that followed appropriate scientific methods, including the systematic and critical examination of all the relevant evidence. The recommendations from the WHO report (pp. 372-373) are presented below:

- Policy-makers should establish guidelines for ELF field exposure for both the general public and workers. The best source of guidance for both exposure levels and the principles of scientific review are the international guidelines.

- Policy-makers should establish an ELF EMF protection programme that includes measurements of fields from all sources to ensure that the exposure limits are not exceeded either for the general public or workers.

- Provided that the health, social and economic benefits of electric power are not compromised, implementing very low-cost precautionary procedures to reduce exposures is reasonable and warranted.

- Policy-makers and community planners should implement very low-cost measures when constructing new facilities and designing new equipment including appliances.

- Changes to engineering practice to reduce ELF exposure from equipment or devices should be considered, provided that they yield

other additional benefits, such as greater safety, or involve little or no cost.

- When changes to existing ELF sources are contemplated, ELF field reduction should be considered alongside safety, reliability and economic aspects.

- Local authorities should enforce wiring regulations to reduce unintentional ground currents when building new or rewiring existing facilities, while maintaining safety. Proactive measures to identify violations or existing problems in wiring would be expensive and unlikely to be justified.

- National authorities should implement an effective and open communication strategy to enable informed decision-making by all stakeholders; this should include information on how individuals can reduce their own exposure.

- Local authorities should improve planning of ELF EMF-emitting facilities, including better consultation between industry, local government, and citizens when siting major ELF EMF-emitting sources.

- Government and industry should promote research programmes to reduce the uncertainty of the scientific evidence on the health effects of ELF field exposure.

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