STATE OF MINNESOTA

**OFFICE OF ADMINISTRATIVE HEARINGS
FOR THE PUBLIC UTILITIES COMMISSION**

IN THE MATTER OF THE APPLICATION FOR A ROUTE PERMIT FOR THE FARGO TO ST. CLOUD 345 KV TRANSMISSION LINE PROJECT	PUC DOCKET NO. E002/TL-09-1056 OAH DOCKET NO. 15-2500-20995-2

SURREBUTTAL TESTIMONY OF

Dr. Peter A. Valberg

On Behalf of

APPLICANTS

NORTHERN STATES POWER COMPANY, A MINNESOTA CORPORATION
and GREAT RIVER ENERGY, A MINNESOTA COOPERATIVE CORPORATION

November 30, 2010

Exhibit _____

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I. INTRODUCTION & QUALIFICATIONS

Q. PLEASE STATE YOUR NAME AND YOUR BUSINESS ADDRESS.

A. My name is Dr. Peter A. Valberg and my business address is Gradient, 20 University Road, Cambridge, Massachusetts 02138.

Q. BY WHOM ARE YOU EMPLOYED AND WHAT IS YOUR POSITION?

A. I am a Principal for Environmental Health at Gradient ("Gradient"), and environmental consulting firm specializing in human health risk assessment. My resume is attached as **Schedule 1**.

Q. PLEASE SUMMARIZE YOUR EDUCATIONAL BACKGROUND.

A. My educational background includes an A.B. degree, *summa cum laude*, in Physics and Mathematics from Taylor University, both M.A. and Ph.D. degrees in Physics from Harvard University, and an M.S. degree in Human Physiology from the Harvard University School of Public Health ("Harvard SPH").

Q. WILL YOU SUMMARIZE YOUR EMPLOYMENT EXPERIENCE AND PROFESSIONAL CREDENTIALS?

A. For 25 years, I served as a faculty member in the Department of Environmental Health at Harvard SPH, where I researched and taught toxicology, cell biology, environmental health, and public health.

I have served on advisory panels for the National Institutes of Health, the Health Effects Institute, and the Environmental Protection Agency. I am a member of the International Society for Environmental Epidemiology, the Health Physics Society, the Bioelectromagnetics Society ("BEMS"), and the

Committee on Man and Radiation ("COMAR"). I have served on the Board of Directors of the BEMS.

Q. PLEASE DESCRIBE YOUR EXPERIENCE IN THE AREA OF ELECTRIC AND MAGNETIC FIELDS (COLLECTIVELY "EMF" AND INDIVIDUALLY "EFS" AND "MFS", RESPECTIVELY).

A. Among the research grants I directed as Harvard SPH (funded by the National Cancer Institute) was one on "[MFs] Effects on Macrophages" (macrophages are lung cells that clean the lung of particles deposited from dust present in air we breathe). I also served on the "Harvard Advisory Committee on EMF and Human Health" and the "Peer Review Board on Cellular Technology and Human Health" committees during the period of time when Harvard University (Center for Risk Analysis) had those as active committees. Additionally, I assisted the Health Effects Institute (Boston, MA) in determining the feasibility of launching an EMF research program, and published a summary document on "EMF Mechanisms" in the journal *Radiation Research*.

I have made several presentations on health effects at EMF-related conferences. At the request of the International Congress on Radiation Research ("ICRR"), I organized and chaired a symposium on "Physical aspects of EMF/[radio frequency ("RF")] effects on Biological Systems," at its 11th annual meeting in Dublin, Ireland. I helped organize a conference in the Boston area on "Childhood Leukemia: Electric and Magnetic Fields as Possible Risk Factors." A summary of this workshop was published in the journal *Environmental Health Perspectives*. In 2006, I was asked to present a lecture on

how EFs and MFs interact with living organisms by the Cyprus International Institute for the Environment and Public Health in a symposium on "Electromagnetic Fields: Sources, Health Effects, and Regulations," which took place in Nicosia Cyrus.

I recently worked with the World Health Organization ("WHO") (Geneva, Switzerland) on the health effects of EMF as they apply to cellular telephone technology. An article summarizing some of this work for WHO has been published in *Environmental Health Perspectives*, an a more complete discussion appears in the book: Base Stations and Wireless Networks: Exposures and Health Consequences. International Workshop on Base Stations and Wireless Networks: Exposures and Health Consequences. (Eds.: Repacholi, M.; van Deventer, E.; Ravazzani, P.), WHO, Geneva, Switzerland (2007)).

Additionally, a summary of administrative and regulatory proceedings from 1999-2010 for which I have provided testimony on EMF calculations and potential health effects is attached as **Schedule 2**.

Q. DESCRIBE YOUR EFFORTS TO MAINTAIN YOUR EXPERTISE IN THE AREA OF HEALTH EFFECTS RELATED TO EMF.

A. On a continuing basis, the librarians at Gradient provide me with recently-published articles related to EMF and health effects. I review those publications that are relevant to health risks potentially attributed to extremely low frequency ("ELF")-EMF (i.e. EMF from power lines) exposure.

I also participate in several professional organizations that discuss matters related to EMF. I am a member of BEMS, read its newsletter and subscribe to the society's journal *Bioelectromagnetics*, which published articles relevant to EMF and health effects. Through my membership in COMAR, I receive additional updates on developments on EMF research. I am a member of the Health Physics Society, read its newsletter, and subscribe to their journal *Health Physics*. Important EMF articles are published in *Health Physics*, and I review each issue as it comes into my office. I am also a full member of the Society of Toxicology, and at each annual meeting I identify and attend any talks or abstracts dealing with EMF. I subscribe to the society journal *Toxicological Sciences*, and review those articles relevant to the society journal. I am also a Fellow of the Academy of Toxicological Sciences. I am a member of the Society for Risk Analysis and continue to examine how EMF is evaluated relative to other societal and environmental exposures.

Q. YOU HAVE DISCUSSED BOTH "ELF" AND "RF" MFS. WILL YOU PLEASE EXPLAIN THE DIFFERENCE BETWEEN THESE TWO TYPES OF MFS ?

A. Among many other sources of MFs (e.g., the earth, magnetic resonance imaging), there are two types of MFs, RF-MFs and ELF-MFs, that have received considerable study. Transmission lines and most household appliances create ELF-MF. Cell phones, communication towers, and cell phone towers create RF-MF as well as RF-EFs. Power line magnetic fields operate at 60 Hz (i.e., ELF-MF). The human body is virtually transparent to power-line magnetic fields, and compared to the continuous background level of approximately 100-watts of energy burning in our bodies, the maximum

amount of energy delivered to the whole body by a 1,000 mG, 60-Hz magnetic field is less than 0.00000005 watt.

In contrast, RF-MFs at 900 MHz can heat tissue, depending on the intensity of the RF. The basic reason for this is that electromagnetic energy at radio and microwave frequencies is far more readily absorbed by biological tissues than ELF-MF.

Q. WHAT IS THE PURPOSE OF YOUR SUPPLEMENTAL TESTIMONY?

A. I was retained by the Applicants to provide testimony to address issues related to EMF that have arisen in this route proceeding, including issues raised by NoCapX 2020/U-CAN/NoRCA in comments at public hearings and in recently-issued discovery requests.

Q. WHAT SCHEDULES ARE ATTACHED TO YOUR TESTIMONY?

A. Schedule 1: Resume of Dr. Peter A. Valberg

Schedule 2: Administrative and regulatory proceedings (1999-2010) for which Dr. Peter A. Valberg has provided testimony on EMF calculations and potential health effects

Schedule 3: Direct Testimony provided by Dr. Peter A. Valberg for *In the Matter of the Route Permit Application by Great River Energy and Xcel Energy for a 342 kV Transmission Line from Brookings County, South Dakota to Hampton, Minnesota*, MPUC Docket No. E002/TL-08-1474; OAH Docket No. 7-2500-20283-2

Schedule 4: November 2010 Fact Sheet published by the International Commission on Non-Ionizing Radiation Protection

Schedule 5: NoCapX 2020/U-CAN/NoRCA Information Request No. 5

Schedule 6: Applicants' Responses to NoCapX 2020/U-CAN/NoRCA Information Request Nos. 6 and 7

II. PRIOR TESTIMONY

Q. HAVE YOU RECENTLY PROVIDED TESTIMONY FOR A PROJECT PROPOSED BY THE APPLICANTS?

A. Yes. I provided both written and oral testimony during the administrative proceedings for *In the Matter of the Route Permit Application by Great River Energy and Xcel Energy for a 342 kV Transmission Line from Brookings County, South Dakota to Hampton, Minnesota*, MPUC Docket No. E002/TL-08-1474; OAH Docket No. 7-2500-20283-2 ("the Brookings Project"). The pre-filed Direct Testimony I provided in that proceeding is attached as **Schedule 3**. This testimony includes a report I prepared and provides an overview of the scientific research conducted regarding the biological effects of ELF-EMF, focusing on whether ELF-MF affects human health as studies of EFs have not suggested any links to health, and the reviews of public health agencies, like the WHO, demonstrate that EFs are not at issue. The report also assembles the statements of public health agencies that evaluate the potential for ELF-MF health effects.

Q. DO YOU BELIEVE YOUR DIRECT TESTIMONY IS RELEVANT TO THIS PROCEEDING?

A. Yes. My Direct Testimony in the Brookings County—Hampton 345 kV Project proceeding summarized the state of science relating to ELF-MFs and health effects. The report and my testimony accurately summarize the scientific research completed as of the end of 2009 and I hereby reaffirm this testimony here.

Q. ARE THERE ANY UPDATES YOU WOULD LIKE TO ADD TO YOUR PRE-FILED TESTIMONY FOR THE BROOKINGS PROJECT?

A. Yes. Since I last provided testimony in Minnesota, two important reports have been published relating to ELF-MF In May 2010, the President's Cancer Panel published its 2008-2009 Annual Report, which provided comments on MFs. In November 2010, the International Commission on Non-Ionizing Radiation Protection ("ICNIRP") published new suggested guidelines for ELF-MF exposure for the general public.

Q. WHAT CONCLUSIONS WERE PRESENTED BY THE PRESIDENT'S CANCER PANEL ("PANEL") IN ITS 2008-2009 ANNUAL REPORT?

A. On January 27, 2009, the Panel heard testimony concerning both ELF and RF MFs. As explained in my pre-filed rebuttal testimony in the Brookings Project proceeding, transmission lines and most household appliances create ELF-MF. Cell phones, communication towers, and cell phone towers create RF-MF as well as RF electric fields. Regarding ELF-MFs, the Panel recognized that within the scientific community the potential harm from ELF-MFs is disputed. The Panel discussed that prior to 1996, the epidemiologic studies shared three weaknesses: distance to power lines was used to estimate ELF-MF exposures inside of a home, these studies were not blinded, and selection bias was identified. The National Cancer Institute performed a study which attempted to overcome these three issues and, as the Panel stated in their Annual Report, "The study found no significant excess childhood leukemia risk associated with actual [ELF-MF] . . . exposures in the home." The Panel also suggested that further research on this topic be performed. In conclusion the Panel stated

that "U.S. environmental organizations . . . generally conclude that the link between ELF-[MF] and cancer is controversial or weak."

Q. WHAT HAS ICNIRP RECENTLY PUBLISHED REGARDING ELF-MF GUIDELINES?

A. Yes. ICNIRP reviewed scientific studies performed since its last guidelines were published in 1998. ICNIRP noted that, after review of the research, scientific data available do not indicate an effect of ELF-MFs on the neuroendocrine system "in a way that would have an adverse impact on human health." Additionally, that there is no substantial evidence to associate ELF-MF exposure and Parkinson's disease, multiple sclerosis, and cardiovascular diseases, but that evidence for an association between ELF-MF and Alzheimer's disease or amyotrophic lateral sclerosis is inconclusive and evidence for an association between ELF-MF and developmental and reproductive effects is very weak. ICNIRP also reviewed the scientific evidence relating to ELF-MF and increased risk of childhood leukemia and concluded that the evidence "is too weak to form the basis for exposure guidelines." Therefore, as ICNIRP did in its 1998 guidelines for the general public, it declined to establish any chronic exposure guidelines.

ICNIRP only established an exposure guideline for acute effects (*i.e.* retinal phosphenes and other similar effects that go away as soon as the person is removed from the MF). The 2010 ICNIRP general public continuous exposure guideline is suggested to be 2,000 milligauss ("mG"), an increase from the 833 mG guideline from the 1998 ICNIRP report. The fact sheet prepared by ICNIRP is attached to my testimony as **Schedule 4**.

III. CALCULATED MAGNETIC FIELD LEVELS

Q. HAVE YOU REVIEWED THE CALCULATED MAGNETIC FIELD LEVELS PROVIDED BY APPLICANTS IN SCHEDULE 6 TO THE DIRECT TESTIMONY OF DARRIN LAHR AND SCHEDULE 2 TO DANIEL KLINE'S SURREBUTTAL TESTIMONY?

A. Yes.

Q. HOW DO THE MAGNETIC FIELD LEVELS COMPARE WITH OTHER 345 KV PROJECTS YOU HAVE REVIEWED?

A. They are similar. I have reviewed several projects in Massachusetts that involved overhead 345 kV circuits, and the maximum MFs across the right-of-way for these projects were comparable to what is shown in Schedule 2 of the Surrebuttal Testimony of Daniel Kline. Of course, ELF-MFs are dependent on line loading, and many projects are evaluated for MFs at maximum anticipated loading conditions. For example, for a 2007 project involving a 345-kV line, at maximum anticipated loading, peak MFs within the right-of-way were about 350 mG, and edge of right-of-way MFs were about 70 mG.

IV. MAGNETIC FIELD LIMITS

Q. SOME HAVE SUGGESTED THAT MF GUIDELINES SHOULD BE ESTABLISHED AROUND 2 TO 4 MG. DOES THE SCIENTIFIC EVIDENCE SUPPORT SUCH A LIMIT?

A. I reviewed the information request from NoCapX 2020/U-Can/NoRCA and noted the request for the distance from the transmission line where a level of 2

mG is reached. **Schedule 5**. A 2 mG limit is completely at odds with the opinion of major public health agencies in the United States and around the world. As documented in my report (attached as Schedule 2 to Schedule 3 of this testimony), no state agency, no federal agency, and no international public health agency has determined that these levels represent an unacceptable level of power-line MFs.

Also, as explained in that report, the magnetic fields associated with many household appliances exceed 2 mG, even at 2 feet from the appliance (see Table 1, Schedule 2, Valberg Direct). For example, vacuum cleaners have a measured magnetic field of 4-50 mG two feet away from the appliance and have a measured magnetic field of 20-200 mG one foot away from the appliance. To achieve household levels below 2-4 mG, many common appliances would need to be removed from the home, and portions of the home close to the power service drop wires would have to be cordoned off. Public transportation based on AC electric motors would have to be prohibited, and electric cars or hybrid cars would have to be discontinued.

Q. WHAT IS THE LOWEST ACCEPTED MF GUIDELINE BASED ON MEDICAL AND SCIENTIFIC EVIDENCE TO DATE?

A. The lowest guideline based on a medical and scientific analysis is the ICNIRP general-public guideline of 2,000 mG.

V. DISCOVERY

Q. WERE YOU RESPONSIBLE FOR ANSWERING ANY INFORMATION REQUESTS SUBMITTED TO APPLICANTS FROM NOCAPX 2020/U-CAN/NORCA?

A. Yes. I provided responses to request Nos. 6 and 7. They are attached as **Schedule 6**.

VI. CONCLUSION

Q. DOES THIS CONCLUDE YOUR PRE-FILED REBUTTAL TESTIMONY?

A. Yes.

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Peter A. Valberg, Ph.D., Fellow ATS
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Areas of Expertise

Public health, inhalation toxicology, epidemiology, human health risk assessment, risk communication, indoor / outdoor air quality, comparative toxicology, modeling of human exposure and retained dose, health effects of ionizing and non-ionizing radiation.

Education

M.S., Human Physiology and Inhalation Toxicology, Harvard School of Public Health.

Ph.D., Physics, Harvard University, Graduate School of Arts and Sciences.

M.A., Physics, Harvard University.

A.B., Physics and Mathematics, *summa cum laude*, Taylor University.

Professional Experience

2001 – Present (and 1990 – 1998) GRADIENT, Cambridge, MA
Principal. Environmental consulting practice includes inhalation toxicology; environmental health; human health risk assessment; use of epidemiology in public health decisions; health effects of airborne gases and particles; health effects of ionizing and non-ionizing radiation.

1998 – 2000 CAMBRIDGE ENVIRONMENTAL, INC., Cambridge, MA
Senior Scientist.

1985 – 2000 HARVARD SCHOOL OF PUBLIC HEALTH, Boston, MA
Associate Professor of Human Physiology. (Adjunct, after 1990) Research work included: (1) human health effects of air toxics, (2) lung macrophage function measured with magnetic particles, (3) lung deposition and clearance of radioactive tracer particles.

1987 INSTITUTE OF OCCUPATIONAL HEALTH, Helsinki, Finland
Visiting Researcher. Developed a magnetometric assay to be used for studying pulmonary macrophage function for lung cells lavaged from human subjects.

1984 INHALATION TOXICOLOGY RESEARCH INSTITUTE, Albuquerque, NM
Visiting Scientist. Examined the effect of exercise and hypercapnia on deposition, lung clearance, and lung distribution of inhaled radioactive aerosol.

1976 – 1985 HARVARD SCHOOL OF PUBLIC HEALTH, Boston, MA
Assistant Professor of Respiratory Physiology.

1970 – 1976 AMHERST COLLEGE, Amherst, MA
Assistant Professor of Physics.

Professional Activities

- National Academy of Sciences and National Research Council, Evaluating Health-Risk-Reduction Benefits of USEPA Regulations (2001 – 2003).
- Harvard School of Public Health: Research Advisory Committee Member for NIH-Sponsored Research on "Mechanisms of mortality/morbidity due to air particulate" (1997 – 2005).
- Member of the Committee on Man and Radiation (COMAR) (1999 – 2006).
- Health Effects Institute, Cambridge, MA, *ad hoc* reviewer (1984 – 1994).
- National Research Council, Commission on Life Sciences: Committee on Passive Smoking (1986-1988).
- Editorial Board, *Journal of Aerosol Medicine* (1987– 2000).
- Center for Indoor Air Research, grant-application reviewer (1989 – present).
- NIOSH: Environmental Center Grants, Site Visit Delegation (1990).
- NIH Reviewer: Cardiovascular and Pulmonary Study Section, Radiation Study Section, and Health of the Population Study Section.
- DOE: Office of Health and Environmental Research, reviewer.
- Harvard Center for Risk Analysis: Review of Cellular Telephones (1994 – 1999).
- Physical and Biological Sciences Study Committee, Town of Needham Planning Board.

Professional Affiliations

Fellow of the Academy of Toxicological Sciences • Society of Toxicology (full member) • International Society for Environmental Epidemiology • Society for Risk Analysis • Health Physics Society (full member) • Sigma Xi • American Association for the Advancement of Science • American Conference of Governmental Industrial Hygienists (associate member)

Projects *(abbreviated)*

Carbon Black Manufacturers: Evaluated the toxicology and epidemiology of carbon black inhalation and ingestion.

Charter School in Washington, DC: Prepared a health risk assessment for the school board on the health risks of handling asbestos-containing materials that might release fibers.

City of Newton Health Department: Measured RF levels from a local transmitting antenna, reviewed RF field calculations, and provided scientific literature critique on RF health effects.

Confidential Client: Prepared a risk assessment for a Massachusetts landfill containing both chemical and radioactive waste and including multiple pathways of contaminant uptake by a trespasser.

Confidential Client: Prepared a model predictive of asbestos fiber drift and inhalation health hazard applicable to industrial processes where asbestos-containing materials are used.

Confidential Clients: Prepared an analysis of relative risks of TCE in drinking water *versus* health hazards from background levels of chemicals in air, water, and soil, as well as other routine risks to life and health.

Electric-Power Generating Companies: Prepared and delivered expert reports and public testimony on the potential health effects of airborne emissions from coal fired, gas fired, oil fired, and wood-fired electric utility power generating plants.

Electric Power Research Institute: Reviewed and analyzed the mechanisms by which biological systems may be affected by environmental electric and magnetic fields (EMFs). Organized a public workshop on the causes and characteristics of childhood leukemia.

Engine Manufacturers Association: Prepared critiques of the U.S. EPA and California EPA health assessment documents on the potential carcinogenicity of diesel exhaust and ambient air particulate matter.

Harvard School of Public Health: Continuing Education for Professionals: Prepared material on special topics on inhalation toxicology for graduate students and health professionals: Presented lectures on risk assessment and risk communication.

Health Effects Institute: Prepared an analysis entitled "Ozone Molecular Dosimetry and Interaction with Biological Macromolecules."

Health Effects Institute: Organized, supervised, and documented a feasibility study for the Health Effects Institute initiating a national research program on the health effects of electric and magnetic fields.

Manufacturing Company: Analyzed multi-pathway human health risk for a site contaminated with polychlorinated biphenyls (PCBs) and chlorinated organic solvents. Analyzed experimental data to derive a fraction of PCBs that are picked up from concrete by dermal contact.

Manufacturing Company/FUSRAP Site: Prepared a radionuclide health risk assessment and site management plan for site contaminated by nearby storage of uranium ore.

Massachusetts Department of Public Health: Prepared a public communications essays on what citizens can do to support improved air quality.

Medical Product Manufacturer: Prepared a risk assessment for air toxics produced during malfunction of a medical device used to assist breathing.

Michigan Occupational and Environmental Medical Association (MOEMA): Prepared and delivered a risk assessment tutorial for MOEMA's Continuing Education program.

Mining Company: Evaluated the epidemiological basis for the toxicity of arsenic in soils. Evaluated metals toxicity factors and site-specific bioavailability of metals.

National Institute of Environmental Health Sciences – Division of Research Grants: Revised grant applications for the Radiation Study Section Panel on Health-Effects Research.

Navy Occupational Health and Preventive Medicine Program: Prepared and delivered seminars and workshops to U.S. Navy medical personnel on the current research on electric and magnetic fields (EMFs).

New Mexico Environmental Department: Prepared a health risk assessment for measured and modeled concentrations of 80 airborne chemicals in Albuquerque, NM.

Refinery: Prepared a multipathway human health risk assessment for air emissions from a petroleum refinery. Our risk assessment preparation process was monitored by a Multi-Agency Task Force composed of regulators, educators, union members, and local officials.

School District on Long Island: Assessed possible environmental, occupational, and lifestyle risk factors for early-term miscarriage.

University of Denver: Analyzed the potential health impact of uranium disposal from munitions testing ("depleted uranium") as it was practiced in the 1960's and 1970's.

Uranium Mill: Evaluated the health implications of radioactive substance migration as predicted by different EPA and DOE models.

U.S. Department of Energy: Prepared a risk communication strategy for a nuclear test site where detonation of underground atomic devices had the potential to contaminate groundwater.

U.S. Department of Justice: Prepared an analysis of the health hazards of the Love Canal Superfund site (Niagara Falls, NY).

U.S. Department of Justice: Prepared a report and provided expert testimony on human toxicology with regard to soil contamination at a RCRA site.

U.S. Department of Justice: Prepared reports and provided expert testimony on asbestos, sulfuric acid, and airborne particulate inhalation toxicology.

U.S. Environmental Protection Agency: Provided USEPA with a peer review (scientific critique) of the Agency's draft reference concentration (RfC) methodology for risk assessment.

U.S. Environmental Protection Agency: Analyzed the health risks of a remediation alternative at the Bloody Run Creek section of the Hyde Park Landfill superfund site (Niagara Falls, NY).

U.S. Environmental Protection Agency, Health Effects Research Laboratory: Assisted in preparing a database of non-cancer health effects for 189 Hazardous Air Pollutants.

U.S. Environmental Protection Agency, Environmental Criteria and Assessment Office: Evaluated research proposals on "Indoor and Ambient Air Risk Assessment Methodologies."

Utility: Analyzed the relationship between inhaled carbon monoxide concentration and blood carboxyhemoglobin. Performed sensitivity analysis on all the variables involved.

Waste Management Company: Evaluated health risks for a medical waste incinerator, including a multiple-pathway (ingestion, inhalation, dermal, mothers' milk) health risk assessment.

World Health Organization: Helped prepare a WHO research report on electric and magnetic field (EMF) health effects. Presented a lecture on EMF health effects at a WHO workshop in Geneva, Switzerland. Published review article on RF health effects.

Academic Research Projects *(abbreviated)*

National Heart, Lung, and Blood Inst.:	"Physical Determinants of Lung Function and Dysfunction."
National Heart, Lung, and Blood Inst.:	"Pulmonary SCOR: Chronic Diseases of the Airways."
National Cancer Institute:	"Magnetic Field Effects on Macrophages."
National Inst. of Environ. Health Sci.:	"Inhaled Particle Retention in Normal and Diseased Lungs."
National Heart, Lung, and Blood Inst.:	"Particle Location and Ingestion by Lung Macrophages."
National Inst. of Environ. Health Sci.:	"Factors Influencing Deposition of Inhaled Aerosols."

Publications – *Articles*

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Valberg, PA; Long, CM; Sax, SN. 2006. "Integrating studies on carcinogenic risk of carbon black: epidemiology, animal exposures, and mechanism of action." *Journal of Environmental and Occupational Medicine* 48:1291-1307.

Stout, N; Valberg, PA. 2005. "Bayes' law, sequential uncertainties, and evidence of causation in toxic tort cases." *Michigan Journal of Law Reform* 38(4):781-910.

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Abstracts & Reports *(list available on request)*

Invited Lectures *(past 10 years)*

6/23/08 "Routes of Entry into the Body: Pulmonary Deposition and Clearance of Particles." Presented in the course "Comprehensive Industrial Hygiene: Practical Applications of Basic Principles," Harvard School of Public Health, Boston, MA.

6/25/07 "Routes of Entry into the Body: Pulmonary Deposition and Clearance of Particles." Presented in the course "Comprehensive Industrial Hygiene: Practical Applications of Basic Principles," Harvard School of Public Health, Boston, MA.

3/29/07 "Non-linear Exposure-Response Relationships between Ambient PM_{10} and Daily Mortality." Presentation with Dr. T. Bowers at the Society of Toxicology Annual Meeting, Charlotte, NC. This presentation was selected as one of the *Top 12 Risk Assessment Abstracts at the SOT Meeting.*

11/7/06 "What is EMF? How EMF Interacts with Organisms." Presented at the Cyprus International Institute for the Environment and Public Health symposium on "Electromagnetic Fields: Sources, Health Effects, and Regulations, Nicosia, Cyprus.

6/19/06 "Pulmonary Deposition and Clearance of Particles." Presented in the course "Comprehensive Industrial Hygiene: Practical Applications of Basic Principles," Harvard School of Public Health, Boston, MA.

5/18/06 "Health Hazards of Nanoparticles." Presented at "A Mock Hearing: Environment, Health & Safety" at the NanoBusiness Alliance Meeting, New York City, NY.

4/25/06 "Inhalation Risk Assessment: Extrapolating from Macro-materials to Nano-materials." Overcoming Obstacles to Effective Research Design in Nanotoxicology, Cambridge, MA.

10/6/05 Panelist for: "A Reevaluation of the Association Between Diesel Exhaust Exposure and Lung Cancer." Air & Waste Management Association (AWMA) Specialty Workshop on "Diesel Exhaust," Chicago, IL.

6/20/05 "The Respiratory Tract as a Portal of Entry for Airborne Chemicals in the Work Environment." Lecture at the Harvard School of Public Health course on "Comprehensive Industrial Hygiene," Boston, MA.

6/16/05 "Electromagnetic Fields, Base Stations, and Wireless Networks: Exposures & Health Consequences." WHO Workshop, 15-16 June 2005, at the World Health Organization, Geneva, Switzerland.

2/11/05 "Generation of Charged Aerosols by High-Voltage Electric-Power Lines." American Association for Aerosol Research, Specialty Conference on Particulate Matter, Atlanta, GA.

2/4/05 "Magnetic Microparticles Detect and Probe Cytoplasmic Motions." Bioelectromagnetics Society Winter Workshop, Phoenix, AZ.

6/21/04 "Pulmonary Deposition and Clearance of Particles." Harvard School of Public Health Continuing Education Course on "Fundamentals of Industrial Hygiene," Boston, MA.

1/27/04 "Quantitative and Qualitative Factors that Determine Health Risk: Explaining Risk to Judges, Juries, and Communities." Mealey's Water Contamination Conference, Pasadena, CA.

9/14/02 "Health Effects of Air Pollutants." Annual Scientific Meeting of the Michigan Occupational and Environmental Medicine Association "Current Topics in Occupational and Environmental Medicine," Frankenmuth, MI.

6/18/01 "Pulmonary Physiology, and Lung Deposition and Clearance of Particles." Harvard School of Public Health Continuing Education Course on "Fundamentals of Industrial Hygiene," Boston, MA.

11/14/00 "Effects of Air Pollution on the Human Lung." Lecture in Tufts University course CEE 136, "Air Pollution," Medford, MA.

7/26/00 "Review of Ambient Air Quality as it Relates to Proposed Emission Standards for Massachusetts Power Plants." Testimony before the Massachusetts Department of Environmental Protection, Boston, MA.

1/10/00 "Useful Concepts in the Physics of RF." RF Safety: Science, Compliance and Communication, Electromagnetic Energy Association and the University of Texas Health Science Center, San Antonio, TX.

12/16/99 "Exposure to inhaled pesticides and human health risks." 51st Annual Crop Protection School, Office of Continuing Professional Education, North Carolina State University, Raleigh, NC.

7/21/99 "How do Endogenous Forces Compare to EM Forces and Torques on Electrical Charges and Magnetite?" 11th International Congress of Radiation Research, Dublin Inst. of Technology, Dublin, Ireland.

6/7/99 "Lack of Concordance between Reported Lung Cancer Risk Levels and the Occupation-Specific Potential for Diesel Exhaust Exposure." Third Colloquium on Particulate Matter and Human Health, Durham, NC..

3/8/99 "Relative Risk Issues in Urban Pesticide Exposure and Children's Health." Association of American Pesticide Control Officials, AAPCO States/Industries Forum, Washington, DC.

1/13/99 "Panel Discussion on Health Effects of Wireless Technology." Cape Cod Commission, Deliberations at Cape Cod Community College, Barnstable, MA.

12/8/98 "Review of Health Issues in a Proposed Antenna Upgrade." City of Newton Health Department, Land Use Committee Deliberations, Newton, MA.

11/30/98 "Overview of Radio Wave Health Effects." Wayland, MA, Cellular Telephone Committee, Wayland Town Meeting Warrant.

8/3/98 "Exposure Assessment in Power-line-EMF and Radio-wave Epidemiologic Studies." EPE.215T "Environmental and Occupational Epidemiology," Harvard School of Public Health, Boston, MA.

4/22/98 "Health Risks from Electrical Power Lines and Cellular Telephones." EH.202D "Principles of Environmental Health," Harvard School of Public Health, Boston, MA.

3/23/98 "Inhalation and Dermal Exposure to Occupational Chemicals." Harvard School of Public Health, Continuing Education Course on "Fundamentals of Industrial Hygiene," Boston, MA.

Manuscript Peer Reviewer for the Following Research Journals

American Industrial Hygiene Journal; American Journal of Physics; American Journal of Respiratory Cell and Molecular Biology; American Review of Respiratory Disease; Atmospheric Environment; Bioelectromagnetics; Biophysical Journal; Biorheology; Cell Biophysics; Critical Reviews in Toxicology; Environmental Geochemistry and Health; Environmental Health Perspectives; Environmental Science & Technology; Epidemiology; Experimental Lung Research; Fundamental and Applied Toxicology; Hepatology; Human and Ecological Risk Assessment; Human and Experimental Toxicology; IEEE Biomedical Engineering; IEEE Transactions on Plasma Science; Journal of Aerosol Medicine and Pulmonary Drug Delivery; Journal of Applied Physiology; Journal of Applied Toxicology; Journal of Occupational and Environmental Hygiene; Journal of Occupational and Environmental Medicine; Journal of Occupational Medicine and Toxicology; Journal of Toxicology and Environmental Health; Nature; Nonlinearity in Biology, Toxicology, and Medicine; Radiation Research; Risk Analysis: An International Journal; Regulatory Toxicology & Pharmacology; Science; Tissue & Cell; Toxicology and Applied Pharmacology; Toxicological Sciences; USGS Environmental Geochemistry of Mineral Deposits (Reviews in Economic Geology series).

Administrative and regulatory proceedings (1999-2010) for which Dr. Peter A. Valberg has provided testimony on Electric and Magnetic Field (EMF) calculations and potential health effects

Abbreviations:

PSC = Public Service Commission
CSC = Connecticut Siting Council
www.ct.gov/csc/site/default.asp
MA EFSB = Massachusetts Energy Facilities Siting Board
www.mass.gov/dpu/siting_board.htm
MA DPU = Massachusetts Department of Public Utilities
http://www.mass.gov/dpu
MA DTE = Massachusetts Department of Telecommunications and Energy
Michigan PSC= Michigan Public Service Commission
www.michigan.gov/mpsc

Testimony on Behalf of	Regulatory Board	EMF Testimony Regarding	Date
Sithe West Medway	MA EFSB	Proposed 540 MW, 115-kV, Generation Facility, EFSB 98-10	March 24, 1999
Mystic River Station Redevelopment Project	MA EFSB	Proposed 1,550 MW, 115-kV, Generation Facility, EFSB 98-8	May 21, 25, 1999
Sithe Fore River Station	MA EFSB	Proposed 775 MW, 115-kV, Generation Facility, EFSB 98-7	Aug. 10-13, 1999
IDC Bellingham, LLC	MA EFSB	Proposed 700 MW, 115-kV, Generation Facility, EFSB 97-5	April/May, 1999
Brockton Power, LLC	MA EFSB	Proposed 270 MW, 115-kV, Generation Facility, EFSB 99-1	July 6, 1999
Western Mass. Electric Company	MA DTE	Proposed Agawam 115-kV Substation, DTE 99-35	Oct. 20, 1999
Nickel Hill Energy, LLC	MA EFSB	Proposed 750 MW, 345-kV, Generation Facility, EFSB 99-3	Dec. 6, 1999
Southern Energy Kendall, LLC	MA EFSB	Proposed Upgrade of Generation Facilities (115-kV) EFSB 99-4	March 14, 2000
Commonwealth Assoc., and City of Sunfish Lake (MN), City Council	Mendota Heights, MN, City Council, Public Hearing	Double Circuiting of Xcel Energy Red Rock-Wilson 115-kV Circuit	March 22, 2001
Cambridge (MA) Electric Light Company	MA EFSB	Proposed Underground 115 kV Transmission Line, EFSB 00-3 / D.T.E. 00-103	May 31, 2001
Town of Ashland, MA	Ashland, MA, Zoning Board	Proposed School Construction near 115-kV Transmission Lines	Jan. 28, 2002
Clear Channel Radio	Newton, MA Conservation Commission	Proposed AM Radio Upgrade, DEP 239-0448	Jan. 23, 2003

Testimony on Behalf of	Regulatory Board	EMF Testimony Regarding	Date
Massachusetts Electric Company	MA DTE	Proposed 115-kV Substation, Barnstable, MA, DTE 03-7	April 14, 2003
Cape Wind Associates, LLC (MA)	MA EFSB	Proposed Submarine / Underground 115 kV Line, EFSB 02-2 / DTE 02-53	Sept. 5, 2003
Northeast Utilities	CSC	Shunock 115-kV Substation, Stonington, CT	Nov. 18, 2003
Vermont Electric Company (VELCO)	Vermont Public Service Board (PSB)	Northeast 345-kV Reliability Project (NRP), PSB Docket # 6860	Feb. 23-24, 2004
NSTAR	MA EFSB	Stoughton-to-Boston 345-kV line EFSB 04-1, DTE 04-5, 04-7	July 13, 2004
NSTAR	MA EFSB	Sherborn 115-kV line DTE 04-71	Feb. 24, 2005
CSC	CSC Public Hearing	EMF Best Management Policies	April 20, 2006
ITC Transco	Michigan PSC	120-kV Genoa-to-Prizm Line, MPSC Case # U-14861	Nov. 27, 2006 (prefiled)
CSC	CSC Public Hearing	EMF Best Management Policies	Jan. 9, 2007
ITC Transco	Michigan PSC	345-kV Bismark-to-Troy Line, MPSC Case # U-14933	Feb. 26, 2007
Braintree Electric Light Department	MA EFSB	Thomas J. Watson Power Plant, 115-kV, EFSB 07-01 / DTE / DPU 07-5	Aug. 3, 2007
Montgomery Energy, Billerica Power Partners	MA EFSB	Billerica LLC, Combined Cycle Power Plant, 115-kV, EFSB 07-02	Oct. 23, 25, 30, 2007
Massachusetts Municipal Wholesale Electric Company	MA EFSB	MMWEC Power Plant, 345-kV, EFSB 07-06	Jan. 25, 2008
PPM Energy	MA DTE	Wind Farm Interconnect, 34.5 kV, D.P.U. 07-80,	March 7, 2008
Brockton Power Company, LLC	MA EFSB	Combined Cycle Power Plant. 115-kV, EFSB 07-7 / D.P.U. 07-58 / D.P.U. 07-59	June 19, 26, 2008 July 1, 2008
Related Companies, Waltham, MA, and NSTAR	MA DTE	Re-route of 115-kV Lines D.P.U. 08-01	July 28, 2008
Westfield Land Development Co.	MA EFSB	Pioneer Valley Electric Company (PVEC) Power Plant, 345-kV, EFSB 08-1	Dec. 12, 2008
City of Lynn, MA	MA DPU	Lynn Harbor, MA, Relocation of 115-kV lines, DPU 08-103	June 19, 2009
New England Power Co. *d/b/a* National Grid	MA DPU	Amesbury, MA, K-163, new 115-kV Line, DPU 09-27/09-28	Oct. 20, 2009
Great River Energy and Northern States Power Company	MN PUC	Brookings to Hampton 345 kV transmission line, MPUC 08-1474	Dec. 17, 2009 & public hearings

Direct Testimony and Schedules
Dr. Peter A. Valberg

STATE OF MINNESOTA

OFFICE OF ADMINISTRATIVE HEARINGS
FOR THE PUBLIC UTILITIES COMMISSION

IN THE MATTER OF THE ROUTE PERMIT APPLICATION BY GREAT RIVER ENERGY AND XCEL ENERGY FOR A 345 KV TRANSMISSION LINE FROM BROOKINGS COUNTY, SOUTH DAKOTA TO HAMPTON, MINNESOTA	PUC DOCKET NO. ET2/TL-08-1474 OAH DOCKET NO. 7-2500-20283-2

TESTIMONY OF

Dr. Peter A. Valberg

On Behalf of

APPLICANTS

GREAT RIVER ENERGY, A MINNESOTA COOPERATIVE CORPORATION
AND
NORTHERN STATES POWER COMPANY, A MINNESOTA CORPORATION

October 13, 2009

Exhibit _____

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I. INTRODUCTION AND QUALIFICATIONS

Q. PLEASE STATE YOUR NAME AND YOUR BUSINESS ADDRESS.

A. My name is Peter A. Valberg and my business address is 20 University Road, Cambridge, Massachusetts 02138.

Q. BY WHOM ARE YOU EMPLOYED AND WHAT IS YOUR POSITION?

A. I am a Principal for Environmental Health at Gradient LLC ("Gradient"), an environmental consulting firm specializing in human health risk assessment. My resume is attached as **Schedule 1**.

Q. PLEASE SUMMARIZE YOUR EDUCATIONAL BACKGROUND.

A. My educational background includes an A.B. degree, *summa cum laude*, in Physics and Mathematics from Taylors University, both M.A. and Ph.D. degrees in Physics from Harvard University, and an M.S. degree in Human Physiology from the Harvard University School of Public Health ("Harvard SPH").

Q. PLEASE SUMMARIZE YOUR EMPLOYMENT EXPERIENCE AND PROFESSIONAL CREDENTIALS.

A. For 25 years, I served as a faculty member in the Department of Environmental Health at Harvard SPH, where I researched and taught toxicology, cell biology, environmental health, and public health.

I have served on advisory panels for the National Institutes of Health ("NIH"), the Health Effects Institute, and the Environmental Protection Agency. I am a member of the International Society for Environmental Epidemiology, the

Health Physics Society, the Bioelectromagnetics Society, and the Committee on Man and Radiation ("COMAR"). I have served on the Board of Directors of the Bioelectromagnetics Society.

Q. PLEASE DESCRIBE YOUR EXPERIENCE IN THE AREA OF ELECTRIC AND MAGNETIC FIELDS ("EMF").

A. Among the research grants that I directed at Harvard SPH (funded by the National Cancer Institute) was one on "Magnetic Fields Effects on Macrophages" (where macrophages are lung cells that clean the lung of particles deposited from dust present in the air we breathe). I also served on the "Harvard Advisory Committee on EMF and Human Health" and the "Peer Review Board on Cellular Technology and Human Health" committees during the period of time when Harvard University (Center for Risk Analysis) had those as active committees. Additionally, I assisted the Health Effects Institute (Boston, MA) in determining the feasibility of launching an EMF research program, and published a summary document on "EMF Mechanisms" in the journal *Radiation Research*.

I have made several presentations on health effects at EMF-related conferences. At the request of the International Congress on Radiation Research ("ICRR"), I organized and chaired a symposium on "Physical aspects of EMF / RF effects on Biological Systems," at its 11th annual meeting in Dublin, Ireland. I helped organize a conference in the Boston area on "Childhood Leukemia: Electric and Magnetic Fields as Possible Risk Factors." A summary of this workshop was published in the journal *Environmental Health Perspectives*. In 2006, I was asked to present a lecture on how EMF interacts with living organisms by the Cyprus

International Institute for the Environment and Public Health in a symposium on "Electromagnetic Fields: Sources, Health Effects, and Regulations," which took place in Nicosia, Cyprus.

I recently worked with the World Health Organization ("WHO") (Geneva, Switzerland) on the health effects on EMF as they apply to cellular telephone technology. An article summarizing some of this work for WHO has been published in *Environmental Health Perspectives*, and a more complete discussion appears in the book: Base Stations and Wireless Networks: Exposures and Health Consequences. International Workshop on Base Stations and Wireless Networks: Exposures and Health Consequences. (Eds.: Repacholi, M; van Deventer, E; Ravazzani, P), WHO, Geneva, Switzerland (2007).

Q. DESCRIBE YOUR EFFORTS TO DATE TO MAINTAIN YOUR EXPERTISE IN THE AREA OF HEALTH EFFECTS RELATED TO EMF.

A. On a continuing basis, the librarians at Gradient provide me with recently published articles related to EMF health effects. I review those publications that are relevant to health risks potentially attributed to power-line EMF exposure.

I also participate in several professional organizations that discuss matters related to EMF. I continue to be a member of the Bioelectromagnetics Society ("BEMS"), read its newsletter and subscribe to the society's journal "Bioelectromagnetics," which publishes articles relevant to EMF health effects. Through being a member of COMAR, I receive additional updates on developments in the EMF area. I am a member of the Health Physics Society, read their newsletter, and subscribe to their journal "Health Physics." Important

EMF articles are published in this journal, and I review each issue as it comes in. I am also a full member of the Society of Toxicology, and at each annual meeting, I identify and attend any talks or abstracts dealing with EMF. I subscribe to the society journal, "Toxicological Sciences," and review those articles relevant to EMF. I am also a Fellow of the Academy of Toxicological Sciences. I am a member of the Society for Risk Analysis and continue to examine how EMF is evaluated relative to other societal and environmental risks.

II. EMF REPORT

Q. DID YOU PREPARE A REPORT IN THIS PROCEEDING REGARDING EMF?

A. Yes. At the request of CapX2020, I prepared a report entitled "Power-Line Electric and Magnetic Fields (EMF): Status of Scientific Research on Potential Health Effects." A copy of this report is attached as **Schedule 2**.

Q. WHAT IS THE PURPOSE OF THIS REPORT?

A. This Report provides an overview of the scientific research conducted regarding the biological effects of EMF, focusing on whether EMF affects human cancer. The report also assembles the statements of public health agencies that evaluate the potential for power-line EMF health effects.

III. SUMMARY OF SCIENTIFIC RESEARCH ON EMF

Q. COULD YOU PLEASE SUMMARIZE THE SCIENTIFIC RESEARCH ON POSSIBLE HEALTH EFFECTS OF POWER-LINE EMF.

A. As detailed in my report, scientific investigations of possible health effects of power-line EMF have been taking place around the world for nearly 40 years. Even though the term "EMF health-effects research" is commonly used, the focus of health-effects investigations has been on power-line magnetic fields ("MF"), not electric fields. Studies of electric fields have not suggested any links to health, and the reviews of public health agencies (*e.g.*, the World Health Organization) have not identified health risk concerns relating to power-line electric field. With regard to MF, epidemiologic studies have reported weak, generally inconsistent, associations between the risk of childhood and leukemia and MF. Most of these studies have used surrogates or proxies of MF exposure, and not actual measurements of the relevant MF, and are unable to assign a causal basis for the associations reported. Moreover, scientists have not been able to establish a laboratory animal or mechanistic model relevant to human cancer risk that reliably demonstrates adverse biological changes in response to typical electric-power MF levels. Major studies, including those of the National Toxicology Program, report a lack of adverse effects from MF exposure, even at levels far above those typical of power-line rights-of-way. A limited set of studies have reported some biological effects, however, the effects are of uncertain relevance and most have not been replicated. No standard bioassay of "MF bioeffects" currently exists.

Q. IN YOUR PROFESSIONAL AND EXPERT OPINION, WHAT ARE THE HEALTH RISKS ASSOCIATED WITH EMF?

A. 60-Hz electric power has been used in the United States for nearly a century, and scientific research on EMF has been underway for many decades. Despite such extensive experience with people and animals being exposed to power-line MF, links to human health hazards remain hypothetical and speculative. Public health has improved dramatically over the same period of time that electric-power consumption has increased many-fold. Scientific research cannot prove a negative (*i.e.*, zero risk), but available data has not established either an EMF human health risk or even the factors or parameters of power-line MF on which such a risk might depend. It is my opinion that, among the multitude of environmental exposures that we experience daily, and which can or may have an effect on human health, power-line MF exposure remains an implausible source of human health risk.

IV. CONCLUSION

Q. DOES THIS CONCLUDE YOUR PRE-FILED DIRECT TESTIMONY?

A. Yes.

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Areas of Expertise

Public health, inhalation toxicology, epidemiology, human health risk assessment, risk communication, indoor / outdoor air quality, comparative toxicology, modeling of human exposure and retained dose, health effects of ionizing and non-ionizing radiation.

Education

M.S., Human Physiology and Inhalation Toxicology, Harvard School of Public Health.

Ph.D., Physics, Harvard University, Graduate School of Arts and Sciences.

M.A., Physics, Harvard University.

A.B., Physics and Mathematics, *summa cum laude*, Taylor University.

Professional Experience

2001 – Present (and 1990 – 1998) GRADIENT, Cambridge, MA
Principal. Environmental consulting practice includes inhalation toxicology; environmental health; human health risk assessment; use of epidemiology in public health decisions; health effects of airborne gases and particles; health effects of ionizing and non-ionizing radiation.

1998 – 2000 CAMBRIDGE ENVIRONMENTAL, INC., Cambridge, MA
Senior Scientist.

1985 – 2000 HARVARD SCHOOL OF PUBLIC HEALTH, Boston, MA
Associate Professor of Human Physiology. (Adjunct, after 1990) Research work included: (1) human health effects of air toxics, (2) lung macrophage function measured with magnetic particles, (3) lung deposition and clearance of radioactive tracer particles.

1987 INSTITUTE OF OCCUPATIONAL HEALTH, Helsinki, Finland
Visiting Researcher. Developed a magnetometric assay to be used for studying pulmonary macrophage function for lung cells lavaged from human subjects.

1984 INHALATION TOXICOLOGY RESEARCH INSTITUTE, Albuquerque, NM
Visiting Scientist. Examined the effect of exercise and hypercapnia on deposition, lung clearance, and lung distribution of inhaled radioactive aerosol.

1976 – 1985 HARVARD SCHOOL OF PUBLIC HEALTH, Boston, MA
Assistant Professor of Respiratory Physiology.

1970 – 1976 AMHERST COLLEGE, Amherst, MA
Assistant Professor of Physics.

Professional Activities

- National Academy of Sciences and National Research Council, Evaluating Health-Risk-Reduction Benefits of USEPA Regulations (2001 – 2003).
- Harvard School of Public Health: Research Advisory Committee Member for NIH-Sponsored Research on "Mechanisms of mortality/morbidity due to air particulate" (1997 – 2005).
- Member of the Committee on Man and Radiation (COMAR) (1999 – 2006).
- Health Effects Institute, Cambridge, MA, *ad hoc* reviewer (1984 – 1994).
- National Research Council, Commission on Life Sciences: Committee on Passive Smoking (1986-1988).
- Editorial Board, *Journal of Aerosol Medicine* (1987– 2000).
- Center for Indoor Air Research, grant-application reviewer (1989 – present).
- NIOSH: Environmental Center Grants, Site Visit Delegation (1990).
- NIH Reviewer: Cardiovascular and Pulmonary Study Section, Radiation Study Section, and Health of the Population Study Section.
- DOE: Office of Health and Environmental Research, reviewer.
- Harvard Center for Risk Analysis: Review of Cellular Telephones (1994 – 1999).
- Physical and Biological Sciences Study Committee, Town of Needham Planning Board.

Professional Affiliations

Fellow of the Academy of Toxicological Sciences • Society of Toxicology (full member) • International Society for Environmental Epidemiology • Society for Risk Analysis • Health Physics Society (full member) • Sigma Xi • American Association for the Advancement of Science • American Conference of Governmental Industrial Hygienists (associate member)

Projects *(abbreviated)*

Carbon Black Manufacturers: Evaluated the toxicology and epidemiology of carbon black inhalation and ingestion.

Charter School in Washington, DC: Prepared a health risk assessment for the school board on the health risks of handling asbestos-containing materials that might release fibers.

City of Newton Health Department: Measured RF levels from a local transmitting antenna, reviewed RF field calculations, and provided scientific literature critique on RF health effects.

Confidential Client: Prepared a risk assessment for a Massachusetts landfill containing both chemical and radioactive waste and including multiple pathways of contaminant uptake by a trespasser.

Confidential Client: Prepared a model predictive of asbestos fiber drift and inhalation health hazard applicable to industrial processes where asbestos-containing materials are used.

Confidential Clients: Prepared an analysis of relative risks of TCE in drinking water *versus* health hazards from background levels of chemicals in air, water, and soil, as well as other routine risks to life and health.

Electric-Power Generating Companies: Prepared and delivered expert reports and public testimony on the potential health effects of airborne emissions from coal fired, gas fired, oil fired, and wood-fired electric utility power generating plants.

Electric Power Research Institute: Reviewed and analyzed the mechanisms by which biological systems may be affected by environmental electric and magnetic fields (EMFs). Organized a public workshop on the causes and characteristics of childhood leukemia.

Engine Manufacturers Association: Prepared critiques of the U.S. EPA and California EPA health assessment documents on the potential carcinogenicity of diesel exhaust and ambient air particulate matter.

Harvard School of Public Health: Continuing Education for Professionals: Prepared material on special topics on inhalation toxicology for graduate students and health professionals: Presented lectures on risk assessment and risk communication.

Health Effects Institute: Prepared an analysis entitled "Ozone Molecular Dosimetry and Interaction with Biological Macromolecules."

Health Effects Institute: Organized, supervised, and documented a feasibility study for the Health Effects Institute initiating a national research program on the health effects of electric and magnetic fields.

Manufacturing Company: Analyzed multi-pathway human health risk for a site contaminated with polychlorinated biphenyls (PCBs) and chlorinated organic solvents. Analyzed experimental data to derive a fraction of PCBs that are picked up from concrete by dermal contact.

Manufacturing Company/FUSRAP Site: Prepared a radionuclide health risk assessment and site management plan for site contaminated by nearby storage of uranium ore.

Massachusetts Department of Public Health: Prepared a public communications essays on what citizens can do to support improved air quality.

Medical Product Manufacturer: Prepared a risk assessment for air toxics produced during malfunction of a medical device used to assist breathing.

Michigan Occupational and Environmental Medical Association (MOEMA): Prepared and delivered a risk assessment tutorial for MOEMA's Continuing Education program.

Mining Company: Evaluated the epidemiological basis for the toxicity of arsenic in soils. Evaluated metals toxicity factors and site-specific bioavailability of metals.

National Institute of Environmental Health Sciences – Division of Research Grants: Revised grant applications for the Radiation Study Section Panel on Health-Effects Research.

Navy Occupational Health and Preventive Medicine Program: Prepared and delivered seminars and workshops to U.S. Navy medical personnel on the current research on electric and magnetic fields (EMFs).

New Mexico Environmental Department: Prepared a health risk assessment for measured and modeled concentrations of 80 airborne chemicals in Albuquerque, NM.

Refinery: Prepared a multipathway human health risk assessment for air emissions from a petroleum refinery. Our risk assessment preparation process was monitored by a Multi-Agency Task Force composed of regulators, educators, union members, and local officials.

School District on Long Island: Assessed possible environmental, occupational, and lifestyle risk factors for early-term miscarriage.

University of Denver: Analyzed the potential health impact of uranium disposal from munitions testing ("depleted uranium") as it was practiced in the 1960's and 1970's.

Uranium Mill: Evaluated the health implications of radioactive substance migration as predicted by different EPA and DOE models.

U.S. Department of Energy: Prepared a risk communication strategy for a nuclear test site where detonation of underground atomic devices had the potential to contaminate groundwater.

U.S. Department of Justice: Prepared an analysis of the health hazards of the Love Canal Superfund site (Niagara Falls, NY).

U.S. Department of Justice: Prepared a report and provided expert testimony on human toxicology with regard to soil contamination at a RCRA site.

U.S. Department of Justice: Prepared reports and provided expert testimony on asbestos, sulfuric acid, and airborne particulate inhalation toxicology.

U.S. Environmental Protection Agency: Provided USEPA with a peer review (scientific critique) of the Agency's draft reference concentration (RfC) methodology for risk assessment.

U.S. Environmental Protection Agency: Analyzed the health risks of a remediation alternative at the Bloody Run Creek section of the Hyde Park Landfill superfund site (Niagara Falls, NY).

U.S. Environmental Protection Agency, Health Effects Research Laboratory: Assisted in preparing a database of non-cancer health effects for 189 Hazardous Air Pollutants.

U.S. Environmental Protection Agency, Environmental Criteria and Assessment Office: Evaluated research proposals on "Indoor and Ambient Air Risk Assessment Methodologies."

Utility: Analyzed the relationship between inhaled carbon monoxide concentration and blood carboxyhemoglobin. Performed sensitivity analysis on all the variables involved.

Waste Management Company: Evaluated health risks for a medical waste incinerator, including a multiple-pathway (ingestion, inhalation, dermal, mothers' milk) health risk assessment.

World Health Organization: Helped prepare a WHO research report on electric and magnetic field (EMF) health effects. Presented a lecture on EMF health effects at a WHO workshop in Geneva, Switzerland. Published review article on RF health effects.

Academic Research Projects *(abbreviated)*

National Heart, Lung, and Blood Inst.:	"Physical Determinants of Lung Function and Dysfunction."
National Heart, Lung, and Blood Inst.:	"Pulmonary SCOR: Chronic Diseases of the Airways."
National Cancer Institute:	"Magnetic Field Effects on Macrophages."
National Inst. of Environ. Health Sci.:	"Inhaled Particle Retention in Normal and Diseased Lungs."
National Heart, Lung, and Blood Inst.:	"Particle Location and Ingestion by Lung Macrophages."
National Inst. of Environ. Health Sci.:	"Factors Influencing Deposition of Inhaled Aerosols."

Publications – *Articles*

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Abstracts & Reports *(list available on request)*

Invited Lectures *(past 10 years)*

6/23/08 "Routes of Entry into the Body: Pulmonary Deposition and Clearance of Particles." Presented in the course "Comprehensive Industrial Hygiene: Practical Applications of Basic Principles," Harvard School of Public Health, Boston, MA.

6/25/07 "Routes of Entry into the Body: Pulmonary Deposition and Clearance of Particles." Presented in the course "Comprehensive Industrial Hygiene: Practical Applications of Basic Principles," Harvard School of Public Health, Boston, MA.

3/29/07 "Non-linear Exposure-Response Relationships between Ambient PM_{10} and Daily Mortality." Presentation with Dr. T. Bowers at the Society of Toxicology Annual Meeting, Charlotte, NC. This presentation was selected as one of the *Top 12 Risk Assessment Abstracts at the SOT Meeting.*

11/7/06 "What is EMF? How EMF Interacts with Organisms." Presented at the Cyprus International Institute for the Environment and Public Health symposium on "Electromagnetic Fields: Sources, Health Effects, and Regulations, Nicosia, Cyprus.

6/19/06 "Pulmonary Deposition and Clearance of Particles." Presented in the course "Comprehensive Industrial Hygiene: Practical Applications of Basic Principles," Harvard School of Public Health, Boston, MA.

5/18/06 "Health Hazards of Nanoparticles." Presented at "A Mock Hearing: Environment, Health & Safety" at the NanoBusiness Alliance Meeting, New York City, NY.

4/25/06 "Inhalation Risk Assessment: Extrapolating from Macro-materials to Nano-materials." Overcoming Obstacles to Effective Research Design in Nanotoxicology, Cambridge, MA.

10/6/05 Panelist for: "A Reevaluation of the Association Between Diesel Exhaust Exposure and Lung Cancer." Air & Waste Management Association (AWMA) Specialty Workshop on "Diesel Exhaust," Chicago, IL.

6/20/05 "The Respiratory Tract as a Portal of Entry for Airborne Chemicals in the Work Environment." Lecture at the Harvard School of Public Health course on "Comprehensive Industrial Hygiene," Boston, MA.

6/16/05 "Electromagnetic Fields, Base Stations, and Wireless Networks: Exposures & Health Consequences." WHO Workshop, 15-16 June 2005, at the World Health Organization, Geneva, Switzerland.

2/11/05 "Generation of Charged Aerosols by High-Voltage Electric-Power Lines." American Association for Aerosol Research, Specialty Conference on Particulate Matter, Atlanta, GA.

2/4/05 "Magnetic Microparticles Detect and Probe Cytoplasmic Motions." Bioelectromagnetics Society Winter Workshop, Phoenix, AZ.

6/21/04 "Pulmonary Deposition and Clearance of Particles." Harvard School of Public Health Continuing Education Course on "Fundamentals of Industrial Hygiene," Boston, MA.

1/27/04 "Quantitative and Qualitative Factors that Determine Health Risk: Explaining Risk to Judges, Juries, and Communities." Mealey's Water Contamination Conference, Pasadena, CA.

9/14/02 "Health Effects of Air Pollutants." Annual Scientific Meeting of the Michigan Occupational and Environmental Medicine Association "Current Topics in Occupational and Environmental Medicine," Frankenmuth, MI.

6/18/01 "Pulmonary Physiology, and Lung Deposition and Clearance of Particles." Harvard School of Public Health Continuing Education Course on "Fundamentals of Industrial Hygiene," Boston, MA.

11/14/00 "Effects of Air Pollution on the Human Lung." Lecture in Tufts University course CEE 136, "Air Pollution," Medford, MA.

7/26/00 "Review of Ambient Air Quality as it Relates to Proposed Emission Standards for Massachusetts Power Plants." Testimony before the Massachusetts Department of Environmental Protection, Boston, MA.

1/10/00 "Useful Concepts in the Physics of RF." RF Safety: Science, Compliance and Communication, Electromagnetic Energy Association and the University of Texas Health Science Center, San Antonio, TX.

12/16/99 "Exposure to inhaled pesticides and human health risks." 51st Annual Crop Protection School, Office of Continuing Professional Education, North Carolina State University, Raleigh, NC.

7/21/99 "How do Endogenous Forces Compare to EM Forces and Torques on Electrical Charges and Magnetite?" 11th International Congress of Radiation Research, Dublin Inst. of Technology, Dublin, Ireland.

6/7/99 "Lack of Concordance between Reported Lung Cancer Risk Levels and the Occupation-Specific Potential for Diesel Exhaust Exposure." Third Colloquium on Particulate Matter and Human Health, Durham, NC..

3/8/99 "Relative Risk Issues in Urban Pesticide Exposure and Children's Health." Association of American Pesticide Control Officials, AAPCO States/Industries Forum, Washington, DC.

1/13/99 "Panel Discussion on Health Effects of Wireless Technology." Cape Cod Commission, Deliberations at Cape Cod Community College, Barnstable, MA.

12/8/98 "Review of Health Issues in a Proposed Antenna Upgrade." City of Newton Health Department, Land Use Committee Deliberations, Newton, MA.

11/30/98 "Overview of Radio Wave Health Effects." Wayland, MA, Cellular Telephone Committee, Wayland Town Meeting Warrant.

8/3/98 "Exposure Assessment in Power-line-EMF and Radio-wave Epidemiologic Studies." EPE.215T "Environmental and Occupational Epidemiology," Harvard School of Public Health, Boston, MA.

4/22/98 "Health Risks from Electrical Power Lines and Cellular Telephones." EH.202D "Principles of Environmental Health," Harvard School of Public Health, Boston, MA.

3/23/98 "Inhalation and Dermal Exposure to Occupational Chemicals." Harvard School of Public Health, Continuing Education Course on "Fundamentals of Industrial Hygiene," Boston, MA.

Manuscript Peer Reviewer for the Following Research Journals

American Industrial Hygiene Journal; American Journal of Physics; American Journal of Respiratory Cell and Molecular Biology; American Review of Respiratory Disease; Atmospheric Environment; Bioelectromagnetics; Biophysical Journal; Biorheology; Cell Biophysics; Critical Reviews in Toxicology; Environmental Geochemistry and Health; Environmental Health Perspectives; Environmental Science & Technology; Epidemiology; Experimental Lung Research; Fundamental and Applied Toxicology; Hepatology; Human and Ecological Risk Assessment; Human and Experimental Toxicology; IEEE Biomedical Engineering; IEEE Transactions on Plasma Science; Journal of Aerosol Medicine and Pulmonary Drug Delivery; Journal of Applied Physiology; Journal of Applied Toxicology; Journal of Occupational and Environmental Hygiene; Journal of Occupational and Environmental Medicine; Journal of Occupational Medicine and Toxicology; Journal of Toxicology and Environmental Health; Nature; Nonlinearity in Biology, Toxicology, and Medicine; Radiation Research; Risk Analysis: An International Journal; Regulatory Toxicology & Pharmacology; Science; Tissue & Cell; Toxicology and Applied Pharmacology; Toxicological Sciences; USGS Environmental Geochemistry of Mineral Deposits (Reviews in Economic Geology series).

Power-Line Electric and Magnetic Fields (EMF): Status of Scientific Research on Potential Health Effects

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October 5, 2009

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1.0 Introduction and Summary Overview

This Report provides an overview of scientific research regarding biological effects of electric and magnetic fields (EMF) as relevant to whether EMF affect human cancer risk. EMF are produced by both natural sources and by the voltages and currents associated with our society's use of electric power, and these electric-power fields are often designated as extremely-low-frequency (ELF) EMF, or 60-cycle AC (60-Hz) EMF. In Europe, electric power is supplied as 50-cycle AC (50-Hz), and the fields produced by the associated voltages and currents would also be ELF-EMF. In the discussions below, the term "power-line fields" will encompass both 50- and 60-Hz fields. It is also the case that most of the attention has focused on the magnetic-field part of EMF, and this will be emphasized through the use of the abbreviation "MF," when appropriate, rather than EMF.

1.1 Electric Charges Create Electric and Magnetic Forces

EMF are produced by positive and negative charges. Electric charges are present in all matter, although most objects are electrically neutral, because positive and negative charges are present in equal numbers. When the balance of electric charges is altered, we experience "electricity," such as the force of attraction between a comb and our hair, or the drawing of sparks after walking on a synthetic rug in the wintertime. When objects have electrical charges of the same polarity (positive *vs*. positive, or negative *vs*. negative) they repel, whereas objects with opposite electrical charges attract (positive *vs*. negative, or negative *vs*. positive) attract. The term "field" is used to describe the force per unit charge, *e.g.*, "electric field."

When electrical charges are in motion, they exert "magnetic" forces on each other. Magnetic forces hold permanent magnets on steel surfaces, turn compass needles in the earth's magnetic field, and generate the forces between the moving and stationary parts of electric motors. Even in electrically uncharged (neutral) objects such as magnets, it is the motion of electric charges at the microscopic, atomic level that creates attractive and repulsive magnetic forces. Again, the term "field" is used to describe the force per unit current, *e.g.*, "magnetic field."

As defined above, electric field (EF) is the force per unit charge experienced by an electric charge at rest, and magnetic field (MF) is the force per unit current experienced by an electric current, or by charges in motion. Electric and magnetic fields exist near wherever electricity is being generated, near wherever electricity is moving in electric wiring, and near wherever there are operating electric appliances.

The amount of electric charge on a metal wire is expressed by the voltage, and thus the voltage also creates an electric field that exerts forces on other nearby charges. When electric charges in the conductor are in motion, they produce an electric current, measured in amperes, and a wire with an electric current creates a magnetic field that exerts forces on other electric currents. The EMF in the vicinity of electricity merely tells us that an electric charge standing or moving in this location will experience pushing or pulling forces. An electrically neutral object with no internal moving charges would feel no forces.

1.2 Sources of EMF in Our Environment

Every day, each of us encounters a wide variety of natural and man-made EMF.

The buildup of electrical charges on an object or on a wire can be expressed by a voltage, and the higher the voltage, the higher the nearby electric field. Accumulation of electrical charge in clouds produces slowly-varying electric fields. In thunderstorms, the electric fields produced are so intense that the clouds are occasionally discharged by a lightning bolt. The measurement units for electric field are "volts per meter" (V/m) or "kilovolts per meter" (kV/m), where a kilovolt is 1,000 volts. Electric fields in the outside air, due to atmospheric electricity, are typically 10 to 100 V/m, but can reach several kV/m during thunderstorms. Electric fields are easily blocked by metallic objects, walls, trees, and even your clothes and skin, and electric fields have not been of issue in the EMF health investigations.

Electrical charges in motion produce magnetic fields. Electrical currents in wires produce magnetic fields, and currents in the earth's molten core produce a steady magnetic field, which causes a compass needle to turn. Magnetic fields are measured in units called "milligauss" (mG), and the earth's magnetic field has a strength of about 550 mG. A gauss (G) equals 1,000 mG. Another unit for magnetic field levels is the microtesla (μT), where 1 μT = 10 mG. Many childhood toys contain magnets, and we all have used "refrigerator" magnets to hold items on metal surfaces. These magnets generate fields of about 100,000 to 500,000 mG. A common medical diagnosis procedure, magnetic resonance imaging ("MRI"), uses fields of about 20,000,000 mG.

Both electric and magnetic fields become weaker as you move farther away from the source.

1.3 EMF can be Either Steady, or Can Change in Time

When voltages and currents are steady, or unchanging in time, they are often called direct-current or "DC." In the United States, electric power is delivered with a current that washes back and forth (*i.e.*, flows in alternating directions) 60 times a second, and this type of current is called alternating current or "AC," and is termed "60-Hz" electric power. Consequently, the EMF from this type of electric power also alternates in size and direction, repeating the cycle every $1/60^{th}$ of a second. The nature of the electric and magnetic fields, as defined above, remains the same, but generally, the time-varying part of EMF is measured separately from whatever steady electric and magnetic fields may also be present. Of course, if your body and the cells within it move and rotate in the presence of a steady field, it is experienced as a time-varying field. Likewise, if you spin a magnet at a rate of 60 times a second, you would get an AC magnetic field, just like the fields produced by electric power use. If you turn a flashlight battery end over end 60 times a second, you get a 60-Hz, AC electric field, just like the fields produced by electric power use.

"EMF" in this report refers to 60-Hz power-frequency electric and magnetic fields, sometimes called extremely-low-frequency ("ELF") fields. Power-frequency, or 60-Hz, EMF exist nearby any operating electrical equipment. EMF are created by wires or electrical appliances using electricity. Everyone is exposed to these fields at home when you turn on a TV, lamp, or fan; use your computer to e-mail a friend; use a washer or dryer; or use an electric oven or microwave to heat your dinner. ELF-EMF from computers, copiers, air conditioning, electric pencil sharpeners, *etc.* surround us at work and at school as well.

ELF-EMF are much different from the high-frequency electromagnetic fields associated with radio, TV, radar, and cell-phone signals. Radio and TV electromagnetic waves are meant to propagate

away from the antenna, and carry radiofrequency ("RF") energy to the receiver. The EMF from power lines is too low in frequency to carry energy away, and the electric energy stays on the utility lines. Therefore, electric-power EMF should not be called "radiation" or "emissions." Even more important, neither electric-power EMF nor RF electromagnetic waves should be confused with "ionizing radiation" such as X-rays. Ionizing radiation, like X-rays, is dramatically different from EMF and RF and has enough energy to alter chemical bonds and damage biological molecules, something that the lower frequencies of EMF and RF cannot do.

1.4 60-Hz EMF: Levels and Public-Health Agency Guidelines

The interest in EMF is almost exclusively limited to the magnetic fields (MF), which will be the focus of this report. As you might expect, MF levels depend on how much electricity is being used and how close you are to operating appliances. MF can be easily measured, and levels of MF exposure vary from location to location and from home to home. A study of levels of power-line magnetic fields in typical U.S. homes found that, in locations distant from operating appliances, the fields ranged between 0.5 mG and 4 mG, with an average of 0.9 mG. Levels rise as you get closer to the sources of these fields, and fields in the 100's of mG can be found near electrical devices. Anything that generates, distributes, or uses electricity creates magnetic fields. Table 1 lists some appliances and machines commonly found in homes or offices and the magnetic field levels (in mG) found nearby them. [1]

Table 1: Range of magnetic fields (in milligauss = mG), measured near operating appliances – xx

Appliances	Distance from the appliance					
	½ Foot		1 Foot		2 Feet	
Air Cleaners	110 –	250	20 –	50	3 –	8
Can Openers	500 –	1,500	40 –	300	3 –	30
Electric Ranges	20 –	200	½ –	30	½ –	9
Hair Dryer	1 –	700	½ –	70	½ –	10
Microwave Ovens	100 –	300	1 –	200	1 –	30
Pencil Sharpeners	20 –	300	8 –	90	5 –	30
Power Saws	50 –	1,000	9 –	300	1 –	40
Vacuum Cleaners	100 –	700	20 –	200	4 –	50
Washing Machines	4 –	100	1 –	30	½ –	6

There are no U.S. federal standards setting specific limits on residential MF levels. There is no federal certification program on the MF near appliances, so, for example, advertisements on appliances making claims of federal government power-line MF certification are false. Some guidelines for allowable EMF levels in public places have been developed by international agencies, and these levels are in accordance with the scientific analyses of public-health agencies. For 60-Hz MF, the International Committee on Electromagnetic Safety (ICES) proposed 9,040 mG, the International Commission on Non-Ionizing Radiation Protection proposed 833 mG, and the Australian Radiation Protection and Nuclear

[1] National Institute of Environmental Health Sciences. 2002. "Questions and Answers About EMF." NIEHS and the U.S. Department of Energy (DOE), 2002. http://www.niehs.nih.gov/health/topics/agents/emf/docs/emf2002.pdf

Safety Agency (ARPANSA) proposed 3,000 mG. Tables 3 and 4 in Section 4.1 identify some other guidelines. Some guidelines are technology-based (designed to maintain the *status quo* on utility rights-of-way), as discussed in Section 4.1.

1.5 60-Hz EMF: Status of Health-Effects Investigations

Scientific investigations of possible health effects of power-line EMF have been taking place around the world for nearly 40 years. One type of study, epidemiology, looks for "associations," which means checking to see whether the frequency of occurrence of two events are correlated. For example, such a study might report that, as ice cream sales increase, admissions to the hospital for heat-stroke also increase, and this would be described as a positive "association." As another example, one would find that there is a positive association between sunrise occurring and roosters crowing. However, we all recognize that ice cream does not cause heat strokes and roosters do not cause the sun to rise. Thus, an "association" does not necessarily mean there is a causal connection.

Even though the term "EMF health-effects research" is commonly used, it should be noted at the outset that the focus of health-effects investigations has been on power-line magnetic fields (MF), not electric fields. Studies of electric fields have not suggested any links to health, and the reviews of public health agencies (*e.g.*, the World Health Organization) demonstrate that electric fields are not at issue.

EMF health-effects research was triggered initially by an association reported between an index of power-line MF and statistics on whether or not a child had leukemia.[2] Some subsequent epidemiological studies of children also reported a weak association between increased risk of leukemia in relation to presumed exposure to power-line MF. The epidemiology studies were expanded to include studies on occupational EMF exposure and diseases in electrical workers. Statistics of cancer risk for electrical workers, who experience higher power-line MF levels over a lifetime than residents or children, have not shown health effects linked to MF exposure. Over the more than 30 years elapsed since the first study, epidemiology has not yielded more definitive links to MF exposure as the studies improved in design and included larger populations of subjects. Thus, epidemiology findings remain suggestive and inconclusive. Epidemiological studies of other cancer types have not found any power-line MF associations.

Because of the suggestive statistical associations, worldwide research programs were undertaken, using an extensive variety of laboratory experiments to determine whether or not laboratory evidence does or does not support a MF health risk. Experiments with animals and cells showed that MF at levels much higher than typically near power-lines can interact with biological systems and cellular chemistry. These interactions were transient and reversible, and were not found to lead to adverse health effects, let alone cancer risk. A large number of studies with laboratory animals exposed, over their lifetimes, to MF levels a thousand-fold higher than near power lines yielded "no-effect" results, going contrary to the weak statistical associations reported for childhood leukemia risk.

Laboratory research with isolated cells and biophysical analyses have not identified plausible mechanisms by which MF at levels encountered near transmission lines or appliances can lead to the creation or stimulation of tumor cells. Likewise, scientists have been unable to find mechanisms that could link low-level MF exposure to other hypothesized adverse health effects.

[2] Wertheimer N, Leeper E. 1979. Electrical wiring configurations and childhood cancer. *Am J Epidemiol*. 109:273-84.

In summary, there is little consistent evidence from the sum total of the epidemiology that suggests an ELF-EMF health risk, and the results among the studies remain weak and poorly linked to actual MF exposures. Importantly, scientists have not been able to establish a laboratory-animal or mechanistic model relevant to human cancer risk that reliably demonstrates adverse biological changes in response to typical electric-power MF levels.

1.6 EMF Literature Review: Approach to Identify Relevant Studies

This Report provides an overview of peer-reviewed scientific research on biological effects of EMF as whether human cancer risk is affected by exposure to power-line MF. Potentially relevant, published articles on MF health effects were identified through literature searches, and by examining EMF-specific databases.

The selection of the EMF research literature identified in this Report placed emphasis on potential relevance of MF levels created by electric-utility power lines to risk of human health effects such as cancer. A key consideration is the integration of the three main lines of scientific evidence:

(i) Epidemiology,
(ii) Laboratory-Animal Studies, and
(iii) Mechanisms of Action.

A central focus of our literature identification was on power-line MF and health endpoints related to possible cancer risk, specifically childhood leukemia. The following pages provide general summaries of the three main lines of scientific evidence, and some recent key publications are identified.

2.0 Lines of Scientific Inquiry

2.1 Epidemiology

Epidemiology is the statistical analysis of disease patterns observed in human populations**.** As already noted, the possibility of power-line effects on childhood cancer risk was initially raised by an epidemiology report in 1979 (see footnote 2), and since that time, some of the numerous follow-up epidemiology studies have reported weak associations between surrogate markers of power-line magnetic field exposure and an increased risk of childhood leukemia. Because of these studies, the International Agency for Research on Cancer (IARC), which is part of the World Health Organization (WHO), classified power-line MF as a "possible" (Group 2B) carcinogen in 2002.[3] Even though the epidemiology correlations continue to provide the strongest suggestions of MF health risk, the results among the studies remain weak and inconsistent, and poorly linked to actual MF exposures.

Epidemiology provides statistical, correlative results in human populations, but such associations are not able to establish causation. That is, while a laboratory scientist can precisely set exposure conditions, randomly allocate groups to be exposed or not-exposed, do careful pathology on the outcome,

[3] IARC Vol. 80: "Non-Ionizing Radiation, Part 1: Static and Extremely Low-Frequency (ELF) Electric and Magnetic Fields," World Health Organization, 2002. http://monographs.iarc.fr/ENG/Monographs/vol80/volume80.pdf
IARC classified power-frequency magnetic fields as "possibly carcinogenic," based on "limited" evidence from humans concerning childhood leukemia, "inadequate" evidence from humans concerning all other cancer types, and "inadequate" evidence from animals. Power-frequency electric fields were judged "not classifiable" (Group 3) on the basis of "inadequate" evidence from both humans and animals.

and read the results blindly (*i.e.*, without knowing the exposure history), epidemiology is an observational science and cannot utilize any of these rigorous scientific methods.

For epidemiology studies of power-line MF carried out during the 1980 to 2005 time period, Figure 1 below provides a graphical summary, which shows an overall absence of an effect on risk.

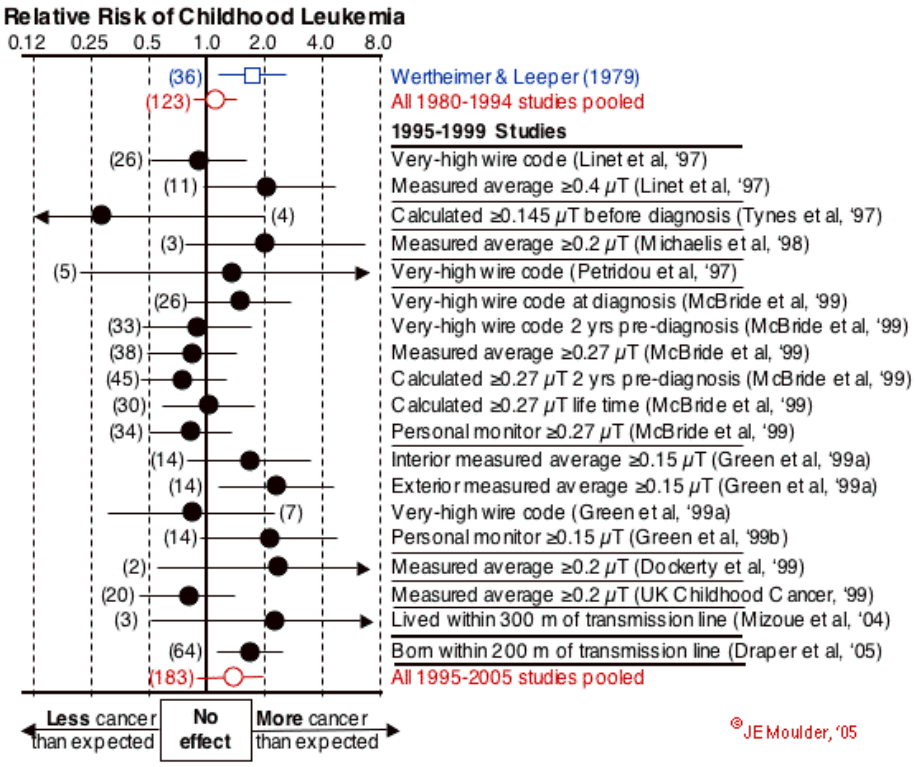

Figure 1. Studies of power-line MF and relative risks (RR) of childhood leukemia (1980 – 2005). (Note 1 μT = 10 mG) RR's are shown with 95% confidence intervals. In parentheses are the numbers of leukemia cases (*i.e.*, the size of the study). The pooled RR's (open circles) weigh each study on its population size (a measure of the statistical power of the study), and treats all power-line MF exposure-assessment methods of equal validity (courtesy of Dr. John E. Moulder). [4]

The central line marked "1.0" is the point at which there is neither an increase nor a decrease in relative risk (RR) of leukemia, and to the right is increasing risk, and to the left is decreasing risk. The individual symbols (solid dots, or circles) mark the results reported by the studies identified, and the horizontal lines extending from these dots show the range of uncertainty due to random chance alone. There are only 2 studies where random chance has been ruled out (called "statistically significant," meaning the range of uncertainty does not overlap the central line). Figure 1 illustrates that the childhood leukemia studies cluster around the RR = 1.0, or "no effect" line and do not yield a consistent association between power-line MF and the risk of leukemia. The two open circles at the top and bottom provide a pooled summarization of the studies reported in the years specified, and because the horizontal lines extending from these open dots also cross the RR = 1.0 line, the summary statistics suggest "no effect," meaning that even the effects of random chance alone have not been ruled out.

[4] Figures 1 and 2, Citation: Moulder, J. E. 2005. "Electromagnetic fields and human health. An extensive list of frequently asked questions and references." 9/05, at http://www.mcw.edu/gcrc/cop/powerlines-cancer-FAQ/toc.html

The interpretation of the EMF epidemiology remains uncertain because the reported RR's deviate from 1.0, the "no effect" result, only to a minor degree. Thus any deviation seen from 1.0 could be the result of random chance or bias in the studies. Bias (systematic error) would mean that the confidence interval derived from population-size considerations alone is an underestimate of uncertainty in the results, For example, systematic errors could have arisen from selection bias (methods for selecting cases and controls are not equivalent), MF exposure misclassification (the MF exposures are not accurately measured), and confounding (the MF exposure surrogate used selects for some other, non-MF population characteristic that produced the observed deviation from RR = 1.0). Confounding factors relate to the fact that the higher and lower MF exposure categories are, for example, also markers for higher and lower socioeconomic status, greater or lesser degrees of traffic congestion in the neighborhood, or age of residential housing stock. Because the set of factors that might affect risk of childhood leukemia is not well known, the co-incident change of these factors with the MF exposure categories will "confound" the association seen, that is, make it impossible to reliably interpret.

Figure 1 demonstrates that the MF epidemiology data are "inconclusive" or "weak." Very few of the studies relied on actual MF measurements, and none of the exposure assessments were based on mechanisms of MF interaction with biology. As noted, an epidemiologic study that reports "statistically significant" associations is only testing that significance against the role of random chance, which is governed by the size of the population studied. If other sources of uncertainty in epidemiologic studies were to be quantitatively included in the confidence interval (*e.g.*, confounding factors, measurement error, selection bias, misclassification), the error bars would become wider and increasingly overlap a null outcome, RR = 1.0 (*i.e.*, "no association"). Reviews of MF epidemiology emphasize this point, namely, that the error bars in reported results do not reflect these other sources of uncertainty, and consequently the results are less indicative of an actual link than one might at first imagine.

Consequently, epidemiology is not useful for setting MF standards or guidelines, as summarized in the Schüz and Ahlbom (2008) analysis: [5]

> " *no mechanism to explain* [the childhood leukemia] *finding has been established and no support for a causal link emerged from experimental studies. Chance or bias cannot be ruled out with reasonable confidence as an explanation for the observed association. If the association is causal, it explains only a small fraction of childhood leukaemia cases.*"

2.2 Laboratory Animal Studies

Laboratory-animal studies have examined the biological effects of EMF exposure in mammalian species, where biological reactions to EMF are expected that would be similar to those in humans. Interpretation of power-line MF epidemiology can be made less clouded and less uncertain, by comparison to results from laboratory scientific investigations. However, these other lines of evidence weigh against assigning a causal basis to the associations reported by epidemiology. Scientists have not been able to identify an established laboratory bioassay or animal model by which power-line MF can be shown to consistently initiate or accelerate biological changes related to cancer risk, or specifically, to childhood leukemia risk.

Although lifetime exposure to high levels of 60-Hz magnetic fields has been tested in numerous animal studies (using different species), the results have failed to show that 60-Hz magnetic fields can

[5] Schüz J, Ahlbom A. 2008. "Exposure to electromagnetic fields and the risk of childhood leukaemia: a review." *Radiation Protection Dosimetry. 2008;* 132:202-11.

initiate or exacerbate any cancer or pre-cancerous condition, even in genetically modified and susceptible animals. This is shown by the National Toxicology Program (NTP) research campaign, which tested elevated 60-Hz MF exposures extensively and represents the largest series of laboratory studies, because the scope and quantity of animals tested are unlikely to ever be duplicated. The NTP study found no cancer risks at high MF exposure levels (10,000 to 20,000 mG, see Fig. 2 below). [6] Such animal testing is the foundation (or "gold standard") for probing health effects, because it is often through such exhaustive animal studies that regulators and public-health agencies can determine what (if any) aspect of an exposure (*e.g.*, chemicals or "MF") should potentially be mitigated or regulated.

Figure 2 below summarizes major laboratory animal experiments using exposures to power-line MF ranging from about 50 to 20,000 mG. It can be seen that the results cluster around a Relative Risk = 1.0, or "no effect" line, with no evident dose-response slope. That is, in addition to the fact that the uncertainty bars, the so called "95% confidence intervals" overlap the no-effect line, there is no trend showing any hint of increasing RR's with increasing levels of MF exposure.

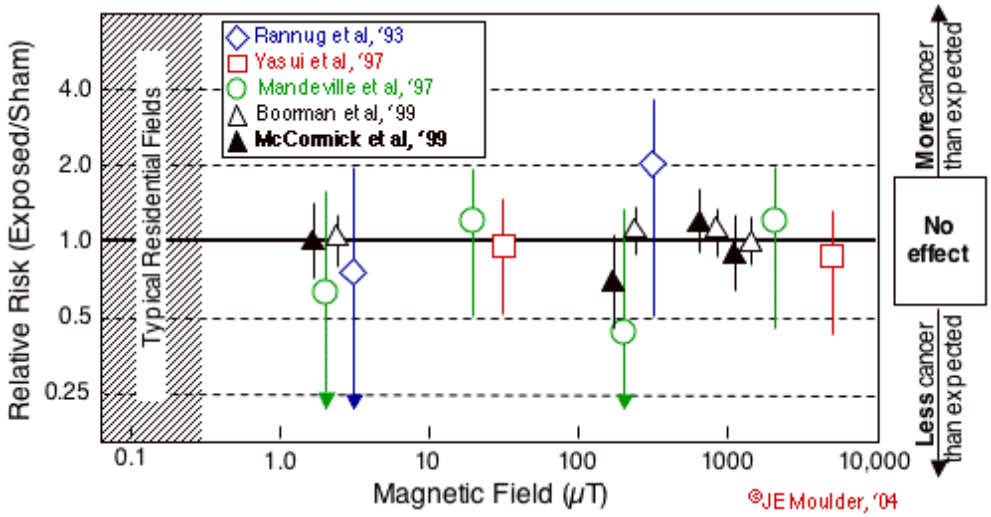

Figure 2: Studies of power-line MF and potential for causing cancer in animals. (Note, 100 μT = 1,000 mG) Animal were exposed over their lifetimes, and total malignant tumors or overall survival were evaluated. The RR (exposed/sham) expresses increases or decreases in animals with tumors or in the number of deaths during the experiment. 95% confidence intervals are shown. On the left hand side of the chart, the shading provides a comparison of the animal MF exposure levels to typical 24-hour average residential fields, which range up to about 0.5 μT (or 5 mG) (figure courtesy of Dr. John E. Moulder).

6 National Toxicology Program (NTP), lifetime laboratory-animal tumorigenicity studies:
Boorman GA, McCormick DL, Ward JM, Haseman JK, Sills RC. 2000. Magnetic fields and mammary cancer in rodents: a critical review and evaluation of published literature. *Radiat Res*. 153:617–626.
Boorman GA, Rafferty CN, Ward JM, Sills RC. 2000. Leukemia and lymphoma incidence in rodents exposed to low-frequency magnetic fields. *Radiat Res*. 153:627–636.
Boorman GA, McCormick DL, Findlay JC, *et al*. 1999. Chronic toxicity/oncogenicity evaluation of 60 Hz (power frequency) magnetic fields in F344/N rats. *Toxicol Pathol*. 27:267–278.
McCormick DL, Boorman GA, Findlay JC, *et al*. 1999. Chronic toxicity/oncogenicity evaluation of 60 Hz (power frequency) magnetic fields in B6C3F1 mice. *Toxicol Pathol*. 27:279–285.
McCormick DL, Ryan BM, Findlay JC, *et al*. 1998. Exposure to 60 Hz magnetic fields and risk of lymphoma in PIM transgenic mice. *Carcinogenesis.* 19:1649–1653.

2.3 Mechanisms of Action

Power frequency EMF are at the very lowest end of an electromagnetic spectrum that encompasses frequencies that range from very high in the case of "ionizing energy," such as X-rays with frequencies of a billion-billion of cycles per second (Hz), down through ultraviolet (UV) light, visible light, infrared (IR) light, and then, in descending order, microwaves (100 billion Hz), radio waves (100 million Hz), and power frequencies (60 Hz) (Table 2, below). The higher the frequency of the electromagnetic waves, the shorter the wavelength, and the higher the "photon" energy. Photon energies below visible light are "non-ionizing," meaning they cannot break chemical bonds. Power-line EMF are very low frequency fields (50 – 60 Hz) with extremely long wavelengths of 5,000 km (3,100 miles), and the photon energy of these waves is extremely weak and can neither break chemical bonds nor heat living tissue.

Because power-line EMF cannot break up molecules, it cannot directly affect the information content of genes, *i.e.*, deoxyribonucleic acid (DNA). To determine if power-line EMF could cause DNA damage or other health effects, scientists have carefully examined the physics of the interaction of electromagnetic fields with matter. In order for the EMF from power lines to influence living cells, the electromagnetic fields must in some manner deposit sufficient energy in cells to modify molecules (*e.g.*, DNA) or structures (*e.g.*, cell membranes) in the living organism. Studies of "mechanisms of action" use the laws of physics, chemistry, and biology to predict and understand how an exposure to power-line EMF can alter the function of biological structures like cell membranes or DNA molecules. Extensive efforts by scientists worldwide on mechanistic EMF research have not been able to identify plausible mechanisms or causal pathways by which typical levels of power-line EMF can cause adverse health effects.

Table 2: The electromagnetic spectrum includes a continuum of increasing photon energy, extending from power-line EMF at the very lowest end, up through radio waves, light energy, ultraviolet light, x-rays, and gamma-rays (at the very highest end of photon energies)

ELF	**AM Radio**	**FM / TV**	**Microwave and Radar**	**Radiant Heating, Infrared**	**Sun Lamps, Visible Light**	**Medical X-Rays**	**α-, β-, γ-Rays**
♦ Power lines, 50 – 60 Hz		♦ Cell phones, ~ 1 – 2 GHz		♦ Human body heat	♦ Vision	→ Ionizing	♦ Cosmic rays → → → →
← ← ← (*induced*	← ← ← *currents*)	← ← ← (*RF heating*	← ← ← *currents*)	← ← ← (*photo —*	Non-ionizing← *chemistry*)	(*molecular*	*damage*)

EMF interactions with biological systems have been analyzed carefully in view of how such fields interact with matter. [7] The applicability of fundamental physics to all systems, and to biology in

[7] Lacy-Hulbert A, Metcalfe JC, Hesketh R. 1998. Biological responses to electromagnetic fields. *FASEB J*. 12:395–420.

Committee on Man and Radiation (COMAR). 2000. Possible health hazards from exposure to power-frequency electric and magnetic fields -- a COMAR Technical Information Statement. *IEEE Eng Med Biol Mag*. 19:131–137.

Brain JD, Kavet R, McCormick DL, Poole C, Silverman LB, Smith TJ, Valberg PA, Van Etten RA, Weaver JC. 2003. Childhood leukemia: electric and magnetic fields as possible risk factors. *Environ Health Perspect*. 111:962–970.

particular, permits evaluation of the interaction of EMF with ions, molecules, cells, and organisms. First of all, power-line electric fields are not able to penetrate to the interior of the body, so the only consideration has to do with the possible effects of MF. The conclusions are that MF at typical power-line levels do not create disturbances that are detectable above the many sources of biological impact (electrical and other "noise") that naturally occur in living systems. [8] Examination of all possible aspects of power-line MF exposure has revealed no firm basis on which to attribute a potential for adverse biological effects, for example, to the magnetic-field magnitude, to the fundamental frequency or to harmonics, to continuous exposure or to intermittent exposure, to time-average fields or to peak fields, to constant amplitude MF, or to transients in MF. An idea being evaluated is "contact currents," which, if true, would mean that the epidemiological associations arise through factors that are not MF at all, but happen to vary with MF. [9] Over the years, many ideas have been proposed in this area, and many analyses have been performed, but diligent attention by scientists has not yielded identified aspects, levels, or durations of power-line MF exposure that can biophysically be traced to increased cancer risk. Without any understanding of mechanism, it remains unknown as to what, if any, aspect of power-line MF exposure should be controlled or mitigated to reduce risks.

3.0 Pre–2002 Reviews of EMF and Health by Public Health Agencies

A variety of international scientific "blue-ribbon" panels have reviewed, and continue to review, EMF health effects research. Overall, the absence of robust findings from careful, replicated laboratory studies causes health agencies to be cautious about relying on the reported epidemiological links with power-line MF levels. The statistical, epidemiologic results are suspected to arise from such factors as selection bias and unmeasured or uncontrolled confounding. Scientific guideline-setting committees do not consider the epidemiologic evidence to be adequate for guideline development. No major public-health agency has set guidelines based on distance from power-line rights-of-way. Some agencies have provided guidelines for acceptable, continuous-exposure of the general public to power-line magnetic-field levels, and these values range from about 800 mG to 9,000 mG. [10] It is helpful to review some of

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Valberg PA, Kavet R, Rafferty CN. 1997. Can low-level 50/60 Hz electric and magnetic fields cause biological effects? *Radiation Research.* 148:2–21.

[8] Weaver JC, Vaughan TE, Martin GT. 1999. Biological effects due to weak electric and magnetic fields: the temperature variation threshold. *Biophysical Journal.* 76:3026–30.

Weaver JC, Vaughan TE, Adair RK, Astumian RD. 1998. Theoretical limits on the threshold for the response of long cells to weak extremely low frequency electric fields due to ionic and molecular flux rectification. *Biophysical Journal* 75:2251–2254.

[9] Kavet R. 2005. Contact current hypothesis: summary of results to date. *Bioelectromagnetics* Suppl 7:S75–85.

Niple JC, Sahl JD, Kelsh MA, Kavet R. 2005. Equipment grounding affects contact current exposure: a case study of sewing machines. *Ann Occup Hyg*. 49(8):673-82.

[10] ICNIRP (International Commission for Non-Ionizing Radiation Protection). 1998. Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz). *Health Physics* 74:494–522.

Herbertz J. 1998. Comment on the ICNIRP guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz). *Health Physics* 75:535.

Matthes R. 1998. Response to questions and comments on ICNIRP. *Health Physics* 75:438–439.

Koops FB. 1998. New ICNIRP guidelines for human exposure to 50 Hz E- and M-fields. *Health Physics* 75:437–438.

the history (particularly prior to the IARC report in 2002) as to the myriad of public health agencies that have addressed, analyzed, and provided conclusions on the EMF issue.

3.1 Oak Ridge Associated Universities Expert Panel (1992)

In the early 1990's, the U.S. Department of Labor commissioned an expert panel to study reports that attributed adverse health effects to EMF from power-lines, household appliances, and video display terminals. For this report, Oak Ridge Associated Universities coordinated the analysis and established a panel of expert scientists, who published their conclusions in 1992. [11] The executive summary of the Oak Ridge report states that:

> "*This review indicates that there is no convincing evidence in the published literature to support the contention that exposures to extremely low-frequency electric and magnetic fields (ELF-EMF) generated by sources such as household appliances, video display terminals, and local power lines are demonstrable health hazards*."

3.2 American Medical Association (1994)

In 1994, The American Medical Association adopted recommendations [12] regarding EMF Health effects. In addition to encouraging research and continuing to monitor developments, the adopted recommendations stated:

> "*No scientifically documented health risk has been associated with the usually occurring levels of electromagnetic fields*."

International Committee on Electromagnetic Safety (ICES) / Institute of Electrical and Electronics Engineers (IEEE). 2002. "C95.6-2002 IEEE Standard for Safety Levels with Respect to Human Exposure to Electromagnetic Fields, 0-3 kHz", Prepared by IEEE Subcommittee 3, ISBN 0-7381-3389-2, 2002. http://www.ieee.org/web/standards/home/index.html

Australian Radiation Protection and Nuclear Safety Agency (ARPANSA). 2006. Draft document: "Radiation Protection Standard: Exposure Limits for Electric & Magnetic Fields – 0 Hz to 3 kHz." http://www.arpansa.gov.au/pubs/comment/dr_elfstd.pdf

[11] Health Effects of Low-Frequency Electric and Magnetic Fields. 1992. Report to the Committee on Interagency Radiation Research and Policy Coordination by the Oak Ridge Associated Universities Panel. ORAU 92/F-8 and NTIS Publication #029-000-00443-9. 368 pp.

[12] Effects of Electric and Magnetic Fields. 1994. Report of the American Medical Association (AMA), Council on Scientific Affairs. Chicago: AMA (December 1994). http://www.ama-assn.org/ama/pub/category/13682.html

3.3 Swedish National Board of Health and Welfare (1995)

In January of 1995, the Swedish National Board of Health and Welfare released a report that noted the lack of substantial evidence regarding power-line MF health effects: [13]

> "*The existing epidemiological data cannot be used to support any definite conclusions as to whether exposure to electromagnetic fields increases the cancer risk in any organ system*."

3.4 American Cancer Society (1996)

The Epidemiology and Surveillance Research group of the American Cancer Society reviewed the epidemiology data suggesting increases in cancer risk from exposure to power-line MF. They noted that, in 1996, the idea that exposure to power-line MF might contribute to cancer causation had been under investigation for nearly two decades. [14] They reviewed all the available epidemiologic observations suggesting that exposure to MF may or may not promote human carcinogenesis. They concluded that:

> "*While* [epidemiological] *observations may suggest a relationship* [to risk] *for leukemia and brain cancer in particular, the findings are weak, inconsistent, and inconclusive.*"
> "*The weakness and inconsistent nature of epidemiologic data, combined with the continued dearth of coherent and reproducible findings from experimental laboratory research, leave one uncertain and rather doubtful that any real biologic link exists between EMF exposure and carcinogenicity.*"

3.5 National Academy of Sciences (1997)

In 1996, the U.S. Congress requested that the National Academy of Sciences (NAS) of the National Research Council review the scientific literature regarding EMF effects on health. In 1997, the NAS issued a 356-page report, [15] concluding that the NAS review of the evidence did not indicate that exposure to power-line MF was a human health hazard, stating:

> "*Based on a comprehensive evaluation of published studies relating to the effects of power-frequency electric and magnetic fields on cells, tissues, and organisms (including humans), the conclusion of the committee is that the current body of evidence does not show that exposure to these fields presents a human-health hazard. Specifically, no*

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13 Electric and Magnetic Fields and Health Effects. 1995. Report of the Swedish National Board of Health and Welfare (In Swedish, English summary). Stockholm (Sweden): SoS - Rapport 1995:1.

14 Electromagnetic field exposure and cancer: a review of epidemiologic evidence. 1996. Report of the American Cancer Society, by Heath, C. W., CA Cancer Journal for Clinicians 46: 29-44. http://caonline.amcancersoc.org/cgi/content/abstract/46/1/29

15 Possible Health Effects of Exposure to Residential Electric and Magnetic Fields. 1997. Report of the National Research Council, Committee on the Possible Effects of Electromagnetic Fields on Biologic Systems. Washington: National Academy Press. http://www.nap.edu/openbook.php?isbn=0309054478

conclusive and consistent evidence shows that exposures to residential electric and magnetic fields produce cancer, adverse neurobehavioral effects, or reproductive and developmental effects."

3.6 International Commission on Non-Ionizing Radiation Protection (1998)

The International Commission on Non-Ionizing Radiation Protection of the International Radiation Protection Association (ICNIRP-IRPA, 1998) [16] has published guidelines on limits of exposure to 50/60-Hz electric and magnetic fields. The guidelines are based on analyses of the scientific literature and on review articles published by the World Health Organization, which concluded that no biological effects could be expected for magnetic fields smaller than 50,000 mG. The ICNIRP guidelines, which incorporate safety factors, state that occupational exposure continuing throughout the working day should be limited to 60-Hz magnetic fields below 4,167 mG. The guidelines also state that exposure for members of the general public should be limited to 833 mG, and general-public magnetic field exposure between 1,000 and 10,000 mG should be limited to a few hours per day. Overall, ICNIRP concluded:

"*In the absence of evidence from cellular or animal studies, and given the methodological uncertainties and in many cases inconsistencies of the existing epidemiologic literature, there is no chronic disease outcome for which an etiological relation to EMF exposure can be regarded as established.*"

3.7 National Institute of Environmental Health Sciences (1999)

The National Institute of Environmental Health Sciences, in a 1999 report to the U.S. Congress, [17] summarized the six years of accelerated laboratory EMF research conducted under the U.S. EMF-RAPID (Research and Public Information Dissemination) program:

"*[Power-line MF] exposure cannot be recognized as entirely safe because of weak scientific evidence that exposure may pose a leukemia hazard . . . . The NIEHS does not believe that other cancers or non-cancer health outcomes provide sufficient evidence of a risk to currently warrant a concern.*"

"*Virtually all of the laboratory evidence in animals and humans, and most of the mechanistic studies in cells fail to support a causal relationship.... The lack of consistent, positive findings in animal or mechanistic studies weakens the belief that this association is actually due to [power-line MF] . . .*"

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[16] Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields. 1998. Report of the International Commission on Non-ionizing Radiation Protection of the International Radiation Protection Association. Health Physics 74:494-522. http://www.icnirp.de/pubEMF.htm

[17] Health Effects from Exposure to Power-Line Frequency Electric and Magnetic Fields. 1999. Report of the NIEHS to the U.S. Congress. NIH Publication No. 99-4493. 67 pp. http://www.niehs.nih.gov/health/docs/niehs-report.pdf

3.8 National Academy of Sciences (1999)

In 1999, the National Academy of Sciences / National Research Council evaluated the scientific and technical content of research projects conducted under the U.S. EMF-RAPID program. [18]

> "*Results of the EMF-RAPID program do not support the contention that the use of electricity poses a major unrecognized public-health danger*."

> "*No finding from the EMF-RAPID program alters the conclusions of the previous NRC review on the Possible Effects of [EMF] on Biologic Systems (NRC 1997). In view of the negative outcomes of EMF-RAPID replication studies, it now appears even less likely that [EMF] in the normal domestic or occupational environment produce[s] important health effects, including cancer*."

The report "recommends that no further special research program focused on possible health effects of power-frequency magnetic fields be funded."

3.9 California Department of Health Services (2000)

The "California EMF Program," which operated within the CA DHS, developed a fact sheet entitled "Electric and Magnetic Fields: Measurements and Possible Effect on Human Health — What We Know and What We Don't Know in 2000." [19] The fact sheet concluded:

> "*Public concern about possible health hazards from the delivery and use of electric power is based on data that give cause for concern, but which are still incomplete and inconclusive and in some cases contradictory. A good deal of research is underway to resolve these questions and uncertainties. Until we have more information, you can use 'no and low cost avoidance' by limiting exposure when this can be done at reasonable cost and with reasonable effort, like moving an electric clock a few feet away from a bedside table or sitting further away from the computer monitor*."

3.10 American Cancer Society (ACS) (2000)

The position of the ACS on the risk of power-line electric and magnetic fields is put in the category of "non-ionizing radiation" to contrast it with the known effects of "ionizing radiation" which applies to high-frequency electromagnetic waves, above the region of the spectrum that includes ultraviolet light (UV), on into X-rays, radionuclide decay emissions (gamma rays, alpha rays, beta rays), and cosmic rays. The position of ACS, which is posted on their website in August 2009, [20] is:

> "***Non-ionizing radiation:*** *Electromagnetic radiation at frequencies below ionizing radiation and UV levels has not been proven to cause cancer. Some studies suggest it is associated with cancer, but most of the now extensive research in this area does not.*

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[18] Research on Power-Frequency Fields Completed Under the Energy Policy Act of 1992 National Academy of Sciences. 1999. Final Report: Evaluation of the EMF RAPID Program, National Research Council, National Academy Press, June 1999, 107 pp. http://www.nap.edu/catalog/9587.html

[19] California Environmental Health Investigations Branch, 2000: http://www.ehib.org/emf/longfactsheet.PDF

[20] The American Cancer Society (ACS). 2001 (up to 7/2009). "Unproven Risks – Non-Ionizing Radiation" (2008) http://www.cancer.org/docroot/NWS/content/NWS_2_1x_The_Environment_and_Cancer_Risk.asp

Low-frequency radiation includes radio waves, microwaves, and radar, as well as power frequency radiation arising from electric and magnetic fields associated with [AC] *electric currents (from cellular phones and household appliances, for example).*

3.11 U.K. National Radiation Protection Board (NRPB) (2001)

The National Radiological Protection Board (NRPB) [The name of the NRPB has been changed to the Health Protection Agency, HPA] has a statutory responsibility for advising UK government departments on standards of protection for exposure to non-ionizing radiation. This covers static and low frequency electric and magnetic fields and radiofrequency radiations, and as far as power-line EMF, the NRPB concluded that:

"*Laboratory experiments have provided no good evidence that extremely low frequency electromagnetic fields are capable of producing cancer, nor do human epidemiological studies suggest that they cause cancer in general. There is, however, some epidemiologic evidence that prolonged exposure to higher levels of power frequency magnetic fields is associated with a small risk of leukaemia in children. In the absence of clear evidence of a carcinogenic effect in adults, or of plausible explanation from experiments on animals or isolated cells, the epidemiological evidence is currently not strong enough to justify a firm conclusion that such fields cause leukaemia in children. Unless however, further research indicates that the finding is due to chance or some currently unrecognized artifact, the possibility remains that intense and prolonged exposures to magnetic fields can increase the risk of leukaemia in children*." [21]

3.12 Minnesota Department of Health (2002)

The Minnesota Department of Health, through an Interagency Working Group on EMF, reviewed the EMF literature, and the report states that [22]

"*MDH concludes that the current body of evidence is insufficient to establish a cause and effect relationship between EMF and adverse health effects. However, as with many other environmental health issues, the possibility of a health risk from EMF cannot be dismissed. […] Based on its review, the policy recommendations of the Work Group include: apply low-cost EMF mitigation options in electric infrastructure construction projects; encourage conservation; encourage distributed generation; continue to monitor EMF research; encourage utilities to work with customers on household EMF issues; and provide public education on EMF issues*."

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[21] ELF Electromagnetic Fields and the Risk of Cancer. 2001. Report of an Advisory Group on Non-Ionising Radiation http://www.hpa.org.uk/web/HPAwebFile/HPAweb_C/1194947420620

[22] A White Paper on Electric and Magnetic Field (EMF) Policy and Mitigation Options. 2002. Report of the Minnesota State Interagency Working Group on EMF Issues, Sept. 2002. http://www.capx2020.com/Images/EMFWhitePaper2002.pdf

4.0 Current Guidelines and Post-2002 Public Health Agency Positions on EMF

The U.S. has no federal regulatory standards limiting occupational or residential exposure to 60-Hz EMF. Table 3 shows guidelines suggested by national and world health organizations. Table 4 lists guidelines that have been adopted by various states in the U.S. The first table shows levels, which are designed to be protective against any adverse health effects, but which should not be viewed as demarcation lines between safe and potentially hazardous levels of EMF. The second table shows (US State) guidelines that have generally been adopted to maintain the *status quo* of typical EMF on and near transmission-line rights-of-way (ROWs), and are not health-based.

4.1 Quantitative EMF Guidelines

Table 3: 60-Hz EMF Guidelines Established by Health & Safety Organizations

Organization	Magnetic Field	Electric Field
American Conference of Governmental and Industrial Hygienists (ACGIH) (occupational)	10,000 mG [(a)] 1,000 mG [(b)]	25 kV/m [(a)] 1 kV/m [(b)]
International Commission on Non-Ionizing Radiation Protection (ICNIRP) (general public, continuous exposure)	833 mG	4.2 kV/m
Non-Ionizing Radiation (NIR) Committee of the American Industrial Hygiene Assoc. (AIHA) endorsed (in 2003) ICNIRP's occupational EMF levels for workers	4,170 mG	8.3 kV/m
Institute of Electrical and Electronics Engineers (IEEE) Standard C95.6 (general public, continuous exposure)	9,040 mG	5.0 kV/m
U.K., National Radiological Protection Board (NRPB) [now Health Protection Agency (HPA)]	833 mG	4.2 kV/m
Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), Draft Standard, Dec. 2006 [(c)]	3,000 mG	5.0 kV/m
*Comparison to **steady** (DC) EMF, encountered as EMF outside the 60-Hz frequency range:*		
Earth's magnetic field and atmospheric electric fields, steady levels, typical of environmental exposure [(d)]	[550 mG]	[0.2 kV/m up to > 12 kV/m]
Magnetic Resonance Imaging Scan, static magnetic field intensity [(d)]	[20,000,000 mG]	---

(a) represents ACGIH guidelines for the general worker.

(b) represents ACGIH guideline for workers with cardiac pacemakers.

(c) http://www.arpansa.gov.au/pubs/comment/dr_elfstd.pdf; and http://www.arpansa.gov.au/News/events/elf.cfm

(d) These EMF are steady fields, and do not vary in time at the characteristic 60-cycles-per-second that power-line fields do. However, if a person moves in the presence of these fields, the body experiences a time-varying field.

Table 4: State EMF Standards and Guidelines for Transmission Lines

State / Line Voltage	Electric Field		Magnetic Field	
	On ROW	Edge ROW	On ROW	Edge ROW
Florida [c] 69 – 230 kV	8.0 kV/m	2.0 kV/m [f]	--	150 mG
230 – 500 kV	10.0 kV/m	2.0 kV/m [f]		200 mG
> 500 kV	15.0 kV/m	5.5 kV/m [f]		250 mG [e]
Massachusetts	--	1.8 kV/m	--	85 mG
Minnesota	8.0 kV/m	--	--	--
Montana	7.0 kV/m [a]	1.0 kV/m [b]	--	--
New Jersey	--	3.0 kV/m	--	--
New York [c]	11.8 kV/m 11.0 kV/m [d] 7.0 kV/m [a]	1.6 kV/m	--	200 mG
Oregon	9.0 kV/m	--	--	--

Key: ROW = right of way; mG = milligauss; kV/m = kilovolts per meter

Notes: -- no guidelines

([a]) Maximum for highway crossings
([b]) May be waived by the landowner
([c]) Magnetic fields for winter-normal, maximum line current-carrying capability
([d]) Maximum for private road crossings
([e]) includes 500 kV double-circuit lines built on existing ROW's
([f]) Includes the property boundary of a substation

Sources: "Questions and Answers About EMF." National Institute of Environmental Health Sciences and U.S. Department of Energy, 2002.
Florida, see: http://www.dep.state.fl.us/legal/Rules/siting/62-814/62-814.doc

4.2 International Agency for Research on Cancer (2002)

Because workers generally experience higher levels of all types of exposures, occupational studies have generally been at the forefront of identifying potentially hazardous circumstances requiring regulatory limits. If power-line MF were responsible for increased leukemia risk in the residential studies, it would stand to reason that increases in risk should be much greater in occupational studies. In fact, the trend is in the opposite direction. In its 2002 review of "Static and Extremely Low-Frequency (ELF) Electric and Magnetic Fields", IARC (International Agency for Research on Cancer, an agency of the World Health Organization) concluded that, despite considerably greater EMF exposure occurring in occupations, there was no increased cancer risk for power-line workers: [23]

> *There was no consistent finding across studies of an exposure–response relationship and no consistency in the association with specific sub-types of leukaemia or brain tumors.*

[23] International Agency on Research in Cancer, 2002: Non-Ionizing Radiation, Part 1: Static and Extremely Low-Frequency (ELF) Electric and Magnetic Fields" http://monographs.iarc.fr/ENG/Monographs/vol80/mono80.pdf

IARC classified power-line magnetic fields as a "possible" (Group 2B) carcinogen in 2002, based on weak associations between surrogate markers of power-line magnetic field exposure (such as "wire code" or distance from power-lines) and an increased risk of childhood leukemia reported in some epidemiology studies. [24] IARC found no credible support for association of power-line MF with risks of any other cancers. IARC Group 2B substances include such items as coffee, iron supplements, talcum powder, nickel metal, sassafras bark, and pickled vegetables. [25]

4.3 World Health Organization (2007)

The statistical associations reported between surrogates for power-line MF exposure and childhood leukemia risk remain poorly understood. Support for these associations having a causal basis in MF levels has not been forthcoming from continued animal research and mechanistic analysis. Scientists still have no established laboratory bioassay or animal models relevant to human cancer risk that show biological changes related to power-line MF exposure leading to tumors. Thus, problems continue to cloud the interpretation of the epidemiology. As the WHO recently stated in their 2007 review of Extremely Low Frequency Fields: [26]

> "*Uncertainties in the hazard assessment* [of epidemiological studies] *include the role that control selection bias and exposure misclassification might have on the observed relationship between magnetic fields and childhood leukaemia. In addition, virtually all of the laboratory evidence and the mechanistic evidence fail to support a relationship between low-level ELF magnetic fields and changes in biological function or disease status. Thus, on balance, the evidence is not strong enough to be considered causal, but sufficiently strong to remain a concern.*" [p. 12]

Also, regarding disease outcomes, aside from childhood leukemia, the WHO in 2007 reached similar conclusions to the IARC 2002 conclusions, in that WHO stated that:

> "*A number of other diseases have been investigated for possible association with ELF magnetic field exposure. These include cancers in both children and adults, depression, suicide, reproductive dysfunction, developmental disorders, immunological modifications, and neurological disease. The scientific evidence supporting a linkage between ELF magnetic fields and any of these diseases is much weaker than for childhood leukaemia and in some cases (for example, for cardiovascular disease or breast cancer) the evidence is sufficient to give confidence that magnetic fields do not cause the disease*." [p. 12]

Furthermore, in their "Summary and Recommendations for Further Study" WHO emphasized that:

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[24] IARC classified power-frequency magnetic fields as "possibly carcinogenic," based on "limited" evidence from humans concerning childhood leukemia, "inadequate" evidence from humans concerning all other cancer types, and "inadequate" evidence from animals. Power-frequency electric fields were judged "not classifiable" (Group 3) on the basis of "inadequate" evidence from both humans and animals.

[25] International Agency on Research on Cancer. 2009. http://monographs.iarc.fr/ENG/Classification/crthgr02b.php

[26] The World Health Organization (WHO) 2007 monograph, the "Environmental Health Criteria Volume N°238 on Extremely Low Frequency Fields" (446 pages), available on the WHO website: http://www.who.int/peh-emf/publications/elf_ehc/en/index.html Also: http://www.who.int/mediacentre/factsheets/fs322/en/index.html

> "*the limit values in [power-line MF] exposure guidelines [not] be reduced to some arbitrary level in the name of precaution. Such practice undermines the scientific foundation on which the limits are based and is likely to be an expensive and not necessarily effective way of providing protection.*" [p. 12]

WHO concluded that:

> "*given both the weakness of the evidence for a link between exposure to ELF magnetic fields and childhood leukaemia, and the limited impact on public health if there is a link, the benefits of exposure reduction on health are unclear. Thus, the costs of precautionary measures should be very low* [p. 13]."

4.4 Health Protection Agency, United Kingdom (2007)

The UK Health Protection Agency has concluded that the epidemiological evidence on power-line MF is inadequate to support a causal interpretation: [27]

> "*In the absence of clear evidence of a carcinogenic effect in adults, or of a plausible explanation from experiments on animals or cells, the epidemiological evidence is currently not strong enough to justify a firm conclusion that magnetic fields cause leukaemia in children. Nevertheless, the International Agency for Research on Cancer judged that this finding provided limited evidence for an excess risk in humans, and it evaluated power frequency magnetic fields as being "possibly carcinogenic" to humans. In addition, IARC considered the evidence for excess cancer risks of all other kinds, in children and adults, as a result of exposure to electric and magnetic fields to be inadequate*."

4.5 Australian Radiation Protection and Nuclear Safety Agency (2006 – 2009)

A draft power-line EMF standard was proposed in December 2006 by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA). The ARPANSA draft document can be found at the website http://www.arpansa.gov.au/pubs/comment/dr_elfstd.pdf, and its title is: "Radiation Protection Standard: Exposure Limits for Electric & Magnetic Fields – 0 Hz to 3 kHz." The ELF-EMF standard was addressed again in 2008, in a "Forum on the Development of an ELF Standard," and the presentations can be found at http://www.arpansa.gov.au/News/events/elf.cfm.

The ARPANSA proposed value for acceptable "General Public" exposure to 50-Hz EMF is 5 kV/m for the electric field, and 300 μT for the magnetic field, the latter being equal to 3,000 mG. Thus, ARPANSA's proposed 3,000 mG guideline is somewhat higher than the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines, where the general public magnetic-field guideline is 1,000 mG for 50-Hz MF (833 mG for 60-Hz MF). It is somewhat lower than the ICES/IEEE

[27] UK Health Protection Agency (HPA), Radiation Protection Division, , C. Muirhead, *et al*., 2007. "Burden of disease from radiation exposure" http://www.hpa.org.uk/web/HPAwebFile/HPAweb_C/1194947371160 (The UK HPA used to be known as the UK National Radiation Protection Board [NRPB])

magnetic field guideline for public exposure to 50-Hz MF, which is 10,000 mG (9,040 mG for 60-Hz MF). A recent fact sheet from ARPANSA [28] states:

> "*the majority of scientists, and Australian radiation health authorities in particular, do not regard chronic exposure to 50 Hz electric and magnetic fields, at the levels commonly found in the environment, as a proven health risk.*"

4.6 Scientific Committee on Emerging and Newly Identified Health Risks (2009)

Upon request of the European Commission, an opinion on the possible health effects of EMF on health was recently formulated by the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR). [29]

> "*The [IARC] opinion, that ELF magnetic fields are a 'possible' carcinogen, chiefly based on childhood leukaemia results, is still valid. There is no generally accepted mechanism to explain how ELF magnetic field exposure may cause leukaemia. Animal studies have not provided adequate evidence for a causal relationship.*"

The SCENIHR committee concluded that (1) there was no consistent relationship between ELF exposure and self-reported symptoms; (2) that it was unlikely that breast-cancer risk or cardiovascular-disease risk was linked to ELF EMF exposure; and (3) that the effects of ELF EMF on neurodegenerative disease and brain tumors remain uncertain. In summary, even though the sum total of the epidemiology correlations continues to provide a suggestion of EMF health risk, the results among the studies remain weak and inconsistent, and poorly linked to actual EMF exposures. Importantly, scientists have been unable to establish a laboratory-animal or mechanistic model relevant to human cancer risk that reliably demonstrates biological changes in response to power-line EMF exposure that leads to an increased tumor risk.

In their most recent update (2009),[30] SCENIHR continues to endorse their earlier conclusion, that is, no new studies support a causal relationship between ELF fields and self-reported symptoms, and:

> "*SCENIHR updates the previous opinion and concludes the following: The new information available is not sufficient to change the conclusions of the 2007 opinion. The few new epidemiological and animal studies that have addressed ELF exposure and cancer do not change the previous assessment that ELF magnetic fields are a possible carcinogen and might contribute to an increase in childhood leukaemia. At present, in vitro studies did not provide a mechanistic explanation of this epidemiological finding.*"

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[28] Australian Radiation Protection and Nuclear Safety Agency (ARPANSA). 2009. EMF Fact Sheet http://www.arpansa.gov.au/radiationprotection/FactSheets/is_emf.cfm

[29] Ahlbom A, Bridges J, de Seze R, Hillert L, Juutilainen J, Mattsson MO, Neubauer G, Schüz J, Simko M, Bromen K. 2008. Possible effects of electromagnetic fields (EMF) on human health--opinion of the scientific committee on emerging and newly identified health risks (SCENIHR). *Toxicology* 246(2-3):248-50.

[30] "Health Effects of Exposure to EMF," SCENIHR http://ec.europa.eu/health/ph_risk/committees/04_scenihr/docs/scenihr_o_022.pdf

4.7 International Commission on Non-Ionizing Radiation Protection (2009)

The ICNIRP draft 2009 report has concluded that the epidemiological associations with power-line MF might well be the result of selection bias, confounding, and chance, and the results cannot be interpreted as showing a causal relationship: [31]

> "*Research that followed the first study has suggested that there may be an association between residential ELF magnetic fields and childhood leukemia risk, although it cannot be excluded that a combination of selection bias, some degree of confounding and chance could explain the results. Two pooled analyses indicate that an excess risk may exist around 0.3-0.4 μT, although the authors of those analyses cautioned strongly that their results cannot be interpreted as showing a causal relationship between magnetic fields and childhood leukemia. In principle, there are several alternative explanations for these findings, such as causation, bias, chance and confounding. Epidemiologists have made extensive efforts to assess the findings and have evaluated bias, confounding and chance as possible explanations, but concluded that, at most, some of the observed association might be due to bias and that chance is an unlikely explanation. At the same time, no biophysical mechanism has been identified and the experimental results don't support the notion that exposure to ELF magnetic fields is a cause of childhood leukemia*."

4.8 Wisconsin Public Service Commission (2008, 2009)

The Wisconsin Public Service Commission recently made a comprehensive review of the scientific literature on health effects of EMF, and provided their conclusions in a recent document "Electric & Magnetic Fields (EMF)." The summary section of this report states that [32]

> "*Many scientists believe the potential for health risks for exposure to EMF is very small. This is supported, in part, by weak epidemiological evidence and the lack of a plausible biological mechanism that explains how exposure to EMF could cause disease. The magnetic fields produced by electricity are weak and do not have enough energy to break chemical bonds or to cause mutations in DNA. Without a mechanism, scientists have no idea what kind of exposure, if any, might be harmful. In addition, whole animal studies investigating long-term exposure to power-frequency EMF have shown no connection between exposure and cancer of any kind*."

Thus, the Wisconsin PSC, like other agencies, continues to conclude that the reported epidemiological associations of health risks with power-line MF are weak and are not supported by other lines of scientific evidence.

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[31] http://www.icnirp.de/openELF/ICNIRPConsultationELF0709.pdf

[32] http://psc.wi.gov/thelibrary/publications/electric/electric12.pdf "Electric & Magnetic Fields (EMF)," Public Service Commission of Wisconsin, 2009, 27 pp. Also, http://psc.wi.gov/thelibrary/publications/electric/electric10.pdf "Environmental Impacts of Transmission Lines," PSC of Wisconsin, 2008, 15 pp.

5.0 Discussion of Certain Articles / Reports Often Mentioned in the EMF Context

The paragraphs provided below discuss articles and reports that are often the focus of debate regarding the potential health effects of EMF exposure.

5.1 Air Ions from Power-Transmission Lines, the "Henshaw Effect" (1996-1999)

Denis Henshaw and his colleagues at the Bristol University's Physics department (UK) proposed that a possible mechanism for a health risk from power lines derived from the air ions (air molecules that have acquired an electrical charge) that are produced *via* corona discharge near some high-voltage transmission lines. [33] The suggestion was that the ions produced by minute spark discharges around high-voltage conductors are blown away downwind from the power lines and electrically charge existing airborne particles in the outdoor, ambient air. When such particles are inhaled, the likelihood of their deposition onto lung and airway surfaces is greater than for a similar uncharged particle. Thus, if the particles normally present in outdoor air are capable of causing diseases, the "Henshaw Effect" would cause increased disease rates by virtue of this electrically-driven, increased retention in the lungs.

Although the individual events envisioned in this theory are plausible, there are many flaws to considering it a possible mechanism explaining the childhood leukemia epidemiology. First of all, the Henshaw group provides no evidence that lung deposition of airborne particles downwind of transmission lines is increased compared to upwind. Second, there is no hint that particles in outdoor, ambient air are a risk factor for leukemia, and hence, even assuming increased lung deposition would not be viewed as increasing risk. Third, if this mechanism were at work, you would expect a greater effect downwind of transmission lines *versus* upwind. Such an asymmetry has not been observed. Finally, the National Radiation Protection Board (NRPB, UK) reviewed the "Henshaw Effect" hypothesis in 2001,[34] and concluded:

> "*The physical principles for enhanced aerosol deposition in large electric fields are well understood. However, it has not been demonstrated that any such enhanced deposition will increase human exposure in a way that will result in adverse health effects to the general public*."

It should be recognized that the 1996 – 1999 Henshaw and colleagues' papers were considered by the 2002 IARC Working Group, which nonetheless concluded that the evidence for power-line electric fields being a risk factor for cancer was "inadequate," for both humans and animals. As a consequence, IARC determined that ELF electric fields were "not classifiable" with respect to carcinogenicity.

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[33] Fews AP, Henshaw DL, Keitch PA, Close JJ, Wilding RJ. 1999a. Increased exposure to pollutant aerosols under high voltage power lines. *Int J Radiat Biol.* 75(12):1505-21.

Fews AP, Henshaw DL, Wilding RJ, Keitch PA. 1999b. Corona ions from power lines and increased exposure to pollutant aerosols. *Int J Radiat Biol.* 75(12):1523-31.

Henshaw DL, Ross AN, Fews AP, Preece AW. 1996. Enhanced deposition of radon daughter nuclei in the vicinity of power frequency electromagnetic fields. *Int J Radiat Biol.* 69(1):25-38.

[34] NRPB / HPA. "Electromagnetic fields and the risk of cancer." p. 23 of 179 pp.
http://www.hpa.org.uk/web/HPAwebFile/HPAweb_C/1194947420620
http://www.hpa.org.uk/web/HPAweb&HPAwebStandard/HPAweb_C/1195733757485#concs

5.2 Draper *et al*. study in England and Wales (2005)

The Draper *et al*.[35] investigators conducted a case-control study to examine a possible association between distance of home address at birth from high-voltage power lines and incidence of leukemia and other cancers in children living in England and Wales. Using postcode for residence location at birth, Draper *et al*. found a slightly increased odds ratio of leukemia in children whose home address at birth was within 200 meters of high-voltage power lines compared to those who were born >600 m. There was a trend in risk in relation to the reciprocal of distance to the line, but no actual electric or magnetic field measurements or calculations were made. No excess risk for any other childhood cancer was found to be related to proximity to lines. The investigators were puzzled because they found associations at much larger distances from the line than would be expected from any power-line MF impact. The authors acknowledged that at these distances (> 200 m) the average magnetic field from the transmission lines would be much less than residential MF exposure from other sources. The authors also noted that there is no accepted biological mechanism to explain the epidemiologic results, and suggest that the relationship may be due to chance, or to selection bias, or to confounding.

5.3 California Department of Health Sciences Evaluation (2002)

In the California Department of Health Services (DHS) report, three DHS epidemiologists specifically evaluated the overall power-line MF epidemiology as it existed in 2002.[36] The report states:

> "*Three epidemiologists who worked for the California Department of Health Services (CADHS) reviewed studies about possible health problems from electric and magnetic fields (EMFs) [...] To one degree or another, all three of the DHS scientists were inclined to believe that EMFs can cause some degree of increased risk of childhood leukemia, adult brain cancer, Lou Gehrig's Disease [ALS], and miscarriage. They strongly believe that EMFs are not universal carcinogens, since there are a number of cancer types that are not associated with EMF exposure. To one degree or another they are inclined to believe that EMFs do not cause an increased risk of breast cancer, heart disease, Alzheimer's Disease, depression, or symptoms attributed by some to a sensitivity to EMFs.*"

The DHS report never identifies quantitatively what they mean by "some degree" of increased leukemia risk, and subsequent to the report, the state of California has not issued any general-public guidelines on allowable EMF exposure. The DHS epidemiologists did not allow for the non-supportive, negative results from animal studies or mechanistic studies, because they felt the epidemiology was "observational," and the laboratory results were more "theoretical." However, no matter how complex the human body is, the constraints imposed by physical law and experimental studies are real and cannot be easily disregarded. If, as the DHS authors asserted, "observation is the ultimate test of truth," then they should have also recognized that physical laws and laboratory studies are firmly based on reproducible and validated "observations."

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[35] Draper G, Vincent T, Kroll ME, Swanson J. 2005. Childhood cancer in relation to distance from high voltage power lines in England and Wales: a case-control study. *British Medical Journal* 330:1290-1293.

[36] An Evaluation of the Possible Risks From Electric and Magnetic Fields (EMF) From Power Lines, Internal Wiring, Electrical Occupations and Appliances. 2002. Report of the California Department of Health Services (CADHS), , California EMF Program, 1515 Clay Street, 17th Floor, Oakland, CA 94612. http://www.ehib.org/emf/RiskEvaluation/riskeval.html

The overall scientific evidence that is used to establish the existence of a human health hazard is often illustrated as a "three-legged stool," where weakness or non-existence in any one leg makes the stool unstable. That is, lack of support from all three lines of evidence restricts the conclusions we can draw about health risk. The three legs were listed at the end of Section 1 and are (i) exposure/disease correlations in human populations (epidemiology), (ii) empirical laboratory animal studies at controlled and elevated levels of exposure, and (iii) *in vitro* and/or mechanistic studies of the toxin's mode of action. DHS's discussion of EMF evidence acknowledges the lack of support from animal studies and mechanistic studies [legs (ii) and (iii)]. However, the agency dismissed too readily this absence of supporting data. In fact, much of the evidence from legs (ii) and (iii) not only fails to provide support for an EMF health risk, but also suggests an absence of health risks. There is strong counter-evidence available in the areas of animal studies and mechanism, and the DHS 2002 evaluation did not allow for the importance of these opposing findings.

It is helpful to note that an independent California Scientific Advisory Panel (SAP) reviewed the DHS study, and did not agree with the DHS conclusions: [37]

> "*If* [the SAP] *were to carry out their own extensive review using the same assessment guidelines, they might come to somewhat different conclusions and arrive at lower estimates of risks from EMFs. In raising this issue, the* [SAP] *panel members considered the following factors;*
> *(1) EMFs have very low energy;*
> *(2) Biological effects of EMFs have not been demonstrated in animal models;*
> *(3) Consistent dose-response relationships have not been demonstrated between EMF exposure and several health outcomes;*
> *(4) SAP members give more weight to negative studies than did the DHS reviewers;*
> *(5) Given the lack of biological mechanism, SAP members give more credence to the possible effects of* [epidemiology] *"confounders" than did the DHS reviewers.*

Hence, the California analyses do not conclude that EMF represents a significant health risk.

5.4 BioInitiative Report (2007)

The "BioInitiative Report" is similar to other EMF reports that can be found on the Internet, *i.e.*, reports that diverge markedly from the scientific consensus viewpoint. [38] The BioInitiative Report was not authored by any well-established research group, *e.g.*, either a medical association, a government body, a professional society, a recognized risk assessment organization, or a public health group. It appears to be a group of individuals, including some EMF scientists, but also activists and journalists, who can be recognized as having strong feelings on the subject of EMF health impacts, but who have viewpoints that are not supported by broadly-based public health science. The Report authors do not cite to any public-health agencies that endorse their proposed guidelines; and in fact, these guidelines illustrate how far out from the scientific mainstream the Report lies (*e.g.*, on page 4: "the existing public safety standards limiting these radiation levels in *nearly every country of the world* look to be *thousands of times too lenient*;" and on page 8 "increased risk for childhood leukemia starts at levels almost *one*

[37] California Science Advisory Panel: Final Letter, 2002. http://www.ehib.org/emf/RiskEvaluation/SAPFinalLetter.doc

[38] "*BioInitiative Report: A Rationale for a Biologically-based Public Exposure Standard for Electromagnetic Fields (ELF and RF)*" http://www.bioinitiative.org/

thousand times below the safety standard") (italics added). Such statements confirm the isolated nature of the BioInitiative Report viewpoints.

The conclusions of the BioInitiative Report are inconsistent with and contradictory to the conclusions reached by previous expert panels, and by public health organizations. This can be appreciated by the contrast between the agency opinions I cite in my report *versus* text from the BioInitiative Report. For example, SCENIHR (See Section 4.6) disagrees with the BioInitiative Report:

> "*The BioInitiative Report is one of several reports and statements by scientists diverging from the scientific position taken by other research groups, including that of the SCENIHR.*" [39]

In fact, at a recent EMF Symposium (2009) sponsored by the European Commission, the authors themselves (of the BioInitiative Report) expressed reservations as to the conclusions of the Report:

> "*The BioInitiative Group stated that it does not intend to establish a standard of evidence and that it does not claim to have proven any association between EMF and health effects. As the BioInitiative Report is a compilation of individual contributions, each under the responsibility of his / her author, several of these authors stated that they do not support the conclusions of the Report.*" [40]

5.5 Japanese Study, Kabuto *et al.* (2006)

In the Kabuto *et al*. study [41] the investigators measured weekly the mean magnetic field (MF) levels in a child's bedroom for about 300 leukemia cases and about 600 controls. Their analysis reported that children whose bedrooms had MF levels of 4 mG or higher (compared to < 1 mG) had an elevated odds ratio of being a case *versus* a control. However, the authors acknowledge that their result may be at least partly due to selection bias (the participation of cases was only 50%, and of controls was considerably less [below 30%]). The magnitude of the excess risk went down nearly tenfold if the possibility of selection bias was taken into account. Moreover, this single study with a population size of about 900 should be viewed in the context of much larger studies, such as the United Kingdom Childhood Cancer study (population size about 4,500), which found no association of increased risk for childhood cancer and exposure to power-line electric and magnetic fields. [42]

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[39] "Health Effects of Exposure to EMF" SCENIHR (2009), p. 12

[40] "Report of the workshop on EMF and Health: Science and Policy to address public concerns." Directorate General for Health & Consumers, European Union, Brussels, Feb. 11-12, 2009. Available at: http://ec.europa.eu/health/ph_risk/documents/ev_20090211_mi.pdf

[41] Kabuto M, Nitta H, Yamamoto S, *et al*. 2006. Childhood leukemia and magnetic fields in Japan: a case-control study of childhood leukemia and residential power-frequency magnetic fields in Japan. *Int. J Cancer*. 119:643-50.

[42] UKCC Study Investigators. 1999. Exposure to power-frequency magnetic fields and the risk of childhood cancer, Report of the UK Childhood Cancer Study Investigators. *Lancet* 354:1925-1931.

5.6 Dr. De-Kuh Li and G. Lee studies on MF and Spontaneous Abortions (2002)

A study in California by Dr. D.-K. Li and colleagues, in combination with a study by Dr. Gerri Lee and colleagues, suggested the possibility that power-line MF may be a risk factor for miscarriage. [43] Although published in 2002, these study results have not been replicated in other studies. Moreover, it has been noted by other epidemiologists that the magnetic field measurements in this study may have acted as surrogate markers for other maternal exposures or biologically important indices that may predispose to miscarriage. [44] For example, exercise and hot tub use have also been reported as risk factors for miscarriage, and the use of such equipment may also be correlated to measured MF levels. [45] The UK Health Protection Agency reviewed these findings in 2004, [46] and concluded they could not be relied upon:

> "*The parameter that provided evidence of a risk – namely magnetic field strength – was not chosen* a priori *on the basis of biological or epidemiological reasons to believe it might be of plausible etiological relevance; the results were sensitive to choice of breakpoint, which was made on the basis of the observed data* [and not *a priori*]*; and the study was not a standard prospective study, as more than half of the spontaneous abortions occurred before the* [power-line MF] *measurements were made; compliance was low, and the possibility of selection bias was not excluded*." (p. 36)

As summarized in 2006 by University of North Carolina epidemiologist Dr. David Savitz, "these [2002] findings may be due to an artifact resulting from a laudable effort to integrate behavior and environment." Thus, at present, the role of power-line MF in risk of adverse pregnancy outcome, if any, cannot be determined, because important confounding factors in the relevant studies have not been addressed.

5.7 Ahlbom *et al*. Pooled Analysis of MF Epidemiologic Studies (2000)

This analysis relied upon data from previously-reported power-line MF epidemiologic studies, and determined that the overall result of combining studies yielded a net association of leukemia risk with power-line MF. [47] However, the authors noted that non-power-line MF explanations of the link could not be ruled out:

> "*In summary, the 99.2% of children residing in homes with exposure levels < 0.4 μT had estimates compatible with no increased risk, while the 0.8% of children with exposures*

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[43] Li DK, Odouli R, Wi S, Janevic T, Golditch I, Bracken TD, Senior R, Rankin R, Iriye R. 2002. A population-based prospective cohort study of personal exposure to magnetic fields during pregnancy and the risk of miscarriage. *Epidemiology* 13: 9-20.

Lee GM, Neutra RR, Hristova L, Yost M, Hiatt RA. 2002. A nested case-control study of residential and personal magnetic field measures and miscarriages. *Epidemiology* 3:21-31.

[44] Savitz DA. 2002. Magnetic fields and miscarriage. *Epidemiology* 13(1):1-4.

[45] Savitz DA, Herring AH, Mezei G, Evenson KR, Terry JW Jr, Kavet R. 2006. Physical activity and magnetic field exposure in pregnancy. *Epidemiology* 17(2):222-225.

[46] NRPB. 2004. "Review of the Scientific Evidence for Limiting Exposure to Electromagnetic Fields, (0 – 300 GHz). http://www.hpa.org.uk/web/HPAwebFile/HPAweb_C/1194947383619 (p. 36)

[47] Ahlbom A, Day N, Feychting M, Roman E, Skinner J, Dockerty J, Linet M, McBride M, Michaelis J, Olsen JH, Tynes T, Verkasalo PK. 2000. A pooled analysis of magnetic fields and childhood leukaemia. *Br J Cancer*. 83:692-698.

> *>/= 0.4 μT had a relative risk estimate of approximately 2, which is unlikely to be due to random variability. The explanation for the elevated risk is unknown, but selection bias may have accounted for some of the increase*." [Emphasis added]

The Ahlbom *et al*. meta analysis supports the view that power-line MF levels are not the likely causal basis of the increased leukemia risk.

5.8 Power-Line MF and Studies of Brain-Cancer Risk (2005 – 2009)

The potential role of power-line MF exposure and risk of brain cancer has been examined in several studies, and an absence of risk is supported by both the conclusions of IARC, as discussed in Section 4.2, and by other studies,[48] including a recent (2008) meta analyses of the causes of brain-cancer risk. [49]

For the occupational study in Norway (Klaeboe *et al*. 2005), increasing power-line MF exposure was actually correlated with decreased brain-cancer risks:

> "*Analysis of occupational exposure showed an inverse association for all brain tumours. All endpoints investigated, except gliomas in the intermediate exposure category, showed reduced risks.* [In the high power-line MF exposure category, glioma risk was reduced] *The inverse association was even more pronounced for meningiomas*."

For the occupational study in the U.S. (Coble *et al*. 2009), the authors concluded:

> "*We investigated the association between occupational exposure to extremely low-frequency magnetic fields (MFs) and the risk of glioma and meningioma. No statistically significant elevation in ORs or trends in ORs across exposure categories was observed using four different exposure metrics for the three tumor types analyzed. Occupational exposure to MFs assessed using job modules was not associated with an increase in the risk for glioma, glioblastoma, or meningioma among the subjects evaluated in this study.*"

The meta-analysis authors state in their conclusions for adults:

> "*To update past meta-analyses on occupational electromagnetic fields (EMF) and adult brain cancer and leukemia, we collected and evaluated all relevant 1993 to 2007 publications. The lack of a clear pattern of EMF exposure and outcome risk does not support a hypothesis that these exposures are responsible for the observed excess risk.*"

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[48] Klaeboe L, Blaasaas KG, Haldorsen T, Tynes T. 2005. Residential and occupational exposure to 50-Hz magnetic fields and brain tumours in Norway: a population-based study. *Int J Cancer*. 115(1):137-41.

Coble JB, Dosemeci M, Stewart PA, Blair A, Bowman J, Fine HA, Shapiro WR, Selker RG, Loeffler JS, Black PM, Linet MS, Inskip PD. 2009. Occupational exposure to magnetic fields and the risk of brain tumors. *Neuro Oncol.* 11(3):242-9.

[49] Kheifets L, Monroe J, Vergara X, Mezei G, Afifi AA. 2008. "Occupational electromagnetic fields and leukemia and brain cancer: an update to two meta-analyses." *J Occupational and Environmental Medicine* 50:677-88.

Mezei G, Gadallah M, Kheifets L. 2008. Residential magnetic field exposure and childhood brain cancer: a meta-analysis. *Epidemiology*. 19:424-30.

And for children:

> "*We conducted a meta-analysis of studies on magnetic field exposure and childhood brain tumors to evaluate homogeneity in the results, to examine reasons for heterogeneity, and to derive a summary effect estimate. For measured or calculated exposures above 0.3 or 0.4 μT, the summary odds ratio was 1.68 (0.83-3.43)* [not significant]*, with no differences by method of exposure assessment. No single study had a substantial effect on the summary estimates. With the exception of high cut-point analyses (0.3/0.4 μT), where the possibility of a moderate risk increase cannot be excluded, no increase in childhood brain cancer risk was evident for any of the exposure metrics.*

Thus, there is no basis to assert that power-line MF increase brain-cancer risk.

5.9 Summary

The conclusions of these studies do not change the factual conclusion that power-line MF exposure is not an established cause of health effects, as has been detailed throughout this report. As has been noted, the overall weight of evidence, combining the epidemiology with laboratory-animal and mechanistic research, fails to support a role for power-line MF in disease risk. Although the results of some studies have been interpreted to support such a risk, such research has not been confirmed by other studies or verified in studies designed to replicate the finding of an adverse health outcome.

6.0 Overall Summary

In the time period since the IARC 2002 ELF-EMF review, there have been no studies that have established a causal relationship between power-line MF exposures and risk of human disease. In fact, from the initial, hypothesis-generating study of 1979 to the present day, EMF studies have become increasingly larger and better designed, and should have zeroed in on any adverse health effect. However, in contrast, the power-line MF epidemiology studies have remained, weak, inconsistent, and variable in outcome, failing to show an increase over time in strong, positive associations with health risk.

Laboratory animal and mechanistic studies of power-line magnetic-field bioeffects do not support the existence of an increased cancer risk. Epidemiologic studies of power-line fields have reported weak, but somewhat inconsistent, associations between MF and risk of childhood leukemia. However, uncertainties in the interpretation of these statistical associations prevent a conclusion that a causal effect of MF *per se* is involved. In an overview of childhood leukemia risk factors, Brain *et al*. (2003) concluded that: [50]

> "*Epidemiological associations between [MF] and childhood leukemia have made [power-frequency fields] a suspected risk factor. Animal data on the effects of exposure, however, are overwhelmingly negative regarding [power-frequency field] exposure, per se, being a significant risk for [leukemia]. We may fail to observe laboratory effects from exposure, because typical power-line [fields] do not give a 'dose' detectable above the many sources of 'noise' in biological systems. We may fail to detect effects in bioassay systems because the [power-frequency fields] themselves are not the causal exposure in the epidemiologic associations.*"

Hence the weak epidemiology, and the lack of health-effect evidence from either laboratory animal work or *in vitro* / mechanistic studies, support the conclusion that the low levels of 50-60-Hz power-line MF typical of the home, occupational, and most electric transmission environments are not likely to lead to adverse health effects. A few epidemiological studies have suggested a possible increase in risk of Alzheimer's disease arising from exposure to ELF fields, but the validity of these associations and their mechanistic basis are unclear. Available laboratory and *in vitro* studies have given little or no support for a role of ELF-EMF in disease risk, and generally have been carried out at levels that are considerably higher than the levels encountered by the general public and analyzed in the epidemiology studies. Consequently, the scientific research literature to date remains an insufficient basis for assigning any actual health risk to power-line MF exposure levels.

An important integrative consideration is that modern societies such as the US have used electric power for many decades, at an increasing rate since the early 1900's. During this period of time, some rural portions of the population that did not have electricity, were provided electric service, so that both the number of people using electricity and their per-capita use have increased dramatically. Yet, over the same interval, life expectancy has increased significantly, and age-specific rates of diseases have declined. Time trends in US population health statistics do not support the hypothesis that power-line MF from increasing delivery / use of "household electric power" contribute to increasing disease rates.

[50] Brain JD, Kavet R, McCormick DL, Poole C, Silverman LB, Smith TJ, Valberg PA, Van Etten RA, Weaver JC. 2003. "Childhood leukemia: electric and magnetic fields as possible risk factors." *Environmental Health Perspt*. 111 :962-70.

7.0 Some Key Articles Published since the IARC 2002 EMF Assessment

7.1 Representative epidemiology

(1.) Kabat GC, O'Leary ES, Schoenfeld ER, *et al*.; EBCLIS Group. 2003. Electric blanket use and breast cancer on Long Island. *Epidemiology* 14:514-20.

(2.) Tynes T, Haldorsen T. 2003. Residential and occupational exposure to 50 Hz magnetic fields and hematological cancers in Norway. *Cancer Causes and Control*. 14:715-20.

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8.0 List of Acronyms and Abbreviations

A	–	amps = amperes of electric current
AC	–	alternating current
ACS	–	American Cancer Society
AM	–	amplitude modulated
ACGIH	–	American Conference of Governmental Industrial Hygienist
AIHA	–	American Industrial Hygiene Association
ARPANSA	–	Australian Radiation Protection and Nuclear Safety Agency
ANSI	–	American National Standards Institute
B		magnetic flux density (units are Teslas or gauss)
CADHS	–	California Department of Health Services
DC	–	direct current
DNA	–	deoxyribonucleic acid = genetic material in cell nucleus
EBCLIS	–	Electromagnetic Field and Breast Cancer Long Island Study
EC	–	European Commission
EF	–	electric field (units are volts/meter, equivalent to newtons/coulomb)
EHV	–	extra high voltage
ELF	–	extremely low frequency (1 – 300 Hz)
EMF	–	electric and magnetic fields
EU	–	European Union
FM	–	frequency modulated
G	–	gauss, a unit of magnetic field strength
H		magnetic field strength (units are amperes/meter [A/m])
HPA	–	Health Protection Agency (UK)
Hz	–	Hertz = cycles per second
ICES	–	International Committee on Electromagnetic Safety
IEEE	–	Institute of Electrical and Electronics Engineers
IARC	–	International Agency for Research on Cancer
ICNIRP	–	International Commission on Non-Ionizing Radiation Protection
kV	–	kilovolt, 1,000 volts
KVA	–	kilovolt-ampere, a unit used to express electric power
kV/m	–	kilovolts per meter, a unit of electric field strength
MDH	–	Minnesota Department of Health
MF	–	magnetic field (sometimes called “B-field,” units of Tesla or newtons/amp–m)
mG	–	milligauss = one-thousandth of a gauss = 0.001 G
microT	–	microtesla = μT = one-millionth of a Tesla
MRI	–	magnetic resonance imaging
MW	–	megawatts = one million watts = a unit of electrical power
MW-hr	–	megawatt-hours = a unit of total electrical energy = electrical power × time
NAS	–	National Academy of Sciences
NIEHS	–	National Institute of Environmental Health Sciences
NIR	–	non-ionizing radiation
NRC	–	National Research Council
NRPB	–	National Radiation Protection Board (UK)
NTP	–	National Toxicology Program
OR	–	odds ratio
ORAU	–	Oak Ridge Associated Universities

PSC	–	public service commission
RAPID	–	research and public information dissemination
RF	–	radio frequency
RR	–	relative risk
ROW	–	right of way
SAP	–	Scientific Advisory Panel
SCENHIR	–	Scientific Committee on Emerging and Newly Identified Health Risks
T	–	Tesla = 10,000 gauss, like gauss, Tesla is a unit of magnetic field strength
TV	–	television
µT	–	microtesla = one-millionth of a Tesla = 10 mG
UK	–	United Kingdom
UKCCS	–	United Kingdom Childhood Cancer Study
V	–	volts or voltage
V/m	–	volts per meter, a unit of electric field strength
W	–	watts = electrical power; watts = volts × amps
W-hr	–	watt-hour
WHO	–	World Health Organization

INTERNATIONAL COMMISSION ON NON-IONIZING RADIATION PROTECTION

FACT SHEET

ON THE GUIDELINES FOR LIMITING EXPOSURE TO TIME-VARYING ELECTRIC AND MAGNETIC FIELDS (1 Hz – 100 κHz) PUBLISHED IN HEALTH PHYS 99(6):818-836; 2010.

ICNIRP is the internationally recognized body that sets guidelines for protection against adverse health effects of non-ionizing radiation. It has recently published Guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz to 100 kHz); this fact sheet describes the content of these guidelines and their scientific background.

The guidelines replace previous recommendation given by ICNIRP for this frequency range. They are derived from the current scientific knowledge as described in extensive reviews especially those of the World Health Organization and ICNIRP. Some of the recommendations given in the new document deviate from former ones. Where appropriate, such differences are explained in detail.

The main interaction of low frequency time-varying electric and magnetic fields (EMF) with the human body is the induction of electric fields and associated currents in the tissues. In addition, exposure to low frequency electric fields can cause surface electric charge effects.

The responsiveness of electrically excitable nerve and muscle tissue to electric stimuli including those induced by exposure to low frequency electric and magnetic fields has been well established. A minimum electric field threshold of about 4-6 V m^{-1} has been calculated for peripheral nerve stimulation, using a heterogeneous human model and data from volunteer exposure to the switched gradient fields of magnetic resonance (MR).

The most robustly established effect of electric fields below the threshold for direct nerve or muscle excitation is the induction of magnetic phosphenes, a perception of faint flickering light in the periphery of the visual field. They are thought to result from the interaction of the induced electric field with electrically excitable cells in the retina. This is formed as an outgrowth of the forebrain and can be considered a good but conservative model of processes that occur in CNS tissue in general. The threshold for induction of phosphenes in the retina has been estimated to lie between about 50 and 100 mV m^{-1} at 20 Hz. The evidence for neurobehavioral effects on brain electrical activity, cognition, sleep and mood in volunteers exposed to low frequency electric and magnetic fields is much less clear.

The scientific data available so far do not indicate that low frequency electric and/or magnetic fields affect the neuroendocrine system in a way that these would have an adverse impact on human health. There is no substantial evidence for an association between low frequency exposure and diseases such as Parkinson's disease, multiple sclerosis, and cardiovascular diseases. The evidence for an association between low frequency exposure and Alzheimer´s disease and amyotrophic lateral sclerosis is inconclusive. The evidence for an association between low frequency exposure and developmental and reproductive effects is very weak.

A considerable number of epidemiological reports, published particularly during the 1980s and '90s, indicated that long term exposure to 50-60 Hz magnetic fields might be associated with an increased risk of childhood leukemia. Two pooled analyses indicate that an excess risk may exist for average exposures exceeding 0.3-0.4 μT. However, a combination of selection bias, some degree of confounding and chance could possibly explain the results. In addition, no biophysical mechanism has been identified and the experimental results from the animal and cellular laboratory studies do not support the notion that exposure to 50-60 Hz magnetic fields is a cause of childhood leukemia.

It is the view of ICNIRP that the currently existing scientific evidence that prolonged exposure to low frequency magnetic fields is causally related with an increased risk of childhood leukemia is too weak to form the basis for exposure guidelines. Thus, the perception of surface electric charge, the direct stimulation of nerve and muscle tissue and the induction of retinal phosphenes are the only well established adverse effects and serve as the basis for guidance.

Based on the review of the scientific evidence summarized above, ICNIRP recommends the following limits on exposure:

Occupational exposures: In the frequency range 10 Hz to 25 Hz, occupational exposure should be limited to fields that induce electric field strengths in CNS tissue of the head (i.e., the brain and retina) of less than 50 mV m^{-1} in order to avoid the induction of retinal phosphenes. These restrictions should also prevent any possible transient effects on brain function. These effects are not considered to be adverse health effects; however, ICNIRP recognizes that they may be disturbing in some occupational circumstances and should be avoided, but no additional reduction factor is applied. At lower frequencies the limit value for the induced electric field strength rises in reverse proportion to frequency. At higher frequencies, up to 400 Hz the limit value rises proportional to frequency. At frequencies in the range 400 Hz to 3 kHz occupational exposure should be limited to fields that induce electric field strengths in all parts of the body of less than 800 mV m^{-1} in order to avoid peripheral and central myelinated nerve stimulation. At frequencies above 3 kHz the limit value rises proportionally with frequency.

In controlled environments, where workers are informed about the possible transient effects, exposure in the range 1 Hz to 400 Hz, should be limited to fields that induce electric fields in the head and body of less than 800 mV m^{-1} in order to avoid peripheral and central myelinated nerve stimulation. This value has been obtained by applying a reduction factor of 5 to the peripheral nerve stimulation threshold of 4 V m^{-1} in order to account for the uncertainties described above. These restrictions rise proportionally with frequency above 3 kHz.

General public exposures: In the frequency range 10 Hz to 25 Hz, general public exposure should be limited to fields that induce electric field strengths in CNS tissue of the head (i.e., the brain and retina) of less than 10 mV m^{-1}, in order to avoid the induction of retinal phosphenes. These restrictions should also prevent any possible transient effects on brain function. A reduction factor of 5 has been applied to the phosphene threshold of 50 mV m^{-1} in order to account for uncertainties. Above and below this frequency range, the basic restriction rises. At 1000 Hz it intersects with basic restrictions that protect against peripheral and central myelinated nerve stimulation. Here, a reduction factor of 10, with respect to the above mentioned stimulation threshold of 4 V m^{-1}, results in a basic restriction of 400 mV m^{-1}, which should be applied to the tissues of all parts of the body.

The rationale for these guidelines limits can be found in full in "Guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz to 100 kHz) Health Physics 99(6):818-836; 2010."

The main changes, compared with previous recommendations by ICNIRP are:

- The basic restrictions are based on induced internal electric fields, instead of induced current density, as this is the physical quantity that determines the biological effect. Previous health risk

assessments were based on induced current density as most experimental data at that time were based on this metric. Now, sufficient information based on induced internal electric fields is available to use this metric in guidelines.

- Previous guidelines were set to prevent effects on nervous system functions and a limitation of induced current density in CNS tissue only was recommended. Phosphenes were not considered to be an adverse effect. ICNIRP now considers the effects on the retina as a model of effects in the brain and the phosphene threshold provides a basis for limiting exposure as specified above. In addition, stimulation effects on peripheral and central myelinated nerves have been included as explained above. This leads to an exposure limitation in any tissue of the body. The limit values were based on current scientific evidence and not simply converted on the basis of tissue conductivity from the former guidance on induced current density.

The table summarizes the basic restrictions

Exposure characteristic	Frequency range	Internal electric field (V m^{-1})
Occupational exposure		
CNS tissue of the head	1 - 10 Hz	0.5 / f
	10 Hz - 25 Hz	0.05
	25 Hz - 400 Hz	2 x 10^{-3} f
	400 Hz - 3 kHz	0.8
	3 kHz - 10 MHz	2.7 x 10^{-4} f
All tissues of head and body	1 Hz - 3 kHz	0.8
	3 kHz - 10 MHz	2.7 x 10^{-4} f
General public exposure		
CNS tissue of the head	1 - 10 Hz	0.1 / f
	10 Hz - 25 Hz	0.01
	25 Hz - 1000 Hz	4 x 10^{-4} f
	1000 Hz - 3 kHz	0.4
	3 kHz - 10 MHz	1.35 x 10^{-4} f
All tissues of head and body	1 Hz - 3 kHz	0.4
	3 kHz - 10 MHz	1.35 x 10^{-4} f

Notes:
- f is the frequency in Hz
- All values are rms
- in the frequency range above 100 kHz, RF specific basic restrictions need to be considered additionally.

Reference levels: Reference levels have been determined by mathematical modeling for the exposure conditions where the variation of the electric or magnetic field over the space occupied by the body is relatively small, i.e., uniform exposures. They are calculated for the condition of maximum coupling of the field to the exposed individual, thereby providing maximum protection. Frequency dependence and dosimetric uncertainties were taken into account. At the power frequency (50 Hz) the reference levels for occupational exposure are 10 kV m^{-1} for the electric field, and 1 mT for the magnetic field. With

respect to general public exposure the reference levels are 5 kV m^{-1} for the electric field and 200 µT for the magnetic field.

For a very localized source with a distance of a few centimeters from the body, the only realistic option for the exposure assessment is to determine dosimetrically the induced electric field, case-by case. With greater distances the distribution of the field becomes less localized but is still non-uniform, in which case it is possible to compare the spatial average along the body or part of it with the reference levels. Contact current may result in shock and burn hazards. Therefore reference levels for contact current are given for frequencies up to 100 kHz.

The main changes compared to the previous recommendations are:

- While in 1998 dosimetric considerations were based on simple geometrical models, the new guidelines use data from computational simulations based on anatomically detailed human body models.
- The revised basic restrictions as well as the dosimetric models used result in reference levels that deviate in some areas from previous ones. There is a tendency for magnetic field reference levels to be less conservative, whereas the electric field reference levels are, with some exceptions, basically unchanged.

Additional advice is given on how to apply the guidelines in the case of simultaneous exposure to electric and magnetic fields, to multiple frequency fields and to non-sinusoidal fields. There is no fundamental change compared with previous advice.

Protective Measures: ICNIRP notes that protection of people exposed to electric and magnetic fields could be ensured by compliance with all aspects of these guidelines. Appropriate protective measures must be implemented when exposure results in the basic restrictions being exceeded. Engineering controls should be undertaken in conjunction with administrative controls. In the workplace, additionally personal protection measures can be used, but these should be regarded as a last resort. It is also essential to implement rules that will prevent interference with medical electronic devices, detonation of electro-explosive devices, and fires and explosions resulting from ignition of flammable materials by sparks. All this is in line with previous advice.

Long-Term Effects: As noted above, epidemiological studies have found that everyday chronic low-intensity power frequency magnetic field exposure is associated with an increased risk of childhood leukemia. However, laboratory studies have not supported this association and a causal relationship between magnetic fields and childhood leukemia or any other long term effect has not been established. The absence of established causality is the reason why the epidemiological results have not been addressed in the basic restrictions. ICNIRP is well aware that these epidemiological results have triggered concern within the population in many countries. It is ICNIRP´s view, that this concern is best addressed within the national risk management framework. Risk management in general is based on many different aspects, including social, economic, and political issues. ICNIRP in this context provides scientifically based advice only. Additional risk management advice, including considerations on precautionary measures, has been given for example by the World Health Organization and other entities.

Further details can be found in Health Physics 99(6):818-836; 2010.

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To: Northern States Power Company and Great River Energy

Docket No.:	OAH 15-2500-20995-2 PUC No. ET-2/TL-09-1056		
Response To:	NoCapX 2020, U-CAN & NoRCA	Information Request No.	5
Date Received:	November 18, 2010		

Request No. 5:

Regarding magnetic field chart in Darrin Lahr's testimony, for those columns not reaching 2mG or less at 300 feet from centerline, using same assumptions, at what distance is a level of 2mG or less achieved? Please provide this information in an extension of the chart accompanying the testimony.

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Northern States Power Company and Great River Energy

Docket No.:	OAH 15-2500-20995-2 PUC No. ET-2/TL-09-1056		
Response To:	NoCapX 2020, U-CAN & NoRCA	Information Request No.	6
Date Received:	November 18, 2010		

Request No. 6:

Has the World Health Organization found a mG level of concern? Identify that mG level of concern. Provide supporting documents.

Response:

The World Health Organization ("WHO") has not established any magnetic field "level of concern" or exposure guidelines. The WHO has evaluated scientific evidence of the relationship between chronic low-intensity exposures, such as those from power lines, and adverse health effects. The WHO reported in 2007 that scientific evidence suggesting that every day, chronic low-intensity magnetic field exposure poses a health risk is based on epidemiological studies demonstrating a pattern of increased risk for childhood leukemia. Although laboratory and biophysical mechanistic evidence has failed to demonstrate causation, the WHO concluded that the evidence is sufficiently strong to remain a concern and that further research in this area is warranted, but due to the uncertainties about the existence of chronic effects (like childhood leukemia), international exposure guidelines should not "be reduced to some arbitrary level in the name of precaution" and only little to no cost precautionary procedures should be used.

The WHO concluded that "the main conclusion from the WHO reviews is that [magnetic field] exposure below the limits recommended in the ICNIRP [International Commission on Non-Ionizing Radiation Protection] international guidelines do not appear to have any known consequence on health." See http://www.who.int/peh-emf/standards/en/. At the time of the 2007 WHO report, the ICNIRP international guidelines stated that continuous exposures below 833 mG do not appear to have any acute health consequences.

Last month, ICNIRP revised its general public continuous exposure guideline for acute effects to 2,000 mG. **Attachment 1** (November 2010 Fact Sheet published by the International Commission on Non-Ionizing Radiation Protection). In establishing the revised guideline, ICNIRP reviewed scientific studies performed since its last guidelines were published in 1998. ICNIRP noted that, after review of the research, scientific data available do not indicate an effect of extra low frequency magnetic fields on the neuroendocrine system "in a way that would have an adverse impact on human health." Additionally, ICNIRP stated that that there is no substantial evidence to associate magnetic field exposure and Parkinson's disease, multiple sclerosis, and cardiovascular diseases, but

that evidence for an association between magnetic fields and Alzheimer's disease or amyotrophic lateral sclerosis is inconclusive and evidence for an association between magnetic fields and developmental and reproductive effects is very weak. ICNIRP also reviewed the scientific evidence relating to extremely low magnetic fields and increased risk of childhood leukemia and concluded that the evidence "is too weak to form the basis for exposure guidelines."

Response by: Dr. Peter A. Valberg
Title: Principal
Department: Gradient LLC
Date: November 30, 2010

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Docket No.:	OAH 15-2500-20995-2 PUC No. ET-2/TL-09-1056		
Response To:	NoCapX 2020, U-CAN & NoRCA	Information Request No.	7
Date Received:	November 18, 2010		

Request No. 7:

Has any mG level been scientifically proven to be safe? Identify that level. Provide supporting documents.

Response:

The question incorrectly assumes that science can prove that an effect will not occur. The scientific method fundamentally tests hypotheses by doing experiments whose results either do or do not reject the hypotheses, but rejecting a hypothesis cannot prove that something is impossible. For example, we cannot prove the non-existence of water flowing uphill. We can only say that this phenomenon has not been reliably observed and is contrary to scientific principles. One of the areas of science that has been exhaustively tested by experiment, and is generally accepted as reflecting "laws of the universe" is our level of understanding of the physical nature of matter and how it interacts with electric and magnetic fields. Biological systems are not exempt from these physical laws, and biophysical analyses have consistently yielded the result that power-line magnetic fields cannot initiate the changes necessary for a cell to become a cancer cell.

The complete absence of a cancer signal in carefully designed and completed, long-term, animal exposures to very elevated levels of power-line magnetic fields is a reliable line of evidence that power line magnetic fields do not cause cancer. In addition, the complete absence of a plausible mechanism whereby extremely low frequency magnetic fields acting on whole animals, organ cultures, isolated cells, or even molecules can give rise to even pre-cancerous changes is a reliable line of evidence that power line magnetic fields do not cause cancer.

Response by: Dr. Peter A. Valberg
Title: Principal
Department: Gradient LLC
Date: November 30, 2010