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MISSOURI PUBLIC SERVICE COMMISSION

CASE NO. EA-2014-0207

SURREBUTTAL TESTIMONY OF

WILLIAM H. BAILEY, Ph.D.

ON BEHALF OF

GRAIN BELT EXPRESS CLEAN LINE LLC

October 14, 2014

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I. QUALIFICATIONS

Q. Please state your name and business address.

A. My name is William H. Bailey, Ph.D. My business address is 17000 Science Drive, Suite 200, Bowie, MD 21705.

Q. What is your occupation and by whom are you employed?

A. I am a Principal Scientist in the Center for Exposure Assessment and Dose Reconstruction of Exponent, Inc. Exponent is a scientific research and engineering firm engaged in a broad spectrum of activities in science and technology.

Q. What is your educational background?

A. I earned a Ph.D. in neuropsychology from the City University of New York. I received two additional years of training in neurochemistry at The Rockefeller University in New York City under a fellowship from the National Institutes of Health. My education includes a BA from Dartmouth College received in 1966 and an MBA from the University of Chicago awarded in 1969.

Q. Please describe your professional background and experience.

A. I am a scientist and researcher focusing on environmental health sciences. My work involves reviewing, analyzing, and conducting health research. Much of my work over the past 30 years relates to the exposure and potential biological, environmental, and health effects associated with electrical facilities and devices, including electric utility facilities, electrified railroad lines, industrial equipment, appliances, and medical devices that produce electromagnetic fields across a wide range of frequencies. Since 1986, I have been a visiting research scientist at the Cornell University Weill Medical College. I also have been a visiting lecturer at Rutgers University, the University of Texas (San

Antonio), and the Harvard School of Public Health in the field of bioelectromagnetics. From 1983 through 1987, I was head of the Laboratory of Neuropharmacology and Environmental Toxicology at the New York State Institute for Basic Research. For the previous seven years, I was an Assistant Professor in Neurochemistry at The Rockefeller University. I am a member of The Rockefeller University Chapter of Sigma Xi, a national scientific honor society; the Health Physics Society; International Committee on Electromagnetic Safety, Subcommittees 3 and 4 – Safety Levels with Respect to Human Exposure to Fields; the Bioelectromagnetics Society; the IEEE Engineering in Medicine and Biology Society; the Conseil International des Grands Réseaux Électriques; the American Association for the Advancement of Science; the New York Academy of Sciences; the Society for Neuroscience; the Air & Waste Management Association; the Society for Risk Analysis; and the International Society of Exposure Analysis.

Q. Have you served as a reviewer and scientific advisor on health-related issues for state and federal agencies or scientific organizations?

A. Yes. I have reviewed research for the National Institutes of Health, the National Science Foundation, and other government agencies. Specifically regarding transmission lines, I served on a Scientific Advisory Panel convened by the Minnesota Environmental Quality Board to review the health and safety aspects of a high-voltage transmission line. In addition, I served as a consultant regarding transmission line health and safety issues for the Vermont Department of Public Service, the New York State Department of Environmental Conservation, and the staffs of the Maryland Public Service Commission and the Maryland Department of Natural Resources.

I have also worked with the National Institute of Occupational Safety and Health, the Oak Ridge National Laboratories, the U.S. Department of Energy, and the Federal Railroad Administration to review and evaluate health issues related to electric and magnetic fields (EMF) from power lines and other sources. In addition, I assisted the U.S. EMF Research and Policy Information Dissemination program to evaluate biological and exposure research as part of its overall risk assessment process.

Further, I worked with scientists from 10 countries to evaluate possible hazards from exposure to static electric and magnetic fields and extremely low frequency (ELF) EMF for the International Agency for Research in Cancer (IARC), a division of the World Health Organization (WHO) located in Lyon, France. I also was an invited participant in the workshop convened by the International Committee on Non-Ionizing Radiation Protection (ICNIRP) to update guidelines for human exposures to alternating current (AC) EMF. I have reviewed ICNIRP's draft guidelines for direct current (DC) and AC magnetic fields as well. Most recently, I have served as an advisor to the U.S. Department of Energy, and several government agencies in Canada and the Netherlands on topics relating to scientific research on EMF health and safety.

Q. Have you published or presented your research in bioelectromagnetics and other areas to the scientific community?

A. Yes. I have published or presented more than 50 scientific papers on this and related subjects. These publications and presentations are listed in my curriculum vitae, attached as **Exhibit WHB-1**.

II. PURPOSE OF TESTIMONY

Q. What is the purpose of your testimony?

A. I have been asked to assess the scientific issues related to potential health effects of electric and magnetic fields raised in the testimonies of Dennis Smith and other witnesses in the Grain Belt Express Clean Line LLC Application for Certificate of Convenience and Necessity, Case: EA-2014-0207.

Q. What are the sources of electric and magnetic fields in the Grain Belt Express Project?

A. The project consists of two distinct sources of electric and magnetic fields.

1. The largest source is the proposed 750-mile, overhead, ±600-kilovolt (kV) DC transmission line that connects a converter station in Dodge City, Kansas, to converter stations near Center, Missouri, and Sullivan, Indiana at the Illinois/Indiana border.

2. The second source is the converter stations and associated AC interconnection facilities: the Kansas converter station will convert AC electricity generated by wind turbines and other sources to DC electricity for transport over the DC transmission line. At the terminal converter stations in Missouri and at the Illinois/Indiana border, the DC electricity will be converted back to AC electricity and transmitted to the AC grid.

Q. What portions of the project described above are of interest to the Public Service Commission of Missouri and relevant to the Rebuttal Testimony of Dr. Smith and other witnesses in this proceeding?

A. Of the total length of the project, approximately 206 miles of the DC transmission line will operate in the State of Missouri. Additionally, the Project will include a DC/AC converter station proposed to be located in Ralls County, along with associated AC

interconnection facilities tapping an the existing 345-kV AC transmission line located on the same parcel as the converter station.

III. EXPOSURE TO ELECTRIC AND MAGNETIC FIELDS

Q. What are electric and magnetic fields?

A. Electric charges are contained in objects in our environment. When the numbers of positive and negative charges in an object are equal, the object is described as electrically neutral. When the object contains more of one charge or the other, the net charge gives rise to an electric field. Magnetic fields are created by the movement of electric charges or by the movement of electrons in certain materials such as permanent magnets.

Electricity is the movement of electric charges. Consequently, electric and magnetic fields are properties of the space surrounding anything that generates, transmits, or uses electricity. Electric fields occur when voltage is applied to these objects, while magnetic fields result from the current flowing through these objects. Just as the heat from a radiator decreases as one moves farther away, the levels of both electric fields and magnetic fields decrease with distance from the source. Electric fields are blocked by most conductive objects (such as trees, fences, and walls), including the human body, while magnetic fields are not.

Q. How are the intensities of electric and magnetic fields measured?

A. Electric fields are measured in units of volts per meter (V/m) or kilovolts per meter (kV/m), where 1 kV/m is equal to 1,000 V/m. Magnetic fields in the United States are most commonly measured in units of gauss (G) or milligauss (mG), where 1 G is equal to 1,000 mG. Both electric and magnetic fields quickly diminish with increasing distance from the source.

Q. Are all electric and magnetic fields the same?

A. No. Both electric and magnetic fields are characterized by their frequency (i.e., the number of times full cycles of field direction changes occur each second). Frequency is measured in hertz (Hz). A related characteristic is wavelength, which is inversely related to frequency – the lower the frequency, the longer the wavelength and vice versa. Frequency and wavelength of EMF greatly affect how these fields interact with physical material and living cells or organisms. Thus, any potential effects of these fields and the relevant scientific literature need to be evaluated separately according to the frequency characteristic of the source. For example, the oscillating nature of AC magnetic fields causes weak currents and voltages to be induced in nearby conductive objects as described by Faraday's law. Magnetic fields that do not oscillate (i.e., static magnetic fields) do not induce currents and voltages in conductive objects.

Q. What electric and magnetic field frequencies are associated with the proposed Grain Belt Express project?

A. The Grain Belt Express DC transmission line is designed to transport DC electricity. Thus, the dominant fields produced by the line are DC fields, which are commonly referred to as "static" fields because their characteristic frequency is at or about 0 Hz and they do not change their direction each second. There are many DC transmission lines and facilities now operating in the United States and Canada[1] and still more that are proposed or under construction.

The short interconnection lines between the project converter stations and the AC electric grid will be sources of AC electric and magnetic fields that oscillate at a

[1] *See* http://www.cleanlineenergy.com/technology/hvdc/history for example.

dominant frequency of 60 Hz. These AC fields are ubiquitous in our communities because all lines, devices, appliances, wiring, etc., connected to our AC electric power system produce electric and magnetic fields at this frequency. By way of clarification, the abbreviation EMF is typically used by scientific and engineering professionals to refer to AC electric and magnetic fields in the ELF range between 30 and 300 Hz. Often, the general public refers to EMF when speaking of fields at other frequencies such as the static geomagnetic field of the earth or the radiofrequency (RF) fields produced by mobile phones. For that reason, the abbreviation ELF EMF is sometimes used to avoid this confusion.

The fields from the converter equipment are quite low at the boundaries of converter station sites because they diminish rapidly with distance within the large confines of the site. Thus, fields at the boundaries of the site from the project are dominated by static fields where the DC line connects to the converter station, and by AC fields from the interconnection to the nearby electric grid.

Q. What are the background levels of static and AC electric and magnetic fields that people encounter in daily life?

A. Static electric fields are natural phenomena that arise from various sources. The most common sources are distant storm fronts (10-20 kV/m), storm clouds over a lake (40 kV/m), static electricity (i.e., charge separation) such as that which occurs after walking across a carpet (up to 100 kV/m), and the surface charge on the body from static cling (up to 500 kV/m).

Static magnetic fields are also natural phenomena produced by the flow of electric currents. The earth produces an ever-present background geomagnetic field

that originates from the electrical currents in the earth's molten core and crustal sources. The geomagnetic field varies with latitude. For instance, it is highest at the magnetic poles and lowest at the equator (~700 and ~300 mG, respectively). Man-made DC magnetic fields result from a number of sources including battery operated appliances (3,000-10,000 mG), electrified railways (<10,000 mG), and magnetic resonance imaging machines (15-40 million mG).

AC ELF fields. Magnetic fields at ELF frequencies in US homes average about 1 mG, when not near a particular source. In the immediate vicinity of electrical household appliances and power tools, ELF magnetic fields levels rise to several hundreds of mG. In any event, ELF electric fields are typically below 20 V/m in US households and derive mostly from indoor sources because buildings shield AC electric fields from outside sources (as well as DC electric fields).

Q. What frequencies of electric and magnetic fields do witnesses Smith, Lange, Kielisch, and speakers Lori Smith (Dr. Smith's wife) and Carol Ann Smith refer to?

A. These witnesses refer almost entirely to AC ELF electric and magnetic fields, or to RF fields as summarized below. Except for a single unreplicated study of rats exposed to static electric fields (that has not been subjected to peer review associated with publication in a scientific journal (Ciesler et al., 2007)), these witnesses have not referenced a single scientific publication concluding that the electric or magnetic fields from a DC line would have adverse effects on persons, animals, or the environment.

Table 1. Identification of frequencies of electric and magnetic fields referenced in rebuttal witness testimony

Name	Quote or Document	Source	Frequency		
			ELF	RF	DC
Dennis Smith	"...one of those documents makes a statement of grave concern to me ... [in] IARC Monograph ... Vol 80 ... 'Extremely low-frequency magnetic	Smith rebuttal testimony, p. 3, lines	✓		

Name	Quote or Document	Source	Frequency		
			ELF	RF	DC
	fields are possibly carcinogenic to humans (Group 2 B)'"	11-19.			
Dennis Smith	"A review of the BioInitiative Report in 2012 was the first document to raise my concern over the health risks of a HVDC line." [DS-5]	Smith rebuttal testimony, p. 5, lines 3-15.	✓	✓	
Dennis Smith	"...additional studies that indicate adverse health effects of exposure to the fields produced by a HVDC line."	Smith rebuttal testimony, p. 5, lines 21-23; p. 6, lines 2-23.			
	Hafeez et al. (2013) [DS-4]		✓		[2]
	Fragopoulou et al. (2010) [DS-6]		✓	✓	
	Blank and Goodman (2009) [DS-7]		✓	✓	
	Sermage-Faure et al. (2013) [DS-8]		✓		
	Pall (2013) [DS-9]		✓	✓	[3]
	Cieslar et al. (2007) [DS-10]				✓
	Huss et al. (2008) [DS-11]		✓		
	Carrubba and Marino, 2008 [DS-12]		✓		[4]
Shawn Lange	"... The following studies show correlation between static EMF and health effects:	Lange rebuttal testimony, p. 4, line - 16.	✓		
	The influence of Static Electric Field ... [Cieslar et al., 2007]				✓
	BioInitiative 2012 ..."		✓	✓	
Shawn Lange	"Yes, the World Health Organization (WHO and International Agency on Cancer Research (IACR) [*sic*] have classified radiofrequency electromagnetic field as a Group 2B carcinogen."	Lange rebuttal testimony, p. 4, lines 20-22.		✓	
Shawn Lange	"...the following [static electric and magnetic field] studies do not conclude EMF causes long-term health effects....	Lange rebuttal testimony, p. 5, lines 13-28.			✓
Shawn Lange	"The WHO has stated [in regard to long-term health effects of EMF] 'Despite many studies, the evidence for any effect [of ELF magnetic fields] remains highly controversial. However, it is clear that if electromagnetic fields do have an effect on cancer, then any increase in risk will be extremely small. The results to date contain many inconsistencies, but no large increases in risk have been found for any cancer in children or adults.'"	Lange rebuttal testimony, p. 6, lines 2-6.	✓		
Kurt Kielisch	References to 1996 'USA Today' survey, Cigna (2012), Mayo Clinic (2013) book, unknown property owner comment on discussion with	Kielisch rebuttal testimony, p. 7, line 9-p. 8, line 19.	✓		

[2] This only includes a summary of EMF exposures of HVDC lines, not health effects of HVDC lines.

[3] There is no discussion of static fields in this paper. A table lists a few short-term studies of cells exposed to static fields of unknown intensity, but none of the responses are of a character that signifies an adverse effect or that can be extrapolated to a living person or animal.

[4] Most of this review pertains to AC magnetic and electric fields; the few data summarized on responses to static magnetic fields are not indicative of harm.

Name	Quote or Document	Source	Frequency		
			ELF	RF	DC
	Medtronic, and BPA brochure about pacemakers.				
Lori Smith	"In regard to health … In fact, the EPA and the World Health Organization have ruled EMF as a Class 2-B carcinogen."	Transcript of August 14, 2014, public hearing, Jefferson City, p. 47, lines 10-14.	✓		
Carol Ann Smith	"Now, according to a study, children who are raised for the first five years of life within 300 meters, which is 985 plus feet, have a lifetime risk that is 500 percent higher for developing some kinds of cancer. And it is also the biggest concern is [*sic*] childhood leukemia. Also, according to the same study, breast cancer risks increase."	Transcript of August 14, 2014, public hearing, Jefferson City, p. 116, lines 22-p. 117, line 3.	✓		

Table 1 above shows that the documents cited in rebuttal testimony and public statements focus on AC ELF EMF, such as those associated with the operation of the AC transmission interconnection that will connect the proposed converter station in Ralls County to the local AC transmission network. This interconnection, however, is very short, and all of the AC interconnection facilities will be located on the same parcel of land as the converter station.

The statements by witnesses and speakers, except for the instance noted above, do not cite to any research that would support health concerns relating to electric and magnetic fields originating from the long DC transmission line in Missouri.

IV. RESPONSE TO THE REBUTTAL TESTIMONY OF DENNIS SMITH, DO

Q. Have you reviewed the Rebuttal Testimony of Dennis Smith?

A. Yes.

Q. Can you briefly summarize your assessment of the rebuttal testimony filed by Dennis Smith, DO?

A. The Rebuttal Testimony of Dennis Smith contains a number of errors which render his conclusions scientifically invalid. Moreover, his conclusions are inconsistent with those of major reviews conducted by multidisciplinary expert panels on behalf of a number of

well-respected national and international health and scientific agencies. The principal limitations of his rebuttal testimony include, among others, the lack of proper distinction between the types of EMF I described above (i.e., static and ELF fields), which in turn led him to reference a number of studies that are not relevant to DC or static fields; the lack of clearly articulated methods for selecting and presenting studies; the erroneous interpretation of the IARC classification system of carcinogens; and the heavy reliance on the BioInitiative report, which primarily deals with ELF EMF (not static fields) and presents flawed views inconsistent with the opinions held by authoritative scientific expert panels. I will elaborate on each of these points in more detail.

Q. Can you explain what you mean by lack of proper distinction between types of EMF?

A. As I explained previously, EMF is characterized by its frequency. The frequencies of electric and magnetic fields associated with transmission lines relevant here are DC fields (~0 Hz) and ELF AC fields.

At the beginning of his rebuttal testimony, Dr. Smith responds to a question about "the potential health effects of the EMFS [*sic*], static magnetic fields, and static electric fields from Grain Belt's proposed line" (p. 2, lines 16-18). In his response, however, he attempts to rebut Dr. Galli's statement concerning static EMF by asserting that "there is evidence that fields produced by HVDC lines … cause human health effects as well as effects on animals" (p.2, line 23 – p. 3, line 2). In his rebuttal testimony, however, he cites as evidence for this opinion research studies that do not address static fields, and therefore are not directly relevant to the DC transmission line of the Grain Belt Express project:

- BioInitiative report, 2012 (DS-5)[5] – a compilation of reviews of selected research studies on ELF and RF fields.
- Fragopoulou et al., 2010 (DS-6)[6] – a position statement offered by authors of the BioInitiative report and others that expresses concerns about ELF and RF fields.
- Blank and Goodman, 2007 (DS-7)[7] – present a hypothesis that ELF and RF fields act by a common pathway activated by heating and some chemicals. Dr. Blank is an author of a section of the BioInitiative report.
- Sermage-Faure et al., 2013 (DS-8)[8] – a comparison of distances from birth addresses of children with and without leukemia to AC transmission lines;
- Pall, 2013 (DS-9)[9] – reviews research that supports the author's hypothesis that one specific type of ion channel in cell membranes is affected by "extremely low and microwave frequency range electromagnetic fields" (p. 1);
- Huss et al., 2008 (DS-11)[10] – study of neurodegenerative diseases and ELF (not static) fields from AC transmission lines;
- Carrubba and Marino, 2008 (DS-12)[11] – review of brain electrical activity recorded from human subjects during exposure principally to ELF and low-frequency fields.

[5] Rebuttal Testimony of Dennis Smith, p. 5, lines 3-18 referencing Schedule DS-5.
[6] Rebuttal Testimony of Dennis Smith, p. 7, lines 7-9 referencing Schedule DS-6.
[7] Rebuttal Testimony of Dennis Smith, p. 7, lines 10-14 referencing Schedule DS-7.
[8] Rebuttal Testimony of Dennis Smith, p. 7, lines 17-20 referencing Schedule DS-8.
[9] Rebuttal Testimony of Dennis Smith, p. 8, lines 11-14 referencing Schedule DS-9.
[10] Rebuttal Testimony of Dennis Smith, p. 9, lines 8-10 referencing Schedule DS-11.

Q. Do you agree with Dr. Smith's notion that "by simply moving in and out of these static fields there becomes an AC component"[12] that would also mean that a person walking through a natural static electric field or the magnetic field of the earth is also exposed to ELF fields that have properties like those at power frequencies of 60 Hz in the U.S. and Canada?

A. No, his reasoning is flawed. Walking or moving through static fields will not create an exposure like that produced by our AC power system. The 60 Hz frequency of AC fields means that full cycles of field direction changes occur 60 times per second; such an oscillation is impossible for a human being to achieve for any period of time, not to mention long-term.

Q. Dr. Smith claims that changing wind velocity will results in "changes within the line that will produce EMFs" (p. 8, lines 8-10). Do changes in wind speed affect the type or magnitude of EMF carried in transmission lines?

A. The changing wind speed will affect the current flow on the transmission lines transporting electricity from the converter stations. This may affect the strength of the magnetic field near the line as the magnitude of the magnetic field varies directly with current flow. However, the magnetic field from the line can be expected to be at or below the expected values[13] based upon the capacity of the project. The magnitude of the electric field from the line, however, will not vary as the voltage on the line is controlled

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[11] Rebuttal Testimony of Dennis Smith, p. 6, lines 21-23; p. 9, lines 17-20 referencing Schedule DS-12.

[12] Rebuttal Testimony of Dennis Smith, p. 8, lines 6-7.

[13] Clean Line Energy Partners, LLC. Understanding Electric and Magnetic Fields in Association with HVDC Transmission Lines, 2011.

within strict limits. The type of EMF, however, whether it is AC or DC, does not depend on wind speed.

Q. Should Dr. Smith's allegation that Dr. Galli "interprets the documents to support his stand on the impact of EMFs from transmission lines"[14] mean that Dr. Galli has misrepresented the conclusions of the agencies cited on p. 22 of his testimony?

A. No, Dr. Galli has not misrepresented the conclusions expressed by these national and international agencies.

It should be noted that Dr. Galli's reference to the reports of these agencies on p. 22 of his testimony pertain to their assessments of exposures to "DC EMF" or static fields. Dr. Smith' response on page 3 of his rebuttal testimony at lines 14-19 to Dr. Galli's testimony was to focus on a conclusion in the 2002 *Evaluation of Carcinogenic Risks to Humans* (Vol. 80) report of the IARC cited by Dr. Galli that addressed a different exposure – AC ELF EMF.

Q. On page 4 of his rebuttal testimony at lines 11-14, Dr. Smith cites a paper by Hafez et al. (2013) included in his Schedule DS-2 that describes the magnetic field exposure from a ±450 kV HVDC line as "25 microTesla [250 milligauss]." Dr. Smith then opines that "[t]his level of EMF is above safe exposure levels recommended in scientific sources and papers since the latest reference quoted by Clean Line" (Smith rebuttal testimony, p. 4, lines 13-14). Is Dr. Smith's opinion correct?

A. Unfortunately, Dr. Smith does not reference the sources for this assertion. But, a static magnetic field of 250 mG produced by a ±450 kV HVDC line is far less than the

[14] Rebuttal Testimony of Dennis Smith, p. 3, lines 10-11.

geomagnetic field of the earth in Missouri, which is about 530 mG.[15] The maximum static magnetic field produced by the Grain Belt Express DC line at full load is just under 900 mG. At periods of low wind generation the load would be even less. Depending upon how the line is orientated with respect to the earth's geomagnetic field, the total resulting static magnetic field might be somewhat higher or lower. In any event, the 250 mG cited by Dr. Smith or the higher magnetic field level cited by the Compnay are both far below scientifically-based exposure limits. The 250 mG value is more than 7,000 fold lower that the 4,000,000 mG limit on exposure of the general public recommended by ICNIRP, an affiliate of the WHO (footnote 12 on p. 22 of the Galli testimony) and more than 2,000-fold lower than a limit on general public exposure of 1,180,000 mG recommended by the International Committee on Electromagnetic Safety (ICES) for slowly varying magnetic fields just above 0 Hz (footnote 10 on p. 22 of the Galli testimony).

i. <u>WEIGHT-OF-EVIDENCE SCIENTIFIC APPROACH</u>

Q. Could you please explain what the proper methods are for reviewing and drawing valid conclusions from the scientific literature?

A. The generally accepted method for health risk evaluation (i.e., the evaluation of the scientific literature for evidence for or against a potential causal association between an environmental exposure and health outcomes), is the weight-of-evidence approach. This is a standard scientific method and is employed by regulatory, scientific, and health agencies worldwide.

Q. Please describe the weight-of-evidence approach.

[15] http://www.ngdc.noaa.gov/geomag-web/#igrfwmm

A. The weight-of-evidence approach includes the systematic identification and review of the relevant literature for a specific exposure and potentially related health outcome. The reviewed scientific literature includes epidemiologic studies of humans observed in their natural environments, laboratory studies of animals (*in vivo* studies) and laboratory studies of cells and tissues (*in vitro* studies). These types of studies provide complementary information regarding potential biological and health effects of the exposure in question. Each of the identified studies in these scientific areas is then individually evaluated for their overall quality. The scientific quality of each study determines how much weight the individual study receives in the overall evaluation. High quality studies are given greater weight, while lower quality studies contribute less, and poor quality studies are sometimes given no weight at all.

Q. Has the weight-of evidence approach been applied to the evaluation of static electric and magnetic field by authoritative expert panels?

A. Yes. Multidisciplinary expert panels – on behalf of a number of national and international health and scientific agencies – have reviewed the available scientific literature regarding potential health effects of static electric and magnetic fields using this approach. These include, for example, the IARC in 2002, the WHO in 2006, the United Kingdom's Health Protection Agency (HPA) in 2008, ICNIRP in 2009, and the European Commission's Scientific Committee on Emerging and Newly Identified Health Risk (SCENIHR) in 2013. None of these agencies found reliable evidence of biologically harmful effects resulting from static magnetic fields below exposure levels of several tens of thousands of gauss. These levels are several thousand-fold higher than the maximum static magnetic fields associated with the operation of the proposed DC line, which are

comparable in magnitude to the geomagnetic fields of the earth. Regarding electric fields, the only effects are associated with direct perception and potential microshocks similar to those encountered when touching a door knob after walking across a rug during the winter.

Q. Has the weight-of evidence approach been applied to the evaluation of ELF electric and magnetic fields by authoritative expert panels?

A. Yes. Multidisciplinary expert panels on behalf of a number of national and international health and scientific agencies have also reviewed the available scientific literature on potential health effects of ELF electric and magnetic fields using the same approach. These evaluations include those conducted by the NIEHS (1999), IARC (2002), WHO (2007), ICNIRP (2010), and SCENIHR (2013). While these reviews acknowledged the limited epidemiologic evidence with respect to ELF magnetic fields and childhood leukemia, they also concluded that experimental evidence does not support a cause-and-effect relationship with any cancer. No adverse health effects were identified in association with exposure to ELF electric fields. On its website, the WHO currently states that "[b]ased on a recent in-depth review of the scientific literature, the WHO concluded that current evidence does not confirm the existence of any health consequences from exposure to low level electromagnetic fields." The WHO website also states that "[w]ith more and more research data available, it has become increasingly unlikely that exposure to electromagnetic fields constitutes a serious health hazard."[16]

Q. Does the Rebuttal Testimony of Dennis Smith indicate that he objectively weighed the scientific research he reviewed in formulating his opinions?

[16] http://www.who.int/peh-emf/about/WhatisEMF/en/index1.html

A. No. While Dr. Smith alleges that "I strive to practice evidence-based medicine" (Smith Rebuttal Testimony, p. 4, lines 17-18), his rebuttal testimony does not support that claim. A group of experts in evidence-based medicine that comprise the internationally renowned Cochrane Collaboration Group prepare "systematic reviews of primary research in human health care and health policy, and are internationally recognized as the highest standard in evidence-based health care. They investigate the effects of interventions for prevention, treatment, and rehabilitation. They also assess the accuracy of a diagnostic test for a given condition in a specific patient group and setting."[17] The Cochrane Collaboration identifies the essence of evidence-based medicine as starting with:

> A systematic review [that] attempts to collate all empirical evidence that fits pre-specified eligibility criteria in order to answer a specific research question. It uses explicit, systematic methods that are selected with a view to minimizing bias, thus providing more reliable findings from which conclusions can be drawn and decisions made (Antman 1992, Oxman 1993). The key characteristics of a systematic review are:
>
> - a clearly stated set of objectives with pre-defined eligibility criteria for studies;
> - an explicit, reproducible methodology;
> - a systematic search that attempts to identify all studies that would meet the eligibility criteria;

[17] http://www.cochrane.org/cochrane-reviews

- an assessment of the validity of the findings of the included studies, for example through the assessment of risk of bias; and
- a systematic presentation, and synthesis, of the characteristics and findings of the included studies.

While reviews performed for national and international agencies follow such precepts to ensure objectivity, there is no evidence that Dr. Smith has practiced what he preaches as summarized below.

First, Dr. Smith's rebuttal testimony references studies that are not relevant to static fields. Second, the Rebuttal Testimony of Dennis Smith also appears to selectively reference or cherry-pick studies that support his views without due consideration of the quality of the studies and the remaining scientific literature. All the references included in the Rebuttal Testimony of Dennis Smith are included to suggest a causal association. Yet, this occurs only because he selected studies that appear to show an association between exposures and health conditions even when more recent studies with improved methodology that did not show an association were also available. For example, Dennis Smith referenced a study of ELF (not static) EMF and neurodegenerative diseases that suggested an association (Huss et al., 2008 [DS-11]),[18] but did not reference the study by Frei et al. (2013), which examined the same issue with improved methodology and reported no association. Both selective reporting based on outcome, and disregarding study quality, is contrary to the weight-of-evidence approach. Dennis Smith also demands "conclusive evidence that EMFs do not pose health related risks."[19] This ignores the limitations of the scientific method given that science cannot provide absolute

[18] Rebuttal Testimony of Dennis Smith, p. 6, lines 18-20; p. 9, lines 8-10.
[19] Rebuttal Testimony of Dennis Smith, p. 2, line 22.

proof for the lack of an effect. In assessing potential risks, scientists repeatedly test hypotheses to reduce scientific uncertainty about the possibility of an effect. Currently available scientific data, however, does not show that short – or long-term exposure – to static electric or magnetic fields at the levels associated with this project results in any adverse health effects.

Dr. Smith also makes unsupported claims in his rebuttal testimony regarding the non-linear statistical models and "illogical response of the human body." In support of these claims, he mentions asbestos as an example (page 4, lines 17-23) and references the paper by Carrubba and Marino (DS-12) (page 9, lines 16-20). However, neither of these two examples provides any support for the alleged "illogical" response of the human body. Asbestos is classified into Group 1 (carcinogenic to humans) by IARC. The latency period between exposure to asbestos and cancer development is typically many decades (30-40 years). This long latency, however, does not provide any support for his claim that linear models fail to describe human responses to environmental agents. Instead, it simply means that it takes a long time to develop a response. The article by Carrubba and Marino (2008) he references states that some of the changes in brain activity in response to outside stimuli are non-linear in nature. A non-linear relationship between stimuli and response, however, does not suggest "illogical" response. On the contrary, a non-linear relationship is a logical statistical relationship; it is simply different from a direct, one-to-one correspondence. While there is variability in human responses to outside stimuli, it is not illogical. The varying degree of susceptibility among various individuals is also factored in, by the use of safety factors, in all existing safety limits and

guidelines. Risk assessments of environmental exposures consider both linear and non-linear responses to environmental agents.

ii. **EVALUATION OF CARCINOGENICITY**

Q. Can you briefly explain the IARC classification process for carcinogenicity?

A. The IARC classification of carcinogenicity is based on weight-of-evidence evaluation of two main streams of evidence: epidemiologic studies in humans and *in vivo* laboratory animal studies. A third component, from *in vitro* laboratory studies, may be also used to provide information on the mechanism of the potential carcinogenesis. The overall evidence from human and animal studies is then separately categorized into one of four categories: (1) sufficient, (2) limited, (3) inadequate evidence of carcinogenicity, or (4) evidence suggesting lack of carcinogenicity. Based on a combination of the two streams of evidence, the exposure is then classified into one of five mutually exclusive categories: Group 1 (carcinogenic to humans); Group 2A (probably carcinogenic to humans); Group 2B (possibly carcinogenic to humans); Group 3 (not classifiable as to its carcinogenicity to humans); and Group 4 (probably not carcinogenic to humans). The Group 1 classification typically requires sufficient evidence from studies of humans, and the Group 2A classification is used when there is limited evidence from studies of humans and sufficient evidence from experimental animal studies. The Group 2B classification is used for an agent when there is limited evidence from studies of humans and less than sufficient evidence from animal studies. Group 3 is used when the evidence of carcinogenicity is inadequate in studies of humans and inadequate or limited in studies of experimental animals. Finally, Group 4 is used when there is evidence suggesting lack of

carcinogenicity in studies of humans and of experimental animals. This classification system is summarized in Table 2 below.

Table 2. International Agency for Research on Cancer (IARC) criteria for classifying exposure as to the strength of the evidence for carcinogenicity

Group	Criteria
Group 1 *Carcinogenic to humans*	• Sufficient evidence of carcinogenicity in humans
Group 2A *Probably carcinogenic to humans*	• Limited evidence of carcinogenicity in humans and • Sufficient evidence of carcinogenicity in experimental animals
Group 2B *Possibly carcinogenic to humans*	• Limited evidence of carcinogenicity in humans and • Less than sufficient evidence of carcinogenicity in experimental animals
Group 3 *Not classifiable as to its carcinogenicity to humans*	• Inadequate evidence of carcinogenicity in humans and • Inadequate or limited evidence of carcinogenicity in experimental animals
Group 4 *Probably not carcinogenic to humans*	• Evidence suggesting lack of carcinogenicity in humans • Evidence suggesting lack of carcinogenicity in experimental animals

Q. How were static and ELF fields classified by IARC?

A. We have to distinguish between static and ELF fields. For static fields, which have primary relevance for DC transmission lines, both static electric and static magnetic fields were classified into Group 3 (i.e., not classifiable as to its carcinogenicity to humans). These classifications were based on inadequate evidence for carcinogenicity in humans and the lack of data relevant to carcinogenicity in animals.

ELF electric fields were similarly categorized into Group 3 based on inadequate evidence and lack of carcinogenicity data in humans and laboratory animals, respectively. Only ELF magnetic fields were classified into Group 2B, based on limited evidence of carcinogenicity in humans and inadequate evidence in laboratory animals.

Q. Were the examples with Group 2B classification appropriately presented in the Rebuttal Testimony of Dennis Smith?

A. No. Dennis Smith used two incorrect and misleading examples to insinuate that agents with Group 2B classification are "known to cause cancer in humans."[20] The two examples Dennis Smith used are the Human Immunodeficiency Virus (HIV) and the Human Papilloma Virus (HPV). HIV has two subtypes, HIV-1 and HIV-2. While the subtype HIV-2, which is endemic in West Africa, is classified in Group 2B, the cancer causing type HIV-1, which is most common globally and also in the United States, is classified into Group 1. The other example, HPV, is even more misleading as HPV has more than 100 subtypes. While some of the HPV subtypes (e.g., types 26, 53, 66, 67, 70, 73, 82) are indeed classified into Group 2B, the cancer causing types (e.g., types 16, 18, 31, 33, 35, 39, 45) are classified into Group 1. There are also HPV subtypes that are classified into Group 2A (e.g., type 68) and into Group 3 (e.g., types 6 and 11). Thus, the HIV and HPV examples, with respect to their carcinogenicity, are presented in a misleading manner in the Rebuttal Testimony of Dennis Smith.

Q. What is the BioInitiative report and who authored it?

A. The BioInitiative report was authored by the BioInitiative Working Group, which is a self-selected volunteer group of scientists and EMF activists. The BioInitiative Working Group did not represent or act on behalf of any recognized or authoritative scientific, health, or regulatory agency. In their own view, the BioInitiative report provides an overview of the scientific literature on potential health effects of ELF and RF EMF. The BioInitiative report concludes that current exposure guidelines are inadequate and calls for up to several thousand-fold reductions in ELF and RF EMF exposure limits. The BioInitiative report was completed in 2007 and then updated in 2012. Both versions

[20] Rebuttal Testimony of Dennis Smith, p. 3, line 22 through p. 4, line 5.

were posted on the internet and not peer-reviewed. Dennis Smith also incorrectly characterized the BioInitiative report as a "meta-analysis."[21] Meta-analysis is a quantitative statistical technique to combine results of similar studies, in order to arrive at an overall joint estimate of the potential association and to evaluate potential reasons for heterogeneity in the results. No meta-analysis of research studies was presented in the BioInitiative report.

Q. Does the BioInitiative report discuss potential effects of static electric and magnetic fields associated with DC lines?

A. No. Although, among the many hundreds of references, the BioInitiative report cites a handful of *in vitro* studies related to static electric and magnetic fields, but it does not specifically deal with potential effects of static fields; and thus, contrary to statements[22] in the Rebuttal Testimony of Dennis Smith, it is not directly pertinent to the assessment of potential health effects of static fields such as those produced by transmission lines carrying DC electricity.

Q. Is the BioInitiative report consistent with reviews and conclusions of authoritative health and scientific agencies?

A. No. The conclusions of the BioInitiative report are wholly inconsistent with the conclusions of authoritative health risk assessments conducted by national and international governmental, health, and scientific agencies, such as the WHO, IARC, ICNIRP, and the U.S. National Institute of Environmental Health Sciences. None of these agencies concluded that environmental exposures to static, ELF, or RF fields at levels below current scientifically-established guidelines pose any risk to human health.

[21] Rebuttal Testimony of Dennis Smith, p. 5, line 16.
[22] Rebuttal Testimony of Dennis Smith, p. 5, lines 3-18.

The BioInitiative report has been widely criticized in the scientific community, for example, by the Health Council of the Netherlands and the Australian Centre for Radiofrequency Bioeffects Research, for not following generally accepted scientific methods, such as the well-established weight-of-evidence assessment, when reviewing the scientific literature on EMF and health. The criticisms included selective reporting of positive studies in support of a specific conclusion, lack of consideration of study quality, and the heavy reliance on *in vitro* studies of tissues and cells, as opposed to *in vivo* laboratory animal studies and epidemiologic research. These flaws explain why their conclusions are largely inconsistent with the conclusions of other national and international expert risk assessment panels and the large body of scientific literature. In other words, the conclusions expressed in the BioInitiative report are based on individual opinions of the authors of the individual chapters, without appropriate scientific peer review, and do not represent a consensus opinion.

Q. Is the IARC Monograph referenced by Dennis Smith relevant to the proposed project?

A. Yes. The IARC Monograph, Volume 80, 2002 (DS-2) is an authoritative, weight-of-evidence review of the health literature on static and ELF EMF. As I mentioned, it classified static electric and magnetic fields, and only these are pertinent for DC transmission lines, and ELF electric fields into Group 3. This means that the review did not identify either sufficient or limited evidence from either human or animal studies to support carcinogenicity. It classified ELF magnetic fields into Group 2B based on limited epidemiologic evidence from childhood leukemia studies, which means that some epidemiologic studies reported an association that was credible, but chance, bias, and

confounding could not be ruled out as explanation. Overall, however, the laboratory animal studies did not support of an association. The planned DC transmission line is not a source of ELF magnetic fields.

Q. Dr. Smith points to a single presentation at a scientific conference as indicating risks to humans and animals (Rebuttal Testimony of Dennis Smith, p. 8, line 19 – p. 9, line3). Please discuss the results presented by the study's authors.

A. Cieslar et al. (2007) exposed groups of eight rats in plastic cages to DC electric fields of 16, 25, or 35 kV/m or sham-exposures for 8 hours per day. Blood was collected from groups of rats after 14, 28, and 56 days of exposure and also 28 days after exposure ended. The samples were analyzed for seven hormones. Increases and decreases in hormone levels were most common at exposure levels of 25 and 35 kV/m. After 56 days of exposure and 28 days after exposure ended few differences between the groups were noted. The pattern of responses was suggested to indicate a stress response followed by adaption. Such a response would not be unexpected because of the constant mechanical stimulation of the fur due to the buildup of large static fields on the surface of the ungrounded plastic cages and diminished responses over time due to habituation or the decline of such fields with soiling of the plastic, or both. All groups appear to have been exposed in the same apparatus and the samples were collected from groups at intervals separated by at least 84 days, both of which introduce potential confounding by other factors (e.g. seasonal variation). In addition, the investigators did not report that a blinded analysis was performed to prevent inadvertent bias in the handling of the animals and analysis of the data.

An important consideration is that the Cieslar et al. (2007) study (Schedule DS-10) is not a peer-reviewed scientific publication, but merely a conference presentation. Conference presentations are typically not considered as part of the "published" scientific literature, thus these sources could not be considered to contribute any weight to a proper health risk evaluation. For example, IARC primarily considers published or accepted peer-reviewed scientific publications along with peer-reviewed government publications as sources with sufficient merit for inclusion in risk assessment:

> With regard to biological and epidemiological data, only reports that have been published or accepted for publication in the openly available scientific literature are reviewed by the working groups. In certain instances, government agency reports that have undergone peer review and are widely available are considered (IARC, 2002, p. 11).

Similarly, the European Commission's SCENIHR states that information contributing to their evaluations is primarily "obtained from reports published in international peer reviewed scientific journals ..." (SCENIHR, 2013, p. 10).

Q. What inference can the Commission draw about how the Rebuttal Testimony of Dr. Smith relates to the Grain Belt Express Project?

A. As discussed above, Dr. Smith focuses his rebuttal testimony on the DC transmission line that is part of the Grain Belt Express project. Nowhere in his rebuttal testimony does he discuss the short AC transmission line that is also part of the project. Hence, his almost exclusive references to health and safety aspects of AC ELF EMF do not address

the health and safety issues posed by the static electric and magnetic fields that will be associated with the operation of the Grain Belt Express DC transmission line.

V. RESPONSE TO ADDITIONAL EMF-RELATED TESTIMONIES

Q. Is there an established effect of EMF on cancer survivors?

A. No. While some witnesses made allegations to potential negative effects of "EMF" on cancer survivors at the August 14, 2014, public hearing,[23] there are no published epidemiologic studies examining the potential effects of static electric or magnetic fields on survival after cancer diagnosis. One large international epidemiologic study of exposure to ELF magnetic fields from AC power lines (Schüz et al., 2012) followed up on suggestions from two earlier but smaller studies (Foliart et al., 2006; Svendsen et al., 2007). Schüz et al. reported no association between exposure to ELF magnetic fields and survival or relapse of more than 3,000 children diagnosed with leukemia.

Q. Do you agree with the allegation of Christina Reichert that Dr. Galli's statements on potential health effects of static electric or magnetic fields are misleading (Rebuttal Testimony of Christina Reichert, pp. 18-20)?

A. No. Regarding potential health risks, Ms. Reichert is wrong on several points. First, she misunderstands the nature and magnitude of the microshocks that could be encountered under a DC transmission line. The severity of such shocks, if they occur at all, would be like a harmless shock delivered to the hand from a door knob after walking across a carpeted floor. Second, the IARC classification of both static electric and static magnetic fields into Group 3 (not classifiable as to its carcinogenicity to humans) implies that the currently available evidence is not sufficient and cannot even be classified as "limited" in

[23] Transcript of August 14, 2014, public hearing, vol. 5, p. 46, lines 5-7; p. 66, lines 18-20; p. 116, lines 11-14.

support of a potential effect of static fields on cancer processes. The fact that expert panels have suggested further research to fill gaps in our scientific knowledge cannot be interpreted as evidence for an effect. The currently available scientific evidence does not support the existence of any adverse long-term health effects of exposure to static fields. Regarding magnetic fields, protection from effects of very strong magnetic fields is achieved by adherence to exposure limits recommended by ICNIRP, which is 4,000,000 mG (ICNIRP, 2009). Since static electric fields do not enter the body, ICNIRP has not recommended limits on occupational or public exposure.

Q. Could you please comment on the allegation of Christina Reichert that the two referenced studies on cattle health and productivity are not representative of the proposed line and real farming operations (Rebuttal Testimony of Christina Reichert, p. 21, lines 4-5)?

A. Ms. Reichert's testimony is not correct that "The WHO study 'Effects of HVDC Transmission Lines on Dairy Cattle" states that two studies have been conducted" (Rebuttal Testimony of Christina Reichert, p. 20, lines 12-14). The WHO conducted neither of the two studies cited by Ms. Reichert. Moreover, as an owner of a B&B, her opinion that "[t]hese studies are not representative of the proposed transmission line or real farming operations" (Rebuttal Testimony of Christina Reichert, p. 21, lines 4-5) is uninformed. Both studies are quite relevant to the assessment of potential impacts of the proposed project. Although they were performed around ±400 and ±500 kV DC lines, these lines involved exposures to static fields that also will be produced by the proposed ±600 kV DC transmission line but at a somewhat greater distance. In other words, the nature of magnetic fields would be the same from a 400-kV and a 600-kV line, but the

magnitude of the fields from the latter would be somewhat higher when measured at the same distance from the lower voltage lines. While the two cattle studies examine specific DC transmission lines, which are not identical in all aspects to the proposed project, the fact that the results show no adverse effects on cattle health and productivity should provide reassurance to ranchers.

Q. Do you agree with the characterization by Christina Reichert that "there are misrepresentations regarding the static magnetic fields" in the "Understanding Electric and Magnetic Fields" booklet (Rebuttal Testimony of Christina Reichert, p. 17, lines 12-19)?

A. No. The booklet correctly states "The highest estimated exposure levels of static magnetic fields directly under the line of approximately 900 mG is similar in magnitude to the range of the earth's geomagnetic field (ranging between approximately 300 and 700 mG)." Similar is not identical, especially when we compare these values to scientifically established exposure limits of 4,000,000 mG recommended for the general public by ICNIRP (2009). In addition, this value represents the highest estimate under peak load conditions, which will likely occur during only a small fraction of time during the year.

Q. Could you please comment on the EMF studies referenced in the Rebuttal Testimony of Shawn Lange?

A. Mr. Lange references two studies, a Polish study by Cieslar et al (2007) and the 2012 BioInitiative report, as supporting a "correlation between static EMF and negative health effects."[24] As I discussed above in my response to the Rebuttal Testimony of Dennis

[24] Rebuttal Testimony of Shawn Lange, p. 4, lines 9-16.

Smith, this Polish study does not appear to be a peer-reviewed scientific publication, and is instead only a conference presentation. In my response to the Rebuttal Testimony of Dennis Smith, I also discussed in detail the lack of scientific merit and relevance of the BioIntiative report for static electric and magnetic fields. Mr. Lange also references the press release related to the Group 2B classification of RF fields, which was published as IARC Monograph 102.[25] While IARC does classify RF fields in the 2 B category, RF EMF is a different physical exposure than static electric and magnetic fields. Static electric and magnetic fields were classified into Group 3 by IARC in IARC Monograph 80 (2002). Mr. Lange also references risk evaluation documents from six authoritative national and international scientific and health agencies that "do not conclude [that static] EMF causes long-term health effects" (Rebuttal Testimony of Shawn Lange, p. 5, lines 13-14).

Q. Does the internet search result described in the Rebuttal Testimony of Kurt Kielisch appropriately reflect public perception on potential EMF health effects?

A. There is no way to assess his claim because there is no scientific basis to assume that the number of links accessed in an Internet search is a true reflection of human perception, and more important, the public's buying behavior. A simple internet search for certain key words as described by Mr. Kielisch[26] is not the correct methodology to evaluate public perception about potential health effects of EMF. Assessment of public perception and public opinions on any topic requires thorough and appropriate questioning of a representative sample of the public. For example, public opinion polls on voting preference is not done by simple internet keyword searches, but by conducting interviews

[25] Rebuttal Testimony of Shawn Lange, p. 4, lines 20-22.
[26] Rebuttal Testimony of Kurt Kielisch, p. 4, lines 22-23 through p. 6, line 2.

with a large number of individuals selected as a representative sample from the entire population of eligible voters.

Q. Mr. Kielisch has cited a number of publications that suggest persons with cardiac pacemakers not come close to high-voltage transmission lines.[27] Are the references he cites relevant to high-voltage DC transmission lines?

A. No, these references apply only to sources of AC electric and magnetic fields such as some electrical appliances and AC transmission lines. Because static fields do not induce any appreciable voltages or currents within the body that might be sensed by pacemakers, they do not have the same potential to affect cardiac pacemakers as do strong AC electric field sources. For example, the PC69 standards for electromagnetic compatibility for active implantable medical devices published by the American National Standards Institute and the Association for the Advancement of Medical Instrumentation in 2007[28] specify that implanted medical devices "shall not be affected by static magnetic fields of flux density of up to 1 mT" (1 mT is equal to 10,000 mG). This level is about 20-fold higher than level that could be experienced near the proposed DC line.

Q. Does the short AC interconnection between the converter station and the electrical grid pose a serious risk to persons with pacemakers?

A. The risk is vanishingly small. Sensing of electrical impulses of the heart is key to the normal functioning of implanted cardiac devices, such as pacemakers or implanted cardioverter defibrillators. Sensing of electric signals from other sources may, in principle, result in electromagnetic interference. Power lines, however, are not typical sources of such interference. A recent search (August 2014) of the Manufacturer and

[27] Rebuttal Testimony of Kurt Kielisch, pp. 7-8.
[28] ANSI/AAMI PC69:2007, Section 4. 6, p. 27.

User Facility Device Experience database maintained by the United States Food and Drug Administration has not identified episodes of electromagnetic interference with implanted cardiac devices due to electric or magnetic fields from either AC or DC power lines. The brochures referenced by Mr. Kielisch provide only general advice. Indeed, modern implanted medical devices incorporate various technological safeguards (e.g., shielding by titanium casing, the presence of bipolar leads, and electrical filtering) to minimize the potential for interference (Dyrda and Khairy, 2008). A recently developed procedure by the European Committee for Electrotechnical Standardization to assess the potential risk to workers with an active implantable medical device provides guidelines for reference levels that are sufficient to ensure compliance (CENELEC 50527-1:2010). For ELF of EMF exposure, the recommended reference levels are 5.0 kV/m and 100 μT (i.e., 1,000 mG) for general exposure (Council Recommendation 1999/519/EC). These exposure levels will not be exceeded outside the right-of-way by any likely configuration of the short AC interconnection.

Q. Do the rebuttal testimonies and comments you have reviewed about the Grain Belt Express provide reliable evidence that contradicts the assessments of health and safety issues associated with either static fields or ELF fields performed by panels of experts on behalf of national and international health and scientific agencies?

A. No.

Q. Based on your own review and evaluation of the research literature on exposure to electric and magnetic fields at static or ELF frequencies, do the levels of static electric and magnetic fields and ELF electric and magnetic fields associated with the

proposed Grain Belt Express project, as summarized in the Testimony of Dr. Galli and the Clean Line Energy brochure[29] pose any known risk to human health?

Q. My conclusion, made to a reasonable degree of scientific certainty, is no. The WHO and other scientific and health agencies have thoroughly considered this issue and have concluded that, on balance, the scientific weight of evidence does not support the conclusion that static and ELF fields cause any long-term adverse health effects. Recent research does not provide evidence to alter this overall conclusion. The conclusions of the WHO and other agencies apply to all sources of these fields in our environment, including power distribution lines, transmission lines, and electrical appliances. In addition, electric and magnetic field levels at the edge of the right of way, and beyond the right-of-way edge would be well below international standards, which are protective of public health.

Q. Does it conclude your testimony?

A. Yes.

[29] Clean Line Energy Partners, LLC. Understanding Electric and Magnetic Fields in Association with HVDC Transmission Lines, 2011 (Excerpts are cited in Schedule DS-3 attached to the Rebuttal Testimony of Dennis Smith).

VI. ACRONYMS AND ABBREVIATIONS

AC	Alternating current
DC	Direct current
ELF	Extremely low frequency
EMF	Electric and magnetic fields
G	Gauss
HIV	Human Immunodeficiency Virus
HPA	Health Protection Agency
HPV	Human Papilloma Virus
Hz	Hertz
IARC	International Agency for Research on Cancer
ICES	International Committee on Electromagnetic Safety
ICNIRP	International Commission on Non-Ionizing Radiation Protection
kV	Kilovolt
kV/m	Kilovolts per meter
mG	Milligauss
RF	Radiofrequency
SCENIHR	Scientific Committee on Emerging and Newly Identified Health Risks
WHO	World Health Organization
V/m	Volts per meter

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BEFORE THE PUBLIC SERVICE COMMISSION
OF THE STATE OF MISSOURI

In the Matter of the Application of Grain Belt Express Clean Line LLC for a Certificate of Convenience and Necessity Authorizing it to Construct, Own, Operate, Control, Manage and Maintain a High Voltage, Direct Current Transmission Line and an Associated Converter Station Providing an Interconnection on the Maywood 345 kV transmission line.	))))))))	Case No. EA-2014-0207

AFFIDAVIT OF WILLIAM H. BAILEY, Ph.D.

STATE OF MARYLAND)
) ss
COUNTY OF TALBOT)

William H. Bailey, Ph.D., being first duly sworn on his oath, states:

1. My name is William H. Bailey, Ph.D. I am a Principal Scientist in the Center for Exposure Assessment and Dose Reconstruction of Exponent, Inc.

2. Attached hereto and made a part hereof for all purposes is my Surrebuttal Testimony on behalf of Grain Belt Express Clean Line, LLC consisting of 38 pages, having been prepared in written form for introduction into evidence in the above-captioned docket.

3. I have knowledge of the matters set forth therein. I hereby swear and affirm that my answers contained in the attached testimony to the questions therein propounded, including any attachments thereto, are true and accurate to the best of my knowledge, information and belief.

William H. Bailey, Ph.D.

Subscribed and sworn to before me this 14th day of October, 2014.

Notary Public

My Commission Expires: 9-5-18

RICHARD A. PRICE
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Professional Profile

Dr. William H. Bailey is a Principal Scientist in Exponent's Health Sciences practice. Dr. Bailey specializes in applying state-of-the-art assessment methods to environmental and occupational health issues. His 30 years of training and experience include laboratory and epidemiologic research, health risk assessment, and comprehensive exposure analysis. Dr. Bailey has investigated exposures to alternating current, direct current, and radiofrequency electromagnetic fields, 'stray voltage', and electrical shock, as well as to a variety of chemical agents and air pollutants. He is particularly well known for his research on potential health effects of electromagnetic fields and has served as an advisor to numerous state, federal, and international agencies. Currently, he is involved in research on exposures to marine life from submarine cables and respiratory exposures to ultrafine- and nanoparticles. Dr. Bailey is a visiting scientist at the Cornell University Medical College and has lectured at Rutgers University, the University of Texas (San Antonio), and the Harvard School of Public Health. He was formerly Head of the Laboratory of Neuropharmacology and Environmental Toxicology at the New York State Institute for Basic Research, Staten Island, New York, and an Assistant Professor and NIH postdoctoral fellow in Neurochemistry at The Rockefeller University in New York.

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Publications

Chang ET, Adami H-O, Bailey WH, Boffetta P, Krieger RI, Moolgavkar SH, Mandel JS. Validity of geographically modeled environmental exposure estimates. Crit Rev Toxicol 2014; in press.

Alexander DD, Bailey WH, Perez V, Mitchell ME, Su S. Air ions and respiratory function outcomes: A comprehensive review. J Negat Results Biomed 2013 Sep 9; 12(1):14. doi: 10.1186/1477-5751-12-14.

Perez V, Alexander DD, Bailey WH. Air ions and mood outcomes: A review and meta-analysis. BMC Psychiatry 2013 Jan 15; 13(1):29. doi: 10.1186/1471-244X-13-29.

Bailey WH, Johnson GB, Bishop J, Hetrick T, Su S. Measurements of charged aerosols near ±500 kV DC transmission lines and in other environments. IEEE Transactions on Power Delivery 2012; 27:371–379.

Shkolnikov YP, Bailey WH. Electromagnetic interference and exposure from household wireless networks. 2011 IEEE Symposium on Product Compliance Engineering (PSES), October 1–5, 2011.

Kavet R, Bailey WH, Bracken TD, Patterson RM. Recent advances in research relevant to electric and magnetic field exposure guidelines. Bioelectromagnetics 2008; 29:499–526.

Bailey WH, Wagner M. IARC evaluation of ELF magnetic fields: Public understanding of the 0.4μT exposure metric. Journal of Exposure Science and Environmental Epidemiology 2008; 18:233–235.

Bailey WH, Erdreich L. Accounting for human variability and sensitivity in setting standards for electromagnetic fields. Health Physics 2007; 92:649–657.

Bailey WH, Nyenhuis JA. Thresholds for 60-Hz magnetic field stimulation of peripheral nerves in human subjects. Bioelectromagnetics 2005; 26:462–468.

Bracken TD, Senior RS, Bailey WH. DC electric fields from corona-generated space charge near AC transmission lines. IEEE Transactions on Power Delivery 2005; 20:1692–1702.

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De Santo RS, Bailey WH. Environmental justice tools and assessment practices. Proceedings, American Public Transit Association, 1999.

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Bailey WH. Policy implications. Proceedings, EMF Engineering Review Symposium, Status and Summary of EMF Engineering Research. Bracken TD and Montgomery JH (eds), Oak Ridge National Laboratory, Oak Ridge, TN, April 28–29, 1998.

Bailey WH. Probabilistic approaches to deriving risk-based exposure guidelines: Application to extremely low frequency magnetic fields. In: Non-Ionising Radiation. Dennis JA and Stather JW (eds), Special Issue of Radiation Protection Dosimetry 1997; 72:327–336.

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Bracken TD, Senior RS, Rankin RF, Bailey WH, Kavet R. Magnetic field exposures in the electric utility industry relevant to occupational guideline levels. Applied Occupational and Environmental Hygiene 1997; 12:756–768.

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Book Chapters

Bailey WH. Principles of risk assessment and their limitations. In: Risk Perception, Risk Communication and its Application to EMF Exposure. Matthes R, Bernhardt JH, Repacholi MH (eds), International Commission on Non-Ionizing Radiation Protection, Oberschleißheim, Germany, 1998.

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Technical Reports

Normandeau, Exponent, Tricas T, Gill A. Effects of EMFs from undersea power cables on elasmobranchs and other marine species. U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Regulation, and Enforcement, Pacific OCS Region, Camarillo, CA. OCS Study BOEMRE 2011-09, May 2011.

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Bailey WH. Melatonin responses to EMF. Proceedings, Health Implications of EMF Neural Effects Workshop, Report TR-104327s, EPRI, 1994.

Bailey WH. Recent neurobiological and behavioral research: Overview of the New York State powerlines project. In: Power-Frequency Electric and Magnetic Field Research, EPRI, 1989.

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Bailey WH, Bissell M, Brambl RM, Dorn CR, Hoppel WA, Sheppard AR, Stebbings JH. A health and safety evaluation of the +/- 400 KV powerline. Science Advisor's Report to the Minnesota Environmental Quality Board, 1982.

Charry JM, Bailey WH, Weiss JM. Critical annotated bibliographical review of air ion effects on biology and behavior. Rockefeller University, New York, NY, 1982.

Bailey WH. Avoidance behavior in rats with hereditary hypothalamic diabetes insipidus. Dissertation, City University of New York, 1975.

Selected Invited Presentations

Bailey WH. Measurements of charged aerosols around DC transmission lines and other locations. International Committee on Electromagnetic Safety TC95/ Subcommittee 3: Safety Levels with Respect to Human Exposure to Electromagnetic Fields, 0 – 3 kHz, December 2011.

Bailey WH, Erdreich LS. Human sensitivity and variability in response to electromagnetic fields: Implications for standard setting. International Workshop on EMF Dosimetry and Biophysical Aspects Relevant to Setting Exposure Guidelines. International Commission on Non-Ionizing Radiation Protection, Berlin, March 2006.

Bailey WH. Research-based approach to setting electric and magnetic field exposure guidelines (0-3000 Hz). IEEE Committee on Electromagnetic Safety, December 2005.

Bailey WH. Conference Keynote Presentation. Research supporting 50/60 Hz electric and magnetic field exposure guidelines. Canadian Radiation Protection Association, Annual Conference, Winnipeg, June 2005.

Bailey WH. Scientific methodology for assessing public health issues: A case study of EMF. Canadian Radiation Protection Association, Annual Conference, Public Information for Teachers, Winnipeg, June 2005.

Bailey WH. Assessment of potential environmental effects of electromagnetic fields from submarine cables. Connecticut Academy of Science and Engineering, Long Island Sound Bottomlands Symposium: Study of Benthic Habitats, July 2004.

De Santo RS, Coe M, Bailey WH. Environmental justice assessment and the use of GIS tools and methods. National Association of Environmental Professionals, 27th Annual Conference, Dearborn, MI, June 2002.

Bailey WH. Applications to enhance safety: Research to understand and control potential risks. Human Factors and Safety Research, Volpe National Transportation Systems Center/Dutch Ministry of Transport, Cambridge, MA, November 2000.

Bailey WH. EMF health effects review. EMF Exposure Guideline Workshop, Brussels Belgium, June 2000.

Bailey WH. Dealing with uncertainty when formulating guidelines. EMF Exposure Guideline Workshop, Brussels Belgium, June 2000.

Bailey WH. Field parameters: Policy implications. EMF Engineering Review Symposium, Status and Summary of EMF Engineering Research, Charleston, SC, April 1998.

Bailey WH. Principles of risk assessment: Application to current issues. Symposium on EMF Risk Perception and Communication, World Health Organization, Ottawa, Canada, August 1998.

Bailey WH. Current guidelines for occupational exposure to power frequency magnetic fields. EPRI EMF Seminar, New Research Horizons, March 1997.

Bailey WH. Methods to assess potential health risks of cell telephone electromagnetic fields. IBC Conference—Cell Telephones: Is there a Health Risk? Washington, DC, June 1997.

Bailey WH. Principles of risk assessment and their limitations. Symposium on Risk Perception, Risk Communication and its Application to EMF Exposure, International Commission on Non-Ionizing Radiation Protection, Vienna, Austria, October 1997.

Bailey WH. Probabilistic approach for setting guidelines to limit induction effects. IEEE Standards Coordinating Committee 28: Non-Ionizing Radiation, Subcommittee 3 (0–3 kHz), June 1997.

Bailey WH. Power frequency field exposure guidelines. IEEE Standards Coordinating Committee 28: Non-Ionizing Radiation, Subcommittee 3 (0–3 kHz), June 1996.

Bailey WH. Epidemiology and experimental studies. American Industrial Hygiene Conference, Washington, DC, May 1996.

Bailey WH. Review of 60 Hz epidemiology studies. EMF Workshop, Canadian Radiation Protection Association, Ontario, Canada, June 1993.

Bailey WH. Biological and health research on electric and magnetic fields. American Industrial Hygiene Association, Fredrickton, New Brunswick, Canada, October 1992.

Bailey WH. Electromagnetic fields and health. Institute of Electrical and Electronics Engineers, Bethlehem, PA, January 1992.

Bailey WH, Weiss JM. Psychological factors in experimental heart pathology. Visiting Scholar Presentation, National Heart Lung and Blood Institute, March 1977.

Presentations

Williams AI, Bailey WH. Toxicologic assessment of air ion exposures in laboratory animals. Poster presentation at 53rd Annual Meeting of the Society of Toxicology, Phoenix, AZ, March 26, 2014.

Perez V, Alexander DD, Bailey WH. Air ions and mood outcomes: A review and meta-analysis. Poster presentation at the American College of Epidemiology, Chicago, IL, September 8–11, 2012.

Shkolnikov Y, Bailey WH. Electromagnetic interference and exposure from household wireless networks. Product Safety Engineering Society Meeting, San Diego, CA October 2011.

Nestler E, Trichas T, Pembroke A, Bailey W. Will undersea power cables from offshore wind projects affect sharks? North American Offshore Wind Conference & Exhibition, Atlantic City, NJ, October 2010.

Nestler E, Pembroke A, Bailey W. Effects of EMFs from undersea power lines on marine species. Energy Ocean International, Ft. Lauderdale, FL, June 2010.

Pembroke A, Bailey W. Effects of EMFs from undersea power cables on elasmobranchs and other marine species. Windpower 2010 Conference and Exhibition, Dallas, TX, 2010.

Bailey WH. Clarifying the neurological basis for ELF guidelines. Workshop on Practical Implementation of ELF and RF Guidelines. The Bioelectromagnetics Society 29th Annual Meeting, Kanazawa, Japan, June 2007.

Sun B, Urban B, Bailey W. AERMOD simulation of near-field dispersion of natural gas plume from accidental pipeline rupture. Air and Waste Management Association: Health Environments: Rebirth and Renewal, New Orleans, LA, June 2006.

Bailey WH, Johnson G, Bracken TD. Method for measuring charge on aerosol particles near AC transmission lines. Joint Meeting of The Biolectromagnetics Society and The European BioElectromagnetics Association, Dublin Ireland, June 2005.

Bailey WH, Bracken TD, Senior RS. Long-term monitoring of static electric field and space charge near AC transmission Lines. The Bioelectromagnetics Society, 26th Annual Meeting, Washington, DC, June 2004.

Bailey WH, Erdreich L, Waller L, Mariano K. Childhood leukemia in relation to 25-Hz and 60-Hz magnetic fields along the Washington DC—Boston rail line. Society for Epidemiologic Research, 35th Annual Meeting, Palm Desert CA, June 2002. American Journal of Epidemiology 2002; 155:S38.

Erdreich L, Klauenberg BJ, Bailey WH, Murphy MR. Comparing radiofrequency standards around the world. Health Physics Society 43rd Annual Meeting, Minneapolis, MN, July 1998.

Bracken TD, Senior RS, Rankin RF, Bailey WH, Kavet R. Relevance of occupational guidelines to utility worker magnetic-field exposures. Second World Congress for Electricity and Magnetism in Biology and Medicine, Bologna, Italy, June 1997.

Weil DE, Erdreich LS, Bailey WH. Are 60-Hz magnetic fields cancer causing agents? Mechanisms and Prevention of Environmentally Caused Cancers, The Lovelace Institutes 1995 Annual Symposium, La Fonda, Santa Fe, NM, October 1995.

Bailey WH. Neurobiological research on extremely-low-frequency electric and magnetic fields: A review to guide future research. Sixteenth Annual Meeting of the Bioelectromagnetics Society, Copenhagen, Denmark, June 1994.

Blondin J-P, Nguyen D-H, Sbeghen J, Maruvada PS, Plante M, Bailey WH, Goulet D. The perception of DC electric fields and ion currents in human observers. Annual Meeting of the Canadian Psychological Association, Penticton, British Columbia, Canada, June 1994.

Erdreich LS, Bailey WH, Weil DE. Science, standards and public policy challenges for ELF fields. American Public Health Association 122nd Annual Meeting, Washington, DC, October 1994.

Bailey WH, Charry JM. Particle deposition on simulated VDT operators: Influence of DC electric fields. 10th Annual Meeting of the Bioelectromagnetics Society, June 1988.

Charry JM, Bailey WH. Contribution of charge on VDTs and simulated VDT operators to DC electric fields at facial surfaces. 10th Annual Meeting of the Bioelectromagnetics Society, June 1988.

Bailey WH, Charry, JM. Dosimetric response of rats to small air ions: Importance of relative humidity. EPRI/DOE Contractors Review, November 1986. Charry JM, Bailey WH, Bracken TD (eds). DC electric fields, air ions and respirable particulate levels in proximity to VDTs. International Conference on VDTs and Health, Stockholm, Sweden, June 12–15 1986.

Charry JM, Bailey WH. Air ion and DC field strengths at 10^4 ions/cm^3 in the Rockefeller University Small Animal Exposure Chambers. EPRI/DOE Contractors Review, November 1985.

Charry JM, Bailey WH. DC Electrical environment in proximity to VDTs. 7th Annual Meeting of the Bioelectromagnetics Society, June 1985.

Bailey WH, Collins RL, Lahita RG. Cerebral lateralization: Association with serum antibodies to DNA in selected bred mouse lines. Society for Neuroscience, 1985.

Kavet R, Bailey WH, Charry JM. Respiratory neuroendocrine cells: A plausible site for air ion effects. Seventh Annual Meeting of The Bioelectromagnetics Society, June 1985.

Bailey WH, Charry JM. Measurement of neurotransmitter release and utilization in selected brain regions of rats exposed to DC electric fields and atmospheric space charge. 23rd Hanford Life Sciences Symposium, Richland, WA, October 1984.

Bailey WH, Charry JM, Weiss JM, Cardle K, Shapiro M. Regional analysis of biogenic amine turnover in rat brain after exposure to electrically charged air molecules (air ions). Society for Neuroscience, 1983.

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Goodman PA, Weiss JM, Hoffman LJ, Ambrose MJ, Bailey WH, Charry, JM. Reversal of behavioral depression by infusion of an A2 adrenergic agonist into the locus coeruleus. Society for Neuroscience, November 1982.

Charry JM, Bailey WH. Biochemical and behavioral effects of small air ions. Electric Power Research Institute Workshop, April 1981.

Bailey WH, Alsonso DR, Weiss JM, Chin S. Predictability: A psychologic/ behavioral variable affecting stress-induced myocardial pathology in the rat. Society for Neuroscience, November 1980.

Salman SL, Weiss JM, Bailey WH, Joh TH. Relationship between endogenous brain tyrosine hydroxylase and social behavior of rats. Society of Neuroscience, November 1980.

Bailey WH, Maclusky S. Appearance of creatine kinase isoenzymes in rat plasma following myocardial injury produced by isoproterenol. Fed Assoc Soc Exp Biol, April 1978.

Bailey WH, Maclusky S. Appearance of creatine kinase isoenzymes in rat plasma following myocardial injury by isoproterenol. Fed Proc 1978; 37:889.

Bailey WH, Weiss JM. Effect of ACTH 4-10 on passive avoidance of rats lacking vasopressin (Brattleboro strain). Eastern Psychological Association, April 1976.

Prior Experience

President, Bailey Research Associates, Inc., 1991–2000
Vice President, Environmental Research Information, Inc., 1987–1990
Head of Laboratory of Environmental Toxicology and Neuropharmacology, New York State Institute for Basic Research, 1983–1987
Assistant Professor, The Rockefeller University, 1976–1983

Academic Appointment

- Visiting Fellow, Department of Pharmacology, Cornell University Medical College, New York, NY, 1986–present

Prior Academic Appointments

- Visiting Scientist, The Jackson Laboratory, Bar Harbor, ME, 1984–1985
- Head, Laboratory of Neuropharmacology and Environmental Toxicology, NYS Institute for Basic Research in Developmental Disabilities, Staten Island, NY, 1983–1987
- Assistant Professor, The Rockefeller University, New York, NY, 1976–1983
- Postdoctoral Fellow, Neurochemistry, The Rockefeller University, New York, NY, 1974–1976
- Dissertation Research, The Rockefeller University, New York, NY, 1972–1974
- CUNY Research Fellow, Dept. of Psychology, Queens College, City University of New York, Flushing, NY, 1969–1971
- Clinical Research Assistant, Department of Psychiatry, University of Chicago; Psychiatric Psychosomatic Inst., Michael Reese Hospital, and Illinois State Psychiatric Inst, Chicago, IL, 1968–1969

Teaching Appointments

- Lecturer, University of Texas Health Science Center, Center for Environmental Radiation Toxicology, San Antonio, TX, 1998
- Lecturer, Harvard School of Public Health, Office of Continuing Education, Boston, MA, 1995, 1997
- Lecturer, Rutgers University, Office of Continuing Education, New Brunswick, NJ, 1991–1995
- Adjunct Assistant Professor, Queens College, CUNY, Flushing, NY, 1978
- Lecturer, Queens College, CUNY, Flushing, NY, 1969–1974

Editorship

- Associate Editor, Non-Ionizing Radiation, *Health Physics*, 1996–present

Advisory Positions

- ZonMw – Netherlands Organization for Health Research and Development, 2012; 2007-2008, reviewer for National Programme on EMF and Health
- US Bureau of Ocean Energy Management, Regulation and Enforcement, 2009–2010
- Canadian National Collaborating Centre for Environmental Health, reviewer of Centre reports, 2008
- Island Regulatory and Appeals Commission, province of Prince Edward Island, Canada, 2008
- National Institute of Environmental Health Sciences/ National Institutes of Health, Review Committee, Neurotoxicology, Superfund Hazardous Substances Basic Research and Training Program, 2004
- National Institute of Environmental Health Sciences, Review Committee Role of Air Pollutants in Cardiovascular Disease, 2004
- Working Group on Non-Ionizing Radiation, Static and Extremely Low-Frequency Electromagnetic Fields, International Agency for Research on Cancer, 2000–2002
- Working Group, EMF Risk Perception and Communication, World Health Organization, 1998–2005
- Member, International Committee on Electromagnetic Safety, Subcommittee 3 - Safety Levels with Respect to Human Exposure to Fields (0 to 3 kHz) and Subcommitee 4 - Safety Levels with Respect to Human Exposure (3kHz to 3GHz) Institute of Electrical and Electronics Engineers (IEEE), 1996–present
- Invited participant, National Institute of Environmental Health Sciences EMF Science Review Symposium: Clinical and In Vivo Laboratory Findings, 1998
- Working Group, EMF Risk Perception and Communication, International Commission on Non-Ionizing Radiation Protection, 1997
- U.S. Department of Energy, RAPID EMF Engineering Review, 1997
- Oak Ridge National Laboratory, 1996

- American Arbitration Association International Center for Dispute Resolution, 1995–1996
- U.S. Department of Energy, 1995
- National Institute for Occupational Safety and Health, 1994–1995
- Federal Rail Administration, 1993–1996
- U.S. Forest Service, 1993
- New York State Department of Environmental Conservation, 1993
- National Science Foundation
- National Institutes of Health, Special Study Section—Electromagnetics, 1991–1993
- Maryland Public Service Commission and Maryland Department of Natural Resources, Scientific Advisor on health issues pertaining to HVAC Transmission Lines, 1988–1989
- Scientific advisor on biological aspects of electromagnetic fields, Electric Power Research Institute, Palo Alto, CA, 1985–1989
- U.S. Public Health Service, NIMH: Psychopharmacology and Neuropsychology Review Committee, 1984
- Consultant on biochemical analysis, Colgan Institute of Nutritional Science, Carlsbad, CA, 1982–1983
- Behavioral Medicine Abstracts, Editor, animal behavior and physiology, 1981–1983
- Consultant on biological and behavioral effects of high-voltage DC transmission lines, Vermont Department of Public Service, Montpelier, VT, 1981–1982
- Scientific advisory committee on health and safety effects of a high-voltage DC transmission line, Minnesota Environmental Quality Board, St. Paul, MN, 1981–1982
- Consultant on biochemical diagnostics, Biokinetix Corp., Stamford, CT, 1978–1980

Professional Affiliations

- The Health Physics Society (Affiliate of the International Radiation Protection Society)
- Society for Risk Analysis
- International Society of Exposure Analysis
- New York Academy of Sciences
- American Association for the Advancement of Science
- Air and Waste Management Association
- Society for Neuroscience/International Brain Research Organization
- Bioelectromagnetics Society
- The Institute of Electrical and Electronics Engineers/Engineering in Medicine and Biology Society
- Conseil International des Grands Réseaux Électriques