Health Issues Related to the Static and Power-Frequency Electric and Magnetic Fields (EMFs) of the Soitec Solar Energy Farms

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Memorandum on Scientific Information Related to Human Health Effects

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1 Summary of Conclusions

Tierra del Sol Solar LLC, Rugged Solar LLC, LanWest Solar LLC, LanEast Solar LLC, and Soitec Solar Development LLC (applicants) have proposed four solar farm projects in southeastern San Diego County (collectively, the Proposed Project). These four projects include the Tierra del Sol, Rugged, LanEast, and LanWest solar farms. A Draft Programmatic Environmental Impact Report (DPEIR) was prepared to analyze the potential environmental impacts associated with the Proposed Project. The Tierra del Sol and Rugged solar farms were analyzed at a project-level of detail in the DPEIR because the applicants are seeking project-level approvals for those projects. The LanEast and LanWest projects were analyzed at a programmatic level of detail in the DPEIR because no project-level approvals are being sought and sufficient project-level data has not yet been developed at this time.

The analysis in this memorandum focuses on the Tierra del Sol and Rugged solar farms because project-level detail is available for those projects, however, it is equally applicable to the LanEast and LanWest solar farms assuming they are constructed using technology and layout comparable to those of the Tierra del Sol and Rugged solar farms.

This memorandum reaches three conclusions:

- There is no agreement among scientists that time-varying EMFs comparable to those of the project pose a potential health risk, and there are no defined or adopted CEQA/NEPA impacts concerning a health risk from EMF exposures;

- EMFs from the CPV trackers would not be significant outside each project's boundary;

- The static electric and magnetic fields of the Proposed Project are highly localized, very much weaker than limits found in all safety guidelines, and imperceptible at all locations accessible to the public. They pose no known concern for human health.

2 Introduction

Each of the proposed projects would introduce static and power-frequency (principally 60-Hz) electric and magnetic fields into the environment. Static fields would be produced by the CPV (Concentrator Solar Photovoltaics) modules and associated cabling for the 1 kV (1000 volt) DC underground collection system. The DC-to-AC inverters are a source of alternating electric and magnetic fields with a principal frequency of 60-Hz and also higher frequencies (harmonic frequencies). The overhead and underground transmission lines used to transfer power from the projects to the power grid also are sources of power-frequency electric and magnetic fields.

Recognizing that there is public interest and concern regarding potential health effects from exposure to electric and magnetic fields (EMFs) from power lines and other utility infrastructure, this section provides information regarding EMFs associated with electricity generation and transmission facilities with an emphasis on the potential for effects of the proposed project on public health and safety.

This memorandum supports the conclusion reached in the DPEIR (DPEIR, Sec. 3.1.4.5) that the Proposed Project would not create a health risk under CEQA because there is no agreement among scientists that EMFs comparable to those of the project pose a potential health risk, and there are no defined or adopted CEQA/NEPA impacts concerning a health risk from EMF exposures. The California Public Utilities Commission has addressed potential EMF health risks and established EMF policy (CPUC 1995; CPUC 2006a) with guidelines for project designs to implement the policy (CPUC 2006b), particularly a policy promoting designs that reduce EMFs when that can be accomplished at low-cost or no-cost. San Diego County has no policy to regulate EMF exposure. The information on EMF science and regulatory approaches presented below is given in some depth for the interest and benefit of the public and decision makers.

The recognized adverse effects of electric and magnetic fields (IEEE Std C95.6-2002 2002) occur at field strengths very much greater than can be found in areas accessible to the public near the project sites and associated transmission lines. Safety from recognized potential adverse effects is further enhanced because both electric and magnetic field strengths drop rapidly with increasing distance from EMF sources of the Proposed Project.

In general, EMFs present concerns in addition to those from possible direct influences of fields on tissues and organs of the body. These include potential health risks from induced currents, electric shock, effects on cardiac pacemakers, and nuisance factors due to corona.[1] Corona is associated with audible noise, potential interference with radio and television broadcast reception, and with electronic equipment. Mitigation measures are available in cases where environmental impacts of the just-mentioned nuisance factors could be significant.

2.1 Defining EMFs

Electric fields and magnetic fields occur both naturally and in the operation of many technological devices. Static and low frequency fields broadly relevant to EMFs of the Proposed Project occur naturally due to atmospheric phenomena and earth's geomagnetic field. Technological applications throughout modern society generate EMFs across the electromagnetic spectrum. This spectrum goes from low frequencies, such as the 60 Hz power frequency associated with the generation, transmission, and local distribution of electricity, to frequencies many millions or billions of times greater that are used for communications systems, radar, medical diagnostics, and many other purposes.

Electric and magnetic fields at all frequencies (including static fields) are vector quantities, that is, they have the properties of direction and amplitude (field strength). These fields are created, respectively, by the electric voltage and electric current. Electric power very often is created by a generator whose rotary motion yields alternating current that changes in direction and amplitude at a rate of 60 times per second in North American power systems. Power generation by solar panels uses electronic devices to produce alternating currents from the direct currents of the solar panels. The designations "60 cycle" and "60 Hz" are synonymous because the hertz, abbreviated Hz, is the unit for cycles per second. The frequency of electric power systems in Europe and many other countries is 50 Hz, the frequency at which relevant research has been done.

[1] Corona effects include audible noise, electromagnetic interference with radio or television signals, a glowing region in the air, and heat. Corona-generated audible noise is characterized as a crackling, hissing, or humming that is most noticeable during rain or fog. During fair weather, audible noise may be barely perceptible, depending on line voltage and a variety of factors. The Tierra del Sol 138-kV gen-tie and Rugged Solar 69-kV gen-tie transmission lines would create corona, but the effects would not be as strong as with higher voltage transmission lines such as the 500-kV Sunrise Powerlink.

At the much higher frequencies used for communications, electric and magnetic fields exist in a mutual relationship known as the electromagnetic field. The additional properties of electromagnetic fields make communication systems possible, but the information presented in this memo is restricted to phenomena of EMFs – independent electric and magnetic fields – from power lines operating at frequencies of 50 or 60 Hz. Possible confusion exists because electromagnetic fields also may be abbreviated as "EMFs," but electromagnetic fields can radiate a beam of energy from an antenna, in sharp distinction with the independent electric and magnetic fields of power systems that do not create a radiating energy beam.

2.2 Basic Features of Electric Power Systems and Solar Power Generation

Electric power flows across transmission systems from generating sources to serve electrical loads within the community. The energy for electricity generation may come from sources such as solar conversion panels, water power, and heat, which may be derived from nuclear reactions or the burning of gas, oil, and coal. The power flowing over a transmission line is determined by the transmission line voltage and the current. The higher the voltage level of the transmission line, the lower the amount of current needed to deliver the same amount of power. For example, a 138 kV (138,000 volt) transmission line carrying 200 amperes of current transmits approximately 47,800 kilowatts (kW), whereas a 256 kV transmission line would require only 100 amperes of current to deliver the same 47,800 kW.

The CPV trackers proposed for the Proposed Project create direct current (DC) electricity from sunlight, therefore requiring the use of inverters to create alternating current (AC) electricity suitable for use on the power system. Inverters produce currents that predominantly are at 60 Hz, but higher frequency currents also occur. Consequently, EMFs are created at 60 Hz and at harmonic frequencies. For example, inverter harmonics may be strong at 180-, 300- and 420-Hz, the third fifth and seventh harmonics of 60-Hz, but the strengths of harmonic frequency EMFs of the Proposed Project will be characteristic of the specific electronic and electrical design of the inverter/transformer units and associated equipment. Filters typically reduce most harmonic frequencies such that 60-Hz electric and magnetic fields are the dominant feature in all the parts of the system, that is, those operating at 350-400 V, 34.5 kV, 69 kV and 138 kV.

For the Tierra del Sol project, the 34.5 kV collector trunk would be on the existing right-of-way of the 500 kV AC Southwest Powerlink that is an existing source of 60-Hz EMFs and its 138 kV gen-tie would be routed underground and overhead. The Rugged Solar 69 kV gen-tie transmission line would be underslung on the approved Tule Wind 138 kV transmission line right of way.

2.3 Electric Fields

Whenever AC lines are energized, power-frequency electric fields are created with a field strength that depends directly on the voltage on the line creating it. Electric field strength is typically described in units of kilovolts per meter (kV/m). Electric field strength attenuates (gets weaker) rapidly with increasing distance from the source. Electric fields are strongly reduced at many environmental receptors because they are effectively shielded by trees, walls and roofs of buildings.

A static electric field is a feature of everyday experiences such as when pulling off a sweater, sliding across a fabric car seat, scuffing shoes across a carpet, combing hair, and grooming fur on a pet. These phenomena are more pronounced during dry weather or indoors when humidity is very low. A person walking on a carpet can acquire a voltage of several thousand volts but there is no direct health hazard from such momentary discharges to the body (World Health Organization 2006 sec. 3.2.1). In fair weather, the potential difference between the ionosphere and earth's surface results in a static electric field that averages approximately 130 V/m, but static electric fields of 3 kV/m or more are created under clouds (World Health Organization 2006 sec. 3.1.1) and in dust storms. DC transmission lines, which can be energized at ±400 kV or more, are used for transmission of large quantities of power over long distances. Ground level static electric fields of as much as 20 kV/m can occur beneath DC transmission lines (World Health Organization 2006 sec. 3.2.1), but, in comparison, a typical solar farm DC collector system carries current in cables that create negligible external electric fields.

Some phenomena of power-frequency electric fields are similar to those of static fields because a frequency of 60 Hz involves a relatively slow oscillation of field polarity. The switching of positive and negative current flow at 60 times per second means that polarity changes occur within approximately one-hundredth second. In comparison, at typical radiofrequencies polarity switches within millionths or billionths of a second.

Unlike magnetic fields, which penetrate all non-conducting materials and are therefore unaffected by trees, most building materials, and other obstacles, both static and 60-Hz electric fields are distorted by any object that is within the electric field, including the human body. Even trying to measure an electric field with electronic instruments is difficult because the devices themselves would alter the levels recorded. Determining an individual's exposure to electric fields requires understanding many variables, including the strength and direction of the electric field itself, effectiveness of a person's electrical connection to the earth or other electrical ground, and body surface area within the electric field.

Potential health effects from exposure to electric fields from power lines, substation buswork, switchgear and transformers are typically not a focus of concern because these fields are attenuated by common environmental features such as trees with foliage and the building materials used for homes, offices and manufacturing sites. Levallois et al. (1995) found that even close to a powerline right-of-way, electric fields inside homes are similar to those in homes far from transmission lines.

Electric fields in the vicinity of power lines can cause "spark discharges" that are similar to the static electricity experiences mentioned above. Such electric discharges can occur when touching long metal fences, metal gutters, pipelines, or large vehicles with a potential safety hazard from a startle reaction causing, for example, a dropped tool or a fall from a ladder. A more threatening potential impact to public health from electric transmission lines is the acknowledged hazard of electric shock that results from accidental or unintentional contact by the public with energized wires. The issues of spark discharges and shock hazards are not addressed further because the electric fields associated with the Proposed Project are not strong enough to cause discernible spark discharges except at positions on powerline towers or poles that are inaccessible to the public.

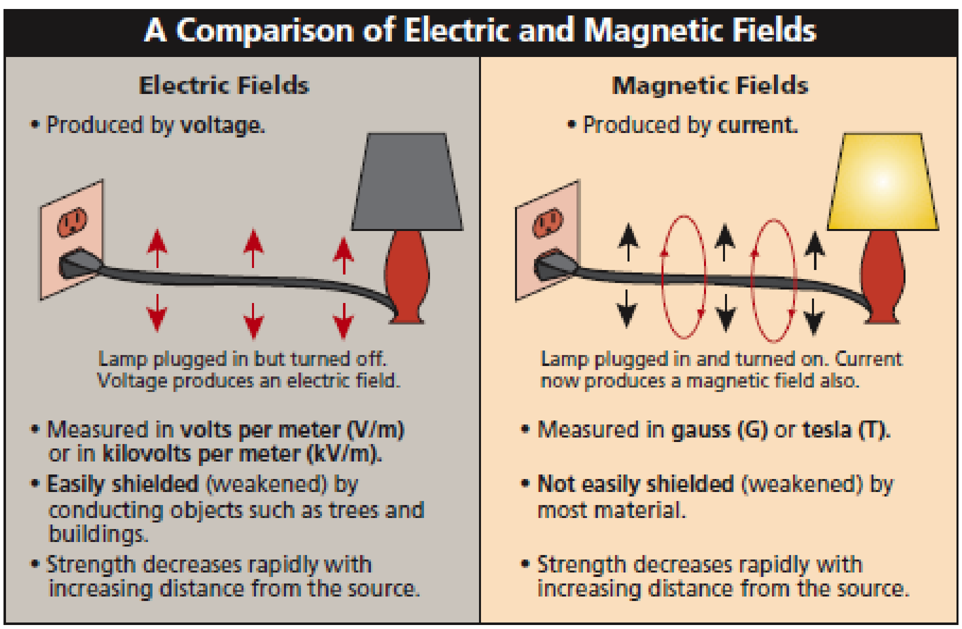
2.4 Magnetic Fields

Magnetic fields are created whenever current flows through power lines at any voltage. The strength of the field is directly dependent on the current in the line. The intensity of a magnetic field is often measured in milligauss (mG) or microtesla (μT). Like electric fields, magnetic fields attenuate rapidly with distance from the source, but unlike electric fields, magnetic fields are not shielded by most objects or materials.

2.5 Contrast between Electric and Magnetic Fields at Appliances

The nature of electric and magnetic fields can be illustrated by considering a household appliance that is plugged into an outlet but not turned on (Fig. 1). As long as it is switched off, no current flows and consequently there is no magnetic field generated in the appliance and its

Figure 1.



An appliance that is plugged in and therefore connected to a source of electricity has an electric field even when the appliance is turned off. To produce a magnetic field, the appliance must be plugged in and turned on so that the current is flowing.

Source: (NIEHS 2002 p 5)

wiring (particularly the electric "cord"). However, when off, an electric field originates from the cord the cord that is energized at the line voltage, typically 115 V (volts), and from any other parts at line voltage. Electric field strength is directly related to the magnitude of the voltage from the outlet, and when the appliance is switched on magnetic field strength is directly related to the magnitude of the current flowing in the cord and appliance. Thus, an appliance operating at 230 V generally has higher electric field strengths than one at 115 V, and the magnetic fields surrounding the cord of an iron that draws perhaps 10 ampere (A) of current would be higher than those surrounding the cord of a typical desk lamp drawing less than 1 A.

3 EMF Sources Associated with the Proposed Project

The following EMF sources are confined to the 420-acre and 765-acre project sites of Tierra del Sol and Rugged, respectively:

- Approximately 2,657 CPV trackers at the Tierra del Sol site and 3,588 CPV trackers at the Rugged site would have localized EMFs due to the DC produced by the panel. During operation, the tracker motors and electronics would create localized EMFs typical of small-scale equipment. EMFs from the panels and related tracking equipment would not be significant outside the solar array area and therefore are not given further consideration.

- A 1 kV DC underground collection system would be a source of EMF near the cables.

- A maximum of 45 (Tierra del Sol) and 59 (Rugged) inverter stations and associated transformers would change the 1 kV DC power into 34.5 kV AC power (with an intermediary stage at 350-400 VAC).

- Tierra del Sol and Rugged each would have 34.5 kV overhead and underground collection systems to link the trackers to the on-site project substation. The 34.5 kV cables would be underground and then transition to overhead poles for the trunk lines leading to a collector substation.

- A collector substation site that includes switchgear for transfer of power on the multiple 34.5 kV lines into the 138 kV (Tierra del Sol) or 69 kV (Rugged) gen-tie transmission lines. Unlike substations typical of the electric power system, for example, the Rebuilt Boulevard Substation, the collector substation does not provide a point of interconnection for system distribution and transmission lines.

- The gen-tie transmission lines would connect each project's on-site collector substations to the Rebuilt Boulevard Substation. The Rebuilt Boulevard Substation is not considered in this memo.

The 138-kV gen-tie line of Tierra del Sol solar farm would be carried northward from the on-site substation on an underground 138-kV cable along Tierra del Sol Road for approximately 0.5 miles, turn to the east for approximately 1-mile, at which point it would transition to an overhead 138 kV structure running northward to a point just east of Jewel Valley Road. At that point the gen-tie line would then again become an underground cable running for approximately 1.5 miles in segments that carry the line in a generally northeasterly direction toward its end at the connection with the Rebuilt Boulevard Substation. EMFs along the overhead portion would be typical for the adopted design typical of this voltage class with magnitudes and spatial extent in the surrounding environment determined by the specific structures and conductor design. Figure 2 illustrates the manner in which electric and magnetic fields attenuate with distance for typical transmission lines of three voltage classes. The magnitude of the peak EMFs and their strength at distances from the 138 kV gen-tie transmission line would likely be comparable to the 115 kV line illustrated with respect to peak magnitude and the decline in strength with distance. EMFs generated by the underground cable would generally be lower in magnitude and spatial extent, except that EMF magnitudes may be relatively high within several feet of an underground cable or cables. As for the overhead sections, magnitudes and spatial extent would be determined by the specific design. EMFs of all 138-kV transmission-line magnetic fields would be greater upon completion of Phase II than for Phase I alone.

The Rugged 69-kV transmission line to be constructed as an underslung overhead line for its entire length of approximately 2.75-miles would be the source of EMFs at levels typical for the adopted design in this voltage class. The magnitudes and spatial extent of environmental EMFs generated by the overhead 69-kV line would be determined by the specific structures and conductor design for the overhead transmission circuit and the specific cable design for underground portions. During operation, nearby EMFs would depend on interaction with the existing 138-kV Tule Wind Project line. Those interactions could reduce or increase total EMFs depending on operational and design factors. Figure 2 illustrates the manner in which electric and magnetic fields attenuate with distance for transmission lines of several voltage classes that are greater than 69 kV. The magnitude of the peak EMFs and their strength at distances from the 69 kV line would be significantly lower and follow a comparable rate of decline in strength with distance.

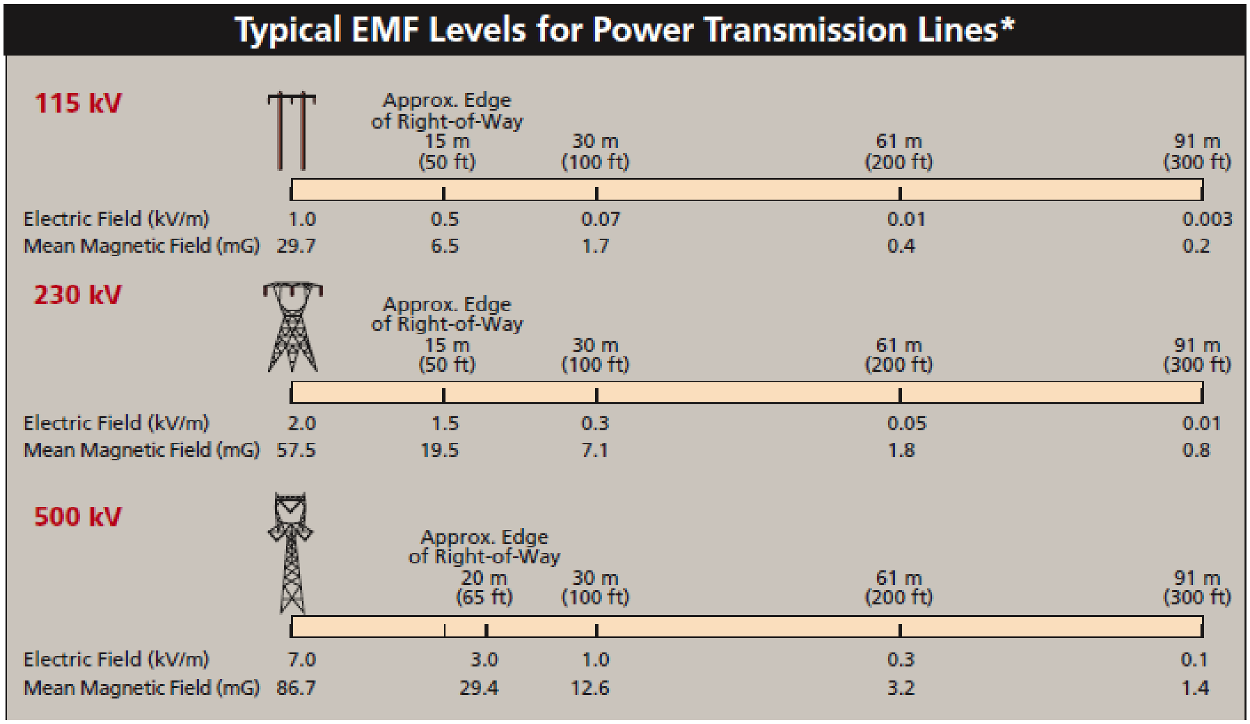
In general, common EMF exposures to the public vary over a range of field intensities and durations in reflection of sources in the home and work environments, electric power distribution system, and infrequently, from proximity to transmission lines. In contrast, for undeveloped and natural areas such as the Proposed Project area, EMFs greater than the very low natural background level are not present except in the vicinity of existing power line corridors, such as the 500 kV Southwest Powerlink (SWPL) that transects the Tierra del Sol project site and the 500 kV Sunrise Powerlink (Sunrise) transmission line that runs proximate to the Rugged project site. Rural areas that resemble undeveloped natural areas may have pole-mounted distribution circuits, and sometimes isolated residential, commercial and industrial buildings, but otherwise are characterized by low natural background EMF levels. Presently, public exposure to 60-Hz EMF in the project area at levels above those typical of residences would be limited to a strip of land parallel to the route for the underground and overhead 138-kV transmission line for Tierra del Sol, and a similar strip of land along co-existing Rugged 69-kV and Tule Wind Project transmission lines.

4 Typical Electric and Magnetic Fields of 60 Hz Transmission Lines

The Proposed Project gen-tie transmission lines will create electric and magnetic fields similar to those of other transmission lines of similar design, operating at the same voltage, and carrying similar currents. In the absence of particular designs for the 138 kV and 69 kV transmission lines of Tierra del Sol and Rugged projects, respectively, it is useful to consider the features of generic high-voltage AC transmission lines. Figure 2 illustrates that for all three voltage levels shown, and for the different support designs (dual poles or steel lattices, both with conductors suspended from a horizontal beam), both the electric and magnetic fields drop off in strength with distance from the tower.

For the 115 kV transmission line shown, the electric fields drops to approximately one-half of maximum at 50 ft from the tower and is just 7 percent of maximum at 100 ft. The magnetic fields drop to approximately one-fifth of maximum at 50 ft. and approximately 6% of maximum at 100

Figure 2



Source: (NIEHS 2002 p 37)

ft, with continuing decreases at greater distances. Numerous factors of a specific engineering design determine the actual field strengths and their patterns of decay with distance from the tower. The most significant design factors are line voltage, line current, conductor height above ground, and spatial arrangement of the conductors. In cases, there can be more than one circuit in parallel on the same right-of-way and two circuits on the same tower, as in the case of the 69 kV line of the Rugged Solar project that is placed beneath an existing 138 kV line. Nearby parallel circuits can reduce or increase the fields generated by one line in isolation depending on both design and operational factors. Most of the just-mentioned features of power transmission lines are fixed features of an installation, but load current and therefore magnetic field strength vary with the amount of power being transmitted. The power transmitted from a solar energy project varies with time-of-day, cloud cover, and seasonal changes in daylight duration.

5 Regulatory Standards and Guidelines for EMF Exposures

5.1 Scientific Background

For more than 45 years, questions have been asked regarding the potential health effects of EMFs from power lines resulting in a considerable body of research conducted to provide a foundation for a science-based response. Initial studies focused primarily on interactions with the electric fields from power lines. The subject of magnetic field interactions began to receive additional public attention in the 1980s as research increased in response to studies showing a possible association with cancer, particularly, childhood leukemia. A substantial amount of research investigating both electric and magnetic fields has been conducted worldwide over the past several decades. However, public health risks, particularly for magnetic field exposures to children, remain a subject of controversy because, according to many individual scientists and scientific panels that have reviewed the voluminous research findings, the data on that topic are inconclusive.

At sufficiently high levels, external extremely low frequency (ELF) fields can interact with - tissues through electrical effects due to currents induced in tissues and cells of the body. High-level effects of induced body currents are precluded if exposures are below the limits set by health and safety standards. (The process of induction is found widely in electrical technology. One common device relying on induction is the electric transformer where current in one coil induces current in another nearby coil. Similarly, an electromagnet powered by an alternating current works by inducing current in a nearby conducting metallic object, resulting in an attractive force that can lift the object. Contact with an electrical conductor stands in sharp contrast to induction and, of course, is the way in which electrical injuries occur.)

However, the electric currents induced by ELF fields commonly found in the environment – even those from transmission lines, substations, and transformers – are very weak when compared to certain electric currents that occur naturally in the body, such as those that control the beating of the heart and others generated by muscular activity. Only some utility employees get close enough to transmission lines and electrical machinery to experience induced electricity comparable to the electrical phenomena of natural biological functions. Of course, EMF-induced currents in the body also are vastly weaker than the currents found in electrical machines themselves, such as transformers, motors and magnets.

Research related to EMF can be grouped into four broad categories: a) mechanistic; b) cellular level studies; c) animal and human experiments; and d) epidemiological studies. Epidemiological studies, while carrying great weight in public health evaluations, have provided mixed results. Some studies show an apparent relationship between magnetic fields and health effects but other studies of comparable design do not. Laboratory studies with cells, animals, and humans, and studies investigating a possible mechanism for health effects (mechanistic studies) provide little or no evidence to support a magnetic field influence on health, especially, cancer.

Public interest and concern specifically regarding magnetic fields from power lines increased following publication in 1979 of the results of a single epidemiological study that observed an association between the wiring configuration on electric power lines outside homes in greater Denver and the incidence of childhood cancer (Wertheimer and Leeper 1979). Following publication of the Wertheimer and Leeper study, many epidemiological, laboratory, and animal studies regarding EMF have been conducted attempting to confirm the validity of the finding and determine a plausible mechanism, most of which focused on exposures to power-frequency magnetic fields.

The wide use of electricity results in background levels of EMFs in nearly all locations where people spend time – homes, workplaces, schools, cars, the supermarket, etc. A person's average exposure depends upon the sources they encounter, how close they are to them, and the amount of time they spend there. In most U.S.A. homes, background magnetic field levels average about 1 milligauss (mG) due to wiring within the home, electrical appliances, and power lines outside the home (Zaffanella 1993). Since the intensity of magnetic fields diminishes quickly with distance from the source, distance from a power line reduces the effect on the magnetic field level within the home. In fact, the strongest magnetic fields that are encountered indoors are from electrical appliances.

In accord with national findings, ambient magnetic fields in homes and buildings in several western states also averaged approximately 1 mG, and in rooms with appliances magnetic fields

Table 1. Typical 60-Hz Electric Field Values for Appliances at ~12 Inches

Appliance	Electric Field Strength (kV/m)
Electric blanket*	0.250
Broiler	0.130
Stereo	0.090
Refrigerator	0.060
Iron	0.060
Hand mixer	0.050
Phonograph	0.040
Toaster	0.040
Coffee pot	0.030
Vacuum cleaner	0.016
Electric range	0.004

Source: (Miller 1974 Table IV-VI).
* 1 to 10 kV/m next to blanket wires (Enertech Consultants 1985)

ranged from 9 to 20 mG (Severson et al. 1988; Silva et al. 1988). Immediately adjacent to appliances (within 12 inches), electric and magnetic field values are much higher, as illustrated in Tables 1 and 2 that indicate typical sources and levels of electric and magnetic field exposure from appliances for the general public.

5.2 Methods to Reduce EMF Levels

EMF levels from an AC transmission line can be reduced by shielding, field cancelation, or increasing the distance from the line. Shielding of electric fields can be actively accomplished by placing trees or other physical barriers along the transmission line ROW and by common building materials used in home construction. Magnetic fields can be reduced either by cancelation or by increasing distance from the source, but shielding a large volume is impractical and is used only in a few scientific research laboratories. Cancelation can be achieved between two or more nearby circuits by taking advantage of the three-phase design used in power transmission. Placement of conductors with oppositely-directed fields of the same magnitude close to each other on a tower or pole can reduce fields significantly. Similarly, underground cables usually place the three phase conductors close together, or even wrapped into one concentric cable, thereby obtaining considerable field cancelation nearby. Field cancelation techniques have has practical limitations because of the need to avoid arcing between phases if overhead high-voltage wires are placed too close together.

Although static electric fields also can be effectively shielded by trees and building materials, field-canceling configurations on towers and poles may not be practical. Concentric DC cables and bipolar DC cables placed close to each other have excellent field cancelation properties, comparable to those of AC cables.

For both AC and DC sources of EMFs, placement of overhead power line conductors at greater heights above ground, burying underground cables more deeply, and increasing the width of the ROW can achieve significant field reductions for nearby people.

Table 2. Magnetic Field Near Household Appliances

Appliance	Magnetic Field (mG) at 1 foot
Can opener	40 to 300
Coffee maker	1
Crock pot	1
Dishwasher	6 to 30
Electric range	8 to 30
Electric oven	1 to 5
Garbage disposal	8 to 20
Microwave oven	1 to 200
Mixer	5 to 100
Refrigerator	2 to 20
Toaster	3 to 7
Clothes washer	2 to 30
Clothes dryer	1 to 3
Fans / blowers	0.4 to 40
Iron	1 to 3
Portable heater	1 to 40
Vacuum cleaner	20 to 200
Baby monitor	0 to 2
Hair dryer	1 to 70
Electric shaver	20 to 100
AC adapter	0 to 7.5
Circular saws	10 to 250
Compact fluorescent bulb	0 to 0.1
Digital clock	0 to 8
Electric drill	25 to 35
Fluorescent fixture	2 to 40
Fluorescent desk lamp	6 to 20
TV (1980s era)	9 to 20
TV – flat screen LCD	0 to 2.5

Sources: (NIEHS and US DOE 1995); (EPRI 2012b)

5.3 Scientific Panel Reviews on Power-Frequency EMF

Numerous panels of expert scientists have convened to review the data relevant to the question of whether exposure to power-frequency EMF is associated with adverse health effects. These evaluations have been conducted in order to advise governmental agencies or professional standard-setting groups. In a typical procedure, scientific panels first evaluated the available studies individually, not only to determine what specific information they can offer, but also to evaluate the validity of experimental designs, methods of data collection, nature and quality of the data, data analysis, and suitability of the authors' conclusions. Subsequently, the individual studies, with their previously identified strengths and weaknesses, were evaluated collectively in an effort to identify whether there is a consistent pattern or trend in the data that would lead to a determination of possible or probable hazards to human health resulting from exposure to these fields.

Expert panel reviews have been prepared by international agencies such as the World Health Organization (WHO, 1984, 1987, 2001 and 2007) and the international Non-Ionizing Radiation Committee of the International Radiation Protection Association (IRPA/INIRC, 1990) and governmental agencies of a number of countries, such as the U.S. EPA, the National Radiological Protection Board of the United Kingdom, the Health Council of the Netherlands, and the French and Danish Ministries of Health. As noted below these scientific panels have varied conclusions on the strength of the scientific evidence concerning health risks from exposure to power frequency EMF.

The U.S. Congress passed legislation that resulted in EMF RAPID, a program of scientific research, public information, and health risk assessment to inform government policy. Its conclusions were derived from extensive analysis of existing scientific research and from the results of studies conducted under EMF RAPID in neurophysiology, behavior, reproduction, development, cell physiology, genetics, cancer, and melatonin (the hormone regulating circadian rhythm). In May 1999 the director of the National Institute of Environmental Health Sciences (NIEHS) submitted to Congress its report titled, "Health Effects from Exposure to Power-Line

Frequency Electric and Magnetic Fields," containing the following conclusion regarding power-frequency EMF health effects:

> Using criteria developed by the International Agency for Research on Cancer (IARC), none of the Working Group considered the evidence strong enough to label ELF-EMF exposure as a known human carcinogen or probable human carcinogen. However, a majority of the members of this Working Group concluded that exposure to power-line frequency ELF-EMF is a possible carcinogen. (NIEHS 1999)

In June 2001, a scientific working group of IARC (an agency of WHO) reviewed studies related to the carcinogenicity of EMF. Using the standard IARC classification system used for chemicals in the environment and foods, magnetic fields were classified as "*possibly carcinogenic to humans*" based on epidemiological studies. "Possibly carcinogenic to humans" is a classification used to denote an agent for which there is *limited evidence of carcinogenicity in humans* and *less than sufficient evidence of carcinogenicity in experimental animals*. Other agents identified as *possibly carcinogenic to humans* include gasoline exhaust, styrene, welding fumes, and coffee (WHO, 2001).

On behalf of the California Public Utilities Commission (CPUC), the California Department of Health Services (DHS) completed a comprehensive review of existing studies related to EMF from power lines, particularly those involving several potential health risks (Neutra et al., 2002). This risk evaluation was undertaken in 2000-2002 by three DHS staff epidemiologists using Bayesian analytic techniques instead of the weight-of-the-evidence approach used by other expert panels. The conclusions found in the executive summary are:

- To one degree or another, all three DHS scientists are 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. For adult leukemia, two of the scientists are "close to the dividing line between believing or not believing" and one was "prone to believe" that EMFs cause some degree of increased risk.
- All strongly believe that EMFs are not universal carcinogens because there are a number of cancer types that are not associated with EMF exposure.

· To one degree or another all three 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 sensitivity to EMFs. However, all three scientists had judgments that were "close to the dividing line between believing and not believing" that EMFs cause some degree of increased risk of suicide.

· All strongly believe that EMFs do not increase the risk of birth defects, or low birth weight.

The DHS scientists were more inclined to believe that EMF exposure increased the risk of the above health problems than the majority of the members of scientific committees that have previously convened to evaluate the scientific literature. With regard to why the DHS review's conclusions differ from those of other recent reviews, the report states:

> The three DHS scientists thought there were reasons why animal and test tube experiments might have failed to pick up a mechanism or a health problem; hence, the absence of much support from such animal and test tube studies did not reduce their confidence much or lead them to strongly distrust epidemiological evidence from statistical studies in human populations. They therefore had more faith in the quality of the epidemiological studies in human populations and hence gave more credence to them.

In addition to the uncertainty regarding the level of health risk posed by EMF, individual studies and scientific panels have not been able to determine or reach consensus regarding what level of magnetic field exposure might constitute a health risk. In some early epidemiological studies, increased health risks were discussed for daily time-weighted average field levels greater than 2 mG. However, the IARC scientific working group indicated that studies with average magnetic field levels of 3 to 4 mG played a pivotal role in their classification of EMF as a possible carcinogen.

An extensive WHO review (World Health Organization 2007) concluded that evidence for a link between extremely low frequency magnetic fields and health risks is based on epidemiological studies demonstrating a consistent pattern of increased risk for childhood leukemia. However, "...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." For the many other diseases considered and for numerous laboratory studies, the WHO panel found "inadequate" or "no evidence" of health effects at low exposure levels.

A 2009 European Commission report identified a research gap concerning the association of ELF EMF exposures with neurodegenerative diseases and put the need for a multidisciplinary research as "very important and given high priority based on their relevance for fundamental understanding of the issue and/or their relevance for public health" (Scientific Committee on Emerging and Newly Identified Health Risks 2009). In Australia, ARPANSA provides an EMF fact sheet that concludes, "The scientific evidence does not firmly establish that exposure to 50 Hz electric and magnetic fields found around the home, the office or near powerlines is a hazard to human health" (ARPANSA), and organizations such as ICNIRP (2009; 2010), ICES (2010), and ACGIH (2006) continue to review and refine their guidelines and standards.

EMF health issues continue to be the subject of research and examination in the context of regulatory standards and guidelines. EPRI, which describes itself as "the only organization in North America funding long-term, multidisciplinary EMF research," sponsors research and scientific meetings in areas of current interest, and provides a semi-annual public newsletter on EMF research (EPRI 2014).

5.4 Regulatory Standards and Guidelines for EMF Exposures: Policy in California

Government agencies outside the U.S.A. and international- and U.S.-based standards-setting bodies have developed detailed guidance for EMF exposure across a wide range of frequencies with specific focus on power-frequency EMF. Those shown in Table 3 are notable for extended reviews of the scientific literature, risk assessment narratives, and technical details far beyond those tabulated here. These scientific reviews consistently found no conclusive evidence of human health effects below the recommended standard or guideline levels and recognized as inconclusive the epidemiologic findings concerning an association of childhood leukemia with apparent magnetic field exposures. IEEE also developed detailed procedures for field measurements and computations (IEEE Std C95.3.1-2010 2010).

Table 3. Selected international and national standards and guidelines for exposure to 60-Hz frequency electric and magnetic fields (unperturbed rms values).

Source	E-field strength[(a)] (kV/m)	B-field strength[(a)] (mG)	Notes	Reference
General public				
Health Council of the Netherlands	4.17	833	Reference level, whole body	(Health Council of the Netherlands: ELF Electromagnetic Fields Committee 2000); (Health Council of the Netherlands 2008)
Health Protection Agency (UK)	4.17	833	Reference level, whole body	(Radiation Protection Division and Health Protection Agency 2005)
ICNIRP	4.17	833	Reference level, whole body	(ICNIRP 2010)
IEEE Std C95.6	5[(a)]	9040[(b)]	Maximum permissible exposure	(IEEE Std C95.6-2002 2002)
Occupational				
ACGIH; AIHA[(c)]	25	10,000		(American Conference of Governmental Industrial Hygienists 1991); (AIHA 2002)
ICNIRP, HPA (UK)[(d)]	8.33	4,170	Reference level, whole body	(ICNIRP 2010); (Radiation Protection Division and Health Protection Agency 2005)

Notes:
(a) Whole body; 10 kV/m within a powerline ROW.
(b) Exposure to head and torso; for arms or legs, MPE = 632,000 mG.
(c) Ceiling values (ACGIH: American Council of Government and Industrial Hygienists; AIHA: American Industrial Hygiene Association).
(d) These are reference levels (not exposure limits).

In the absence of conclusive findings of a health hazard from exposure to power-frequency EMF, there are no federal exposure limits at power-frequencies adopted as guidelines or put into law. However, various federal agencies have sponsored and collaborated on research and policy questions, including the Environmental Protection Agency (EPA), Department of Defense, National Institute of Occupational Safety and Health (NIOSH), Department of Energy (DOE), and National Institute of Environmental Health Sciences (NIEHS). The latter two agencies collaborated under the Congressionally mandated EMF RAPID program that concluded with the 1999 report to Congress cited above (NIEHS 1999).

Likewise, no state has determined there is conclusive evidence for adverse health effects of ELF EMF exposures, but several states have developed regulatory guidance for electric utilities and particularly new transmission line projects, in the face of uncertain and inconclusive research. In some states, only electric fields are considered, in others, only magnetic fields, and in others rules were developed for both field types. A 2002 white paper treats EMF policy considerations and reviews regulatory positions in several states (Minn. W.G. 2002). Table 4 below lists rules and guidance for transmission lines in 9 states. In cases, such as North Dakota, EMF level is not specified, but a right-of-way width is specified. Some rules were determined from existing right-of-way widths to set benchmarks for the corresponding field strengths. In contrast, Florida specifies maximum electric and magnetic fields at the edge of the right-of-way and within the right-of-way.

The Calilfornia Public Utilities Commission (CPUC) established (1995) and reaffirmed (2006a) an EMF policy that does not specify EMF field strength limits but instead requires new construction to use designs and equipment that result in lower environmental EMF levels. Implementation of the CPUC field reduction policy was formulated in terms of “low-cost, no-cost” steps for EMF reduction, where “low-cost” was set at roughly 4% of total project cost. Thus, during the design phase, new facilities for electricity generation, transmission, distribution and related substations can show compliance by no-cost steps such as, for example, selection of a design that reduces EMFs by the choice of overhead line electrical phasing that takes advantage of opportunities for EMF reduction by field cancelation. Relocation of substation electrical equipment on a substation site provides another example of a no-cost option. Methods of field reduction that increase project cost, such as increasing pole or tower height, or using underground cables would be appropriate and necessary if they result in numerically significant field reductions within a cost of approximately 4% of total project cost.

Table 4. Transmission line EMF-based siting considerations of selected states.*

State	Application	Location	Electric Field (kV/m)	Magnetic Field (mG)	Notes, References
California	Project	Project	[(a)]	[(a)]	California Public Utilities Commission, General Order 131-D (http://www.cpuc.ca.gov/PUBLISHED/Graphics/589.PDF); Decision D.06-01-042
Connecticut	Project	Project		best practices for no-cost/low-cost (4%) mitigation	Siting Council assess compliance with PA 04-286, PA 04-246, PA 07-4, and best mgt. practices http://www.cga.ct.gov/2001/rpt/2001-R-0666.htm, including special focus on sensitive receptors, and possible undergrounding. K.E. McCarthy, Health effects of electric and magnetic fields, # 2009-R-0280, Office of legislative Research, 8/5/2009,see (http://www.cga.ct.gov/2009/rpt/2009-R-0280.htm) (accessed 6/11/2013); www.ct.gov/csc/cwp/view.asp?a=3&q=311180)
Florida [(b)]	>500 kV	In ROW	15	--	Electric and Magnetic Field Regulations: S. 62-814.450 Florida Statutes; Ch. 62-814, Florida Register & Florida Administrative Code) https://www.flrules.org/gateway/ChapterHome.asp?Chapter=62-814
	" "	Edge of ROW & substa. boundary	5.5	250	
	≤500kV & >230kV	In ROW	10	--	
	" "	Edge of ROW & substa. boundary	2	200	Exception of 250 mG for double ckt. ROWs and certain other ROWs existing before 1989
	≤230 kV	In ROW	8	--	
	" "	Edge of ROW & substa. boundary	2	150	
Minnesota	> 200 kV	In ROW	8		
Montana [(b)]	> 69 kV	Edge of ROW	1		(Administrative Rules of Montana 2005)
	Road crossings	In ROW	7		

State	Application	Location	Electric Field (kV/m)	Magnetic Field (mG)	Notes, References
New Jersey	all	Edge of ROW	3	--	Guideline
New York	> 125 kV, > 1 mile length	Edge of ROW	1.6	200	Interim magnetic field standard for maximum design current.
	Public roads	In ROW	7		
	Public roads	In ROW	11		
	Other terrain	In ROW	11.8		
North Dakota	Route siting	Route	--	--	Avoid siting within 500 ft. of a residence, school, or place of business (EMFs not specified); may be waived; NDCC 49-22-08 (North Dakota 2013)
Oregon[b]	≥230 kV, ≥10 miles	In ROW	9	--	Energy Facility Siting Council

* The Edison Electric Institute Generation and Transmission Siting Directory provides state-by-state information on all aspects of power system siting, including EMF considerations in transmission line siting where rules exist (EEI 2012).

[(a)] Submit design plan that reduces EMFs at no cost or low cost (up to approximately 4% of project cost), prioritized by land use; usually applied to magnetic fields only

[(b)] Regulations in Florida, Montana and Oregon were codified.

6 Health and Safety Considerations for Static Electric and Magnetic Fields

Static (zero frequency) electric and magnetic fields will occur on each of the solar farm sites in association with the underground 1-kV DC collector systems within the boundaries of each project. As noted above in section 2.3, overhead high-voltage DC transmission lines that can operate at much greater voltages such as ±500 kV can create large static electric fields near the line. These high-voltage lines also create air ions and static magnetic fields that can come into consideration in environmental reviews. However, the Proposed Project involves a very different source of static EMF because the CPV trackers and underground 1-kV cables create EMFs that are localized to the immediate area near a CPV tracker or collector cable, and are expected to be insignificant outside the site boundary.

Specific quantitative data on the EMF produced by a CPV tracker and collector cable depend on the particular equipment used. Static electric fields can be measured with commercially available instruments based on the classic electric field mill design, while static magnetic fields can be measured with a variety of commercially available gaussmeters (magnetometers). Project electric fields can be considered in context of naturally occurring atmospheric electric fields that, as mentioned above (section 2.32.3), range from a fair-weather average of 130 V/m to much greater levels during storms and near high-voltage DC transmission lines. Static magnetic fields can be compared with the naturally occurring static geomagnetic field that is approximately 470 mG at the Proposed Project locations.

People can detect electrostatic fields of several thousand volt per meter, such as occur under storm clouds because hair on the arm, head or elsewhere becomes charged. The resulting small forces deflect the hairs, which stimulate touch sensors in the skin surface causing a tingling sensation. Slight movements of body hair in a strong electrostatic field are the mechanism for perception of a static electric field for all practical exposure situations (Reilly 1998 p 357). Electrostatic effects like these are sharply distinguished from effects of the considerable currents that can flow upon direct contact with a live electric conductor, potentially causing the serious hazards of electric shock. Project electrostatic fields can be anticipated to be lower than typical ambient atmospheric levels (that are of the order of 100 V/m) at distances of several meters from an aboveground conductor at 1 kV and at much closer distances from aboveground and underground cables. Consequently, both electrostatic effects and electric shock do not appear possible for off-site exposures from Proposed Project static electric fields.

Static magnetic fields at levels in the environment near CPV trackers, onsite DC cables, or in the general environment outside the Proposed Project solar farms, cannot be perceived by human beings. However, rapid head movement in very much stronger magnetic field can produce apparent light flashes (magnetophosphenes) in the visual field, providing a sensitive benchmark for magnetic field perception. Magnetophosphenes are due to stimulation of neuronal cells in the retina. The threshold for magnetophosphenes in an alternating magnetic field at 20-Hz (frequency of greatest sensitivity) is approximately 10 mT, or 100,000 mG. Magnetophosphenes also would occur if it were possible to move the head at a 20-Hz rate in a static magnetic of 10 mT or greater. From these considerations it is evident that the threshold static magnetic field for magnetophosphenes due to rapid head movement would be greater than 100,000 mG. For this reason, the very much weaker static magnetic fields of the proposed solar farm projects would be imperceptible.

Static magnetic fields at utility solar generation facilities have been measured and characterized with regard for electrical equipment found at solar facilities (EPRI 2012a). Measurements were made as close as 1 inch from equipment. At such close separations, static magnetic fields were measured at up to 2,000 mG at a DC fuse box and 3,000 mG at an inverter. The static fields attenuated to very much lower levels at distances greater than inches from the equipment and nowhere, including at the fuse box and inverter, did static magnetic fields exceed exposure guidelines of IEEE, ICNIRP or ACGIH (see Table 5).

In summary, the static electric and magnetic fields of the solar farm projects are highly localized, very much weaker than limits found in all safety guidelines, and imperceptible at all locations accessible to the public. They pose no known concern for human health.

Table 5. Guidelines for maximum permissible exposures to static (0-Hz) electric and magnetic fields.

Source	E-field strength (kV/m)	B-field (mT)	Notes	Reference
General public				
ICES-IEEE	5[(a)]	118 (1,180,000 mG)	Electric field: whole body exposure; Magnetic field: torso and head exposure	(IEEE Std C95.6-2002 2002; IEEE Std C95.3.1-2010 2010)
ICNIRP	[(c)]	400 (4,000,000 mG)	Magnetic field: applies to any part of body	(ICNIRP 2009)
Occupational				
ACGIH	25	60/600[(b)]	24-h average (TLV-TWA-8) for whole body/ extremities	(ACGIH 2011)
ICES-IEEE	20	353 (3,530,000 mG)	Magnetic field exposure to torso and head	(IEEE Std C95.6-2002 2002)
ICNIRP	[(d)]	2,000/8,000	head, trunk/limbs	(ICNIRP 2009)

Notes:
(a) Electric field limit is 10 kV/m within a powerline right-of-way.
(b) TLV-TWA-8 shown in table; ceiling values (not to exceeded): 2000/5000 mT for whole body/extremities; 0.5 mT for pacemakers and other implanted medical electronics (ACGIH: American Council of Governmental Industrial Hygienists).
(c) Limit at 1 Hz is 5 kV/m.
(d) Limit at 1 Hz is 20 kV/m.

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Research Physicist, Jerry L. Pettis Memorial Veterans Medical Center, Loma Linda, California. Electrophysiological research on invertebrate and mammalian nervous system interactions with ELF electric and magnetic fields. Theory of the biophysical transduction of ELF signals in biological systems. Design and develop instrumentation; design and develop computer techniques for data acquisition and data analysis. Design and develop apparatus for use by my colleagues in investigations of field exposure of cells, tissues and animals. Supervise technical personnel, manage laboratory and electronics shop. April, 1978–May, 1993.

National Institute of Environmental Health Sciences (NIEHS) Fellow and UCLA Postdoctoral Scholar, Environmental Neurobiology Laboratory (W.R. Adey, director) of the Brain Research Institute at UCLA (C.D. Clemente, director). Biophysics and physiology of the neuronal membrane; brain response to self-generated fields (EEG) and to external fields. Experimental research on invertebrate neurophysiology. May 1976–March 1978.

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Graduate studies in physics at State University of New York, Buffalo, New York. Instructor in astronomy and physics. Doctoral thesis research in experimental atomic and molecular physics (beam resonance spectroscopy); dissertation, "Elastic scattering cross sections of metastable barium on helium and argon." MS, June 1971, PhD, February 1975.

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"Attributable Fraction Estimates for EMF Exposures," NIEHS and DOE (RAPID Program), Principal Investigator, 1997–1999.

"Policy Analysis for Public Schools (K–12) and School District Day Care Centers Pertaining to Possible Health Effects from Power Frequency Electromagnetic Fields (EMFs)," California Department of Health Services and Public Health Institute of California, Electric and Magnetic Fields Program (under subcontract to EcoAnalysis, Inc.), 1995–present.

"Estimating the Potential Public Health Risks Attributable to Residential Exposures to Power Frequency Electric and Magnetic Fields Using Data from Epidemiologic Studies and Exposure Assessment Research, Southern California Edison Co., 1994–1996.

"Animal Models and Tissue Culture Studies of Possible Brain Tumor Promotion by Simulated Cellular Car Phone RF Fields," Motorola, Inc., (co-investigator), 1991–1993.

"Tissue Interactions with Non-Ionizing Electromagnetic Fields," U.S. Department of Energy (co-investigator), 1978–1993.

"Information Concerning Regulation of Electromagnetic Fields of Electric Power Facilities," State of Florida, Department of Environmental Regulation (principal investigator), 1986–1987.

Assay for Tumor Promotion by Sinusoidal 60-Hz Electric Fields Using C3H/10T1/2 Fibroblast Cultures," Southern California Edison Co. (co-investigator), 1986–1990.

"Tests of a Model for Macromolecular Migration on Myoblast Cell Surfaces Exposed to Alternating Electric Fields," Office of Naval Research (principal investigator), 1984–1986.

"Bioeffects of Electric Fields, Neurophysiological and Sensory Behavior: Studies of Frequency and Field Strength Dependencies," Southern California Edison Co. (co-principal investigator), 1979–1986.

"Cellular and Organismal Response to Combined Kilohertz and other Nonionizing Electromagnetic Fields," Office of Naval Research (co-investigator), 1984–1987.

"Electromagnetic Radiation and Biological Systems," National Center for Radio logical Devices (formerly Bureau of Radiological Health), Department of Health and Human Services (researcher), 1979–1983.

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Consultant to Nevada Energy – EMF health and safety (transmission line and substation) of Bordertown Project as subcontractor to Enertech (2012 -2013).

Consultant to EPRI – Preparation of resource paper on environmental, health and safety issues of HVDC transmission (2011- 2012).

Consultant to Seattle City Light -- framework for utility managers on issues of health and safety of power frequency electric and magnetic fields, Seattle, WA, 2009-present.

Consultant to City of Yucaipa on RF fields near a 4-G cellular network base station and related health & safety issues, 2009-2010.

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Chairman, NIH Center for Scientific Review, Special Emphasis Panel (Electromagnetics), Feb., 2008; Invited reviewer 1993 -

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California Department of Education— workshops on transmission line setback policy at school facilities, participant, contributor of written analysis and comments, 2005 – 2006.

ANATEL (Federal Telecommunications Agency) Brasilia, Brazil, 2000–2001.

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EMF Science Review Symposium for Epidemiological Research Findings, organized by the National Institute of Environmental Health Science for the NIEHS/DOE EMF *RAPID* Program.
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Member, Bioelectromagnetics Committee on a National Research Plan on Electric and Magnetic Field Health Effects Research, 1991–1992.

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Consultant to the Seattle City Council on policy, regulations, and scientific literature concerning non-ionizing radiation from telecommunications facilities (radiofrequency fields), Seattle, WA, 1991.

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Scientific Advisor, World Health Organization, "Working Group on Criteria Document on Health Effects of ELF Fields," Geneva, Switzerland, 1980–1984.

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Member, Scientific Advisory Panel on Health Effects of Electric Fields, Bonneville Power Administration, Vancouver, WA, 1980.

***HONORS and AWARDS*:**

Chairman, "Bioelectromagnetics 2005", Dublin, Ireland. Outstanding Environmental Analysis Document award (2005) by AEP San Diego Chapter as Dudek team member on CPUC/SDG&E Otay Mesa Power Purchase Agreement Transmission Project EIR. President (2001-2002) of The Bioelectromagnetics Society. EEEL Outstanding Paper Award, National Institute of Standards and Technology, 1994. NIEHS Fellow, 1974–1976. Listed in: Who's Who in American Science, Guide to Energy Specialists. Sternfeld Prize in Philosophy (1963). New York State Regents Science and Engineering Scholarship (1959–1963).

***MEMBERSHIPS*:**

American Association for Advancement of Science, American Physical Society, Bioelectromagnetics Society, European Bioelectromagnetics Association, Biophysical Society, Society for Neuroscience.

Bioelectromagnetics Society (BEMS) activities: Member, Long-range planning committee (2002-2005); President (2001-2002); Chairman, Publications Committee (1998-2001); Member, Board of Directors, (1998-2001; 1986–1989); chairman, Membership Committee (1987–1989).

***SELECTED INVITATIONS to SPEAK*:**

2006: Progress in Electromagnetics Research Symposium (PIERS), Cambridge, MA, March.

2004: Gordon Research Conference on Bioelectrochemistry, invited speaker and chairperson of session on biophysical mechanisms for RF and MRI, New London, CT, July; International workshop: "Biological Effects of Electromagnetic Fields", Kos, Greece, invited speaker and member of Advisory Committee, October;

2003: "Mobile Telephony and Health". Finnish National Research Programme 1998-2003, Helsinki, Finland, October 17.

2002: International workshop: "Biological Effects of Electromagnetic Fields", Rhodes, Greece; Workshop: "Epidemiological Considerations in Electromagnetics", (The Bioelectromagnetics Society), Washington, D.C.

2001: Asia-Pacific Radio Science Conference (International Union of Radio Scientists – URSI), Tokyo, Japan.

***LICENSURE*:**

General Radiotelephone Communications Certificate (formerly First Class Certificate), Federal Communications Commission, Washington, DC.

***PUBLICATIONS and REPORTS*:**

Kuehn S, Kelsh MA, Kuster N, Sheppard AR, Shum M, 2013. Analysis of mobile phone design features affecting radio frequency power absorbed in a human head phantom. Bioelectromagnetics 34(6):479-488.

Shum M, Sheppard AR, Zhao K, Kelsh MA, 2011. An evaluation of self-reported mobile phone use compared to billing records among a group of engineers and scientists. Bioelectromagnetics 32:37-48.

Kelsh MA, Shum M, Sheppard AR, McNeely M, Kuster N, Lau E, Weidling R, Fordyce T, Kuhn S, Sulser C. 2010. Measured radiofrequency exposure during various mobile-phone use scenarios. J Expo Sci Environ Epidemiol 21(4):343-354.

Sheppard AR, Swicord ML, Balzano Q, 2008. Quantitative evaluations of mechanisms of radiofrequency interactions with biological molecules and processes. Health Phys 95(4):365-396.

Balzano Q, Foster KR, Sheppard AR, 2007. Field and temperature gradients from short conductors in a dissipative medium. Online publication in Int. J. Antennas and Propagation 2007, 5760:1-8.

Swicord ML, Sheppard AR, Balzano Q, 2007: Comment on "Denaturation of hen egg white lysozyme in electromagnetic fields: A molecular dynamics study" [J. Chem. Phys. 126 091105 (2007)] J. Chem. Phys. 127, 117101; Online publication in JCP: BioChemical Physics at http://jcp-bcp.aip.org

Balzano Q, Sheppard AR (2007). RF Nonlinear Interactions in Living Cells–I: Non-equilibrium Thermodynamic Theory (erratum). Bioelectromagnetics 28(1):47.

Erdreich LS, Van Kerkove MD, Scrafford C, Barraj L, Shum M, MM, Sheppard AR, Kelsh MA. 2007. Factors that influence RF power output of GSM mobile phones. Radiation Research 168:253-261.

Sheppard AR, Blackman CF (eds) 2004. The Bioelectromagnetics Society: history of the first 25 years. Internet URL http://bioelectromagnetics.org/doc/bems-history.pdf. Frederick, MD: The Bioelectromagnetics Society, 44 p. Print copy available from cafepress.com, Hayward, CA.

NCRP Scientific Committee 89-4 (2003): Biological effects of modulated radiofrequency fields (NCRP Commentary No. 18). National Council on Radiation Protection and Measurements, Bethesda, MD, 52 p.

Balzano Q, Sheppard AR, 2003: RF Nonlinear Interactions in Living Cells–I: Non-equilibrium Thermodynamic Theory. Bioelectromagnetics 24:473-482.

Sheppard AR, Swicord, ML, 2002: Biophysical Considerations for Selection of Averaging Volumes for Radiofrequency Standards. Biological Effects of Electromagnetic Fields: 2nd International Workshop, October, Rhodes, Greece, p 712-718.

Sheppard AR, Glaser R (2002): Report from a Workshop on: "Physical Effects of Pulsed RF Fields at Microscopic and Molecular Dimensions (Microdosimetry)" December 2001, Dresden (Germany).

Balzano Q, Sheppard AR, 2002: The precautionary principle and sound public policy. Journal of Risk Research, 5(4):351-369.

Sheppard AR, Kavet R, and Renew DC (2002): Exposure Guidelines for Low-Frequency Electric and Magnetic Fields: Report from the Brussels Workshop. Health Physics 83(3):324-332.

Greenland S, Sheppard AR, Kaune WT, Poole C, Kelsh MA (2001): Pooled analysis of magnetic fields, wire codes, and childhood leukemia: In reply. Epidemiology 2001;12:472-474.

Glaser R, Portier C, Sheppard A (rapporteurs) (2001). Report from a Workshop on: "Biological and Biophysical Research at Extremely Low- and Radio-Frequencies". Forschungsgemeinschaft Funk, Bonn (Germany). Available (Dec. 2001) at: http://www.fgf.de/english/fup/meeting/index.html.

Greenland S, Sheppard AR, Kaune WT, Poole C, Kelsh MA (2000): A pooled analysis of magnetic fields, wire codes, and childhood leukemia. Epidemiology 9(6):624-634.

Sheppard, AR (2000): Environmental and ecological considerations for static and ELF electric power transmission line projects. Matthes R, Bernhardt JH, Repacholi M (eds): Effects of Electromagnetic Fields on the Living Environment, Proceedings, International Seminar on Effects of electromagnetic Fields on the Living Environment, Ismaning, Germany, ICNIRP 10/2000, p 211-230.

Sheppard, AR, Kelsh, MA, Florig, HK (1998): Health Risks and Costs That May Be Attributable to Electric and Magnetic Field Exposures in California Public Schools. Report to Public Health Insitute and California Department of Health Services, Oakland, CA, 51 pp.

Sheppard, AR (1998). Where does the energy go? Microwave energy absorption in biological objects on the microscopic and molecular scales (Chap. 13). In: GL Carlo (ed) *Wireless Phones and Health: Scientific Progress*. Boston: Kluwer Academic Publishers, pp. 165-175.

— (1997). Biological and Health effects of electric and magnetic fields from video display terminals. A technical Information Statement. COMAR VDT sub-committee, AR Sheppard, chairman. *IEEE Engineering in Medicine and Biology 16(3)*:87-92.

Sheppard, AR (1997). Biological research in North America (Chapter 7). In: Kuster N, Balzano Q, Lin JC (eds), *Mobile Communications Safety*. Chapman & Hall, London, pp. 173-193.

Sheppard, AR (in preparation, 1997). Significance and Limitations of Laboratory Studies on ELF Fields. Proceedings of the National Council on Radiation Protection and Measurements.

Sheppard, AR and Q Balzano (1995). Comments on "Absorbed Energy distribution from radiofrequency electromagnetic radiation in a mammalian cell model: effect of membrane-bound water," by Liu and Cleary. *Bioelectromagnetics 16(6)*:407.

Sheppard, AR (1995). Comments on "Trivial influences: a doubly stochastic poisson process model permits the detection of arbitrarily small electromagnetic signals." *Bioelectromagnetics 16:*12-16.

Sheppard, AR (1993). Epidemiologic and Laboratory Research on Potential Human Health Effects from Exposure to Power Frequency Electric and Magnetic Fields. A Background Paper. NTIS # PB-94114485. Minnesota Environmental Quality Board, St. Paul, August, 71 pp.

Misakian, M, AR Sheppard, D Krause, ME Frazier and DL Miller, 1993. Biological, Physical, and Electrical Parameters for In Vitro Studies with ELF Magnetic and Electric Fields: A Primer. *Bioelectromagnetics 14(Sup. 2)*:1-73.

Sheppard, AR and WR Adey, 1993. Electrical models for nerve cells exposed to ELF electric fields. In: *Electricity and Magnetism in in Biology and Medicine*, M Blank, ed. San Francisco Press, San Francisco, pp. 540-542.

Stell, M, AR Sheppard and WR Adey, 1993. The effect of moving air on detection of a 60-Hz electric field. Bioelectromagnetics 14(1):67-78.

Jones, RA and AR Sheppard, 1992. An integrated ELF magnetic-field generator and incubator for long-term in vitro studies. *Bioelectromagnetics 13(3):*199-207.

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Lyle, DB, X Wang, RD Ayotte, AR Sheppard, and WR Adey, 1991. Calcium uptake by leukemic and normal T-lymphocytes exposed to low frequency magnetic fields. *Bioelectromagnetics 12(3):145-156*.

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Sheppard, AR, 1987. Effects of a 60-Hz magnetic field on a spontaneously active neuronal system. Proceedings of the Ninth Annual Conference of the IEEE Engineering in Medicine and Biology Society, IEEE #87CH2513-0, Boston, November. pp. 79-80.

Lin-Liu, S and AR Sheppard, 1987. Tests of a model for macromolecular migration on myoblast cell surfaces exposed to alternating electric fields. Final Report on Contract N00014-84-K-0707, Office of Naval Research, Arlington.

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Bawin, SB, Sheppard, AR, Mahoney, MD, Abu-Assal, M and Adey, WR, 1986. Comparison between the effects of extracellular direct and sinusoidal currents on excitability in hippocampal slices. *Brain Research 362*: 350-354.

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Sheppard, AR, 1982. Biological effects of radio frequency radiation. In: Proceedings of the Lighting-Electromagnetic Compatibility Conference, R.R. Verderber, SM Berman, eds. LBL-15199, UC-95d. Lawrence Berkeley Laboratory, Berkeley, CA, March. pp. 9-23.

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Sheppard, AR, 1979. Magnetic interactions in man and other mammals: an overview. In: *Magnetic Field Effects on Biological Systems*, Tom S. Tenforde, ed., Plenum Press, New York, pp. 33-37.

Sheppard, AR, SM Bawin and WR Adey, 1979. Models of long-range order in cerebral macromolecules: effects of sub-ELF and of modulated VHF and UHF fields. *Radio Science*, *14*, No. 6S, 141-145.

Bawin, SM, AR Sheppard and WR Adey, 1978. Possible mechanisms of weak electromagnetic coupling in brain tissue. *Bioelectrochemistry and Bioenergetics*, *5*: 67-76.

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ABSTRACTS of SELECTED MEETING PRESENTATIONS:

Balzano Q, Sheppard AR, Bit-Babik G 2013. Medium Geometry: The Dominant Factor of In Vitro Exposure. Thirty-fifth Annual Meeting of BEMS, Thessaloniki, June.

Balzano Q, Sheppard AR, Bit-Babik G 2013. Thermal dosimetry and thermodynamics of in vitro rf bioassays. PIERS 2013 in Taipei, March.

Balzano Q, Sheppard AR, Bit-Babik G 2012. Thermal dosimetry and thermodynamics in test tubes and Petri dishes. EMC EUROPE 2012, International Symposium on Electromagnetic Compatibility, Rome, September 17-21.

Balzano Q, Sheppard AR 2011. A Simple Method to Compute Meniscus Effects on SAR at the bottom of Petri Dishes. Thirty-third Annual Meeting of BEMS, Halifax, Nova Scotia, June.

Balzano Q, Sheppard AR 2010. Considerations on the exposure of cell preparations in petri dishes. Thirty-second Annual Meeting of BEMS, Seoul, Korea, June.

Balzano Q, Sheppard A, Swicord M 2010. Considerations on the limitations of rf bioresearch. PIERS 2010 in Xi'an, CHINA, 22-26 March 2010.

Swicord ML, Balzano Q, Sheppard AR, 2010. A Review of Physical Mechanisms of Radiofrequency Interaction with Biological Systems. 2010 Asia-Pacific Symposium on Electromagnetic Compatibility, Beijing International Conference Center, April 12-16, Beijing, China.

Balzano Q, Sheppard A, Swicord M 2009. Establishing biophysical mechanisms of EM fields: Not an easy task. Thirty-first Annual Meeting of BEMS, Davos, Switzerland, June.

Sheppard AR, Balzano Q 2008. Would temperature-based exposure limits improve RF safety standards? Thirtieth Annual Meeting of BEMS, San Diego, June.

Shum M, Sheppard AR, Lau E, Erdreich L, Kuster N, McNeeley M, Kelsh M 2008. Factors Affecting Radiofrequency Power Output of Mobile Phones. Thirtieth Annual Meeting of BEMS, San Diego, June.

Kelsh M, Sheppard A, Shum M, Zhao K 2008. Recall Studies of Reported Mobile Phone Use: Analysis of Longer-Term Recall Accuracy: Summary of Existing Research and Implications for Epidemiologic Studies. Thirtieth Annual Meeting of BEMS, San Diego, June.

Balzano Q, Sheppard AR, Swicord ML 2008. Advances in rf bioeffect mechanisms. PIERS 2008 in Hangzhou, Hangzhou, China, 24 - 29 March.

Shum M, Erdreich LS, Van Kerkhove MD, Scrafford C, Barraj L, McNeely M, Sheppard AR, Kelsh M 2007. Factors that influence RF power output of GSM mobile phones. American Industrial Hygiene Association CE, June, Philadelphia, PA.

Sheppard AR 2006. RF interactions with biological molecules and processes: Quantifying thermal and non-thermal mechanisms. PIERS 2006 in Cambridge, Cambridge, USA, 26 - 29 March.

Shum M, Kelsh M, Lau E, Sheppard AR, Kuster N, McNeely M 2006. Correlation of power control setting to radiofrequency power levels from software modified phones. Twenty-eighth Annual Meeting of the Bioelectromagnetics Society (p 282), Cancun, Mexico.

Shum M, Kelsh M, Lau E, Sheppard AR, McNeely M, Kuster N 2006. Evaluation of Mobile Phone Handset Exposures Using a Portable Phantom System (p 63). Twenty-eighth Annual Meeting of the Bioelectromagnetics Society, Cancun, Mexico.

Kelsh M, Shum M, Fordyce T, Sheppard AR 2006. Evaluation of Power Output of Software Modified Mobile Phones as a Function of Time of Day. Twenty-eighth Annual Meeting of the Bioelectromagnetics Society (p 66), Cancun, Mexico.

Swicord ML, Sheppard AR 2005. Biophysical Mechanisms for Effects of RF Energy. 11th IPEM Annual Scientific Conference, Glasgow, 7-9 September.

Swicord ML, Sheppard AR 2005. Biophysical Mechanisms for Thermal and Non-thermal Effects of RF Energy. Kunming, China. The Fourth International Seminar on Electromagnetic Fields and Biological Effects. September.

Foster KR, Sheppard AR, Swicord ML 2005. What mechanisms are responsible for biological effects of RF fields? Froehlich Centenary International Symposium: Coherence and Electromagnetic Fields in Biological Systems, July 14, Prague, Czech Republic.

Sheppard AR. 2005. Cooperativity as an amplifier of physical effects in bioelectromagnetics. Twenty-seventh Annual Meeting of BEMS, Bioelectromagnetics 2005, Dublin, Ireland.

Sheppard AR, Swicord ML, Astumian RD, Balzano Q, Barnes FS, Glaser R, Foster KR, Prohofsky EW, Weaver JC 2005. Biophysical Mechanisms for Effects of RF Energy: Report of a Multi-investigator Review. II- Nonthermal Interactions. Twenty-seventh Annual Meeting of BEMS, Bioelectromagnetics 2005, Dublin, Ireland.

Swicord ML, Sheppard AR, Astumian RD, Balzano Q, Barnes FS, Glaser R, Foster KR, Prohofsky EW, Weaver JC 2005. Biophysical Mechanisms for Effects of RF Energy: Report of a Multi-investigator Review. I - Fields and Energy Absorption at Tissue, Cellular, and Molecular Levels. Twenty-seventh Annual Meeting of BEMS, Bioelectromagnetics 2005, Dublin, Ireland.

Weingart M, Kelsh M, Shum M, Sheppard AR, Kuster N 2005. Statistical analysis of the influences of technology, antenna, mobile phone shape and position on SAR measurements from FCC compliance testing data. Twenty-seventh Annual Meeting of BEMS, Bioelectromagnetics 2005, Dublin, Ireland.

Balzano Q, Sheppard AR 2005. Possible differences in the RF exposure of cells in test tubes versus flasks or petri dishes. Twenty-seventh Annual Meeting of BEMS, Bioelectromagnetics 2005, Dublin, Ireland.

Sheppard AR 2004. Magnitude of cooperativity required in models for nonthermal biochemical effects. 3rd International Workshop in Biological Effects of electromagnetic fields. October, Kos, Greece.

Sheppard AR, Balzano Q, Erdreich L, Swicord L, Kelsh MA 2004. Methods for estimation of exposures to radiofrequency energy from mobile phone base stations. International Society for Environmental Epidemiology (ISEE), August, New York City.

Sheppard AR, Balzano Q, Foster KR, Swicord ML 2004.New Perspectives On Rf Energy Absorption Over Brief Times And Small Distances For Molecular, Cellular, And Anatomical Systems. Twenty-sixth Annual Meeting of the Bioelectromagnetics Society, Washington, D.C.

Balzano Q, Sheppard AR, Foster KR, Swicord ML 2004. Field and temperature gradients in tissues near resonant short wires. Twenty-sixth Annual Meeting of the Bioelectromagnetics Society, Washington, D.C.

Kelsh M, Sheppard AR, Kuster N, Shum M, Fröhlich J, McNeeley M, 2004. Improving radiofrequency exposure assessment in epidemiologic studies of mobile phone users: an overview of research design and preliminary data. Twenty-sixth Annual Meeting of the Bioelectromagnetics Society, Washington, D.C.

Shum M, Sheppard AR, Kelsh M, Kuster N, Fröhlich J, McNeeley M, Chan N 2004. Pilot study to determine environmental factors that influence rf exposure from mobile phones. Twenty-sixth Annual Meeting of the Bioelectromagnetics Society, Washington, D.C.

Shum M, Kelsh M, Sheppard A, Chan N, Kuster N, Frohlich J, Erdreich L, Van Kerkhove M, McNeely M 2004. Improved assessment of cell phone exposure
for epidemiologic studies. May, AIHCE (American Industrial Hygiene Association & ACGIH), Atlanta.

Sheppard, AR 2003. Applying biophysics and dosimetry to research on biological effects of mobile phone radiofrequency energy. Proceedings, Mobile Telephone and Health. Final Seminar of the Finnish National Research Programme 1998-2003, Helsinki, October.

Sheppard AR, Balzano Q, Swicord ML, 2003. Exposure assessment for epidemiologic studies of exposure to EMFs from mobile telephone base stations. Twenty-fifth Annual Meeting of the Bioelectromagnetics Society, Maui, Hawaii, June.

Balzano, Q and AR Sheppard, 2002. Thermodynamic theory and experimental methods for detection in vitro of nonlinear interactions of rf energy with biological cells. Twenty-fourth Annual Meeting of the Bioelectromagnetics Society, Quebec City, Quebec, Canada, June.

Balzano, Q and AR Sheppard, 2001. A test for demodulation of rf energy by non-linearities of cellular preparations. Twenty-third Annual Meeting of the Bioelectromagnetics Society, St. Paul, MN, June.

Sheppard AR, Kelsh MA, Kaune WT, Greenland S, Mrad R, 1999. Estimates of the attributable fraction of childhood leukemia in relation to power frequency magnetic fields from pooled data of thirteen epidemiologic studies. Twenty-first Annual Meeting of the Bioelectromagnetics Society, Long Beach, Cal., June.

Greenland S, Sheppard AR, Kelsh MA, Kaune WT, 1999. A pooled analysis of magnetic fields, wire code, and childhood leukemia. Society for Epidemiologic Research, June.

Sheppard AR, Kelsh MA, Florig HK, 1999. Background risks and health care costs for diseases potentially related to exposure to power frequency electric and magnetic fields. Twenty-first Annual Meeting of the Bioelectromagnetics Society, Long Beach, Cal., June.

Sheppard AR, Swicord ML, 1999. How large a tissue volume is required for averaging microwave heating of biological tissue? Implications for safety standards. Twenty-first Annual Meeting of the Bioelectromagnetics Society, Long Beach, Cal., June.

Sheppard AR, Kelsh MA, Kaune WT, Greenland S, 1998. Estimated attributable fraction for childhood leukemia in association with residential power frequency magnetic field exposures. Twentieth Annual Meeting of the Bioelectromagnetics Society, St. Pete Beach, June.

Swicord ML, Balzano Q, Sheppard AR, 1998. Microdosimetry is not relevant to microwave biological research. Twentieth Annual Meeting of the Bioelectromagnetics Society, St. Pete Beach, June.

Sheppard AR, Kelsh MA, Kaune WT, Greenland S, 1997. Unified magnetic field exposure assignments for epidemiologic studies of childhood cancer. Annual Review of Research on Biological Effects of Electric and Magnetic Fields from the Generation, Delivery & Use of Electricity, US Department of Energy, Electric Power Research Institute, San Diego, November.

Sheppard AR, Florig HK, Jostes J, Geissinger LG, Bernstein B, Henrion M, 1997. A guidebook for local agencies and communities facing emf issues in california public schools and daycare centers. Annual Review of Research on Biological Effects of Electric and Magnetic Fields from the Generation, Delivery & Use of Electricity, US Department of Energy, Electric Power Research Institute, San Diego, November.

Sheppard AR, 1996. Models for bioelectromagnetic interactions are unified by the dielectric properties of living systems. Third Annual Michaelson Research Conference, Colorado Springs, August.