Electric and Magnetic Fields (EMF) Memo

Overview of EMF:

- Electric fields are produced by voltage, or the pressure behind the flow of electricity, while magnetic fields are produced by current
- Electric fields are measured in volts—or kVs—per meter (V/m and kV/m, respectively), and magnetic fields are typically measured in milliGauss (mG)
- EMF levels rapidly decrease in strength as the distance from the source increases.
- This analysis area is based on scientific modeling that demonstrates that EMF levels from electrical facilities are measurable up to 300 feet, after which, according to the World Health Organization, field strength diminishes to background levels equivalent to those found far away from electrical facilities (World Health Organization 2018).
- At distances greater than 300 feet, electric and magnetic fields produced by electrical facilities cannot be distinguished from those present from other background sources found in the environment.
- Solar facilities produce negligible electric fields.[1]

Overview of High-Voltage Lines and Substation at the Palmer-Williams Creek WSEO:

In the project area, there is:

- Two 345-kV lines owned by Public Service Company of Colorado (Xcel)
- Two 115-kV lines owned by Tri-State Generation and Transmission (Tri-State)
- One 230-kV line owned by Colorado Springs Utilities (CSU)

The table below presents typical electric and magnetic fields resulting from standard distribution, 115-kV, and 345-kV transmission lines, compared with the International Commission on Non-Ionizing Radiation Protection (ICNIRP) recommended exposure limits These EMF levels are the expectations for existing transmission lines at the point of interconnection and location of the proposed Williams Creek Substation:

Line Voltage*	Exposure Limit†	Center Line (Peak Value)	100 Feet	200 Feet	300 Feet
24 kV					
Electric (kV/m)	4.2	0.04	0.0	0.0	0.0
Magnetic (mG)	2,000	14.0	0.0	0.0	0.0
115 kV					
Electric (kV/m)	4.2	1.0	0.07	0.01	<0.01
Magnetic (mG)	2,000	30.0	1.7	0.4	0.2
345 kV					
Electric (kV/m)	4.2	4.5‡	0.7	0.2	0.06
Magnetic (mG)	2,000	72.1	9.9	2.5	1.1

Source WAPA (2017).
* By comparison, the average household background magnetic field range is 1–2 mG, with the average electric field up to 0.02 kV/m (20 volts) (WAPA 2017).
† Electric and magnetic field levels for 24 kV line are adapted from Hydro-Québec (2011).
‡ Exceeds ICNIRP 2010 continuous exposure limit for the general public.

[1] *See* "Electromagnetic Fields Associated with Commercial Solar Photovoltaic Electric Power Generating Facilities". Available at https://www.ncbi.nlm.nih.gov/pubmed/26023811

Palmer and Williams Creek Substation EMF Impacts

34.5 Distribution Line

EMF resulting from 34.5-kV distribution infrastructure are undetectable outside the transmission corridor. The 34.5-kV transmission line operates at the distribution level where electromagnetic field measurements will be very low (see table above). Distribution lines associated with the proposed project would not impact the health of those living in nearby residences.

230-kV Transmission Line

The 230-kV transmission line between the two substations is approximately 1500 feet. As detailed in the Project layout and Interconnection Insert (see WSEO Map Plan), the immediately adjacent area has five other high-voltage transmission lines. Additionally, the closest residence is over 1.5 miles away. Electromagnetic fields at this distance will not be detectable.

Of relevance, an Environmental Assessment completed by Department of Energy in 2015 looked at electromagnetic fields from transmission lines in a review of impacts from solar facility interconnection and found the following:

> "Transmission lines operate at a power frequency of 60 Hz; at this frequency, for a 230kV transmission line there would be an average EMF level of approximately 58mG directly under the line, and an average level of approximately 7.1mG at a distance of 100 feet. Household electrical appliances also operate at 60 Hz. Examples of measured average magnetic field levels for household appliances include: 8mG for an electric oven, 60mG for a vacuum cleaner, and 150mG for a can opener. This demonstrates that EMF levels within the home can be much higher than those of transmissions lines depending on the size of the line and proximity to the source, though home appliances are often operated less frequently than a transmission line." [2]

Williams Creek Substation

As it pertains to the Williams Creek substation, the following features are important to note:

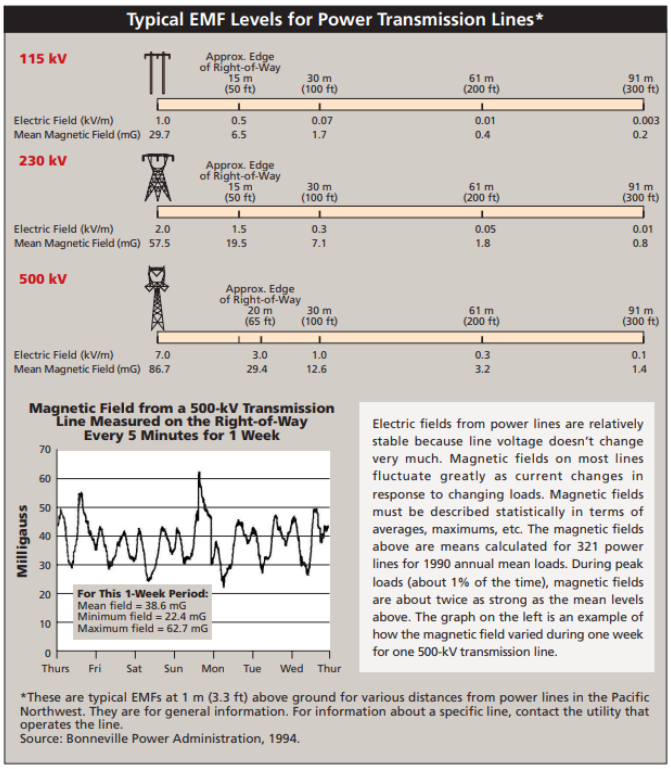
- Substations are not major sources of EMF beyond the extent of the perimeter fence [3]
- Substations produce electric fields of less than 0.1 kV/m and magnetic fields of less than 1 mG because EMF are substantially reduced by typical equipment spacing and local shielding
- According to the World Health Organization, EMF field strength diminishes to background levels usually around 300 feet
- Operating substations produce EMF from some electrical equipment, including transformers and auxiliary components. Most of this equipment is enclosed within metal casing/housing, which eliminates electric fields but not magnetic fields

[2] *See* The Cliffrose Solar Interconnection Project Environmental Assessment (EA-1989) available at: https://www.energy.gov/sites/prod/files/2015/05/f22/EA-1989_Cliffrose_DEA_2015-05.pdf

- The main source of EMF associated with substations is the overhead transmission lines going in and out of the substation facility [4]

The predominate source of EMF will not be from the new Williams Creek Substation or the small distance of additional 230-kv between the Palmer Substation and the Williams Creek Substation. Instead, the existing 345-kV transmission line operated by Xcel will be the main source. As identified in review by Western Area Power Agency and an Environmental Assessment completed by the Bureau of Land Management, electric and magnetic fields don't combine like sound.[5] [6] One field typically only need to be slightly higher to dominate or cancel the other one out. The existing 345-kV line is assumed to be the primary driver of any measurable EMF. No residences are located within a distance that would raise concerns regarding substation or transmission line EMF.

Exposure to these EMF would be limited to within the substation parcel because substations are not major sources of EMF beyond the extent of the substation perimeter fence (National Radiation Lab 2008; WAPA 2017). Especially in light of location and distance, the health of residents in the general area would not be a concern or affected.



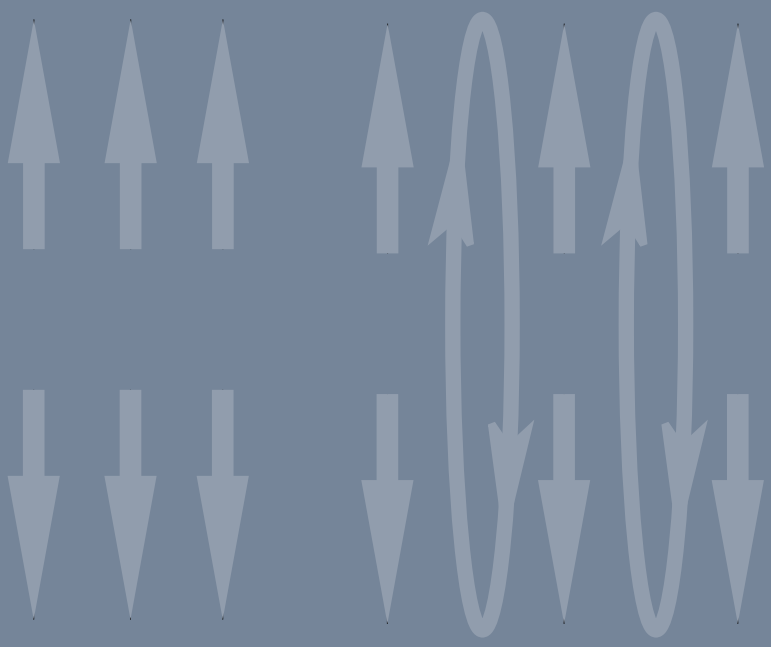
[4] *See* Talvera Substation and Distribution Project Environmental Assessment available at: https://eplanning.blm.gov/epl-front-office/projects/nepa/68992/155696/190517/AUGUST_2018_Environmental_Assessment_EA_Talavera.pdf

[5] *See* Electric and Magnetic Fields at: https://www.wapa.gov/newsroom/Publications/Documents/EMFbook.pdf

[6] Electromagnetic fields (EMF): What are electromagnetic fields? Available at: http://www.who.int/peh-emf/about/WhatisEMF/en/index3.html

Electric and Magnetic Fields

FACTS



NEXT PAGE

WESTERN AREA POWER ADMINISTRATION

EMF Units

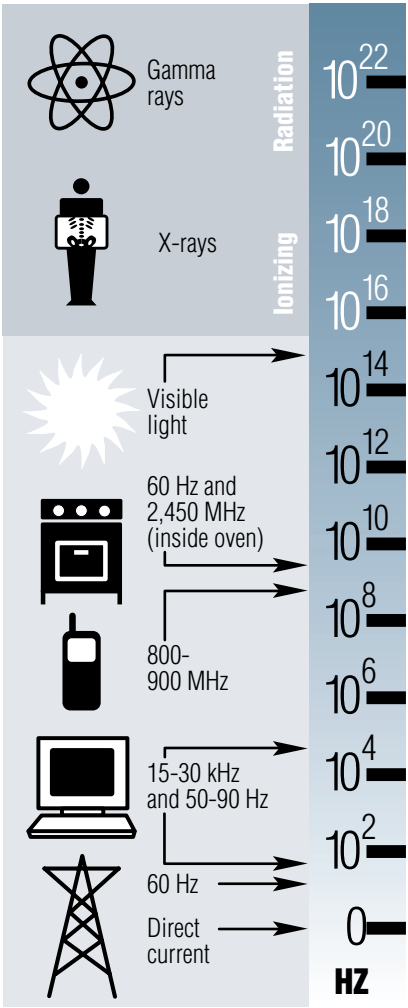
Electric Fields

Usually measured in volts per meter (V/m)
For large fields the units usually used are:
1 kilovolt per meter (kV/m) =
1,000 volts per meter

Magnetic Fields

Usually measured in milliGauss (mG)
Other units sometimes used:
1 microTesla = 10 milliGauss
1 Amp/meter = 0.1257 milliGauss

Electromagnetic Spectrum



Frequency is shown in Hertz (Hz). 1 Hz = 1 cycle per second. (Note that 10^4 means 10x10x10x10 = 10,000 Hz, etc.) kHz = kilohertz = 1000 Hz, MHz = megahertz = million Hz.

Electric power lines are familiar to all of us. They have different shapes, different sized poles and varying numbers of wires. We may not be able to guess how much power they carry, but we all know what they do: they bring electric power to our homes and businesses.

Many of the dramatic improvements in health, safety and quality of life that we benefit from today could not have happened without a reliable and affordable electric supply. But could electricity be bad for our health? Electric and magnetic fields are present wherever electricity is used. Do these fields cause cancer or any other diseases, as some have suggested?

These important and serious questions have been investigated thoroughly during the past three decades. Several tens of millions of dollars have been spent worldwide.

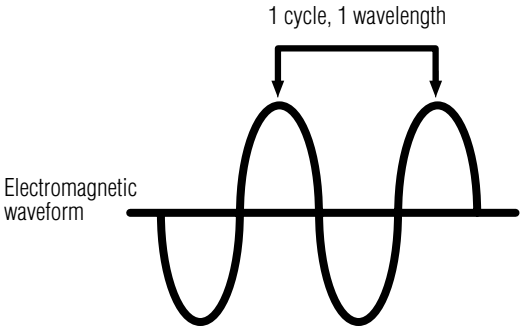
Research on EMF still continues because no clear answers have been found. The balance of scientific evidence to date indicates that these fields do not cause disease. This discussion outlines the EMF issue, summarizes the research conducted to date, and describes what Western Area Power Administration is doing to address concerns about EMF.

Electric and Magnetic Fields

EMFs are produced both naturally and as a result of human activity. The earth has both a magnetic field produced by currents deep inside the molten core of the planet, and an electric field produced by electrical activity in the atmosphere, such as thunderstorms.

A primary characteristic of any field is the frequency. The frequency describes how rapidly an electric or magnetic field oscillates, or cycles backward and forward every second, and is measured in hertz. The earth's electric and magnetic fields do not oscillate. They are called static fields and have a frequency of 0 Hz. Electricity produced in North America produces fields at a frequency of 60 Hz, or 60 cycles per second, and are known as "extremely low frequency" or "power frequency" fields. Fields at that frequency carry very little energy and are only one small part of the electromagnetic spectrum that ranges from fields at a frequency of 0 Hz to frequencies in excess of trillions of Hz. Computers, radios, televisions, cellular telephones, microwave ovens, X-ray equipment and other devices we use daily operate using frequencies within this spectrum. The science and effects of higher frequency fields are quite different from the 60Hz fields this brochure focuses on.

Electromagnetic Waveform



Power frequency electric and magnetic fields occur through human activity wherever electricity is generated, transmitted and used.

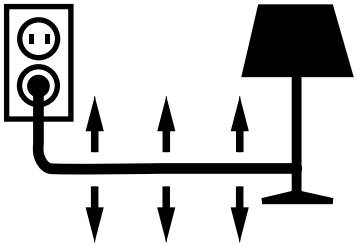
The Difference Between Electric and Magnetic Fields

Electric fields

Electric fields are produced by voltage. Voltage is the pressure behind the flow of electricity. It can be compared to the pressure of water in a hose. Voltage creates electric fields around any electrical device that is plugged in—even if it is not operating. For instance, plugging a lamp or hair dryer

into a wall socket applies voltage to the cord, surrounding it with an electric field. Electric fields are strongest closest to the source and with higher voltages, but decrease rapidly within a short distance from the source. Walls, roofs, trees and vegetation also weaken or shield electric fields. Electric fields are measured in volts per meter.

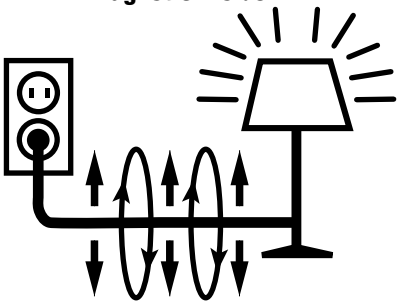
Electric fields



1. Produced by voltage.
   Lamp plugged in but turned off.
   Voltage produces an electric field.
2. Measured in volts per meter (V/m) or in kilovolts per meter (kV/m).

   1 kV = 1000V
3. Easily shielded (weakened) by conducting objects like trees and buildings.
4. Reduced in strength with increasing distance from the source.

Magnetic Fields



1. Produced by current
   Lamp plugged in and turned on.
   Current now produces a magnetic field, also.
2. Measured in gauss (G) or tesla (T)
   1 milligauss (mG) = 0.1 microtesla (μT) milli (m) = 1 thousandth
   micro (μ) = 1 millionth.
3. Not easily shielded (weakened) by most materials.
4. Reduced in strength with increasing distance from the source.

Magnetic fields

Magnetic fields are produced by current, which is the flow of electricity. Current is measured in amperes, or amps, and is similar to the volume of water flowing in a hose when the nozzle is open. Current must be flowing before magnetic fields can be produced. For example, turning on an electric appliance causes magnetic fields to surround the cord and appliance. Magnetic fields are strongest closest to the source, and increase with higher current flow; they also decrease with distance from the source. Unlike electric fields, magnetic fields are not affected by walls or trees, and primarily depend on distance from and strength of the source. Magnetic fields are commonly measured in milliGauss (mG) and in microTeslas (μT).

Typical 60 Hz magnetic field levels from some common home appliances

	Magnetic field 6 Inches from appliance (mG)	Magnetic field 2 feet away (mG)
Electric shaver	100	-
Vacuum cleaner	300	10
Electric oven	9	-
Dishwasher	20	4
Microwave oven	200	10
Hair dryer	300	-
Computers	14	2
Fluorescent lights	40	2
Faxogram machines	6	-
Copy machines	90	7
Garbage disposals	80	2

Exposure

Standards and Guidelines

It is not known if any EMF levels are unsafe. Some nongovernmental organizations have set advisory limits as a precautionary measure based on the knowledge that high levels of fields (more than 1,000 times the EMF found in typical environments) may induce currents in cells or stimulate nerves. The International Commission on Non-Ionizing Radiation Protection has established a continuous magnetic field exposure limit of 0.833 Gauss (833 mG) and a continuous electric field exposure limit of 4.2 kV/m for members of the general public. The American Council of Governmental Industrial Hygienists publishes Threshold Limit Values for various physical agents. The TLV for occupational exposure to 60 Hz magnetic fields has been set as 10 G (10,000 mG) and 25 kV/m for electric fields. Several states have set guidelines for electric and magnetic field levels that must be met for newly constructed transmission lines. These levels at the edge of right-of-way are about 2 kV/m

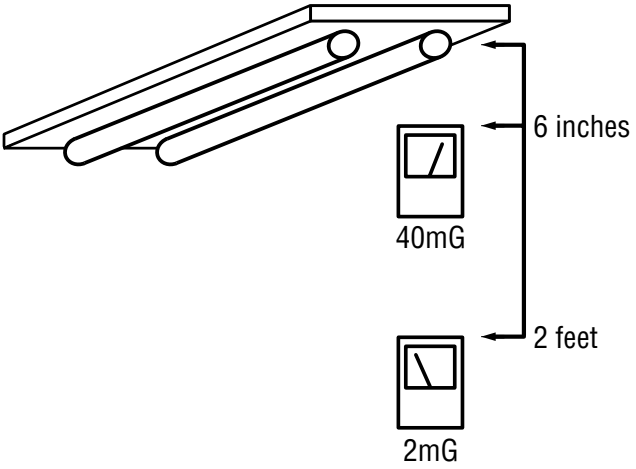
for electric fields and 200 mG for magnetic fields. In most cases, the values are maximum fields that existing lines produce at maximum load-carrying conditions. Researchers have used 2 mG in several studies as the threshold magnetic field value to differentiate between average exposed and more exposed persons. This is based on average fields found in homes, and not for any scientific reason.

Natural sources

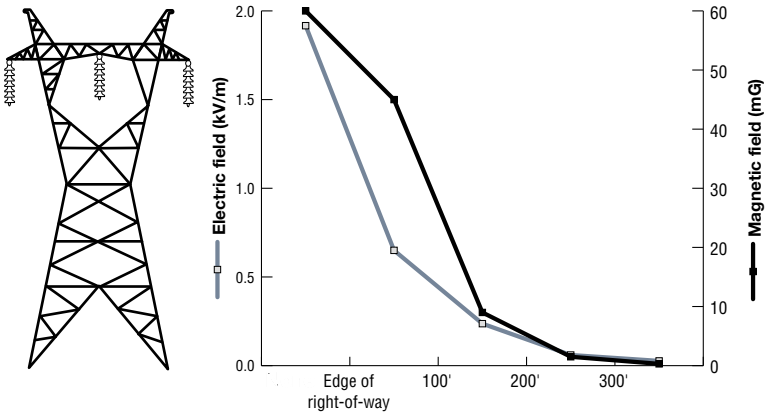
The earth's fields are static, or 0 Hz frequency. The earth's magnetic field which everyone is constantly exposed to is about 500 mG. The earth's electric field is about 100 V/m, but thunderstorms can temporarily increase the field in a given location to several thousand V/m.

Sources within the home

In the home, in addition to the earth's natural fields, there are power frequency fields. All electric appliances produce electric and magnetic fields with a 60 Hz frequency. Fields are greatest closest to the surface of the cord and appliance and drop rapidly in just a short distance. The average household background 60 Hz magnetic field is about 1 to 2 mG. The average background 60 Hz electric field is 1 to 20 V/m.



Typical field level



Typical EMF levels for a 230-kV transmission line

Overhead lines

All overhead lines produce fields. The fields are usually the highest directly under the lines and fall rapidly with distance to the sides of the line. Actual field strengths will, of course, vary depending on the height of the conductors from the point of measurement.

Typical 60 Hz electric and magnetic field levels from overhead power lines

Line voltage	Centerline	Approx. edge of right of way	100 feet	200 feet	300 feet
115 kV					
Electric field kV/m	1.0	0.5	0.07	0.01	0.003
Magnetic field mG	30	6.5	1.7	0.4	0.2
230 kV					
Electric field kV/m	2.0	1.5	0.3	0.05	0.01
Magnetic field mG	57.5	19.5	7.1	1.8	0.8
500 kV					
Electric field kV/m	7.0	3.0	1.0	0.3	0.1
Magnetic field mG	86.7	29.4	12.6	3.2	1.4

Electric fields from power lines are relatively stable because voltage does not change. Magnetic fields fluctuate greatly as current changes in response to changing load. The magnetic fields above are calculated for 321 power lines for 1990 mean loads.

Underground lines

Underground lines can produce higher magnetic fields directly above them than an overhead line would produce at ground level, because the buried cable is closer to the ground surface. Magnetic fields fall away more rapidly than from overhead lines because of some shielding from the earth. There are no external electric fields produced because of the shielding from the earth. Underground lines are more expensive to install and more difficult and expensive to repair than overhead lines. Because of heat generated at higher voltages, most underground cables are lower voltage distribution lines, such as those that provide power to residential neighborhoods.

Substations

EMFs are produced within electric substations, but due to the spacing of electrical equipment measured field strengths are low outside the fence line. Fields close by a substation are mainly produced by the entering power lines.

Other field sources

We are surrounded daily with fields from many other sources having frequencies different than 60 Hz. These sources include emissions from computers, radio and television towers, cellular telephones, weather and air traffic control radar, military and commercial communications systems, household and industrial remote control devices, intrusion detection equipment and many others. Fields from 60 Hz electrical systems are a very small sliver of the total natural and man-made electromagnetic spectrum environment we live in.

Stray voltages

Sometimes, cattle and dairy farmers express concern about a herd's behavior, weight loss or decreased milk production and blame EMFs from nearby transmission or distribution lines. Investigation of the situation normally shows the cause to be stray voltages. Stray voltages are from deteriorating wiring, or defective, or improperly wired or grounded, equipment. While standing on damp earth or other conductive ground, the animal receives a small electric shock when contacting parts of milking equipment, electrically heated or pumped watering facilities or other electric equipment around the farm. Electric companies usually offer stray voltage diagnosis services.

Research into Potential Health Effects

With any issue that involves human health, it is important that scientific research be conducted to find out about possible causes, effects and solutions. Three main types of research are being conducted to determine if EMFs could be related to disease.

Epidemiology

Epidemiology is the study of patterns of disease in populations. Epidemiology looks for any statistical link between exposure to EMF and disease in human populations. Concerns about EMFs were first raised in an epidemiological study when two scientists suggested that levels of fields encountered in some homes might lead to childhood cancer. Since then, other diseases including adult cancers, heart disease, Alzheimer's disease and depression have been examined to determine if there could be a link between them and EMFs.

Epidemiology can only look at populations and observe statistical associations. It cannot eliminate the many other possible factors that could determine the development of diseases and, therefore, cannot prove whether a particular disease is caused by EMFs.

About 20 epidemiological studies have been performed looking at the possible link between magnetic fields and childhood leukemia. Several other studies have looked at other diseases in relationship to magnetic fields for the general population and in the workplace. Some studies have found a weak association with magnetic fields, and others have not. Where there is association suggested, it is usually very near the statistical threshold of significance. When these studies are repeated, the results are generally not reproduced. Replication of results is a basic test of scientific validity. Research continues to look at magnetic fields until a more certain conclusion can be reached.

Very little evidence exists to confirm that electric fields have any association with childhood cancer, and some research suggests specifically they do not.

Theoretical

Theoretical research looks for a possible mechanism that can demonstrate how the fields could react with living systems. A variety of theories have been put forth over the years but no such mechanism has been found that would operate at the levels of fields seen around homes or near power lines.

Biological

The test of any proposed theory or proposed health risk is biological research in the laboratory to observe the effects of EMFs on cells, tissues and organisms. Scientists look for effects that can be successfully replicated in different laboratories for proof that a cause-and-effect relationship exists. Hundreds of EMF-related biological research projects have been conducted. In 30 years of research, there have been no such reproducible results. The evidence from the laboratory is that low EMF levels of the kind experienced by the public do not cause the diseases that have been claimed.

Our use of electricity has increased exponentially over the past 100 years, likely resulting in greater daily exposures to power frequency EMFs. In general, it has been found that rates of cancer, considering improved diagnostic methods, have remained level or decreased somewhat. While many other variables are unaccounted for, these two observations would suggest that exposure to normal 60 Hz field levels is not a major human health issue.

EMF Research References

Research related to possible adverse health effects of EMFs has been in progress for more than 30 years. It is not reasonable to list or summarize the results of past and ongoing research in this document because of the great amount of information. Work conducted by the National Institute of Environmental Health Sciences/Department of Energy EMF Research and Public Information Dissemination Program provides EMF research information and references. The publication *Electric and Magnetic Fields Associated with the Use of Electric Power, Questions and Answers* prepared under the NIEHS/DOE EMF RAPID program, specifically Chapter 6, National and International EMF Reviews, and Chapter 7, References, supplies a comprehensive summary and listing of research. The document is available online at **http://www.niehs.nih.gov/emfrapid**. Another NIEHS report is *Questions and Answers, EMF in the Workplace*.

Additional EMF information resources are available from:

California Department of Health Services
California EMF Program
http://www.dhs.ca.gov/ps/deodc/ehib/emf/general.html

Medical College of Wisconsin, Electromagnetic Fields and Human Health
http://www.mcw.edu/gcrc/cop/powerlines-cancer-FAQ/toc.html

Environmental Health Information Service
http://ehis.niehs.nih.gov/

Microwave News
http://www.microwavenews.com

World Health Organization
http://www.who.int/emf

Limiting Exposure to EMF

Research has not determined if exposure to EMFs could be a health risk. Scientists are studying long-term exposure to low fields, exposure to certain transient waves and other kinds of EMFs. You may prefer to take low- and no-cost steps to limit your exposure to strong fields as a way to reduce potential risk. Some scientists call this "prudent avoidance." For instance, you might:

- Move your motor-driven electric clocks or other electrical devices away from your bed.
- Stand away from an operating microwave oven or other appliances that use a lot of electricity.
- Sit away from the TV and at least an arm's length away from the computer screen and processing unit.
- Decide to use a safety razor instead of an electric one.

While steps like these may lower your exposure to 60 Hz fields, it is far more difficult to limit exposure to EMFs in the rest of the vast electromagnetic spectrum. It is virtually impossible to reduce exposure to broadcast frequencies and radar, for instance. Some scientists have recommended limiting cell phone use as a prudent avoidance measure, however.

Western's EMF Position

Western recognizes the public concern over the possible health effects of electric and magnetic fields. While primary exposure to EMFs for most people is in the home and at work, Western realizes that some people have concerns about EMFs created by our transmission facilities.

In the past 30 years, scientists have studied the relationship, if any, of EMF to human, plant and animal health. Congress mandated in 1992 that Federal agencies and the scientific community research and conduct a comprehensive review of potential EMF effects on health. These studies concluded in 1997 that there is only "weak" evidence that magnetic fields increase the risk of cancer and other human disease.

Scientific research continues on a wide range of questions relating to EMF exposure, and some of this work has hinted at possible health risks. A comprehensive EMF health risk assessment by the World Health Organization is under way, and will likely influence decision making and further research. The research is expected to continue for several more years. Until conclusive or more specific research results are obtained, Western will continue to take prudent actions regarding EMFs.

Western will continue to:

- Provide balanced and accurate information to employees, customers and the public. EMF measurements will continue to be made upon request.
- Support and participate in scientific research on EMF and monitor results of research activities by utility, government and private groups.
- Pursue and implement alternative design and siting approaches for new and upgraded transmission facilities to reduce the public exposure to EMFs, particularly when the siting of the facilities may occur in populated areas.

Western is committed to providing a safe, healthy environment for our employees and safe, reliable and economic electric energy to our customer and communities.

For more information about Western or EMF, call or write your nearest Western office:

Corporate Services Office
Mailing address: P.O. Box 281213, Lakewood, CO 80228-8213
E-mail: CorpComm@wapa.gov
Phone: 720-962-7000
Fax: 720-962-7200

CRSP Management Center
Mailing address: P.O. Box 11606, Salt Lake City, UT 84147-0606
Phone: 801-524-5493
Fax: 970-240-6295

Desert Southwest Region
Mailing address: P.O. Box 6457, Phoenix, AZ 85005-6457
Phone: 602-605-2525
Fax: 602-605-2630

Rocky Mountain Region
Mailing address: P.O. Box 3700, Loveland, CO 80539-3003
Phone: 970-461-7200
Fax: 970-461-7213

Sierra Nevada Region
Mailing address: 114 Parkshore Drive, Folsom, CA 95630-4710
Phone: 916-353-4416
Fax: 916-985-1934

Upper Great Plains Region
Mailing address: P.O. Box 35800, Billings, MT 59107-5800
Phone: 406-247-7405
Fax: 406-247-7408

Western
AREA POWER
ADMINISTRATION

P.O. Box 281213
Lakewood, CO 80228-8213

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PREVIOUS PAGE