Donna L. Nelson
Chairman

Kenneth W. Anderson, Jr.
Commissioner

Rolando Pablos
Commissioner

Brian H. Lloyd
Executive Director

Rick Perry
Governor

Public Utility Commission of Texas

Date: December 17, 2012

To: Chairman Donna L. Nelson
Commissioner Kenneth W. Anderson, Jr.
Commissioner Rolando Pablos

From: Alan Rivaldo
Infrastructure & Reliability Division

Subject: Project No. 40190, Project Relating to Advanced Metering Issues
Report on Health and Radiofrequency Electromagnetic Fields from Advanced Meters

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Recently, some citizens of Texas have expressed concern over the potential health effects of exposure to the radiofrequency emissions from the wireless technology of advanced metering. Some of these individuals have appeared before or submitted comments to the Commission (under Project 40190, *Project Relating to Advanced Metering Issues*) and the Texas Senate Committee on Business and Commerce (at http://www.senate.state.tx.us/75r/senate/commit/c510/c510.htm).

Some have relied on social media as a source of information because it disseminates ideas rapidly and widely, but it also can be inaccurate and lack objectivity. Therefore, Staff decided to investigate the health concerns expressed by citizens and other interested parties. The product of this investigation is the attached document intended to objectively address the issue and help inform decision makers. Staff reviewed recent research on the potential health effects of radio frequency electromagnetic field (RF EMF), reported on the findings, and assessed disputes regarding the findings.

Staff found many scientific research papers published on the effects of EMF on health over a period of nearly 90 years; they number in the thousands. Despite this extensive body of work, scientific research continues, and dozens of papers are published each year.

Staff has determined that the large body of scientific research reveals no definite or proven biological effects from exposure to low-level RF signals. Further, Staff found no credible evidence to suggest that advanced meters emit harmful amounts of EMF.

While many different organizations have performed primary research on health and RF EMF, Staff relied heavily on the following sources:

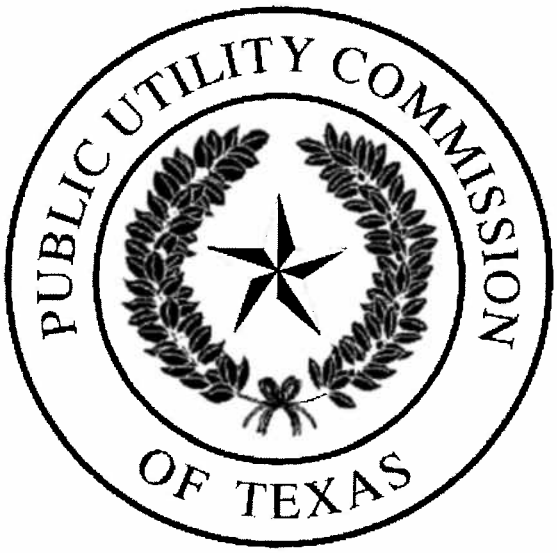
1. The California Council on Science and Technology (CCST), an independent state agency, assessed the available evidence of whether FCC standards provide sufficient protection of public health. Its report also questioned whether additional standards are needed to ensure adequate protection from adverse health effects of wireless communication technology.
2. The Michigan Public Service Commission requested help from Lawrence Berkeley National Laboratory (LBNL) in assessing claims made by some individuals who refuted the findings of the CCST report. The PUCT report summarizes the LBNL work.
3. The measurements and assessments performed by the Electrical Power Research Institute (EPRI), an organization that performs research and provides technical expertise to the electrical utility industry.

Staff found the CCST conclusions, LBNL's work, and the investigations by EPRI to be highly credible and based on sound scientific principles.

Other material Staff reviewed, found valuable, and used to inform the report came from:

- The federal government (FCC, NIH, and other agencies);
- The Canadian government and its provincial health authorities;
- Countries in Western Europe;
- Several municipalities deploying advanced meters;
- Various governmental entities in Australia;
- Academia;
- The United Nations' World Health Organization;
- Utility industry organizations; and
- International standards-settings organizations.

Alan Rivaldo is available to answer any questions you may have.



Health and RF EMF from Advanced Meters

An Overview of Recent Investigations and Analyses

Public Utility Commission of Texas
Infrastructure & Reliability Division
Staff Report

Prepared by Alan Rivaldo
Project No. 40190

December 2012

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Any views presented in this paper do not necessarily represent a Commission decision.

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Executive Summary

This paper is a survey of existing scientific research and analyses that have been performed to investigate the potential health effects of exposure to low-level radio frequency electromagnetic fields emitted by wireless communication devices including smart meters. No independent empirical research has been performed by Public Utility Commission of Texas (PUCT) staff, but the results of several studies are summarized in this report.

Decades of scientific research have not provided any proven or unambiguous biological effects from exposure to low-level radio frequency signals. Further, Staff reviewed all available material and found no credible evidence to suggest that smart meters emit harmful amounts of Electromagnetic Field (EMF) radiation.

Radiation comes in two forms: ionizing and non-ionizing. The methods of data transmittal by smart meters most common in Texas (which communicate wirelessly) and other forms of telecommunications (television, radio, cell phones, satellite) utilize non-ionizing EMF radiation in the Radio Frequency (RF) band, commonly known as RF EMF.

In contrast, ionizing radiation carries an inherently greater amount of energy; it may come from the decay of fissionable material like uranium or from EMF at significantly higher frequencies, such as X-rays or cosmic rays. Because of its inherent high energy, ionizing radiation is known to cause cellular disruption which may lead to various acute or chronic medical problems, including the induction of cancer.

Smart meters do not emit or utilize ionizing radiation.

RF EMF can cause the heating of living tissue (thermal effect) when the tissue is exposed to a certain level of intensity, which is the only known risk of exposure to such emissions. The Federal Communications Commission (FCC) has therefore established two tiers of Maximum Permissible Exposure (MPE) - one tier applies if exposure occurs in an occupational or "controlled" situation, and the other tier applies if the general population is exposed or exposure results from an "uncontrolled" situation. The FCC uses a safety factor for the general population tier that sets the MPE at 1/50th of the level of known thermal effects while the occupational MPE is set at 1/10th of the level. Because smart meters are devices deployed among the general population, the more restrictive of the two safety factors is applied; the MPE for the general population is 80% lower than the occupational MPE.

Many governmental health agencies from around the world, including those at the state, provincial, county, and city levels, in addition to academic institutions and other researchers have stated that there are no known non-thermal effects from exposure to RF EMF. This lack of non-thermal effect includes the effects which manifest from exposure to ionizing radiation. Nonetheless, substantial medical research on any potential non-thermal effects of non-ionizing radiation has been conducted and is ongoing. It is anticipated that medical researchers will continue to perform investigations of both the potential thermal and non-thermal health effects of RF for the foreseeable future.

It is important to note that one must use caution when relying solely on the results of individual research studies because conflicts or inconsistencies may exist among the results of other individual studies. Laymen often may not recognize poorly executed studies, or they can misinterpret the results of properly conducted scientific research. Either circumstance may lead a casual observer to draw errant conclusions. Furthermore, it is impossible to scientifically prove absolute safety (the null hypothesis).

The Electric Power Research Institute (EPRI) has undertaken several substantial investigations of smart meter RF EMF, and found that smart meters comply with the FCC MPE requirements. Furthermore, it found that in-residence exposure to the emissions from a smart meter is greatly mitigated by several factors:

- The intensity of RF EMF is reduced *exponentially* with greater distance from the emitting device;
- The shielding provided by the meter enclosure;
- The home's building materials further weaken the field strength;
- The meter antenna orientation inhibits the inward direction of the field pattern; and
- RF EMF emissions are only intermittent; a smart meter typically transmits 1 - 5% of the time.

Several governmental entities such as the City of Naperville in Illinois, the Vermont Department of Health, the Victorian State Government of Australia, and the City of Richmond in British Columbia, Canada have performed their own tests on RF EMF from smart meters. These tests corroborated the results of EPRI's investigations.

Some smart meter opponents have raised the concern that the meters may interfere with other electronic devices. Smart meters typically communicate using the 902-928 MHz frequency band which is unlicensed spectrum and falls in the vicinity of where some cordless telephones operate. The FCC's technical rules mitigate the potential for the meters to interfere with other electronic devices by requiring them to be tested and certified as compliant with these rules before they can be marketed. Financial penalties can be assessed if one does not comply with the appropriate FCC equipment authorization procedure.

Despite a lack of credible evidence, opponents have challenged the use of common devices that emit RF EMF on the basis of health and environmental concerns. Some of these concerns involved cell phones and towers, some focused on the use of Wi-Fi[1] in schools, and a few were specifically related to smart meter deployments. As a result of concerns about the wireless technology employed by smart meters, the California state legislature commissioned the California Council on Science and Technology (CCST) to perform a study. The CCST, an independent, non-profit organization, solicited input from technical experts and reviewed and evaluated available research information about health impacts of RF emitted by electric appliances and smart meters. The CCST report concluded that:

- The exposure to RF from smart meters was lower than that from many household devices;
- The FCC standard provides adequate protection from known thermal effects;
- There were no identified non-thermal health effects from existing common household devices, including smart meters; and
- There was no call at this time for devising standards to govern the non-thermal effects of RF exposure.

In response to these findings, various parties opposed to smart meters filed comments with the California Public Utilities Commission which questioned or conflicted with the conclusions of the CCST report. As a result, the Michigan Public Service Commission asked Lawrence Berkeley National Laboratory (LBNL) to review the assertions made in those comments. EPRI also provided its opinions on the submitted comments separately. EPRI found that the submitted comments ignored a substantial amount of existing evidence and that the content indicated a general misunderstanding of concepts and basic principles about smart meters. LBNL was far more critical of the meter opponents' comments in its response and provided greatly detailed assessments of what it viewed as shortcomings of the submittals.

[1] Wi-Fi is a popular technology that allows an electronic device to exchange data wirelessly using radio waves over a computer network, including high-speed Internet connections. Wi-Fi products are based on the Institute of Electrical and Electronics Engineers' (IEEE) 802.11 standards.

Some opponents of smart meters have raised the idea of the existence of Electromagnetic Hypersensitivity (EHS), a condition in which certain people seem to be especially susceptible to EMF, exhibiting a wide range of physical afflictions. The World Health Organization (WHO) has issued documents on the topic, including recitations of a number of studies which had been conducted on individuals claiming to suffer from EHS. The studies typically attempted to elicit symptoms under controlled laboratory conditions. The WHO concluded that the symptoms experienced by those who have been described as being hypersensitive were not correlated with EMF exposure, and therefore there was no scientific basis to link EHS symptoms to EMF exposure. It suggested that symptoms experienced by some EHS individuals might arise from environmental factors unrelated to EMF or that the symptoms may be due to pre-existing psychiatric conditions or stress reactions resulting from worrying about EMF health effects, rather than the EMF exposure itself. Further, scientific studies show that people who are ill are highly receptive to negative suggestion and may demonstrate a "nocebo response" as a result of these suggestions.

A few people opposed to the use of wireless technologies have made claims that EMF can be used as a weapon to cause pain, disrupt thought, or alter or control human behavior. Smart meters do not have the capabilities to do these things.

Smart meters are designed to measure a customer's overall electricity usage and deliver that data to the utility. A meter may also offer a limited set of information to an end user if he desires. Smart meters are not intended for, are not designed to, and do not have the capability to harm an individual or direct a person's thoughts or actions.

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Introduction

Some members of the public have expressed concerns over the possible health effects from exposure to electromagnetic fields (EMF) emitted by advanced meters that transmit data wirelessly (smart meters). People have stated their concerns in public forums hosted by the Public Utility Commission of Texas (PUCT) or submitted written comments to the agency. The comments are available on the PUC's website under project 40190.[2] Citizens have also appeared before the Texas Senate Committee on Business and Commerce[3] to make statements. This report is intended to inform decision makers and other parties interested in the topic.

Decades of scientific research have not provided any proven or unambiguous biological effects from exposure to low-level radio frequency signals. In reviewing all available material, Staff found no credible evidence to suggest that smart meters emit harmful amounts of EMF.

This paper begins by explaining radiation which is a word that has several meanings. This document explains the distinction between ionizing and non-ionizing radiation. Also discussed are some fundamental characteristics of radio-frequency EMF (RF EMF) which is the non-ionizing form of radiation utilized by almost all wireless forms of telecommunication and by smart meters that send data through the air.

Because properly understanding radiation and health depends upon understanding the foundations of science, this paper explains the scientific method and outlines what constitutes valid science. Some people have claimed that they can make scientific arguments against the use of wireless communications technology, or describe what they view as its egregious hazards, or produce evidence of harm. This document provides guidance when considering such assertions.

As new technologies continue to pervade our lives, matters of science are addressed more often by our legal system. Public policy must also address technology, and those who craft laws and regulations often rely on external sources to provide subject matter expertise in matters of science, including medicine. This was true for the California Public Utilities Commission (CPUC). CPUC asked the California Council on Science and Technology (CCST) to analyze submittals made by various experts in science and medicine regarding RF EMF.

CPUC received comments that were critical of the CCST report. Various parties responded in defense of the conclusions of the CCST report. This paper summarizes the CCST report, some of the reply comments, and responses to those comments. Staff found the CCST conclusions to be based on sound scientific principles.

Several entities, such as the Electric Power Research Institute (EPRI), have measured the level of RF EMF exposure one would receive from smart meters. This report summarizes the findings of the EPRI investigations as well as those performed by other organizations.

This paper discusses standards for human exposure to EMF and regulations that govern devices which emit EMF. This report provides statements from health agencies of several countries and those made by academia regarding human exposure to RF EMF. This document concludes with a discussion about a purported medical condition called electromagnetic hypersensitivity and the notion of using EMF as a weapon. A chart of acronyms and abbreviations follows, along with an alphabetized list of references and resources.

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[2] <http://interchange.puc.texas.gov/WebApp/Interchange/application/dbapps/filings/pgControl.asp?TXT_UTILITY_TYPE=A&TXT_CNTRL_NO=40190>.

[3] <http://bandc.posterous.com/updated-october-9-2012-agenda-with-links-57790>.

The Science

Background – Radiation, Science

The fear of things that cannot be seen is innate to human beings. Imagine being dropped off alone in a forest in the middle of the night, with no moon to light the way. Are there venomous snakes or scorpions underfoot? Are there other unseen threats nearby? RF EMF is also invisible, so some people may be predisposed to feeling anxious about it.

Fear of the unknown is also common, and to some people, the notion of wireless communications technology is new, or something with which they have no experience. To make matters worse, wireless technology is a form of electromagnetic radiation (EMR), and the term "radiation" is rather ambiguous and commonly misunderstood. Exposure to radiation has been traditionally associated with chronic illnesses (specifically cancer) and death. Lastly, microwave ovens use EMR to cook food and boil water; knowing this, some people may imagine themselves being cooked or boiled alive if exposed to EMR.

Radiation

Radiation can be characterized as energetic particles or waves traveling through matter or space. Radiation can come from natural or man-made sources. For this report, it is important to first know that there are two types of radiation: ionizing and non-ionizing. Making the distinction is crucial because the word "radiation" on its own can evoke images of the victims of the atom bomb or the outcomes of the Chernobyl and Fukushima Daiichi disasters, when in fact the many forms of radiation we encounter in our daily lives are inert.

Ionizing Radiation

Ionizing radiation can come in one of two forms: particulate (e.g. neutron, alpha, or beta particles) or electromagnetic (e.g. gamma, cosmic, or X- rays). Ionizing radiation has such a high energy level that when it hits an atom, typically an electron is stripped away or dislodged from the shell of the atom. This changes the properties of the atom – leaving it with a net positive charge. Note that the high energy level of ionizing radiation is basic to its nature, and distinct from what its *intensity* may be in any given instance.

Ionizing radiation is generally harmful and potentially lethal because it can alter the molecules in living organisms, such as the genetic material of cells. If the genetic material of a cell is altered, it may lead to death of the cell or to cell mutation.

Ionizing radiation can come from outer space or from naturally occurring materials in the terrestrial environment, such as uranium or radon gas. Ionizing radiation can also be introduced into the environment from human activities like nuclear power production, medical and industrial uses, the transportation of radioactive material, mining, and by drilling for oil and gas. *Note that smart meters do not produce or use ionizing radiation.*

Non-Ionizing Radiation

In contrast, the waves of non-ionizing radiation inherently do not possess enough energy to displace electrons from the shell of an electron. Non-ionizing radiation may cause excitation of an electron, moving it to a higher energy state, but not stripping it away.

Electromagnetic radiation whose frequency is between that of extremely low frequency radiation and ultraviolet light is considered non-ionizing radiation. The radio emissions from cell phones, smart meters, and other forms of wireless communication lie between these two extremes. Therefore, radio communication from a smart meter is a form of non-ionizing radiation.

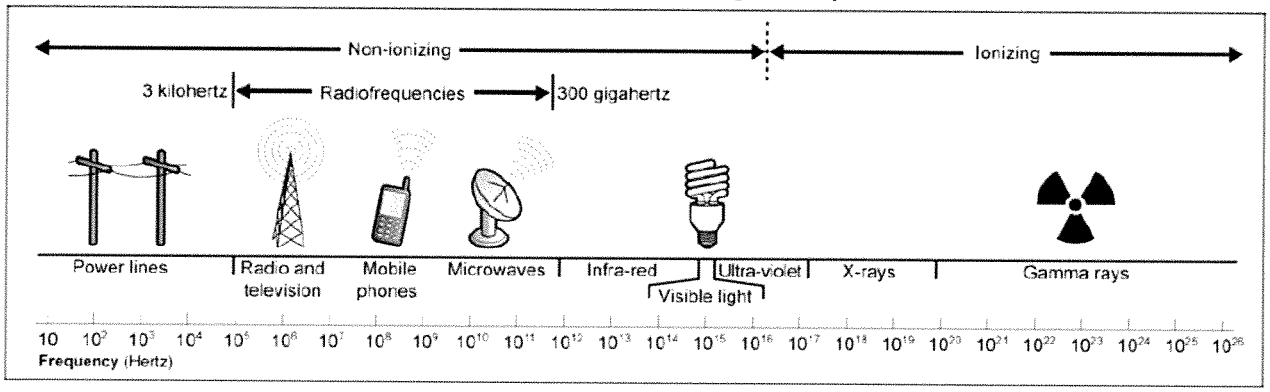
Electromagnetic Spectrum

The various forms of radiation, whether ionizing or non-ionizing, lie on a continuum called the electromagnetic spectrum, as seen in Figure 1. Smart meters that communicate wirelessly use frequencies that are between the frequencies of UHF television channels and those of mobile phones (somewhere between 900 MHz and 2.4 GHz), depending on the wireless technology (or technologies) the meters employ.

Figure 2 shows some of the chart's information in a tabular format. The frequency range in which wireless smart meters transmit data has been emphasized in that figure.

Note that the Public Utility Commission of Texas addressed potential health effects of extremely low frequency (60 Hz) electric power at very high voltages and currents, as is conducted in transmission lines. That report, issued in 1992, was entitled "Executive Summary: Health Effects of Exposure to Powerline-Frequency Electric and Magnetic Fields." The considerations being addressed in this *Health and RF EMF from Smart Meters* report are substantially different from those contemplated in 1992.

Figure 1: Chart of the Electromagnetic Spectrum[4]



[4] Not shown in the chart is the fact that as the frequency (Hz) of radiation increases, the "electron volt" (eV) value increases in a linear fashion. In this context, electron volts serve as a measure of how much energy the radiation carries and therefore the potential it has to excite an electron (or, if it has enough energy, dislodge it from an atom).

Figure 2: Types of Radiation and Their Frequency Ranges

Frequency Range	Top End of Frequency Range (in Hz)	Designation or Abbreviation	Primary Use
Radio. Non-ionizing radiation.			
3 – 30 Hz	30	ELF	Submarine communications
30 – 300 Hz	300	SLF	Not commonly used; electrical power is in this range
300 – 3000 Hz	3,000	ULF	Military communications
3 – 30 kHz	30,000	VLF	Submarine communication
30 – 300 kHz	300,000	LF	Military, AM radio
300 kHz – 3 MHz	3 million	MF	AM radio, shortwave radio
3 – 30 MHz	30 million	HF	Amateur radio, CB radio, aviation radio
30 – 300 MHz	300 million	VHF	VHF TV, FM radio, amateur radio
300 MHz – 3 GHz	***3 billion***	***UHF "microwave"***	***UHF TV, land-based mobile radio, cell phones, smart meters***
3 – 30 GHz	30 billion	SHF "microwave"	WLAN, radars, industrial devices
30 – 300 GHz	300 billion	EHF "microwave"	Short range data transmission
Light. Non-ionizing radiation.			
300 GHz – 400 THz	400 trillion	Infrared (IR)	TV remote controls, heat lamps
400 THz – 770 THz	770 trillion	Visible ("light")	Illumination
Ionizing radiation.			
750 THz – 30 PHz	30 quadrillion	Ultraviolet (UV)	Tanning beds, medical, industrial applications
30 PHz – 30 EHz	30 quintillion	X-Ray	Medicine, scientific, and industrial uses
more than 15 EHz	> 15 quintillion	Gamma ray	Medicine, scientific, and industrial uses

Electromagnetic Fields

An electromagnetic field is the result of the mutual interaction of electric and magnetic fields.[5] An electric field can be most simply described as being produced by stationary charges. A higher voltage yields a stronger electric field. In contrast, a magnetic field is produced by moving charges (typically electrons, i.e., an electric current). A greater current flow yields a stronger magnetic field.

An RF electromagnetic field is an electromagnetic field that is produced by electrical current that is oscillating at a radio frequency, which is defined as a frequency between 3 cycles per second and 300 billion cycles per second. Smart meters typically communicate with one another (or to their data concentrator) in a frequency band that is near 900 MHz.

Electromagnetic (EM) field intensity decreases greatly with distance. There are many variables involved in precisely calculating the anticipated intensity of an EM field from a given distance. To simplify the mathematics involved, it can be reasonably stated that the intensity of an EM wave, which is three-

[5] <http://www.britannica.com/EBchecked/topic/183201/electromagnetic-field>.

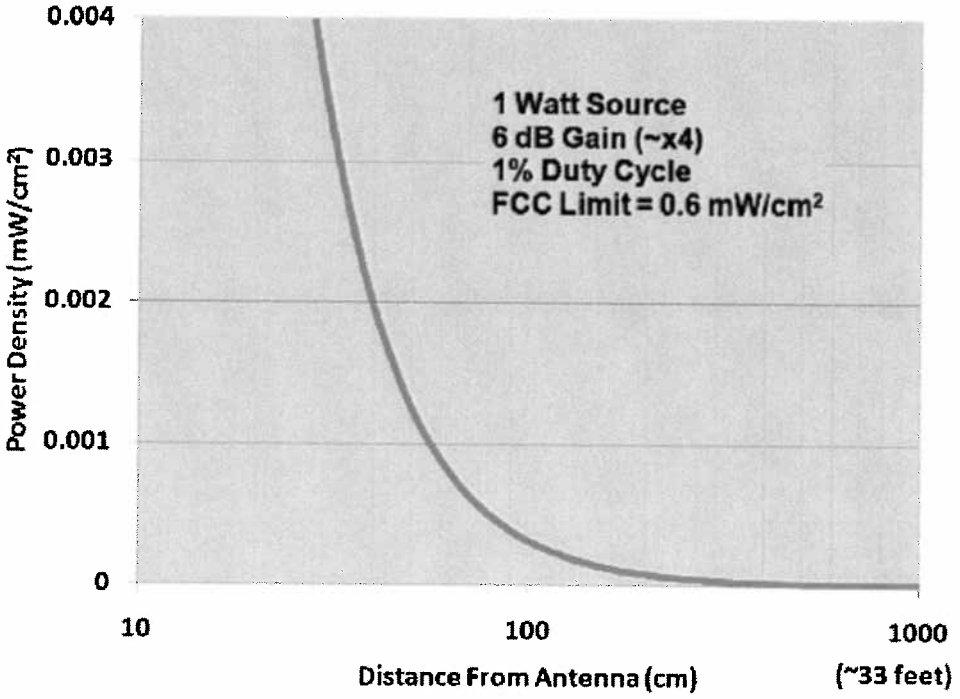
dimensional, decreases exponentially at a rate of approximately the square of the distance from its source. This is known as the inverse-square law,[6] expressed as a mathematical formula by:

$$Y = \frac{1}{X^2} \text{ (where } Y \text{ is the intensity and } X \text{ is relative distance).}$$

For example, if the EM intensity from a smart meter is measured to be Y_0 at an initial distance of 1 foot away, then Y_1, the field intensity from two feet away, would be $(\frac{1}{2^2})Y_0$, or $\frac{1}{4}Y_0$. From a three-foot distance, the intensity Y_2 will be $(\frac{1}{3^2})Y_0$, or $\frac{1}{9}Y_0$. From ten feet away, the field intensity will only be $(\frac{1}{10^2})Y_0$, or 1/100th of what it was at one foot away. Figure 3 shows how the average power density of EMF from a typical smart meter varies with distance.

Upon inspecting the graph, the power density value may appear to become zero, but in actuality it does not; the resolution of the image belies the asymptotic nature of the curve. While the power density may seem to become infinitesimal at the greater distances shown, the radio circuitry of smart meters is sensitive enough to receive and process the signal.

Figure 3: Calculated Average Power Density vs. Distance for a Typical Smart Meter[7]



[6] <http://www.osha.gov/SLTC/radiofrequencyradiation/electromagnetic_fieldmemo/electromagnetic.html#appendix_b>.

[7] Notes: The graph shows expected (calculated) values. The power density is average power density, not instantaneous; measured values will vary around a nominal value. This graph does not account for possible ground reflections, but ground reflections would not change the basic shape of the curve. Graph source: EPRI.

EMF and RF EMF in our Environment

Almost all household devices powered by electricity emit RF EMF in some amount. The FCC has classified devices in three categories – intentional radiators, unintentional radiators, and incidental radiators.

- Intentional radiators deliberately generate and emit RF energy. Typical intentional radiators include cordless telephones, remote control toys, garage door openers, mobile data devices such as iPads, and other low power transmitters.

- Unintentional radiators are devices that generate and use RF energy within the device but are not intended to emit RF energy. Typical unintentional radiators include devices such as personal computers, printers, automobile dashboard electronics, and other digital devices that have internal "clocks" or circuitry used for timing within the device. Radio receivers, such as television receivers and AM/FM radios, are also unintentional radiators.

- Incidental radiators are devices that generate RF energy during the course of their operation but are not intentionally designed to generate or emit that energy. Typical incidental radiators include automobile ignition systems, ceiling fans, vacuum cleaners, electric shavers, and mechanical light switches.

RF EMF also comes from natural sources, such as the sun, the Earth, and the outer layer of the Earth's atmosphere (the ionosphere).

The environment in which we live includes numerous other sources of RF EMF sourced from outside the home. These sources are intentionally transmitted and beyond an individual's control. The transmitting sources emit RF at a much greater intensity than smart meters do, and the signals permeate homes and other buildings. This RF EMF has had a ubiquitous presence both indoors and outdoors since the 1920s when AM radio broadcasts (centered near the 1 MHz frequency) were introduced. In the 1930s, FM radio (around 100 MHz) was introduced, and then in the 1940s and 1950s, the broadcasting of VHF television (50 to 200 MHz) and UHF television (400 to 900 MHz) expanded. Satellite communication started in the 1960s and is now commonplace, including for consumer use. Cellular telephone towers (base stations) have been deployed in increasing numbers since at least the 1990s; they are now considered ubiquitous.

Other sources of RF EMF one may encounter in public and private places are wireless routers, cordless telephones, cellular phones, RF remote control devices, and baby monitors. The intensity of EMF emitted by each of these devices is documented to be well below the threshold that requires any type of notification signage.[8]

The Role of RF EMF in our Country's Infrastructure

The United States of America (U.S.) has had a wireless communications infrastructure in place for nearly a hundred years. For example, radio and television stations have continually broadcasted their programming in all directions for public consumption since the early part of last century. Emergency services like police, fire, and ambulance services have their own dedicated radio spectrum. Municipal governments and the military also transmit data on various frequency bands assigned to them. Citizen's Band and short wave radio are used by individuals and hobbyists, but one could argue that it is also a part of our nation's communications infrastructure that benefits all, especially in times of emergency.

[8] <http://standards.ieee.org/findstds/standard/C95.2-1999.html>.

Satellite transmissions blanket our country from above, using various frequencies in the RF band. Downlinks from satellites are used by the television and radio industries for delivery of syndicated programming to local stations. Satellites also provide Internet access to users in remote areas and television programming for those without access to cable television or who seek an alternative. They also provide subscription-based programming for SiriusXM radio, and to fulfill government functions such as transmitting climate and mapping data and Global Positioning System (GPS) locational and timing information (which is used by utilities). The military also uses satellites for communications and surveillance.

Cell phones and their associated base stations are also a common source of EMF, having become ubiquitous worldwide; the International Telecommunication Union reported that there were six billion mobile phone subscriptions by the end of 2011, nearly one for every human being on the planet.[9]

Some people object to the installation of wireless smart meters on the grounds that they fear exposure to RF and because they do not anticipate benefitting from the devices' advanced capabilities. What they may not realize or acknowledge is that every individual is continuously exposed to RF emitted by a multitude of local television (TV) and radio stations, irrespective of whether one ever chooses to tune into any of them.

When a new radio or TV station begins broadcasting in a community, it introduces a new source of RF to a wide area. While the *exposure* to RF emissions is the primary consideration for the topic of this paper, some opponents of smart meters have called attention to their power output. It is therefore worth noting that the permitted maximum effective radiated power (ERP, which includes antenna gain[10]) of an FM radio station transmitter in the U.S., depending upon its FCC classification, can be as high as 100,000 watts.[11] In contrast, the radio module in a wireless smart meter is only capable of a maximum power output of one watt, and in some implementations, it is even less than that. The ERP of a stationary cell phone base station is limited to either 500 or 1000 watts, depending on its location.[12] The maximum peak ERP of a cell phone in the U.S., for example one operating in the GSM-1900 band and at GSM Power Class Number 30, is two watts.[13]

Despite the fact that radio stations broadcast at power levels that are tens of thousands times higher than those of smart meters, Staff could not find any references to reported health complaints or individuals attributing their health issues to new radio or TV transmissions. Similarly, while a limited number of people may still have some trepidation regarding cellphone towers, their ubiquity and the continued popularity of cell phones and other wireless communication devices seems to have quelled the number of concerns being expressed.

Advanced Metering Infrastructure

Making prudent investments in RF communications technologies has become essential to maintaining our quality of life, and many aspects of the world's infrastructure depend upon it. Many industries, including electrical utilities, use radio communication as an essential tool. Until recently, utilities have traditionally limited their use of radio to telemetry, transmitting system data from distant points along the transmission portion of the electric grid.

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[9] <http://www.itu.int/net/pressoffice/press_releases/2012/70.aspx>.

[10] In this context, this is defined by how well a transmitting antenna converts input power into radio waves headed in a specified direction.

[11] <http://www.fcc.gov/encyclopedia/fm-broadcast-station-classes-and-service-contours>.

[12] <http://www.gpo.gov/fdsys/pkg/CFR-2011-title47-vol2/xml/CFR-2011-title47-vol2-sec22-913.xml>.

[13] <http://www.radio-electronics.com/info/cellulartelecomms/gsm_technical/power-control-classes-amplifier.php>.

Now many of the electric utilities in the U.S. are enhancing the distribution portion of the electrical infrastructure by modernizing its technology. One of the ways electrical utilities are upgrading distribution grid technology is by replacing existing electric meters with Advanced Metering Infrastructure (AMI). The meters being replaced typically have an analog display[14] in the form of a series of dials that indicate accumulated usage and a large spinning aluminum disk that protrudes through the face of the meter. This electromechanical technology is over a century old and has shortcomings.

The most important feature of the meters used in AMI ("smart meters") is that they measure and record usage data in regular intervals[15] and allow for two-way communications between the utility and the customer. These smart meters and their associated communication components form an infrastructure that allow utilities to overcome the old technology's limitations and is now crucial to the utility and to the energy market's proper functioning.

Almost all smart meters used in the U.S. communicate by means of wireless technology. Each utility proposes the technology it will deploy and determines how it is to be configured in order to best suit the needs of its service area. The most common method of communication chosen by Texas utilities has been in the form of a wireless mesh network.

A wireless mesh network topology allows "mesh-enabled" meters to securely route data via other nearby meters and relay devices. These meters and relay devices are connected to several other mesh-enabled devices. All these devices function as signal repeaters and relay the data to an access point. The access point device aggregates, encrypts, and conveys the data to and from the utility (this is known as the backhaul portion of the network). The access point typically uses cellular phone technology to transport this data.[16]

Wireless Technology Standards and Regulation

Intentional radiator devices such as cordless telephones, cellular phone handsets, and smart meters operate in unlicensed spectrum. Unlicensed spectrum is simply a band that has pre-defined rules for both the hardware and the deployment methods of the transmitting radio; they are required to be tested and certified as compliant with these rules before they can be marketed. Financial penalties can be assessed if one does not comply with the appropriate Federal Communications Commission (FCC) equipment authorization procedure.[17] The mitigation of potential interference within the bands is addressed by the FCC definition of technical rules rather than the agency restricting the bands by issuing an exclusive license to use the spectrum.[18,19]

Any person or entity that complies with the rules for the equipment (which are pre-certified by the manufacturer) and its use can establish a license-free network at any time for either private or public purposes. This is why a person can set up a wireless network at home and a utility can set up its smart meter mesh network without having to obtain a license from the FCC. The radio(s) in the smart meter is pre-certified, just as a home user's wireless router is.

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[14] Note that not all meters being replaced have the same appearance. A few of the old meters may have digital displays and solid state circuitry, but are not considered to be AMI.

[15] Due to the limited scope of this paper, the specific market and regulatory aspects of Texas and the ERCOT market and the infrastructure design choices of each of the utilities will not be discussed.

[16] There are several possible variations to the mesh design described above. Take what is outlined here as an example.

[17] <http://transition.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet63/oet63rev.pdf>.

[18] <http://www.wimax.com/wimax-regulatory/what-is-unlicensed-spectrum-what-frequencies-are-they-in>.

[19] U.S. frequency allocations: <http://www.ntia.doc.gov/files/ntia/publications/spectrum_wall_chart_aug2011.pdf>.

The FCC is required by the National Environmental Policy Act of 1969 to evaluate the effect of emissions from FCC-regulated transmitters on the quality of the human environment. At the present time there is no federally-mandated RF exposure standard. However, several non-government organizations, such as the American National Standards Institute (ANSI), the Institute of Electrical and Electronics Engineers (IEEE), and the National Council on Radiation Protection and Measurements (NCRP) have issued recommendations for human exposure to RF electromagnetic fields.[20] The potential hazards associated with RF electromagnetic fields are discussed in the FCC's Office of Engineering and Technologies (OET) Bulletin No. 56, "Questions and Answers About Biological Effects and Potential Hazards of Radiofrequency Electromagnetic Fields."[21]

On August 1, 1996, the FCC adopted the NCRP's recommended MPE limits for field strength and power density for the transmitters operating at frequencies of 300 kHz to 100 GHz. In addition, the FCC adopted the Specific Absorption Rate (SAR) limits for devices operating within close proximity to the body as specified within the ANSI/IEEE C95.1-1992 guidelines.[22] The FCC's requirements are detailed in Parts 1 and 2 of the FCC's Rules and Regulations [47 C.F.R. 1.1307(b), 1.1310, 2.1091, 2.1093].[23,24,25,26]

Studies by EPRI and others have found that the exposure an individual would receive from a smart meter that is 10 feet away is not much different from the range of exposure levels received from TV and radio broadcasts.

The Effects of RF EMF on Living Tissue

There are three scientifically established mechanisms where EMF is known to cause health effects:[27,28]

- Induced voltage gradients and/or electric currents in the body;
- Thermal effects (dielectric heating); and
- Ionizing radiation effects.

The relative importance of these mechanisms depends on the EMF frequency and field strength. Decades of research into EMF and health has produced a large body of scientific literature which national and international standards organizations have reviewed to establish their safe exposure limits. For example, the WHO has formally recognized the International Commission on Non-Ionizing Radiation Protection (ICNIRP) to develop its international EMF exposure guidelines.

At frequencies in the range of 0-3 kHz, induced voltage gradients and/or electric currents in the body are the only known health effects in the presence of strong electric and magnetic fields. Because the purpose of this report is to address smart meters that communicate using RF, induced voltages and currents will not be discussed. Smart meters do not emit ionizing radiation, so that topic will also not be covered in this document. If one would like to know more about the health effects of induced voltages or ionizing radiation, credible resources are freely available elsewhere.

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[20] <http://transition.fcc.gov/oet/rfsafety/background.html>.
[21] <http://transition.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet56/oet56e4.pdf>.
[22] <http://standards.ieee.org/findstds/standard/C95.1-2005.html>.
[23] <http://www.gpo.gov/fdsys/pkg/CFR-2011-title47-vol1/xml/CFR-2011-title47-vol1-sec1-1307.xml>.
[24] <http://www.gpo.gov/fdsys/pkg/CFR-2011-title47-vol1/xml/CFR-2011-title47-vol1-sec1-1310.xml>.
[25] <http://www.gpo.gov/fdsys/pkg/CFR-2009-title47-vol1/xml/CFR-2009-title47-vol1-sec2-1091.xml>.
[26] <http://www.gpo.gov/fdsys/pkg/CFR-2009-title47-vol1/xml/CFR-2009-title47-vol1-sec2-1093.xml>.
[27] <http://www.emfandhealth.com/EMFExplained.html>.
[28] <http://standards.ieee.org/findstds/standard/C95.6-2002.html>.

Thermal effects are the primary health impact when living tissue absorbs enough EMF power to cause heating. This effect is the primary concern in the RF frequency range of 30 MHz to 300 GHz. In theory, the total EMF power absorbed by tissue is determined by the photon energy multiplied by the number of photons per second being absorbed. The practical method used to measure this energy is based on the SAR. For portable devices, the FCC specifies that SAR safety limits are to be used.[29] These safety limits are specified in units of watts per kilogram (W/kg) of body tissue.

Note that the energy from devices that are not intended for use within 20 centimeters of a user, such as smart meters, is measured using a different methodology. The FCC safety limits for these devices, known as Maximum Permissible Exposure (MPE), are specified in units of microwatts per square centimeter ($\mu W/cm^2$).

Existing regulations from the FCC set the SAR and MPE safety limits in the U.S. Other countries such as the United Kingdom (UK), Canada, and Australia have similar standards. International standards regarding safety for commercial products also exist from entities such as the WHO and the ICNIRP and are also similar to the U.S. standards.

The Scientific Method, the Value of Meta-analysis, Laymen Difficulties, and other Cautions

The investigation of RF EMF and its potential effects on health requires an understanding of several fields of science. While the intent of this report is not to impart a deep understanding of all the relevant scientific fields of study, it is still important to have a basic grasp on the concepts and what science itself entails. The latter is referred to as the scientific method.

Meta-analysis is an important tool in science because in some areas of study there are a large number of studies which are similar, and researchers want to have a method of combining them to help facilitate drawing satisfactory conclusions.

People generally have an interest in maintaining their health, so any given research study that shows a positive correlation between a disease and an environmental factor will naturally have the tendency to pique the interest of the public more than one that does not show any correlation. While journalists and news editors have codes of ethics and guidelines for professional conduct,[30,31,32,33] there is a risk that the mass media may sensationalize an individual study which shows such a correlation and be less inclined to report research studies that refute the findings, because documenting something which may be interpreted by an audience as uneventful is not as captivating or lucrative. Studies have revealed that the publishing of misconceptions about alleged effects of exposure to electric or magnetic fields in the popular press is not uncommon.[34,35,36,37] Some less reputable media outlets may be motivated by viewership ratings, subscription renewals, or webpage hits, rather than reporting the news properly. Integrity in the media plays a role in maintaining the integrity of scientific research.

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[29] The FCC defines portable devices as transmitters whose radiating structures are designed to be used within 20 centimeters (approximately eight inches) of the body of the user.
[30] <http://www.rtdna.org/pages/media_items/code-of-ethics-and-professional-conduct48.php?g=36?id=48>.
[31] <http://www.apme.com/?page=EthicsStatement>.
[32] <http://asne.org/content.asp?pl=24&sl=171&contentid=171>.
[33] <http://www.spj.org/ethicscode.asp>.
[34] <http://www.dtic.mil/dtic/tr/fulltext/u2/a275434.pdf>.
[35] <http://www.jmpee.org/JMPEE_PDFs/26-4_bl/JMPEE-Vol26-Pg189-Jauchem.pdf>.
[36] <http://www.jmpee.org/JMPEE_PDFs/28-3_bl/JMPEE-Vol28-3-Pg140-Jauchem.pdf>.
[37] <http://www.jmpee.org/JMPEE_PDFs/30-3_bl/JMPEE-Vol30-Pg165-Jauchem.pdf>.

Understanding the concepts behind science is important because opponents of wireless data transmission technologies have attempted to use science (typically by quoting research studies) as support for their arguments. At the same time, one must remain mindful of the relationships among science, modern media, and the public.

Scientific Method

The modern use of the word "science" is defined both as a reliable body of knowledge that can be logically and rationally explained and also by the method of pursuing that knowledge, namely, the scientific method. Scientific method requires inquiry to be based on evidence that is empirical and measurable and is subject to specific principles of reasoning. More specifically, the scientific method consists of systematic observation, measurement, and experiment, as well as the formulation, testing, and modification of hypotheses.[38]

The following process steps[39] are considered the basic elements of scientific method:

- Formulate a question - to summon an explanation of a specific observation, or it can be open-ended;
- Hypothesis - a conjecture that may explain the observed behavior;
- Prediction - made by determining the logical consequences of the hypothesis;
- Test - investigate (via experiment) whether the real world behaves as predicted by the hypothesis; and
- Analysis - determine what the experimental results demonstrate and decide the next actions to take.

Other components are necessary to the scientific process, even when all the iterations of the steps above have been completed:

- Replication - if an experiment is repeated and does not produce the same results, this implies that the original results were in error. As a result, it is common for a single experiment to be performed multiple times, especially when there are uncontrolled variables or other indications of experimental error. Surprising or significant results may motivate other scientists to also investigate, especially if the results would be important to their own work;
- External review - experts perform a peer review, which is an evaluation of the experiment. These experts give their opinions anonymously to foster unbiased criticism. The peer review does not certify correctness of the results, only that the experiments themselves were sound. Note that the evaluation of the experiment depends on its description being supplied by the experimenter. If the work passes peer review (which may require new experiments requested by the reviewers), it will be published in a peer-reviewed scientific journal. The journal that publishes the results indicates the perceived quality of the work; and
- Data recording and sharing - scientists must record all data very precisely to reduce their own bias and aid in replication by others. This data must be supplied to other scientists who wish to replicate any results. Experimental samples that may be difficult to obtain must also be shared.

Scientific studies are intended to be as objective as possible to reduce any bias in how the results are interpreted. All data and the methodologies employed are to be documented, archived, and shared so that they are available for close scrutiny by other researchers. This gives scientists the opportunity to verify results by attempting to reproduce them and establish statistical measures of the reliability of the experimental data.

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[38] <http://oxforddictionaries.com/definition/english/scientific%2Bmethod>.
[39] <http://en.wikipedia.org/wiki/Scientific_method>.

Meta-analysis

The study of EMF has been going on for decades resulting in a multitude of research studies, many of which possess similar elements. The existence of such large bodies of work makes researchers want to integrate similar studies and attempt to synthesize more definitive conclusions. The traditional method of integration calls for a reviewer to provide a narrative, namely a chronological discourse on previous findings.[40] Gene V. Glass, the statistician and researcher who coined the term meta-analysis, considered the traditional method to be flawed and inexact because reviewers:

- Are unable to deal with the large number of studies on a topic and focus on a small subset of studies, often without describing how the subset was selected;
- Often cite the conclusions of previous reviews without examining those reviews critically; and
- Are usually active and prominent in the field under review. Therefore, they might not be inclined to give full weight to evidence that is contrary to their own positions.

In a meta-analysis, research studies are collected, coded, and interpreted using statistical methods similar to those used in primary data analysis. The result is an integrated review of findings that is more objective and exact than a narrative review.

Inherent Problems and Laymen Difficulties with Scientific Research; Non-traditional Medicine

Science is by no means a discipline of perfection; it depends upon human thought and activity, and is thereby subject to human failings, including the introduction of bias into the process steps outlined above. Most failures can be attributed to inadvertent errors, while some failures can be pinned on researchers that have taken shortcuts through the scientific process. Only rarely have researchers who had been generally considered to be legitimate been found attempting to subvert science for personal benefit, to perhaps gain notoriety, or to secure future research grants.[41]

Findings of scientific misconduct occasionally come to light. In the course of gathering material for this paper, Staff discovered several studies of RF EMF and health that were found to be fraudulent. For example, the U.S. Department of Health and Human Services' (HHS) Office of Research Integrity found that Robert P. Liburdy, Ph.D. engaged in scientific misconduct in biomedical research by intentionally falsifying and fabricating data and claims about the purported cellular effects of EMF that were reported in two of his scientific papers.[42] Another example of misconduct was exposed through an investigation performed by an independent review body at the Medical University of Vienna. The investigation revealed that data was fabricated in two papers authored by lab chief Hugo Rüdiger and his colleagues in 2005 and 2008 which reported DNA breakage in cells exposed to electromagnetic fields. The papers were part of a European Union-funded project called REFLEX.[43]

Some people have made assertions that research studies that had depended upon funding or other support from industry should be considered as unreliable and having tainted results. What is far more important than the sources of funding for research is strict adherence to the scientific process. Rigorous peer reviews, combined with attempts by others to replicate results, tend to remove from consideration studies whose results rely on questionable research practices. Opponents of wireless technology may not understand this, and have expressed dismay when content from studies they favor does not appear in other documents such as

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[40] <http://echo.edres.org:8080/meta>.
[41] <http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0005738>.
[42] <http://grants.nih.gov/grants/guide/notice-files/not99-111.html>.
[43] <http://www.emfandhealth.com/sciencerudigerfraud.pdf>.

the report by the California Council on Science and Technology.[44] There is a risk that opponents may attribute the exclusion of favored material to attempts by government agencies or industry to suppress the truth rather than accepting the idea that the opponents' favored studies were errant or lacked scientific rigor.

Nonetheless, some research studies can receive undeserved notoriety despite shortcomings such as:

- Experiments that are poorly designed or lack sufficient controls;
- Studies that are inadequately peer-reviewed;
- Public revelation of findings that are only preliminary;
- Reports that are unpublished but appear in the popular press;
- Reports published in scientific journals of lesser esteem;
- Conclusions that are drawn to satisfy a political agenda rather than advance human knowledge; and
- Cited primary research studies are old and out of date.

The "BioInitiative Report"[45] is an example of a report that received notoriety despite being viewed negatively by the research community. Its contributors are described as a group of 14 scientists, researchers, and public health policy professionals. The stated purpose of the report was to document "bioeffects, adverse health effects and public health conclusions about impacts of non-ionizing radiation." The document was edited by Cindy Sage, an environmental consultant, and Dr. David O. Carpenter, director of the Institute for Health and the Environment at the State University at Albany (New York).

The report is often cited by opponents of wireless technology, but it was widely criticized by government research agencies and subject matter experts in Australia,[46] Belgium,[47] the European Commission (EC),[48] France,[49] Germany,[50] and the Netherlands.[51] It was also criticized by EPRI[52] and the IEEE.[53] The overall opinion of these institutions was that the report had many shortcomings. Some of the stated criticisms were that the report:

- Provided views that were not consistent with the consensus of science;
- Recommended safety limits that were not supported by the weight of scientific evidence;
- Included selection bias in several research areas;
- Lacked objectivity and balance; and
- Suffered from uneven editing quality.

Some researchers have developed a level of notoriety for their assertions regarding the purported dangers of EMF exposure. Opponents of wireless technology have naturally called upon these people to testify as expert witnesses and this tends to raise their profiles to an even greater degree. These efforts have not always been successful. For example, Carpenter attempted to rely on his work on the BioInitiative Report as one of the qualifications to testify as an expert for intervenors opposed to plans by Hydro Québec, a utility in Canada, to

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[44] <http://www.ccst.us/publications/2011/2011smart-final.pdf>.
[45] <http://www.bioinitiative.org/freeaccess/report/docs/report.pdf>.
[46] <http://www.acrbr.org.au/FAQ/ACRBR%20Bioinitiative%20Report%2018%20Dec%202008.pdf>.
[47] <http://mmfai.info/public/docs/eng/MMF_Viewpoint_BioInitiativeReport.pdf>.
[48] <http://ihcp.jrc.ec.europa.eu/our_activities/public-health/exposure_health_impact_met/emf-net/docs/efrtdocuments/EMF-NET%20Comments%20on%20the%20BioInitiative%20Report%2030OCT2007.pdf>.
[49] <http://www.afsset.fr/upload/bibliotheque/964737982279214719846901993881/Rapport_RF_20_151009_I.pdf>.
[50] <http://www.emf-forschungsprogramm.de/int_forschung/wirk_mensch_tier/Synopse_EMFStudien_2008.pdf>.
[51] <http://www.gezondheidsraad.nl/sites/default/files/200817E_0.pdf>.
[52] <http://emf.epri.com/BioInitiative_Working_Group_Report_Updated_7-09.pdf>.
[53] <http://www.emfandhealth.com/12265_COMAR_2009.pdf>.

install wireless smart meters on homes and businesses. The regulatory authority for the province, The Québec Energy Board (The Board), stated (translated from French):[54]

> "The Board has refused to grant the requested expert status on the grounds that David Carpenter is not a doctor, never had clinical experience with patients and has never personally done any research on the effects of RF health.[55] The Board does not, however, reject his testimony in the case because of his knowledge on the research done by others in this field. It therefore accepted this testimony, subject to establishing the probative value to be accorded."

The Board also did not view Carpenter as independent and unbiased, as required by its rules governing the expectations of expert witnesses. The Board stated (translated from French):[56]

> "Clearly, the witness Carpenter, expert or not, does not meet the criteria of objectivity which the Board is entitled to expect."

Another individual who has been described as an expert by opponents of wireless technology is Magda Havas, a professor at Trent University, a liberal arts institution located in Peterborough, Ontario, Canada. Havas is not a medical doctor; she has a B.S. degree in biology and a Ph.D. in botany (the study of plant life).[57]

While not naming Havas directly, in response to her assertions against the proposed installation of Wi-Fi in several schools in Canada and the U.S., her colleagues at Trent University published a brief statement[58] in the *Peterborough Examiner* newspaper:

> On the issue of health effects of radio frequency waves, a large body of evidence now exists, and the international consensus is described in the references listed at www.trentu.ca/physics/emfrefs.pdf. Based on these considerations, we do not believe that electromagnetic waves associated with Wi-Fi in schools pose a health risk to children or teachers.
>
> Profs Bill Atkinson, Peter Dawson, David Patton, Ralph Shiell, Alan Slavin and Rachel Wortis
> Members of the Department of Physics, Trent University

Havas' critics are not limited to her colleagues at Trent. There are a few websites whose stated goals are to enhance the public's familiarity with sound scientific concepts. These sites state that their contributors seek to promote a better understanding of science and to help others distinguish between evidence-based science and poor science. Some contributors have responded to Havas' activities by creating pages that are dedicated to exposing and explaining what they claim to be significant flaws in her studies, contradictory statements she has made, comments which were not consistent with established facts, and instances where they claim she had misled the public.[59,60,61,62,63,64,65]

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[54] <http://internet.regie-energie.qc.ca/Depot/Projets/111/Documents/R-3770-2011-A-0163-DEC-DEC-2012_10_05.pdf>.
[55] David O. Carpenter holds a medical degree (M.D.) from Harvard but is not accredited to practice medicine.
[56] <http://www.regie-energie.qc.ca/regie/DirectivesInstructions/Regie_RoleExperts_18juillet2011.pdf>.
[57] <http://www.magdahavas.org/dr-magda-havas-bio/>.
[58] <http://www.thepeterboroughexaminer.com/2010/10/15/physicists-see-no-danger-from-wifi-in-schools>.
[59] <http://www.emfandhealth.com/EMF&Health%20EHS%20Poor%20Studies%201.html>.
[60] <http://www.emfandhealth.com/EMF&Health%20EHS%20Poor%20Studies%202.html>.
[61] <http://www.emfandhealth.com/EMF&Health%20EHS%20Poor%20Studies%203.html>.
[62] <http://www.emfandhealth.com/EMF&Health%20EHS%20Poor%20Studies%204.html>.
[63] <http://www.emfandhealth.com/EMF&Health%20EHS%20Poor%20Studies%205.html>.
[64] <http://www.emfandhealth.com/EMF&Health%20EHS%20Poor%20Studies%206.html>.

Note that some of the work that Havas performs involves the study of Electromagnetic Hypersensitivity (EHS), which has not been recognized by the medical or scientific communities as a valid diagnosis.

Some scientists and medical practitioners may be valued as experts by a small segment of the population because their ideas have been proclaimed as novel or superior because they do not conform to the prevailing conclusions of the scientific or medical communities. These researchers and medical professionals may be characterized as fighting the medical or scientific establishments for the benefit of their supporters. The problem is if these maverick researchers become imbued with noble stature because of these impressions, it may put the integrity of true science and medicine at risk.

Scientists prefer to maintain cordial relationships with one another and therefore avoid using the terms "junk science" and "pseudoscience" when referring to research or unconventional medical treatments they find questionable, because these terms are considered pejorative.

While skepticism of research is central to ensuring its quality, it is important to avoid being drawn to the allure of ideas that conflict with the body of scientific evidence. Without an appreciation for the meaning and value of scientific consensus, one risks being distracted by notions that have been discounted by numerous studies conducted in adherence to the scientific method.

Scientific consensus can be described as the collective judgment, position, and opinion of the community of scientists in a particular field of study.[66] In the context of scientific research, consensus is general agreement and not unanimity, which has a stricter meaning. This collective judgment of scientists cannot be used as a valid scientific argument on its own, and that it is not part of the scientific method; it is more the *result* of it.

A consensus can be developed by scientists through replication of experimental results, peer review, and publication of results – key components of the scientific method. When this process is followed iteratively and agreement exists, those within the discipline recognize they have reached a consensus. As scientific research continues and new data is produced by experiment, models are refined. This change may bring about shifts in scientific consensus. How consensus within the scientific community develops over time is a study in its own right.[67]

The challenge for researchers becomes communicating to outsiders (especially laymen) that scientific consensus has been reached. This is because to the uninitiated, the debates through which science progresses may seem to be contestation. Laypeople and others outside the particular field of study who misinterpret these scientific debates as adversarial may reach erroneous conclusions about the science. When scientific debate is misinterpreted in this manner, effective government also may be subject to risk. The risk is that members of the public that have misconceptions about the existence of scientific consensus may exert pressure on their elected leaders to devise public policy that is based on faulty assumptions.

In medicine, one result of misinterpreting scientific debate can be a mistaken belief in a medical diagnosis that the scientific community does not recognize as valid, such as EHS. If the true cause of an affliction is not diagnosed, it can lead to negative consequences for an individual. Medical professionals and others may offer treatments that are not efficacious or have not been properly vetted for safety. The pursuit of these treatments can delay receiving effective medical care.

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[65] <http://www.sciencebasedmedicine.org/index.php/cfls-dirty-electricity-and-bad-science/>.
[66] <http://en.wikipedia.org/wiki/Scientific_consensus>.
[67] <http://asr.sagepub.com/content/75/6/817.full.pdf+html>.

The Internet offers amulets made of crystal or stone, typically worn as a pendant around the neck, that are purported to help an individual overcome EHS or to mitigate the claimed negative health effects of exposure to EMF. No valid scientific explanations are offered to explain the mechanisms by which these items may operate. Dietary supplements are promoted with claims they provide a "strong protective effect" against EMF but have not been assessed by the U.S. Food and Drug Administration (FDA) for safety or effectiveness.

Some physicians offer treatments for EHS and other purported "environmental sensitivities." One such doctor is Dr. William J. Rea of Dallas, Texas. An example treatment by Rea is that he will administer injections of a highly diluted solution of automobile exhaust to provide an "electromagnetic imprint" of the environmental pollutant. Rea claims that a patient's immune system will interact with the injections and desensitize the patient to the substance.

Staff has not been able to locate any other references to the term "electromagnetic imprint" in a medical context.

Rea's treatments had met with controversy, leading the Texas Medical Board to file a complaint against him[68,69,70] that resulted in a Mediated Agreed Order issued in 2010, requiring his consent form to state:

- The injections given are not FDA-approved;
- The patient will be receiving non-traditional medicine (must be in bold and oversized print);
- The effectiveness of the injections is disputed;
- There has been no testing of the contents of the injection or any proven medical effectiveness;
- The therapeutic value of the injections is not established or proven;
- There is no active agent in the therapy being provided; and
- The injections are not endorsed, sanctioned, or approved by the Texas Medical Board.

Rea's controversial treatments were also featured on a segment of ABC News' *Nightline* television program in 2008.[71,72]

Rea appeared before the Texas Senate Committee on Business and Commerce on October 9, 2012 to speak as a medical expert in opposition to wireless smart meters.

Cautions about Anecdotes, Attempts at "Do-it-Yourself" Science, and Reliance on Social Media and Blogs

Opponents of smart meters have provided accounts of ill health or have cited anecdotal reports of health problems that have been attributed by laypeople to the installation of smart meters. Caution must be used when considering anecdotal reports, because they:

- Are prone to human cognitive biases such as confirmation bias;[73]
- Use nonprobability sampling and therefore suffer from self-selection bias;[74]

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[68] <http://www.casewatch.org/board/med/rea/order.shtml>.
[69] <http://www.med.ohio.gov/pdf/Minutes/2011/08-11minutes.pdf>.
[70] <http://www.tmb.state.tx.us/news/press/2010/090210.php>.
[71] <http://abcnews.go.com/Nightline/video?id=5881281>.
[72] <http://www.youtube.com/watch?v=-gx4zxxi0xQ>.
[73] In psychology and cognitive science, confirmation bias is a tendency to search for or interpret information in a way that confirms one's preconceptions, leading to statistical errors. Source: <http://www.sciencedaily.com/articles/c/confirmation_bias.htm>.

- Do not supply a sufficiently large sample size;
- Prevent a rigorous statistical analysis of subject sample data;
- Do not account for a myriad of variables present in the environment (lack of controls); and
- Do not provide evidence that other aspects of the scientific method were followed.

In summary, conclusions drawn primarily from anecdotal reports do not possess scientific merit.

A common tendency for laypeople is to "cherry pick" scientific literature. Cherry picking is the act of pointing to data or individual cases that seem to confirm a particular position, while ignoring a significant portion of data or cases that may contradict the position. Selectively referencing only the studies that support a view is a common example of confirmation bias. Cherry picking may be committed unintentionally. Scientists are not immune to the behavior.

When raising concerns about wireless technology, some opponents have acquired RF EMF measurement equipment and posted online videos[75] showing readings being taken from smart meter installations. These videos have been presented as evidence that the smart meters were emitting RF EMF at levels higher than those claimed by utilities or meter manufacturers. More discerning viewers may question the validity of these videos for the following reasons:

- The videos tend to be brief, relying on fleeting numbers displayed on a readout;
- The data do not appear to be recorded for later study or shared with others;
- No evidence is provided that the operator is certified to use the measuring equipment;
- It is not noted whether the operator received any formal training to avoid, for example, using improper techniques when setting up or handling the equipment;
- Little explanation is offered to help the viewer determine if the appropriate settings were used (such as unit scaling) or whether instantaneous peak or average values were being measured;
- No evidence is given that the equipment was properly calibrated; and
- There may be other tools available which are better suited to the intended use.

One video[76] on YouTube that provides an example of an EMF measurement device being used purports to show the deleterious effects of a smart meter on a shrub situated directly in front of the meter in Stratford, Ontario, Canada. On the afflicted plant, the leaves have curled up and are losing color. There are two shrubs of identical breed on either side of it which do not seem to be as adversely affected. While a shrub is clearly not a human being, some smart meter opponents refer to the video as evidence of its apparent danger to all living things.

The person who recorded the video enabled the "audio analysis" mode on the measurement device, which creates a shrill sound reminiscent of a police siren but with varying pitch. The sound is intended to represent a characteristic signal pattern of the EMF being detected, which helps the device's user to identify the source of emissions. To an individual who has not experienced the operation of this device, the sound it makes in the presence of EMF may seem disturbing and evoke an unpleasant emotional response in the uninitiated.

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[74] Self-selection bias is a specific form of selection bias. Selection bias leads to distortions, because certain characteristics are over-represented in a sample. Self-selection bias introduces other errors. For example, sample populations that are the result of self-selection suffer from a correlation with willingness to be included. There may be a purposeful intent on the part of respondents.

[75] Go to YouTube: <http://www.youtube.com> and search for "smart meter emissions" or other similar phrases.

[76] <http://www.youtube.com/watch?v=IsuP_WBBr2c>.

An interesting observation about this video which some viewers may not notice is that as the camera focuses closely on the vegetation, it is readily apparent that the shrub is infested by what appears to be a large number whiteflies or aphids. These kinds of insects suck juices from the leaves of host plants, and can lead to serious injury, causing wilting, yellowing, leaf drop, and possibly death. As the video camera pans back and forth, one can see that the insects are also on the leaves of the adjacent shrubs, but are not yet as prevalent. The ability for viewers to provide comment is disabled for this particular video, so no one can call attention to the insect infestation or challenge the claims made by the person who posted the video.

The Texas A&M Forest Service estimated that 301 million trees had died across Texas forestlands as a result of the 2011 drought,[77] but to date there have been no known credible reports of dying vegetation attributed to smart meters or other wireless equipment despite the fact that millions of the devices have been deployed in the state.

Many smart meter opponents who have made assertions about the purported detrimental health effects of wireless technology have cited material obtained from blogs,[78] Internet videos, and other forms of social media as sources of information. Blogs may contain items that are topical but they are not to be confused with news sites; contributors to blogs are not held to standards for journalistic integrity. Most of the cited blogs are run by self-described activists who overtly state their opposition to smart meters and for various reasons. While blogs and social media sites have democratized the Internet, enabling almost anyone to widely publish his points of view, caution must be used when considering material obtained from such sources. These sites have many shortcomings, including the following:

- Site content is not vetted for objectivity or a diversity of opinions;
- Inaccurate reporting is common, and errors are rarely corrected;
- Many comments are written in an authoritative manner, promoting speculative statements as factual;
- Provocative language and hyperbole are often used to elicit emotional responses;
- Individuals promoted as experts tend to lack substantial academic credentials or possess credentials that are not associated with the field of study under consideration; and
- There is no assurance that authors resist the influence of advertisers or special interests.

The people who run blogs typically are not scientists and do not realize that an individual study is not to be considered definitive. Much of the research that Staff found cited on blogs was old and may have been out of date, or had been considered unreliable by the scientific community.

Case Law and Matters of Science

The Supreme Court cases *Daubert v. Merrell Dow Pharmaceuticals,*[79] *General Electric Co. v. Joiner,*[80] and *Kumho Tire Co. v. Carmichael*[81] articulated what is known as the "Daubert standard." The standard addressed Rule 702 of the Federal Rules of Evidence,[82,83] and clearly defined a judge's role in playing "gatekeeper," determining whether expert testimony is based on sound scientific reasoning and methodology.

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[77] <http://texasforestservice.tamu.edu/main/popup.aspx?id=16509>.
[78] A blog is a website that typically contains an online personal journal and that sometimes allows users to post their own opinions and commentary or other information.
[79] 509 U.S. 579 (1993).
[80] 522 U.S. 136 (1997).
[81] 526 U.S. 137 (1999).
[82] Pub. L. 93–595, §1, Jan. 2, 1975, 88 Stat. 1937; Apr. 17, 2000, eff. Dec. 1, 2000; Apr. 26, 2011, eff. Dec. 1, 2011.
[83] <http://www.law.cornell.edu/rules/fre/rule_702>.

According to Rule 702, *Testimony by Expert Witnesses,* a witness who is qualified as an expert by knowledge, skill, experience, training, or education may testify in the form of an opinion or otherwise if:

a. The expert's scientific, technical, or other specialized knowledge will help the trier of fact to understand the evidence or to determine a fact in issue;
b. The testimony is based on sufficient facts or data;
c. The testimony is the product of reliable principles and methods; and
d. The expert has reliably applied the principles and methods to the facts of the case.

In 2011, the National Academies published[84] the third edition of its *Reference Manual on Scientific Evidence,*[85] which was developed to guide judges as they encounter scientific evidence at trials. The cases are taken into consideration when government uses the "weight of evidence" to create public health policy and law.[86]

In a matter that is germane to the topic of this report, the Daubert case and the reference manual were both cited in a recent court decision in which the plaintiff claimed his exposure to low-level RF EMF emitted by electronics within his neighbor's house were triggering adverse health effects.[87] The court excluded the plaintiff's evidence because it was not scientifically reliable and consequently granted the defendant's motion for summary judgment for failing to demonstrate causation.[88]

Public Policy

The WHO published "Establishing a Dialogue on Risks from Electromagnetic Fields,"[89] a handbook intended as a guide for decision makers and those who craft policy to help reduce misunderstandings and improve trust through better dialogue when faced with a combination of public controversy, scientific uncertainty, and the need to operate or establish infrastructure facilities that emit EMF. The guide discusses risk assessment, risk perception by the public, and risk management. The document also calls out the need for involvement by individuals or organizations with the right set of competencies. It states that a combination of relevant scientific expertise, strong communication skills, and good judgment are required by those in the areas of management and regulation to properly respond to challenges presented by the topic. The handbook also provides references and suggested reading material for those who seek more information.

[84] <http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=13163>.
[85] <http://www.nap.edu/catalog.php?record_id=13163>.
[86] <http://ajph.aphapublications.org/doi/pdf/10.2105/AJPH.2004.044727>.
[87] Firstenberg v. Monribot and Leith, No. D-101-CV-2010-00029, New Mexico 1st Dist, Santa Fe County, Sept 18, 2012.
[88] <http://www.casewatch.org/civil/firstenburg/dismissal_order.pdf>.
[89] <http://www.who.int/peh-emf/publications/EMF_Risk_ALL.pdf>.

Recent Studies and Expert Opinions

California Council on Science and Technology Report and Responses

In 2010, the CPUC initiated an investigation of smart meters. Several members of the California State Assembly asked the California Council on Science and Technology to provide assistance to the CPUC.

CCST is an independent, not-for-profit 501(c)(3) corporation established in 1988 by the California legislature. It is designed to offer expert advice to the state government and to recommend solutions to science- and technology-related policy issues. CCST's Board of Directors is composed of representatives from its sponsoring academic institutions, as well as the business and philanthropic communities.[90]

The Assembly's request to provide assistance was motivated by concerns expressed by the public about the possibility of health effects from exposure to RF EMF emitted by smart meters. In January 2011, CCST issued "Health Impacts of Radio Frequency from Smart Meters." The document was authored by a project team that consulted with over two dozen experts and sifted through more than one hundred articles and reports which CCST considered as providing a thorough, unbiased overview in a relatively rapid manner. The report identified four key findings:[91]

1. Wireless smart meters, when installed and properly maintained, result in much lower levels of RF exposure than many existing common household electronic devices, particularly cell phones and microwave ovens;
2. The current FCC standard[92,93,94] provides an adequate safety factor against known thermally induced health impacts of existing common household electronic devices and smart meters;
3. To date, scientific studies have not identified or confirmed negative health effects from potential non-thermal impacts of RF emissions such as those produced by existing common household electronic devices and smart meters; and
4. Not enough is currently known about potential non-thermal impacts of radio frequency emissions to identify or recommend additional standards for such impacts.

CCST did not undertake primary research of its own to address issues. Its response was limited to soliciting input from technical experts and to reviewing and evaluating available information from past and current research about health impacts of RF emitted by electric appliances in general, and more specifically by smart meters.

Response to CCST Report: County of Santa Cruz Health Services Agency

Following the release of the CCST report, Poki Stewart Namkung, Health Officer of the County of Santa Cruz Health Services Agency (Santa Cruz), issued a memorandum. The memo was published on January 13, 2012 and is entitled "Health Risks Associated with Smart Meters."[95] The document has gained notoriety for two reasons. The first reason is because it made assertions that were in direct opposition to the CCST report's key

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[90] <http://www.ccst.us/about.php>.
[91] <http://www.ccst.us/publications/2011/2011smart-final.pdf>.
[92] <http://transition.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet65/oet65.pdf>.
[93] <http://transition.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet56/oet56e4.pdf>.
[94] <http://www.gpo.gov/fdsys/pkg/CFR-2011-title47-vol1/xml/CFR-2011-title47-vol1-sec1-1310.xml>.
[95] <http://www.santacruzhealth.org/pdf/2012%20Report%20on%20SmartMeters.pdf>.

findings. The second reason is because the assertions made in the Santa Cruz memo have been used by some smart meter detractors to justify calls for a moratorium on installation of the devices.

The Santa Cruz memo stated that CCST's report did not account for the frequency of transmissions, any reflections of the emissions, banks of smart meters firing simultaneously, or distances closer than three feet. The memo also asserted that smart meters would emit RF EMF almost continuously and that it would not be possible to program them to not operate at 100% of a duty cycle (on continuously). It stated that because of these factors, one could not claim that Smart Meters do not exceed the time-averaged MPE limit adopted by the FCC.

The Santa Cruz memo also stated that RF EMF exposure is additive[96] and consumers may have already increased their exposures to RF EMF emissions in the home through the voluntary use of RF emitting devices.

Michigan Public Service Commission: SGTAP Assessment of Santa Cruz Memo

On March 20, 2012, the Michigan Public Service Commission (MPSC) asked the Smart Grid Technical Advisory Project (SGTAP) to review the Santa Cruz memorandum. SGTAP is located at the Lawrence Berkeley National Laboratory (LBNL) and provides technical assistance and training to state regulatory commissions on topics related to smart grid. Primary SGTAP contributors are Roger Levy, a Research Specialist and owner of Levy Associates, and Janie Page, a Science/Engineering Associate at LBNL and the former Managing Editor at Bioelectromagnetics Society. SGTAP's response provided an analysis[97] of the Santa Cruz memo and called its accuracy and substance into question.

SGTAP noted the following:

1. The Santa Cruz memo made statements that were technically and scientifically incorrect and not supported by any research;
2. The memo did not appear to provide a balanced representation of the research, the risks, or the mitigation options;
3. The memo was instead largely focused on scientifically unsupported claims related to EHS;
4. Only half of the memo's citations met the peer review criteria that Santa Cruz itself had identified as necessary to be considered as a valid source; and
5. Out of the remaining references, half came from a single issue of the journal Pathophysiology,[98] which would only provide a limited acknowledgement to other relevant health, scientific, or industry sources. By relying so much on the journal, Santa Cruz denied exposing itself to a diversity of sources.

Finally, SGTAP noted that science can work toward understanding the causes of any health effects if and when they are observed, but it has never been able to categorically declare *anything* as being completely safe.

SGTAP Comments on Hirsch Document

SGTAP pointed out that the Santa Cruz memo had referred to a five-page document authored by Daniel Hirsch, a lecturer on Nuclear Policy at the University of California, Santa Cruz. This is notable because Hirsch had critiqued the CCST report and opponents of smart meters have cited Hirsch's document as support for their argument.

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[96] Note that the letter stated *additive* not *cumulative*.
[97] <http://eetd.lbl.gov/ea/ems/reports/schsa-042012.pdf>.
[98] <http://www.sciencedirect.com/science/journal/09284680/16/2-3>.

SGTAP concluded that:

1. The Hirsch document was not a formal report. It was a private submittal to the CPUC that did not meet Santa Cruz's own standards for consideration;
2. The educational and professional credentials of neither Hirsch nor his assistants could be identified which may have qualified them to profess expertise on EMF radiation, health, or smart meter operations;
3. The Hirsch document was severely flawed in several respects:
    a. It made arbitrary assumptions;
    b. It changed results that had been independently measured for some RF EMF emitting devices to levels that are not physically possible; and
    c. It further inflated figures that already had been overstated in the CCST report.

EPRI also published a paper critical of the Santa Cruz memo. EPRI's comments will be discussed later in this report.

Michigan Public Service Commission: SGTAP Assessment of AAEM Submittal

On April 12, 2012, the American Academy of Environmental Medicine (AAEM)[99] submitted a letter[100] to the MPSC in opposition to the installation of smart meters in homes and schools. According to AAEM's website, it is an international association of physicians and other professionals interested in the clinical aspects of humans and their environment. AAEM states on its site that it is interested in expanding the knowledge of interactions between human individuals and their environment, as these may be demonstrated to be reflected in their total health.

The AAEM site states that it provides research and education in the recognition, treatment and prevention of illnesses induced by exposures to biological and chemical agents encountered in air, food, and water. The certifying board for AAEM is the American Board of Environmental Medicine (ABEM), founded in 1988.[101] It is worth noting that neither AAEM nor ABEM is recognized by the American Board of Medical Specialties (ABMS).[102,103] Furthermore, the certification criteria required by ABEM are relatively sparse compared to those of ABMS. ABEM requires that an applicant have three years' experience practicing environmental medicine, take the AAEM medical instructional courses, and pass a written and an oral exam.

In contrast, the ABMS certification process involves 3-7 years of residency in the specialty, testing in the specific area of practice, a fellowship program of 1-3 years' duration and an optional subspecialty certification. In order to maintain certification the doctor is subjected to an *ongoing* peer evaluation and improvement process designed and administered by specialists in the specific area of medicine.

As a result of AAEM's letter, MPSC asked SGTAP to review the submittal. SGTAP provided a report[104] on April 18, 2012, which focused on the logical foundation of the AAEM statements and the relevance of its citations to

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[99] <http://www.aaemonline.org/>.
[100] <http://efile.mpsc.state.mi.us/efile/docs/17000/0391.pdf>.
[101] <http://www.americanboardofenvironmentalmedicine.org>.
[102] <http://www.abms.org/Who_We_Help/Physicians/specialties.aspx>.
[103] The ABMS was established in 1933, and is composed of approved medical boards which represent 24 broad areas of specialty medicine. ABMS is the largest physician-led specialty certification organization in the U.S. The American Medical Association's Council on Medical Education plays a significant role in ABMS.
[104] <http://eetd.lbl.gov/ea/emp/reports/aaem-042012.pdf>.

the smart meter issues. SGTAP did not comment on the technical merits of the individual research citations in the AAEM letter.

The SGTAP assessment found the following four aspects of the AAEM submittal to be problematic:

1. AAEM's assertion that research established causality of non-thermal effects;
2. The AAEM research citations and references were unrelated to smart meters;
3. AAEM's claims of electromagnetic hypersensitivity; and
4. AAEM's statements about the RF environment.

The following items provide detail on SGTAP's findings.

Aspect 1: SGTAP's Findings on AAEM's Assertion of Non-thermal Effects Causality

When considering the purported causality of non-thermal effects, recall that RF represents an extremely wide range of radio waves from 3 kHz to 300 GHz that spans eight orders of magnitude.[105] SGTAP stated that the RF EMF range cannot be generalized down to a single signal and that RF EMF is distinguished by a variety of independent characteristics, including frequency and intensity.

SGTAP pointed out that existing research has emphasized the unique characteristics and potential differences in effects from various RF EMF signals and sources. Thus, SGTAP concluded, an RF EMF effect reported at one frequency from one source cannot be presumed to imply an effect at another frequency from a completely different source.

The thermal effects observed as a result of exposure to RF EMF emissions at lower intensities are due to known mechanisms and could imply larger effects at a higher intensity.

Non-thermal effects are different because they appear to be related to distinct characteristics of the biological system being exposed and that symptoms or effects appear at specific frequencies or at distinct combinations of fields but not at others. Because there are no identified clear mechanisms for non-thermal RF EMF effects, there is no basis for someone to extrapolate observed non-thermal effects from one RF EMF source to another.

The AAEM submittal referred to the nine "Hill Criteria"[106] and the results of research studies which AAEM had extended to smart meters. Note that the criteria are most often used for assessing evidence of causation in epidemiological studies to test whether a particular agent is the cause of a selected effect. The criteria are typically employed when it is difficult to establish controls for all experimental variables. Using the criteria in research requires one to infer the causative agents from observational data.

SGTAP pointed out that inference is not proof and stated that the criteria cannot be applied when there are no research-related observational results. SGTAP concluded that it is not appropriate to presume an effect when the RF EMF sources differed in frequency, intensity, and proximity to critical biological tissues. Table 1 was included in the SGTAP report and addresses each criterion in relation to cell phones and smart meters. Reviewing the assessment of these criteria, it appears that the criteria have not been satisfied for cell phones, but it is quite obvious that the Hill criteria have not been satisfied for smart meters. No matter how well the criteria may or may not have been satisfied for cell phones, the significant differences between the two

[105] An order of magnitude is a Power of Ten, so eight orders of magnitude would be 10^8, or a 1 followed by eight zeroes (100,000,000).
[106] <http://www.edwardtufte.com/tufte/hill>.

technologies and the absence of research that specifically addresses smart meter operating characteristics make any attempt to assess smart meters using Hill's criteria moot.

Table 1: SGTAP Assessment Using Hill Criteria

Hill Criteria	Cell phones	Smart Meters
Strength: How large is the effect?	No widespread disease has yet been reported.	No published, peer-reviewed, scientific research at this time.
Consistency: Has the same association been observed by others, in different populations, using a different method?	Limited evidence from INTERPHONE study,[107] interpreted differently by different researchers. Opponents of smart meters focus strictly on Hardell's positive results without acknowledging the other results in the INTERPHONE study.	No published, peer-reviewed, scientific research at this time.[108]
Specificity: Does altering only the cause alter the effect?	A variety of studies has looked at changes in experimental setup to alter the source or size of the exposure with compelling results, most of which are related to distinct endpoints (e.g. oxidative stress markers and pathological changes in brain tissue in AAEM citation 16)	No published, peer-reviewed, scientific research at this time.
Temporality: Does the cause precede the effect?	Hard to discern in some epidemiology studies because hard to know state of individuals prior to study. Generally well controlled in lab studies.	No published, peer-reviewed, scientific research at this time, although some people claim a particular set of symptoms arise shortly after meters are installed.
Biological gradient: Is there a dose response?	Intensity of fields is often assumed as dose in a thermal model. For non-thermal effects, these criteria may not apply until we have a better understanding of dose.	No published, peer-reviewed, scientific research at this time.
Plausibility: Does it make sense? (Hill noted that knowledge of the mechanism is limited by current knowledge).	Mechanisms have not been well developed other than heating processes, where it is assumed that energy accumulates until dissipated.	No published, peer-reviewed, scientific research at this time.

[107] <http://ije.oxfordjournals.org/content/39/3/675.full.pdf>.

[108] For the purposes of the Hill criteria, reported symptoms need to be derived from well-structured research, not self-reported anecdotal reports (e.g. Internet blogs, newspaper articles, complaints/statements to regulatory commissions, etc.).

Coherence: Does the evidence fit with what is known regarding the natural history and biology of the outcome?	Limited coherence – many of the reported effects have unknown etiologies.	No published, peer-reviewed, scientific research at this time.
Experiment: Are there any clinical studies supporting the association?	There are some studies suggesting effects under certain circumstances.	No published, peer-reviewed, scientific research at this time.
Analogy: Is the observed association supported by similar associations?	Presumed to be supported by earlier (generally higher power) microwave studies.	Presumed to be supported by cell phone studies.

Aspect 2: SGTAP's Findings on AAEM's Research Citations and References

SGTAP stated that the citations and references in AAEM's letter were unrelated to smart meters. Smart meters operate in the frequency range of 902 - 928 MHz, and at an intensity of less than 1 watt, but the AAEM submittal cited references in which the frequencies and exposures measured appear to be substantively different from the fields that have been measured from smart meters.

In the one study cited by AAEM that did use a frequency in proximity of the range used by smart meters, the reported Specific Absorption Rate was at much greater field strength than that of a smart meter. Also, the test subject animals' proximity to the RF EMF source most likely would have been impossible to duplicate with a normal wall-mounted smart meter.

Aspect 3: SGTAP's Findings on AAEM's Claims of Electromagnetic Hypersensitivity

SGTAP found two problems with AAEM's claim that EHS had been documented in controlled and double-blind[109] placebo controlled conditions and in which 100% of subjects showed reproducible reactions to a frequency to which they were supposedly most sensitive. SGTAP pointed out that disagreements to the purported reproducibility of these reactions have been documented.

SGTAP also stated that the researcher AAEM had cited claimed that the frequencies involved in living systems are so precise that even the *phase* of a frequency was significant in research results. SGTAP concluded that while AAEM may have considered its cited researcher as credible, that finding would be in direct opposition to AAEM's attempt to extrapolate results from studies that used another frequency.

SGTAP also performed a detailed meta-analysis[110] of available literature and found that there was no evidence that study participants previously described as being "hypersensitive" had an improved ability to detect RF EMF. This was further reinforced by the conclusions drawn by the World Health Organization's (WHO) examination of EHS. The organization found that well-controlled double-blind studies showed no correlation between symptoms and RF EMF exposure.

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[109] In a double-blind experiment, neither the test subjects nor the researchers know who belongs to the control group and who belongs to the experimental group. This is done to lessen the influence of any prejudices and unintentional physical cues on the results.

[110] A meta-analysis is a "study of studies," i.e. a systematic method of evaluating statistical data based on results of several independent studies of the same problem.

SGTAP made special note of the fact that the references cited by AAEM to describe claimed sensitivities among self-identified EHS individuals were at very specific frequencies, none of which were associated with the operation of smart meters.

Aspect 4: SGTAP's Findings on AAEM's Statements about the RF Environment

SGTAP stated that recent measurements revealed that smart meters contribute only a small fraction of the total RF EMF emissions in a typical environment to which the general population is routinely exposed. SGTAP concluded that only a negligible reduction in total existing RF EMF exposures would result if smart meters were eliminated entirely.

Electric Power Research Institute

EPRI[111] is an independent, nonprofit organization that conducts research and development relating to the generation, delivery and use of electricity for the benefit of the public. EPRI provides technology, policy, and economic analyses to promote long-range research and development planning and supports research in emerging technologies. Scientists and engineers from EPRI, along with experts from academia and industry, address the challenges of electricity including reliability, efficiency, health, safety, and the environment.

For more than 30 years, EPRI has taken an active role in characterizing electromagnetic environments associated with power frequency transmission and distribution systems. More recently, the organization has done the same with RF EMF from smart meters. In February 2010, EPRI released a brief overview on RF EMF exposure associated with smart meters entitled "A Perspective on Radio-Frequency Exposure Associated with Residential Automatic Meter Reading Technology."[112] Since that time, EPRI has performed multiple investigations on RF EMF, and the results have been shared with regulators and industry as well as with the general public in an effort to foster a common understanding of RF EMF environments.

EPRI Technical Report on RF Emissions from Two Models of Smart Meters

EPRI has published several documents related to the RF EMF emitted by smart meters. In a December 2011 document[113], EPRI presented the results of a study by Richard Tell Associates[114] which EPRI had sponsored. Richard Tell Associates is a scientific consulting business focused on electromagnetic field exposure assessment, compliance with applicable standards and regulations on RF and power frequency fields and training related to the measurement, analysis and interpretation of electromagnetic fields.

The EPRI study was performed over a period of approximately six months during 2011 and analyzed two different wireless smart meters, a General Electric-I210 and a Landis+Gyr Focus AXR-SD, that Pacific Gas & Electric (PG&E) was in the process of deploying in its service territory. The meters contained two low power transmitters. One transmitter was 1W, to be used for communication in a mesh network, while the other was 0.1W, intended for a potential future Home Area Network (HAN). Each meter was also equipped with one of two different wireless communication packages developed by Silver Spring Networks.

The study found that the RF EMF field levels from the smart meters were below the exposure limits specified by the FCC. Furthermore, calculations determined that as the system was operating, nearly 99.9% of the

[111] <http://www.epri.com/>.
[112] <http://my.epri.com/portal/server.pt?Abstract_id=000000000001020798>.
[113] <http://my.epri.com/portal/server.pt?Abstract_id=000000000001021829>.
[114] <http://www.radhaz.com/>.

meters transmitted 1% or less of the time, and 99% of the meters transmitted less than 0.4% of the time. FCC exposure limits for the general public take these duty cycles[115] into account when estimating potential exposures and are based on a 30-minute average of power density across the body.

Preliminary measurements on the meters were conducted to:

- Determine the magnitude of the RF fields generated by the 1W mesh transmitter;
- Examine the meter's directional characteristics;
- Observe any unusual low frequency emissions in the 5 Hz to 100 kHz band that might be produced by the electronic circuits within the meters; and
- Measure the attenuation by a simulated stucco wall, common in many California homes.

In the next phase of the study, on-site measurements at six residential locations were conducted. This was done to determine typical indoor values of the RF EMF produced by the smart meter installed on a home. In addition, measurements were taken of the composite RF EMF environment where collections of smart meters were aggregated in a small space. This procedure was performed at three different apartment complexes, including one where 112 smart meters were collocated. Short-term duty cycles for several smart meters were also measured. Finally, the investigators took field measurements at a single data collector which gathers meter data from potentially thousands of residences.

Calculating Smart Meter RF EMF Emission Duty Cycles

The study collected and analyzed data transmissions from 88,296 smart meters through the utility's data management system. This large sample revealed the statistical distribution of meter duty cycles and enabled the calculation of the value for time-averaged potential exposure.

The EPRI report stated that the analysis identified one meter in 88,296 that exhibited a maximum duty cycle of 13.9%. It also found that half of the meters exhibited duty cycles not exceeding 0.0465%, 99% of meters had duty cycles not exceeding 0.355%, 99.9% had duty cycles at or below 1.12%, and 99.99% of meters had maximum duty cycles of 4.53% or less. The data confirmed that smart meters, while transmitting intermittently throughout the day, create RF fields for only very small fractions of the day. For example, half of all meters would be expected to actually transmit no more than 40 seconds per 24 hour day.

Considering the Directionality of RF EMF

The study also investigated the directional emission patterns of the meters. It found that the forward direction was strongest; rearward-directed fields were reduced by a factor of ten, and in some cases reductions of a factor of 100 were measured.[116]

Considering Groups of Meters

EPRI's report demonstrated that groups of smart meters mounted on apartment buildings at three different locations did not result in greater peak values of RF EMF fields than those produced by an individual meter. The study did find that average field magnitudes were higher due to the operation of multiple meter

[115] Duty cycle is the time that the radio module in a smart meter is emitting as a fraction of the total time period being considered.

[116] To be more precise, the reductions were 10 and 20 decibels respectively.

transmitters but that higher average composite duty cycles did not change the conclusion that such exposures are compliant with the established FCC limits.

Considering the HAN Transmitter

The HAN radio inside a smart meter is not currently implemented in PG&E's deployment, but the study found that when it was activated, the resulting EMF RF fields were substantially weaker due to their lower effective isotropic[117] radiated power (EIRP).[118] These radios also complied with the FCC exposure limits.

Report Conclusions on RF EMF Exposure

The EPRI report concluded that individuals in smart meter-equipped homes are commonly exposed to RF EMF emissions that are orders of magnitude less than what would occur for an individual standing immediately adjacent to and in front of the meter. It stated that the measurements performed in the six subject California residences found that 99% of the measured peak values were less than 0.8% of the MPE for the general public tier, and 90% of the measured values were less than 0.1% of the MPE.

The report stated that RF EMF emissions from smart meters that transmit data wirelessly are constrained by the low power of the transmitter's power and by the antenna's gain. Estimating smart meter fields is a straightforward calculation based on the EIRP of the meter. Locations where the greatest exposure can occur warrant no special consideration of reflections.

In summary, the EPRI report stated that the smart meter emissions are minute compared to the applicable FCC exposure limits. It also concluded that the smart meters comply with the FCC MPEs whether:

- The peak measured fields are corrected for meter duty cycles;
- Spatial averaging or any other factor that reduces RF fields, such as the construction materials of homes is considered;
- The meters exist in a large group or individually; or
- Individuals are outside near the smart meter or inside their residence.

As expected, the EPRI study found that the strongest fields occurred at the closest distance that measurements were performed (one foot). Typical peak fields at this distance were found to be about 10-15% of the MPE. The study also found that time-averaged and spatially-averaged values, at this point of maximum peak field, were estimated to be at most 0.14% of the FCC MPE, depending on the activity of the meter.

EPRI Comments on the Santa Cruz and AAEM Memoranda

EPRI also provided commentary[119] on the documents that the County of Santa Cruz Health Services Agency and AAEM had issued in response to the report from the CCST. EPRI stated that neither the Santa Cruz memo nor the AAEM document accounted for the large body of research on RF EMF that has been conducted over the past 50 years or the "weight-of-evidence" approach utilized by a large number of expert groups and panels that have convened over the years to assess the literature on RF health science.

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[117] Isotropic means "uniform in all orientations."

[118] EIRP is the amount of power that a theoretical antenna that evenly distributes power in all directions would emit to produce the peak power density observed in the direction of maximum antenna gain.

[119] <http://my.epri.com/portal/server.pt?Abstract_id=000000000001024952>.

EPRI concluded:

> "The transmittal from the Santa Cruz County health officer reflected a misunderstanding of several terms and concepts, including some of the basic principles of how smart meters work."

FCC RF EMF Exposure Guidelines

The 1997 FCC rule on RF EMF exposure was crafted from two earlier guidelines. The first guideline was published by the NCRP in 1986.[120] The second guideline was issued by the IEEE in 1991 and revised in 2005.[121] Before the FCC published its rule, it received endorsements from the U.S. Environmental Protection Agency (EPA), the FDA, and the U.S. Occupational Safety and Health Administration (OSHA). The EPA reaffirmed its opinion in 1999 and 2002.

Both sets of guidelines originated from an extensive review of the literature published in the fields of biology and health, regardless of whether the research had been conducted at non-thermal levels of exposure. NCRP and IEEE both concluded that the only established health effects of RF EMF were associated with tissue heating and that there were no confirmed adverse effects from RF exposure levels below an exposure threshold associated with an elevation in body temperature of about 1.8° F (1° C).

EPRI stated that since the FCC rulemaking, experts have revisited the expanding body of scientific evidence concerning potential health effects from RF EMF exposure. The conclusions were consistent with the position taken by the FCC in 1997.

Furthermore, following a comprehensive review of the scientific literature, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) published exposure limits in 1998 and reaffirmed them in 2009, while the IEEE issued its exposure limits in 2005. EPRI stated that both organizations' numbers were very similar to those of the FCC.

EPRI Addresses the WHO Classification of EMF as a 2B Carcinogen

In the spring of 2011, concerns about RF EMF exposures received significant visibility when the International Agency for Research on Cancer (IARC), a division of the WHO, published the results of its evaluation of potential cancer risks from RF exposures. The "IARC Monographs" identify environmental factors which can increase the risk of cancer in humans. These factors include chemicals, complex mixtures, occupational exposures, physical agents, biological agents, and lifestyle factors. National health agencies can use this information as scientific support for their actions to prevent exposure to potential carcinogens.[122]
According to EPRI, based on what can be considered as limited epidemiologic evidence in studies of cell phones and also limited evidence from a small fraction of all reported animal experiments, IARC classified radiofrequency electromagnetic fields as a "possible" or a Group 2B carcinogen.

To help put things into perspective, one must first understand the hierarchy of IARC categories. The categories, also known as Monograph Groups, consist of the following:

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[120] "NCRP Report No. 86 - Biological Effects and Exposure Criteria for Radiofrequency Electromagnetic Fields".
[121] <http://standards.ieee.org/findstds/standard/C95.1-2005.html>.
[122] <http://monographs.iarc.fr/>.

- Group 1: Carcinogenic to Humans (i.e., sufficient evidence);
- Group 2A: Probably Carcinogenic (less than sufficient evidence);
- Group 2B: Possibly Carcinogenic (limited evidence, less supportive evidence than 2A);
- Group 3: Not Classifiable (inadequate and/or insufficient evidence for classification).[123]

With reference to Monograph Groups 2A and 2B, IARC stated:

> "The terms probably carcinogenic and possibly carcinogenic have no quantitative significance and are used simply as descriptors of different levels of evidence of human carcinogenicity, with probably carcinogenic signifying a higher level of evidence than possibly carcinogenic."[124]

EPRI stated that the IARC 2B classification of RF EMF provides for a range of qualitative interpretations concerning its potential carcinogenicity. This IARC 2B classification indicates that more research information would be required for a more definitive statement in either direction.

EPRI continued, saying that the weight of current evidence still does not provide a basis to conclude that RF EMF can be considered as being "probably" carcinogenic. EPRI also indicated that IARC has near-term plans to evaluate the potential effects of RF EMF on all health outcomes, including cancer.

PUCT Staff's Observations on IARC 2B Carcinogens

There are over 200 substances in the IARC's 2B category, many of which have lengthy chemical names. Casual observers of such a list may become alarmed when they recognize a familiar item on it.[125]

Opponents of smart meters have noted the pending inclusion of RF EMF into the IARC 2B classification, and typically mention the pesticide DDT (dichlorodiphenyltrichloroethane) and elemental lead as also having been placed into the same classification (DDT was added in 1991, lead was added in 1987).

All this must be examined objectively and in the proper context.

Decades ago, DDT was found to have a demonstrable negative environmental impact widely viewed as outweighing its perceived benefits and found to accumulate in living tissue, leading to obvious health issues. For those reasons, it was removed from the market. Note that the potential for cancer is not why the substance was withdrawn.

Lead is also a bioaccumulative substance and has known toxic effects, such as interfering with a variety of body processes including those of the nervous system. As a result, its use has been continually reduced over the past few decades. Again, the potential for lead to cause cancer is generally not why the use of the substance has fallen out of favor.

To date, there is insufficient evidence to declare with confidence that either one of these substances is cancer-causing. Otherwise by now, one or both substances most likely would have been placed under a different IARC classification, namely one that required a higher level of evidence.

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[123] <http://monographs.iarc.fr/ENG/Preamble/CurrentPreamble.pdf>.
[124] <http://monographs.iarc.fr/ENG/Preamble/currentb6evalrationale0706.php>.
[125] See the References and Resources page for the entry under "Way, Tom."

In exploring comments made by some smart meter opponents filed with the Commission or found while researching the issue on the Internet, elemental lead and DDT have been mentioned in conjunction with RF EMF, but there has been no mention of the following well-known, common substances that are also included in the 2B Classification by the IARC:

- Coffee (added 1991);
- Pickled vegetables (added 1993); and
- Talc body powder (added 2010).

Lead and DDT are two substances that are widely known to cause health effects other than cancer and therefore carry with them a stigma. To mention them while excluding other substances which are both commonly used and generally considered benign, such as the ones listed above, and without the proper context, imparts a negative bias. This negative bias may prejudice the observer and alarm and confuse those who may have valid concerns about health and are attempting to understand rather complex concepts.

EPRI Workshops on RF Emissions and Health

In 2011, EPRI hosted two workshops to discuss the IARC classification. A report on the proceedings is available to the public in a document entitled "Program on Technology Innovation: Environmental and Health Issues Related to Radiofrequency Emissions from Smart Grid Technologies - Summary of Two Workshops."[126]

The purpose of the first workshop was to more specifically identify emerging technologies within the electric utility industry whose operation would result in EMF emissions. Such emissions may be produced for purposeful reasons, namely for communications, or might be a byproduct of a technology, such as emissions from appliances powered with variable speed drives.

The second workshop was a gathering of international scientists who shared their expertise to review the most important health issues associated with RF exposure and to identify priorities for further research. This workshop covered all aspects of RF science including exposure assessment, epidemiology, laboratory studies on both animals and humans, and biophysical mechanisms.

As a result of the workshops, EPRI issued a report that functions as a backdrop for potential future research to address environmental and health issues regarding smart grid technologies. It concluded:

- Current research regarding the health implications associated with RF emissions of new technologies has focused primarily on the nearly universal use of cell phones;
- Little information concerning characterization of exposure from projected smart grid and associated technologies is currently available;
- Though no adverse effects of "non-thermal" exposures have been identified, various unresolved questions remain, including a consistent observation of slightly altered brain wave activity in human subjects exposed to radio-frequency fields under laboratory conditions; and
- That the organization was well positioned to inform and educate all stakeholders about environmental risks and risk management options associated with technology deployment and operation.

[126] <http://my.epri.com/portal/server.pt?Abstract_id=000000000001024737>.

EPRI Investigations of RF EMF from Smart Meter Technology and Smart Grid Components

In 2010, EPRI published a 222-page technical report on its investigation of a particular smart meter entitled "An Investigation of Radiofrequency Fields Associated with the Itron Smart Meter."[127] The results indicated that RF EMF from the smart meter was well below the MPE established by the FCC.

For instance, at a distance of one foot, the RF EMF from a meter was not expected to exceed 0.8% of the MPE established by the FCC. For the cell relay, the study found that the RF field would not exceed 0.2% of the MPE. Even at very close distances, such as one foot directly in front of the meter and making the highly unrealistic assumption that the transmitters operate at 100% duty cycle, the resulting exposure was still found to be less than the FCC MPE.

When viewed in the context of a realistic and typical exposure distance of ten feet, the RF fields were much smaller: about 0.008% for the meter and about 0.002% of MPE for the cell relay.

EPRI's study stated that for occupants of a home equipped with a smart meter, interior RF fields were expected to be less than one-tenth as intense simply due to the directional properties of the meter. The investigation found that when a stucco[128] home's construction was included, the realistic value of the interior RF field would be attenuated to about 0.023% of the MPE for a meter and about 0.065% for a cell relay.

The investigators stated that regardless of duty cycle values for meter and cell relay meters, typical exposures that resulted from the operation of smart meters were very low and complied with scientifically-based human exposure limits by a wide margin.

EPRI also produced a brief case study in February 2011 on another smart meter with similar results under the title "Radio-Frequency Exposure Levels from Smart Meters: A Case Study of One Model."[129] In the interest of brevity and to avoid repetition, the findings of that EPRI publication are summarized in Table 2 below. The entire referenced document is publicly available from EPRI.

[127] <http://my.epri.com/portal/server.pt?Abstract_id=000000000001021126>.
[128] Stucco is a common home construction material in California, where this analysis was performed.
[129] <http://my.epri.com/portal/server.pt?Abstract_id=000000000001022270>.

Table 2: EPRI Findings – Radio Frequency Levels from Various Sources[130]

Source	Frequency	Exposure Level (mW/cm^2)	Distance	Time	Spatial Characteristic
Cell phone[131]	900 MHz and 1800 MHz	1-5	At ear	During call	Highly localized
Cell phone base station	900 MHz and 1800 MHz	0.000005-0.002	Tens to a few thousand feet	Constant	Relatively uniform
Microwave oven	2450 MHz	~5 0.05-0.2	2 inches 2 feet	During use	Localized, non-uniform
Local area networks[132]	2400 MHz or 5000 MHz	0.0002-0.001 (wireless router) 0.000005-0.0002 (client card)	3 feet	Constant when nearby	Localized, non-uniform
Radio/TV broadcast	Wide spectrum	0.001 (highest 1% of population) 0.000005 (50% of population)	Far from source (in most cases)	Constant	Relatively uniform
Smart meter[133]	900MHz and 2400 MHz	0.0001 (250mW, 1% duty cycle) 0.002 (1 W, 5% duty cycle) 0.000009 (250 mW, 1% duty cycle) 0.0002 (1 W, 5% duty cycle)	3 feet 10 feet	When in proximity during transmission	Localized, non-uniform

EPRI has also published a document that outlines eight projects involving the study of EMF and RF health and safety which the organization plans to perform in 2013. Most of these projects have multiple parts, several of which are expected to continue into subsequent years. The organization refers to this series of investigations and their resulting products as Program 60.[134] Its estimated funding for the program in 2013 is $5 million. Among the products to be completed in 2013 are:

- A peer review of literature regarding investigations of potential EMF/RF interference with implanted medical devices (e.g. pacemakers);
- A technical report to address emerging concerns about potential EMF effects on behavior and health of honeybees and cattle; and
- A technical update on RF exposure from wireless sources.

[130] FCC rule: From 300 MHz to 1500 MHz, MPE = 0.2 x f/300 mW/cm^2 (f is frequency in MHz); for 1500 MHz and greater, MPE = 1 mW/cm^2. For example, at 900 MHz MPE = 0.2 x (900/300) mW/cm^2 = 0.6 mW/cm^2. Note: Compliance for cell phones is provided by manufacturers, and expressed in terms of SAR, which cannot exceed 1.6 W/kg for any single gram of tissue.

[131] Based on a 3-inch, 250 mW antenna emitting in a cylindrical wave front.

[132] Wireless router based on a 30-100 mW isotropic emitter. Client card based on: Foster KR. 2007.

[133] Based on spatial peak power density with 6 dB (x4) antenna gain. For instantaneous power density during transmission, multiply the value for 1% duty cycle by 100, and the value for 5% duty cycle by 20.

[134] <http://mydocs.epri.com/docs/Portfolio/PDF/2013_P060.pdf>.

EPRI Comments on Sage Report

In January 2010, Sage Associates,[135] an environmental consulting firm whose principal is Cindy Sage,[136] issued a report entitled "Assessment of Radiofrequency Microwave Radiation Emissions from Smart Meters."[137] The report compared RF field levels of smart meters to the FCC's exposure limits and concluded that smart meters and collector meters installed in California were likely to violate the FCC limits, even under normal conditions of installation and operation. The report also compared field levels from smart meters to those from studies that reported biological and health effects.

In February 2010, EPRI addressed the research findings cited in the Sage report in a document titled "EPRI Comment: Sage Report on Radio-Frequency (RF) Exposures from Smart Meters."[138] EPRI found that:

- The Sage report misapplied the specifications in the FCC rule;
- The report findings had not been replicated or were inconsistent with the results of other studies; and
- Virtually every recent mainstream expert scientific review of the RF health literature conducted in North America and Europe either had not confirmed the effects cited in the report or found them indefinite.

Joint White Paper of EEI, UTC, and AEIC

In March 2011, Edison Electric Institute (EEI), Utilities Telecom Council (UTC), and Association of Edison Illuminating Companies (AEIC) jointly issued a white paper[139] entitled "A Discussion of Smart Meters and RF Exposure Issues."

The paper discusses how the location, distance from the transmitter, shielding by meter enclosures, attenuation of building materials, direction of RF emissions, and transmit duty cycle have a significant effect on RF EMF exposure levels. It also reviews the conclusions of several Smart Meter RF studies and actual measurements of Smart Meter RF emissions. Other observations made in the paper include:

- All smart meter radio devices must be certified to the FCC's rules;
- Tests simulating multi-family metering locations containing several meters in close proximity have shown RF exposure levels dramatically less than the FCC limits;
- The FCC limits on MPE for application to the general public were set using safety factors one-fiftieth (1/50th) of the levels of known effects;
- Exposure levels drop significantly:
    - with the distance from the transmitter;
    - with spatial averaging; and
    - in living spaces due to the attenuation effects of building materials.
- Due to shielding of the meter enclosure and signal patterns, RF exposure from the rear of a metering location is nominally one-tenth of that in front of the meter and dramatically below FCC limits, not including the spatial averaging and building material attenuation reductions;

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[135] <http://www.silcom.com/~sage/emf/index.html>.
[136] The Sage website states that Mrs. Sage has been involved in EMF issues as an environmental consultant and public policy researcher since 1982. She holds an M.A. degree in Geology and a B.A. in Biology.
[137] <http://sagereports.com/smart-meter-rf/>.
[138] <http://my.epri.com/portal/server.pt?Abstract_id=000000000001022639>.
[139] <http://www.aeic.org/meter_service/smartmetersandrf031511.pdf>.

- For measurement and calculation purposes, some studies use a 100% duty cycle. However, the maximum operational duty cycle for smart meter systems is less than 50% to prevent message traffic congestion and data packet collisions. The typical duty cycle for smart meter systems is between 1% and 5%;
- An RF exposure comparison of a person talking on a cell phone and a person three and ten feet from a continuously operating smart meter would result in smart meter RF exposure that is 0.08% - 0.8% of a cell phone; and
- In test environments simulating operational conditions, for power (0.250 - 2 watts), duty cycle (2% – 5%) at close distance (one foot) from in front of the transmitter, smart meters produce very low RF exposure to the consumer. They are typically well under 10% of the FCC exposure regulations.

The paper stated that before utilities accept and deploy smart meters, the devices must meet a number of national standards and comply with state and local codes designed to ensure proper operation, functionality, and safety. Specifically, smart meters and smart meter installations are typically designed to conform with and certified to comply with:

- ANSI C12.1, 12.10, and 12.20 standards for accuracy and performance;
- National Electrical Manufacturers Association (NEMA) SG-AMI 1-2009 "Requirements for Smart Meter Upgradeability";
- FCC standards for intentional and unintentional radio emissions and safety related to RF exposure, Parts 1 and 2 of the FCC's Rules and Regulations [47 C.F.R. 1.1307(b), 1.1310, 2.1091, 2.1093];
- Local technical codes and requirements; and
- Utility-specific and customer beneficial business and technical requirements.

The paper also discusses how manufacturers conduct performance and life cycle testing for meters and for major design changes to existing meters, including hardware and firmware. Once the testing is successfully completed, components of the smart meter system are certified by a utility or a third party for production and purchase. Finally, the paper outlines the process utilities use to accept materials and to evaluate each shipment of equipment for quality and compliance to specification after certification and purchasing.

Government and Academia

National Cancer Institute at the National Institutes of Health

The National Cancer Institute (NCI)[140] was established by Congress in 1937 and is one of 27 Institutes and Centers that form the National Institutes of Health (NIH). The NIH is one of the world's foremost medical research centers and is a part of HHS. NIH officials reported that the agency has provided about $35 million for research on health effects of RF energy from mobile phone use from 2001 to 2011.[141]

NCI's main responsibilities include coordinating the National Cancer Program, conducting and supporting cancer research, training physicians and scientists, and disseminating information about cancer detection, diagnosis, treatment, prevention, control, palliative care, and survivorship. Most of NCI's budget is used to fund grants and contracts to universities, medical schools, cancer centers, research laboratories, and private firms in the U.S. and about 60 other countries around the world.

One result of NCI's responsibilities to collect, analyze, and disseminate the results of cancer research conducted in the U.S. and in other countries is its webpage "Cell Phones and Cancer Risk,"[142] that concisely provides information in a Question and Answer format. While the webpage does not explicitly address the wireless communications technologies used by smart meters, if one accepts the notion that these technologies are similar to cell phones, the page offers useful information.

Key points made by NCI:

- Cell phones emit RF energy, a form of non-ionizing EM radiation which can be absorbed by tissues closest to where the phone is held;
- The amount of RF energy to which a cell phone user is exposed depends on the technology of the phone, the distance between the phone's antenna and the user, the extent and type of use, and the user's distance from cell phone towers; and
- Studies thus far have not shown a consistent link between cell phone use and cancers of the brain, nerves, or other tissues of the head or neck. More research is needed because cell phone technology and how people use cell phones have been changing rapidly.

These conclusions were mainly based on the results of some recently published studies including one from early 2012. NCI had reported on the results[143] indicating that while cell phone use in the U.S. had increased substantially over the period from 1992 to 2008 (from nearly zero to almost 100 percent of the population), the country's trends in glioma, the main type of brain cancer hypothesized to be related to cell phone use, did not mirror that increase. Results of this study were published online March 8, 2012 in the British Medical Journal.[144]

The NCI statement generally agreed with its comments[145] regarding the Interphone study[146] released nearly two years prior. The study was an international collaboration and the largest of its kind at the time which had

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[140] <http://www.cancer.gov/cancertopics/factsheet/NCI/NCI>.
[141] <http://www.gao.gov/assets/600/592901.pdf>.
[142] <http://www.cancer.gov/cancertopics/factsheet/Risk/cellphones>.
[143] <http://www.cancer.gov/newscenter/pressreleases/2012/GliomaCellPhoneUse>.
[144] <http://www.bmj.com/content/344/bmj.e1147>.
[145] <http://www.cancer.gov/newscenter/pressreleases/2010/Interphone2010Results>.
[146] <http://ije.oxfordjournals.org/content/39/3/675.full.pdf>.

looked at both glioma and meningioma, another form of brain cancer. It was published online in the International Journal of Epidemiology on May 17, 2010.

FCC Letter: Equipment Authorization, Exposure Limits, and Interference

The FCC is an independent U.S. government agency.[147] The agency was established by the Communications Act of 1934 and is charged with regulating interstate and international communications by radio, television, wire, satellite, and cable. Only three commissioners may be members of the same political party. None of them can have a financial interest in any Commission-related business. The commissioners supervise all FCC activities, delegating responsibilities to staff units and Bureaus.

The FCC's OET laboratory oversees the Equipment Authorization program. This program provides guidelines for the sale and use of equipment using the radio frequency spectrum. The devices subject to these rules must comply with the regulations in order to be considered as operating properly and to not create harmful interference. Subject RF devices may not be imported and/or marketed until they have demonstrated compliance with the technical standards specified by the FCC. These standards may be found in the rule section that governs the service wherein the equipment is to be operated. Financial penalties can be assessed if one does not comply with the appropriate FCC equipment authorization procedure. The Equipment Authorization procedures are publicly available for review.[148]

In March 2010, Cindy Sage sent a letter to the FCC with questions on several topics such as the agency's RF exposure limits, adjacent smart meter installations, and the potential for interference with other devices, especially medical devices. In August 2010, Julius Knapp, Chief of the FCC's Office of Engineering and Technology, responded.[149] The FCC letter explained that SAR evaluations were unnecessary with devices not held against the body and that power density (field strength) measurements were a sufficient and appropriate measure of exposure. The letter explained that FCC field strength limits and SAR limits are both time-averaged figures.

The FCC response pointed out that when the agency grants equipment authorizations (EA), it takes into account the peak power of the device because it is relevant to interference concerns. In contrast, exposure evaluations utilize maximum time-averaged power because that measurement takes into account how often a device will transmit. The purpose of a smart meter is to provide very infrequent information, so it transmits only in occasional bursts.

The FCC letter also addressed multiple adjacent smart meter installations. Since each smart meter has its own antenna, the separation distance of a person from most of the antennas is relatively large so that the potential exposure is quite small. Only one transmitter at a time can communicate with the collector to avoid the packets of data colliding with one another. Therefore, exposure from multiple signals at once does not occur. Signal strength decreases exponentially with distance, and there are additional losses of signal due to not being in the line of sight. In order for a device to be granted an EA, even banks of collocated meters must be compliant to the FCC's public exposure limits. Finally, the letter explained that auditing and review of EA grants is a routine function of the OET laboratory.

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[147] <http://transition.fcc.gov/aboutus.html>.
[148] <http://transition.fcc.gov/oet/ea/procedures.html>.
[149] <http://www.ccst.us/projects/smart/documents/Sage_Letter_from_%20Knapp_FCC.pdf>.

The FCC letter also addressed interference with medical devices, explaining that smart meters operate under Part 15 of the FCC Rules,[150] which specify power limitations to avoid interference. It stated that certain medical devices may need special precautions in many other environments, and that these are generally considered during FDA approval of the individual medical device.

GAO Report: Exposure and Testing Requirements for Mobile Phones Should Be Reassessed

In July 2012, the U.S. Government Accountability Office (GAO) issued a report[151] that recommended the FCC formally reassess and, if appropriate, change its current RF energy exposure limit and mobile phone testing requirements. It suggested that consideration be given to likely usage configurations, particularly when phones are held against the body. The FCC noted that it is currently considering a draft document which has the potential to address the GAO's recommendations.

The GAO also noted that international organizations have updated their exposure limit recommendation in recent years, based on new research whereas the FCC's current standards were based on research prior to 1996. The new international limit had been widely adopted by other countries, including countries in the European Union.

It is important to note that the GAO stated "*the new recommended limit could allow for more RF energy exposure* (emphasis added), but actual exposure depends on a number of factors including how the phone is held during use." Whereas one may argue that new RF exposure limits could be considered germane to smart meters (although RF emissions from smart meters are several orders of magnitude less than the exposure limit), smart meters are not in direct contact with the body.

According to the GAO report, the National Institute of Environmental Health Sciences (NIEHS), a part of the NIH, has a study underway described as "examining the toxicology and carcinogenic effects of RF energy in laboratory animals as part of the National Toxicology Program." The National Toxicology Program is an interagency program whose three core federal agencies are NIEHS, the Centers for Disease Control and Prevention's (CDC)[152] National Institute for Occupational Safety and Health (NIOSH),[153] and the FDA's National Center for Toxicological Research. Total NIH funding for the study was reported to be $25.6 million, and its estimated year of completion is 2015.

According to the GAO report, CDC officials reported that a staff member is collaborating with researchers in seven countries to conduct additional analyses on data collected through the INTERPHONE study to determine whether occupational exposure to RF energy and chemicals was a risk factor for brain cancer.[154]

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[150] <http://www.gpo.gov/fdsys/pkg/CFR-2010-title47-vol1/xml/CFR-2010-title47-vol1-part15.xml>.
[151] <http://www.gao.gov/assets/600/592901.pdf>.
[152] The CDC states that its mission is to collaborate to create the expertise, information, and tools that people and communities need to protect their health – through health promotion, prevention of disease, injury and disability, and preparedness for new health threats.
[153] NIOSH states that its mission is to generate new knowledge in the field of occupational safety and health and to transfer that knowledge into practice for the betterment of workers.
[154] Ibid.

Other Governmental Jurisdictions and Agencies

City of Naperville, Illinois

In early 2011, some utility customers of Naperville, Illinois expressed concerns regarding the RF EMF emissions from the smart grid equipment that was being deployed for the Naperville Smart Grid Initiative (NSGI). To address the concerns, detailed RF measurements were taken from the smart grid equipment, common household devices, and the ambient Naperville RF EMF environment. Engineers from the Naperville Department of Public Utilities performed the RF testing and compared it to permissible FCC power density specifications.

This emissions testing report issued on November 10, 2011 contains the test scope, overall approach, detailed test procedures, the complete set of test data, explanations, illustrations, and conclusions.[155,156] The comprehensive testing resulted in the following key findings:

- The NSGI smart grid equipment emitted RF power densities that are well below the FCC guidelines;
- Measurements of the smart meter equipment's instantaneous or peak RF power densities ranged between 1% and 3.2% of FCC limits at 20 cm in front of the meter. Note that the measurements observed were from a specially programmed continuously transmitting meter, which would yield inflated results when compared with real world situations;
- Measurements of the smart meter equipment average RF power densities ranged between 0.002% and 0.003% of FCC limits at 20 cm in front of the meter over a 30-minute period.
- The maximum backhaul equipment measured instantaneous or peak RF power density observed was 0.0277% of the FCC limit (measured 20 cm directly in front of the antenna); and
- The smart grid equipment average RF power densities were lower than typical household devices such as microwaves, cell phones, and Wi-Fi routers.

NSGI also issued a brochure[157] to put the RF EMF emissions from its smart meters into perspective:

> "...a person sitting 10 feet in front of their smart meter would have to be there for more than 100 years[158] to receive the same RF energy that they would receive from a 3-minute cell phone[159] call. If a person were sitting inside their home 3 feet from the back of a smart meter, they would have to be there for more than 200 years[158] to receive the same RF energy as they would from a 3-minute cell phone[159] call."

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[155] <http://www.naperville.il.us/emplibrary/Smart_Grid/Pilot2-RFEmissionsTesting-SummaryReport.pdf>.
[156] <http://www.naperville.il.us/emplibrary/Smart_Grid/Pilot2RFEmissionsTesting-Final.pdf>.
[157] <http://www.naperville.il.us/emplibrary/Smart_Grid/SmartMeterandRFCommunications.pdf>.
[158] Meter Specifications: Front of meter - Duty Cycle: 0.1%, AMI radio power: 250 mW EIRP, Distance: 10 ft. (305 cm); Behind Meter - Duty Cycle: 0.1%, Distance 3 ft. (91 cm).
[159] Cell Phone Specifications: Duty Cycle 45%, Peak Transmitter Power after antenna: 600 mW EIRP, Distance: 1 cm.

Maine Center for Disease Control & Prevention

On October 25th, 2010 a complaint was filed with the Maine Public Utilities Commission (MPUC) focusing on concerns related to the health, safety, and security of smart meters.[160] The Maine Office of the Public Advocate (OPA) called upon the Maine Center for Disease Control & Prevention (Maine CDC) to comment on health concerns related to the wireless communication technology used in the smart meters being installed by Central Maine Power. The Maine CDC received numerous emails and other communications on the issue, and its Public Health Director, Dr. Dora Anne Mills, reviewed the materials sent to her by both opponents and proponents of smart meters. Dr. Mills assembled several Maine CDC staff for further review of the material.

A report was issued[161] by the Maine CDC on November 8, 2010 to the MPUC and OPA. The Maine CDC reported that its review of national and international government or government-affiliated assessments[162] indicated a broad consensus that studies at the time gave no consistent or convincing evidence of a causal relation between RF exposure in the range of frequencies and power used by smart meters and adverse health effects.

According to the Maine CDC's report, they discovered little information in the assessments that spoke directly about the safety of RF exposure from smart meters. There was, however, much discussion about the safety of mobile phones. Mobile phone use represents an RF EMF exposure qualitatively similar to smart meters in range of frequency, but because the power of mobile phones is higher and typical use entails exposure closer to the body, the resulting exposure to RF EMF appeared to be quantitatively much greater than that from smart meters.

Thus, the report stated, it appeared that the lack of any consistent and convincing evidence of a causal relation between RF EMF exposure from mobile phones and adverse health effects would indicate even less concern for potential health effects from use of smart meters.

Subsequent to the investigation, the Maine CDC and others received several letters from people expressing concerns about the review. In order to ensure that OPA, MPUC, and the correspondents had concise responses, Maine CDC grouped the concerns into eight topic areas and compiled a "Frequently Asked Questions" (FAQ) document[163] published on November 29, 2010, which addressed the concerns.

Vermont Department of Health

In January 2012, the Vermont Department of Health measured the RF EMF emissions at active smart meters that had been installed in the town of Colchester by Green Mountain Power. The resulting report[164] stated that readings from the meters verified that the devices emitted only a small fraction of the RF EMF emitted from a typical cell phone, even at very close proximity to the meter. The readings were well below regulatory limits set by the FCC.

The report stated that the measurements taken directly in contact with a smart meter mounted on the exterior wall of a residence ranged from 50 to 140 microwatts per square centimeter (abbreviated $\mu W/cm^2$),

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[160] <https://www.maine.gov/dhhs/boh/smart_meters.shtml>.
[161] <https://www.maine.gov/dhhs/boh/documents/Smart_Meters_Maine_CDC_Executive_Summary_11_08_10.pdf>.
[162] <https://www.maine.gov/dhhs/boh/documents/Smart_Meters_Review_of_Government_Resources_11_08_10.pdf>.
[163] <https://www.maine.gov/dhhs/boh/documents/smart-meters-faq.pdf>.
[164] <http://healthvermont.gov/pubs/ph_assessments/radio_frequency_radiation_and_health_smart_meters.pdf>.

compared to the FCC's 610 μW/cm^2 MPE limit for the general population.[165] Measurements taken at distances of three feet or more away from the smart meter were at or near background levels of RF EMF.

Monterey County, California

In late 2010, members of the public that had concerns about potential adverse health effects of smart meters asked the Monterey County Board of Supervisors (the Board) to ban the use of smart meters in Monterey County. On January 11, 2011, the Board requested that the Monterey County Health Department review the literature and produce a report that summarized scientific findings related to smart meters and any potential adverse health effects. In March, 2011 the Health Department issued its report, entitled "Review of Health Issues Related to Smart Meters."[166]

The report's conclusions were as follows:

- Currently available literature indicates that exposure to RF energy from smart meters should be less than that experienced by routine mobile phone use;
- Based on the data available at the time of this review, the current FCC standard provides an adequate factor of safety against known thermally induced health impacts of existing common household electronic devices and smart meters;
- Despite extensive studies, there is no consistency of findings across studies regarding an association between non-thermal adverse health effects and exposure to EMFs from mobile phones;
- Due to various factors, further study is warranted to understand the potential for long-term adverse non-thermal health effects of RF energy from sources such as mobile phones;
- The lower exposure levels likely to be experienced from the deployment of smart meters compared to mobile phones should provide consumers some reassurance that there is a lower potential for adverse non-thermal health effects from the operation of smart meters; and
- Some countries have adopted different exposure limits for EMF or placement of EMF arrays and towers in relation to certain populations based on the Precautionary Principle rather than on scientific certainty.

Australia: Smart Meter Installations in the State of Victoria

In Australia, smart meters and other wireless devices used for communication having frequencies similar to mobile and cordless phones, are regulated by the Australian Communications and Media Authority (ACMA). Emissions from these wireless devices must comply with the ACMA Radiocommunications (Electromagnetic Radiation - Human Exposure) Standard 2003 as amended in 2011.[167] This standard mandates the exposure limits set by Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) which were designed to protect against all known adverse health effects. These exposure limits are described in the document "Radiation Protection Standard for Maximum Exposure Levels to Radiofrequency Fields – 3 kHz to 300 GHz."[168]

In 2011, the Victorian state government commissioned an independent study by testing laboratory EMC Technologies to determine the actual levels of RF EMF exposures from smart meters, and make sure that the meters complied with the exposure levels set by ARPANSA.

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[165] The micron symbol, μ, is a prefix that represents 10^{-6}, or one-millionth. 1 μW = one-thousandth of one milliwatt (mW).
[166] <http://publicagendas.co.monterey.ca.us/MG97205/AS97224/AS97230/AI99413/DO99416/DO_99416.pdf>.
[167] <http://www.comlaw.gov.au/Details/F2011C00165>.
[168] <http://www.arpansa.gov.au/pubs/rps/rps3.pdf>.

EMF measurement site surveys were conducted on a range of smart meters installed in various types of houses. The EMF measurements were performed on AMI meters installed by the five major utilities in the state of Victoria. The five utilities have joint programs in place to manage these installations, with the end result being three combined deployments. Most measurements were conducted on single AMI installations but also included a group meter installation (with 9 to 12 meters) from each of the three deployments. In these group meter installations, up to six meters were interrogated simultaneously to measure the maximum combined EMF from multiple transmissions.

EMC Technologies tested both types of electromagnetic exposures produced from smart meters - the EMF generated by the operation of a smart meter and RF emissions related to the built-in two-way communications. EMC Technologies found[169] that the maximum RF EMF power density levels were well below the ARPANSA General Public Limit specified by ARPANSA Radiation Protection Standards, even when the meter was forced to transmit continuously (100% duty cycle). More specifically, exposure levels from smart meters inside dwellings ranged from 0.000001% to 0.0113% of ARPANSA's General Public Limit of 450 $\mu W/cm^2$.

The test results also showed that in measurements made at sites with grouped meters, even with a number of meters being requested for meter data upload, the EMF peak field measured did not increase above the level of a single meter transmission. No two meters were transmitting simultaneously. The report concluded that the maximum RF EMF power density from a group meter installation is expected to not be higher than that of a single meter installation.

RF EMF tests were also conducted on various household appliances that emit RF fields – a wireless modem, microwave oven, baby monitor, mobile phone and cordless phone. The RF EMF levels from the meters, even when measured from a foot away, were lower than the levels from these other common household items. The actual EMF levels from a meter, when measured inside the house, were very low compared to the levels from the abovementioned items.

Smart Meters Have Lower ELF EMF Levels than Electromechanical Meters

Extremely Low Frequency electromagnetic fields (ELF EMF) occur at 50Hz in Australia and at 60Hz in the U.S. and are predominantly found in electric energy generation, transmission, and distribution. Unlike the testing performed by the other organizations in this report, the scope of work in the Australian investigation included the measurement of ELF EMF. Tests were conducted on smart meters and on an electromechanical (i.e., rotating disc) electricity meter, as well as an electric blanket, vacuum cleaner, microwave oven, and CRT (Cathode Ray Tube) television.

In the tests, the 50 Hz fields around the smart meter were lower than those from some other common appliances such as vacuum cleaners and microwave ovens. The levels from other appliances such as hairdryers, power tools, induction cookers, fans, and air conditioners would also be much higher.

Finally, the test results showed that ***the fields from the smart meter are slightly lower than the fields from the analog (electromechanical) meter***. The report concluded that the smart meters themselves do not cause any increase in the power line-related EMF levels and that replacement of the older analog meters with AMI meters would reduce ELF EMF exposure.

[169] <http://www.dpi.vic.gov.au/smart-meters/publications/reports-and-consultations/ami-meter-em-field-survey-repor>.

United Kingdom: Health Protection Agency

In April 2012, the Advisory Group on Non-ionising Radiation (AGNIR), an independent advisor to the Health Protection Agency of the UK, produced a document entitled "Health Effects from Radiofrequency Electromagnetic Fields."[170] The Health Protection Agency is an independent organization that was formed by the UK government in 2003 to protect the public from threats to their health from infectious diseases and environmental hazards. According to its website, it does this by providing advice and information to the general public, to health professionals such as doctors and nurses, and to national and local government.[171]

The report starts out by saying that the quantity and quality of research published on the potential health effects of RF field exposure has increased substantially since AGNIR had last reviewed the subject in 2003. While the publication admitted that limitations to the published research still exist and therefore preclude a definitive judgment, the evidence considered did not demonstrate any adverse health effects of RF EMF exposure at levels below the internationally accepted guideline.

The paper stated that while there were possible effects on Electroencephalography (EEG) patterns, they were not conclusively established and that it was unclear whether such effects would have any health consequences.

The AGNIR document also stated that, in regard to RF EMF exposure that was below guideline levels:

- The evidence indicated that it does not cause symptoms;
- RF cannot be detected by people, even by those who considered themselves sensitive to RF fields;
- The evidence pointed toward no material exposure to the risk of cancer although there is little data on risks beyond 15 years from first exposure;
- RF showed no effect on health not related to cancer; and
- There was a lack of convincing evidence that it caused health effects in adults or children.

Health Canada: Safety Code 6

Health Canada[172] is the Canadian federal department responsible for helping its country's people maintain and improve their health, while respecting individual choices and circumstances. Health Canada's document titled "Limits of Human Exposure to Radiofrequency Electromagnetic Fields in the Frequency Range from 3 kHz to 300 GHz"[173,174] is a code that specifies Canada's radiofrequency exposure guidelines, commonly known as "Safety Code 6 (2009)." The guidelines provide recommended best practices for ensuring compliance with the maximum exposure levels for controlled and uncontrolled environments. The Safety Code 6 (2009) standards are similar to the U.S. FCC standards established in 1997.

Regarding MPE, Safety Code 6 states the following:

> "For frequencies from 100 kHz to 300 GHz, tissue heating is the predominant health effect to be avoided. Other proposed non-thermal effects have not been conclusively documented to occur at levels below the threshold where thermal effects arise."

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[170] <http://www.hpa.org.uk/webc/HPAwebFile/HPAweb_C/1317133827077>.
[171] <http://www.hpa.org.uk/AboutTheHPA/>.
[172] <http://www.hc-sc.gc.ca/ahc-asc/index-eng.php>.
[173] <http://www.hc-sc.gc.ca/ewh-semt/pubs/radiation/radio_guide-lignes_direct-eng.php>.
[174] <http://www.scribd.com/doc/36604752/Safety-Code-6>.

British Columbia Provincial Health

On December 23, 2011 a statement[175] was prepared at the request of the British Columbia (BC) Provincial Health Officer by Mary McBride, a Distinguished Scientist at the Department of Cancer Control of the BC Cancer Agency (BCCA) in Vancouver, BC. The letter had been approved by Dr. David McLean, Head of Cancer Prevention at the BCCA.

The statement indicated that research evidence does not support a conclusion that RF EMF, whether from cell phones or smart meters, can cause brain tumors in adults. With more than 20 years' cell phone use and limited information on a risk of other cancers, the information that BCCA officials possess generally does not support the notion of cancer. The statement admits that while there is no direct information on children, more studies are underway to address gaps in their understanding of RF EMF and cancer risk. The statement concluded by saying that extensive laboratory research to date has not identified any mechanisms that could function in either adults or children which would lead to an excess risk of tumors in general.

Ontario Province: Ontario Agency for Health Protection and Promotion

On September 16, 2010, the Ontario Province of Canada's Agency for Health Protection and Promotion (Ontario Health Agency) issued a brief paper that cautioned against relying on the results of individual research studies regarding the potential health effects from exposure to RF EMF because inconsistencies or conflicts may exist among the results of other individual studies.

The Ontario Health Agency stated that performing reviews of literature that followed an approach of weighing evidence would be far more useful to inform debate and make sound policy than it would be to merely rely on individual studies.

The Ontario Health Agency pointed to the Royal Society of Canada's (RSC) highly credible review from 1999[176] with updates to the review published as recently as 2009.[177,178] The RSC review called for additional research to follow up on new findings from an additional decade of research and noted that there was still no conclusive evidence of adverse health effects at exposure levels that are below the current Canadian guidelines.

The Ontario Health Agency stated that recently published research demonstrated that Wi-Fi exposure is well within recommended limits and is also only a small fraction (less than 1%) of exposure during the typical use of a cell phone. Because of this, much of the research on possible effects of RF EMF has been focused on exposures from cell phones rather than the lower exposures associated with RF uses such as Wi-Fi, and the focus will continue to be on cell phones. The Ontario Health Agency also stated that public exposure, including school children, to Wi-Fi is far lower than what occurs with cell phone use, and that there is no plausible evidence to date that would indicate that current public exposure to Wi-Fi is causing any adverse health effects.

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[175] <http://www.health.gov.bc.ca/pho/issues.html>.
[176] <http://www.rsc.ca/documents/RFreport-en.pdf>.
[177] <http://www.rsc.ca/documents/expert_panel_radiofrequency_update2.pdf>.
[178] <http://www.ncbi.nlm.nih.gov/pubmed/20183523>.

City of Richmond, British Columbia and Vancouver Coastal Health

The BC Hydro and Power Authority is an electric utility in British Columbia. The company serves 1.8 million customers in most areas of the province and is deploying smart meters. On November 14, 2011, the City of Richmond in British Columbia passed a resolution requesting its Medical Health Officer to "conduct an investigation as to whether smart meters pose a health hazard." The response,[179] dated December 20, 2011 and signed by the BC Health Officer and two officers from Vancouver Coastal Health, concluded that the smart meters installed and used by BC Hydro were not a health hazard. Furthermore, the letter stated that "the transmitters in Smart Meters produce electromagnetic fields at levels significantly lower than the maximum allowed for the Canadian public under Health Canada's Safety Code 6."

Other notable findings of the independent consultant, Planetworks Consulting Corporation include:[180,181]

1. Smart meters are active for only a very short duration at a time;
2. The average power density was 0.3795% of Safety Code 6 for a single smart meter;
3. For a bank of ten smart meters, the average power density was found to be 0.4507% of Safety Code 6 (a range from 0.0015% to 1.6835% of Safety Code 6); and
4. The highest power density value recorded from a bank of ten meters was less than 2% of Safety Code 6 limit, while the average power density for both single and a ten meter bank are less than 0.5% of Safety Code 6.

Note that Safety Code 6 requires the power density at the frequency used by the smart meters to be less than 600 $\mu W/cm^2$ for publicly accessible areas (compared to the FCC's limit of 610 $\mu W/cm^2$). One can see that the power density recorded for a ten meter bank is not ten times that of a single meter, as some may suspect. Instead, the average power density for the ten meter bank was found to be only about 1.2 times that of a single meter, while the maximum value from a bank of ten meters was slightly less than twice the maximum value recorded from a single meter.

Norwegian Institute of Public Health

In spring 2010, an Expert Committee was appointed by the Norwegian Institute of Health and commissioned by the Ministry of Health and Care Services and the Ministry of Transport and Communications. The committee was composed of individuals with expertise in environmental and occupational medicine, biology, physics, metrology, biophysics, biochemistry, epidemiology, and philosophy as well as administration and risk management. In 2012, the committee issued its report.

The committee assessed the health hazards from low-level electromagnetic fields generated by radio transmitters. The Committee evaluated the power of the fields, whether they posed a health risk, the current regulatory practice, and whether the threshold limit values for exposure were observed. A press release from the institute described the report conclusions: [182]

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[179] <http://www.health.gov.bc.ca/pho/pdf/vch-response-to-richmond-city-council-re-investigation-into-smart-meters.pdf>.

[180] <http://www.bchydro.com/etc/medialib/internet/documents/smi/SMI_SingleSmartMeter.Par.0001.File.SMI-SingleSmartMeter-2011-Oct-11.pdf>.

[181] <http://www.bchydro.com/etc/medialib/internet/documents/smi/SMI_MeterBank.Par.0001.File.SMI-MeterBank-2011-Oct-11.pdf>.

[182] <http://www.fhi.no/eway/default.aspx?pid=238&trg=MainLeft_5895&MainArea_5811=5895:0:15,2829:1:0:0:::0:0&MainLeft_5895=5825:99168::1:5896:1:::0:0>.

"There is no scientific evidence that low-level electromagnetic field exposure from mobile phones and other transmitting devices causes adverse health effects, according to a report presented by a Norwegian Expert Committee. In addition, the Committee provides advice to authorities about risk management and regulatory practice."

Swedish Council for Working Life and Social Research

The Swedish Council for Working Life and Social Research (FAS) was commissioned by the government of Sweden to monitor issues relating to research into EHS and to document and report on the state of research at regular intervals, starting in 2003. In the executive summary of its 2012 report, FAS stated:[183]

"Extensive research for more than a decade has not detected anything new regarding interaction mechanisms between radiofrequency fields and the human body and has found no evidence for health risks below current exposure guidelines. While absolute certainty can never be achieved, nothing has appeared to suggest that the since long established interaction mechanism of heating would not suffice as basis for health protection."

Health Council of the Netherlands

The Health Council of the Netherlands is an independent scientific advisory body.[184] Its task is to provide the Netherlands government and parliament with advice in the field of public health and health/healthcare research. The agency also addressed EHS in its report, *Electromagnetic Fields: Annual Update 2008*:[185]

"From the good quality scientific data emerges the picture that there is no causal relationship between exposure to radiofrequency electromagnetic fields and the occurrence of symptoms. However, there is a relationship between symptoms and the *assumption* of being exposed and therefore most likely with the risk perception."

World Health Organization

The WHO website contains a wealth of information about EMF, including what it is, links to a database of research citations, national standards, publications, information resources, and meetings. The site also has a link to Germany's EMF-Portal that provides access to research databases.

The organization also hosts the International EMF Project,[186] which was established in 1996 and is open to any WHO Member State government, such as department of health or representatives of other national institutions concerned with radiation protection. The project was established to assess health and environmental effects of exposure to static and time varying electric and magnetic fields in the frequency range 0-300 GHz. The site provides access to 39 ongoing studies, 322 published studies, and 12 studies that have been reported but not published.

There are 54 participating countries and eight international organizations involved in the project. It is fully funded by participating countries and agencies. Its stated key objectives are to:

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[183] <http://www.fas.se/pagefiles/5303/10-y-rf-report.pdf>.
[184] <http://www.gezondheidsraad.nl/en>.
[185] <http://www.gezondheidsraad.nl/sites/default/files/200902.pdf>
[186] <http://www.who.int/peh-emf/project/en/>.

- Provide a coordinated international response to concerns about possible health effects of exposure to EMF;
- Assess the scientific literature and make a status report on health effects;
- Identify gaps in knowledge needing further research to make better health risk assessments;
- Encourage a focused research program in conjunction with funding agencies;
- Incorporate the research results into WHO's Environmental Health Criteria monographs where formal health risk assessments will be made on exposure to EMF;
- Facilitate the development of internationally acceptable standards for EMF exposure;
- Provide information on the management of EMF protection programs for national and other authorities, including monographs on EMF risk perception, communication and management; and
- Provide advice to national authorities, other institutions, the general public and workers, about any hazards resulting from EMF exposure and any needed mitigation measures.

The WHO recognized the following independent scientific institutions for their collaboration:

- U.S. Air Force Research Laboratory, Human Effectiveness Directorate (Brooks Air Force Base, TX);
- Australian Radiation and Nuclear Safety Agency (ARPANSA);
- UK Health Protection Agency - Radiation Protection Division;
- German Federal Office for Radiation Protection (BfS); and
- Institute of Population Health, University of Ottawa, Ontario, Canada.

Some key points are made on the WHO website regarding EMF and health. Among them are the following:

- A wide range of environmental influences causes biological effects. 'Biological effect' does not equal 'health hazard'. Special research is needed to identify and measure health hazards;
- There is no doubt that short-term exposure to very high levels of electromagnetic fields can be harmful to health. Current public concern focuses on possible long-term health effects caused by exposure to electromagnetic fields at levels below those required to trigger acute biological responses;
- Despite extensive research, to date there is no evidence to conclude that exposure to low level electromagnetic fields is harmful to human health;
- The focus of international research is the investigation of possible links between cancer and electromagnetic fields, at power line and radiofrequencies;
- Finding a statistical association between some agent and a specific disease does not mean that the agent caused the disease;
- The absence of health effects could mean that there really are none. However, it could also signify that an existing effect is undetectable with present methods;
- Results of diverse studies (cellular, animal, and epidemiology) must be considered together before drawing conclusions about possible health risks of a suspected environmental hazard. Consistent evidence from these very different types of studies increases the degree of certainty about a true effect; and
- Due to a large safety factor, exposure above the guideline limits is not necessarily harmful to health. Furthermore, time-averaging for high frequency fields and the assumption of maximum coupling for low frequency fields introduce an additional safety margin.

Publications and other specific work outputs from efforts of the WHO, its divisions, and collaborating organizations are noted throughout this report and will not be repeated here.

Comments by Academia on Public Concerns about Wireless Smart Meters

Montréal Polytechnic and McGill University Open Letter

On May 18, 2012, an open letter was issued in support of smart meter technology[187] and signed by 61 scientists and engineers primarily affiliated with one of two universities located in Montréal, Québec, Canada: École Polytechnique de Montréal (Montreal Polytechnic) and McGill University. The few signatories who could be thought to have a conflict of interest through their affiliation with the telecommunications industry or Hydro Québec, the utility in the province deploying more than 3 million smart meters, declared their conflict alongside their names.

In the letter, the Québécois engineers and scientists commented:

> "We believe that the fear of wireless technologies is based primarily on i) a misunderstanding of the nature of radio waves and their interaction with the human body, ii) a misreading of the scientific literature on this subject, and iii) a distrust of local, national and international public health organizations."

The Québec Energy Board, the provincial regulator, took the letter into consideration when rendering its decision[188] to allow Hydro Québec to proceed with its plan to install wireless smart meters in its service territory. The agency stated in its summary[189] (translated from French):

> "The views presented by the public health authorities and the evidence heard by [the Board] on the state of scientific research on the impacts of non-thermal RF on health demonstrate that the emissions from the new generation of smart meters do not present a health risk."

University of Ottawa: RFcom Review Panel Reports

The University of Ottawa's McLaughlin Centre for Population Health Risk Assessment has a project called RFcom[190] that functions as an Internet-based information resource about health effects of wireless technologies. RFcom is managed by a science panel that reviews and reports[191] on the most recent research studies about wireless technology and health from around the world. All studies referenced on its website must meet the following criteria:

- The source must be credible and accountable;
- Material must be peer-reviewed research and data that has been accepted and validated in the Canadian and international communities; and
- All studies must have been carried out by an independent third-party person or organization.

The page contains conclusions and excerpts from reports issued by various organizations from within countries and international bodies including Canada, Denmark, the EC, Finland, France, Germany, Iceland, Netherlands, Norway, Spain, Sweden, the UK, and the U.S. These excerpts overwhelmingly indicate that there is no

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[187] <http://www.polymtl.ca/phys/doc/Lettre_ouverte_de_scientifiques_quebecois_les_compteurs_intelligents.pdf>.
[188] <http://internet.regie-energie.qc.ca/Depot/Projets/111/Documents/R-3770-2011-A-0163-DEC-DEC-2012_10_05.pdf>.
[189] <http://internet.regie-energie.qc.ca/Depot/Projets/111/Documents/R-3770-2011-A-0164-DEC-DEC-2012_10_05.PDF>.
[190] <http://www.rfcom.ca/welcome/index.shtml>.
[191] <http://www.rfcom.ca/panel/index.shtml>.

conclusive evidence to support many of the assertions smart meter opponents are making about the harms of RF EMF exposure and negative health outcomes.

Other Issues

Potential for Interference with Medical Devices

Some people have expressed concern that signals from smart meters could interfere with the operation of implanted electronic devices such as pacemakers or other medical equipment. According to the FCC, because they are electronic devices, there is a potential for such devices to be susceptible to electromagnetic signals that could cause them to malfunction. The FCC stated[192] that there have been anecdotal claims of such effects in the past which involved emissions from microwave ovens but that it has never been shown that the RF energy from a properly operating microwave oven is strong enough to cause such interference. The FCC also stated that the FDA requires pacemaker manufacturers to test their devices for susceptibility to electromagnetic interference (EMI) over a wide range of frequencies and to submit the results as a prerequisite for market approval. Electromagnetic shielding has been incorporated into the design of modern pacemakers to prevent RF signals from interfering with the electronic circuitry in the pacemaker.[193]

Both the FCC and FDA[194] refer to studies which have shown that mobile phones can interfere with implanted cardiac pacemakers if a phone is used in close proximity (within about eight inches) of a pacemaker. Such interference appears to be limited to older pacemakers which may no longer be in use. The agencies recommend that those with pacemakers avoid placing a phone in a pocket close to the location of their pacemaker or putting the phone near the pacemaker location when using the phone.

One of the studies to which the FCC and FDA refer was published in The New England Journal of Medicine[195] in which a total of 980 patients were tested. Seven hundred twenty-five patients were tested with six telephones and 255 were tested with five telephones, providing a total of 5625 tests. Ninety-two tests were eliminated because of incomplete data. Thus, statistical analyses were based on 5533 tests. The study concluded that no interference was observed in any pacemaker at base line. The study stated that while abnormalities of pacing were observed at base line in 23 of 976 patients (2.4%) during testing, evidence of these abnormalities was not considered to be due to interference.

Further, ANSI and the Association for the Advancement of Medical Instrumentation (AAMI) have devised a standard[196] known as ANSI/AAMI PC69:2007 which establishes electromagnetic compatibility test protocols for active implantable cardiovascular devices. The standard is intended for manufacturers of implantable medical devices and consultants who test implantable devices. It specifies test methods related to interference frequencies and their potential effects on implantable devices such as cardiac pacemakers and internal defibrillators. It also requires disclosure of a device's performance issues in the presence of EM emitters where appropriate and provides manufacturers of EM emitters with information about the level of immunity to be expected from active implantable cardiovascular devices.

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[192] <http://transition.fcc.gov/oet/rfsafety/rf-faqs.html#Q22>.
[193] <http://transition.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet56/oet56e4.pdf>.
[194] <http://www.fda.gov/Radiation-EmittingProducts/RadiationEmittingProductsandProcedures/HomeBusinessandEntertainment/CellPhones/ucm116311.htm>.
[195] <http://www.nejm.org/doi/pdf/10.1056/NEJM199705223362101>.
[196] <http://webstore.ansi.org/RecordDetail.aspx?sku=ANSI%2FAAMI+PC69%3A2007>.

Claims of Electromagnetic Hypersensitivity

World Health Organization

The WHO is the directing and coordinating authority for health within the United Nations system. It is responsible for providing leadership on global health matters, shaping the health research agenda, setting norms and standards, articulating evidence-based policy options, providing technical support to countries, and monitoring and assessing health trends.[197]

In December 2005, the WHO International EMF Project created a fact sheet on electromagnetic fields and public health in order to address EHS.[198] The fact sheet describes what was known about the condition, and it provided information for helping people with such symptoms. The information was based on a WHO Workshop on Electrical Hypersensitivity (Prague, Czech Republic, 2004),[199,200] an international conference on EMF and non-specific health symptoms (COST 244bis, 1998),[201] a European Commission report (Bergqvist and Vogel, 1997),[202] and reviews of the literature.

The fact sheet stated that EHS is characterized by a range of non-specific symptoms that lack apparent toxicological or physiological basis or independent verification and that it differs from individual to individual.[203] The sheet stated that the symptoms are certainly real and can vary widely in their severity, and they can be a disabling problem for the affected individual.

The WHO document noted that a number of scientific studies had been conducted where EHS individuals were exposed to EMF similar to what they had attributed to the cause of their symptoms. The aim of the studies was to elicit symptoms under controlled laboratory conditions. The WHO fact sheet stated that the majority of studies indicated that EHS individuals could not detect EMF exposure any more accurately than non-EHS individuals. Double-blind studies which were well-controlled and well-conducted had shown that symptoms were not correlated with EMF exposure. Therefore, it stated, EHS has no clear diagnostic criteria, and there is no scientific basis to link EHS symptoms to EMF exposure.

It had been suggested that symptoms experienced by some EHS individuals might arise from environmental factors unrelated to EMF including flicker from fluorescent lights, glare and other visual problems with video displays, and poor ergonomic design of computer workstations. The fact sheet stated that other factors that may play a role included poor indoor air quality or stress in the workplace or living environment.

Finally, there were some indications that the symptoms may be due to pre-existing psychiatric conditions as well as stress reactions that were a result of worrying about EMF health effects, rather than EMF exposure itself. It explained that EHS is not a medical diagnosis, nor is it clear that it represents a single medical problem. Thus, some medical experts described EHS as an example of a psychogenic illness. A psychogenic illness is a constellation of symptoms suggestive of organic illness, but without an identifiable cause, that

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[197] <http://www.who.int/about/en/>.
[198] <http://www.who.int/mediacentre/factsheets/fs296/en/index.html>.
[199] <http://www.who.int/peh-emf/meetings/hypersensitivity_prague2004/en/index.html>.
[200] <http://ihcp.jrc.ec.europa.eu/our_activities/public-health/exposure_health_impact_met/emf-net/docs/publications/WHO_EMF-NET%20Book.pdf>.
[201] <ftp://ftp.cordis.europa.eu/pub/cost/docs/244bisfinalreport.pdf>.
[202] <https://gupea.ub.gu.se/bitstream/2077/4156/1/ah1997_19.pdf>.
[203] Idiopathic Environmental Intolerance attributed to Electromagnetic Fields (IEI-EMF) is a term that is being increasingly used to describe this disorder.

occurs between two or more people *who share beliefs about those symptoms* (emphasis added). Psychogenic illnesses have made headlines when they have become manifest as a widespread phenomenon.[204]

King's College London: Systematic Review of Provocation Studies for EHS

King's College London's School of Medicine is one of the UK's most renowned centers for medical research and teaching. It has three central London hospital campuses, and its research portfolio is closely aligned to its National Health Service partners. The school has ten research divisions and it hosts 12 externally awarded and funded specialist centers.[205]

In 2005, school researchers performed meta-analyses[206] to identify relevant blind or double-blind EMF provocation studies.[207] According to the researchers, thirty-one experiments testing 725 EHS participants were identified.[208] Out of the 31 studies, 24 found no evidence to support the existence of a biophysical hypersensitivity, whereas seven reported some supporting evidence. For two of these seven studies, the same research groups subsequently tried to replicate their findings but failed. In three of the seven studies, the positive results appeared to be statistical artifacts. The remaining two studies produced mutually incompatible results.

According to the King's College researchers, the meta-analyses found no evidence of an improved ability to detect EMF in EHS participants. They concluded that the symptoms described by EHS sufferers can be severe and are sometimes disabling but that it had proven difficult to demonstrate under blind conditions that exposure to EMF could trigger symptoms. The researchers stated that analyses suggested that EHS was unrelated to the presence of EMF. The researchers stated that more research into this phenomenon was required.

In 2009, a team of researchers from King's College performed an updated systematic review of provocation studies for EMF.[209] The researchers performed an extensive literature search and identified 15 new experiments. This time, 46 blind or double-blind provocation studies were analyzed in total, involving 1175 EHS volunteers to determine whether exposure to EMF is responsible for triggering symptoms in EHS individuals. The researchers determined that no robust evidence could be found to support the theory.

However, the researchers stated, the studies included in the review did support the role of the nocebo effect in triggering acute symptoms in EHS sufferers. A nocebo response is an unpleasant, harmful, or undesirable effect(s) that a subject manifests, typically after receiving a placebo. The nocebo effect has drawn increased interest from the medical community because studies show that patients are highly receptive to negative suggestion.[210]

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[204] <http://www.cmaj.ca/content/172/1/36.full.pdf>.
[205] <http://www.kcl.ac.uk/medicine/about/index.aspx>.
[206] A meta-analysis is a systematic method of evaluating statistical data based on results of several independent studies of the same problem.
[207] A provocation study is a form of medical clinical trial whereby participants are exposed to a substance or situation that is claimed to provoke a response or to a sham substance or device that should provoke no response.
[208] <http://www.aefu.ch/typo3/fileadmin/user_upload/aefu-data/b_documents/themen/elektrosmog/Position_Forschungstand/rubin_Elektrosensib.Provokationsstudie05.pdf>.
[209] <http://www.essex.ac.uk/psychology/EHS/Rubin%20et%20al%20REVIEW_2009.pdf>.
[210] <http://www.aerzteblatt.de/pdf.asp?id=127210>.

Recent Court Decision Regarding Claim of EHS

In a recent court decision in New Mexico, the plaintiff claimed to have health problems triggered by exposure to EMF generated by his neighbor's electrical equipment (e.g. cordless telephones, computer equipment, dimmer switches, and Wi-Fi routers and modems). The court concluded that EHS is not a scientifically recognized disease, excluded the testimony of the plaintiff's two experts, and dismissed the case.[211,212]

Use of EMF as a Weapon

Some opponents of smart meters have spoken of two kinds of weapons being developed by military organizations such as the U.S. Department of Defense[213] or by other countries. Because weapons are typically associated with causing bodily harm or death, they are addressed in this paper.

Both kinds of weapons utilize electromagnetic radiation, but they use it differently and have different end goals. The first kind of weapon to be discussed has been demonstrated to the public. The existence of the second kind of weapon seems to be more speculative.

Directed Energy Weapons

The first type of weapon is known as a directed energy weapon which delivers energy to a target. The target can be humans, electronic equipment, or other military targets, depending on the technology employed. It can be used for purposes other than to destroy a target or kill soldiers. For example, the Active Denial System (ADS) is a weapon under development that is intended for use against humans. It is non-lethal and designed for area denial,[214] perimeter security, and crowd control. The device is mountable on a small armored vehicle.

The ADS works by firing a narrow, high-powered beam of 95 GHz waves at a human target. The energy from an ADS works on a similar principle as a microwave oven, exciting the water and fat molecules in the skin, and instantly heating them (dielectric effect).

How deep a radio wave can penetrate an object depends upon the wave's frequency. The high frequency waves used in ADS penetrate 1/64th of an inch into the top layers of the subject's skin. At that skin depth lie "nociceptors" which are nerve endings sensitive to heat. *Wired* magazine indicated that documents it acquired from the government stated that 83% of the energy impacting the target was instantly absorbed by the top layer of the skin.[215] Being hit by the energy from the ADS gives the victim a sensation of his entire body being exposed to intense heat but without injury taking place. The pain reflex makes the targeted person instinctively pull away in less than a second. To avoid potential trauma to the subject, the trigger on the device only allows the weapon to be fired for three seconds.

The *Wired* article states that the energy delivered to a target is 12 joules per square centimeter.[216] The ADS delivers those 12 joules of energy over a three-second period, which is equivalent to delivering four watts (4000 mW) of power each second per square centimeter.

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[211] Firstenberg v. Monribot and Leith, No. D-101-CV-2010-00029, New Mexico 1st Dist, Santa Fe County, Sept 18, 2012.
[212] <http://www.casewatch.org/civil/firstenburg/dismissal_order.pdf>.
[213] <http://jnlwp.defense.gov/>.
[214] Area denial weapon is used to prevent an adversary from occupying or traversing an area of land. Land mines and punji sticks are examples of denial weapons, albeit ones which are potentially lethal.
[215] <http://www.wired.com/dangerroom/2012/03/pain-ray-shot/>.
[216] <http://www.wired.com/science/discoveries/news/2006/12/72134?currentPage=all>.

The Human Effects Advisory Panel of Penn State concluded that ADS is a non-lethal weapon that has a high probability of effectiveness with a low probability of injury.[217] The limit of damage was the occurrence of pea-sized blisters in less than 0.1% of the exposures (6 of 10,000 exposures).

While this information may be interesting, the existence of such a weapon cannot be credibly used as an argument against employing RF communication devices because:

- The ADS is specifically designed as a weapon, not communications equipment;
- The ADS is very dissimilar to a smart meter because it uses a frequency 100 times higher than the 902-928 MHz band used by the meters' communication module;
- The ADS has an enormous power output. It delivers more than 3.5 million times the instantaneous peak energy of a smart meter radio module; and[218]
- Although the ADS is considered a weapon, it does not cause injury, only brief discomfort.

Cold War Studies on Behavior Modification and Human Vulnerability

The second type of weapon mentioned by opponents of wireless communications technology does not seem to have been displayed or demonstrated as a functioning device. Instead, some people who have provided material to the PUCT or appeared before it, the Texas Senate, or regulatory bodies in other jurisdictions have referred to research that had been performed mostly by Soviet Bloc countries during the Cold War, especially the Soviet Union.

Opponents of wireless technology have pointed to unclassified documents[219,220] produced by the U.S. Defense Intelligence Agency (DIA)[221] during the early 1970s as evidence that the Soviet Union was doing research on EMF along with exploring subject matter that was more unconventional. The stated purpose of the DIA disseminating this information was for preparedness and to develop countermeasures. It may be speculative to assume that more detailed information existed but was kept classified. We are limited to the available documents.

The documents summarize the known research in which the Soviet Union was involved regarding human vulnerabilities to various environmental conditions and behavior modification through the application of certain stimuli. Of particular interest to opponents of wireless technology are the studies performed to determine human vulnerability to EMF and how it could be used to alter a subject's behavior. These weapons were intended for use against an individual rather than a group.

One may be intrigued by the fact that in addition to the cited studies on the effects of EMF on living organisms, the documents also discuss psychology and parapsychology research. For example, some experiments involved telepathic communication, mind altering drugs, sensory deprivation, psychokinesis, and many other

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[217] <http://jnlwp.defense.gov/pdf/heap.pdf>.

[218] ADS exposure: 12 joules/cm^2 delivered over a three-second burst = 4,000 mW/cm^2. Smart meter exposure: 0.0011346 mW/cm^2 instantaneous peak field exposure in front of meter, at a distance of three feet, assuming a 100% duty cycle. Calculated from Table 9-5 of EPRI Report "An Investigation of Radiofrequency Fields Associated with the Itron Smart Meter," Page 9-15.

[219] <http://science.discovery.com/tv/dark-matters/documents/pdf/controlled-offensive-behavior.pdf>.

[220] <http://www.magdahavas.com/wordpress/wp-content/uploads/2011/02/BIOLOGICAL_EFFECTS_OF_ELECTROMAGNETIC_RADIATION-RADIOWAVES_AND_MICROWAVES-EURASIAN_COMMUNIST_COUNTRIES.pdf>.

[221] Although the specific focus of the DIA has changed over the years, its central function has been to provide military intelligence to various facets of the U.S. military community.

seemingly strange topics. The fact that EMF research is mentioned in the same context as these arcane studies may lead some readers to errantly conclude that EMF is equally mysterious.

While some may find the material offered in the documents regarding EMF experiments on animal subjects interesting and germane to the topic of this report, several caveats are in order:

- The material is unclassified (compared to declassified) and offers nothing new – it is a part of the extensive body of knowledge on EMF. Despite the Cold War, scientific research was published and shared between the two sides;
- The material is old and may be out of date;
- The descriptions of the research are only abstracts, providing very little detail;
- The citations are of individual studies. Other studies may have conclusions that are incompatible; and
- Some material sourced from Soviet Bloc nations may be of questionable value. The results could have been subject to the political environment of the era.

The Soviet Bloc was not alone in conducting such research. The U.S. Central Intelligence Agency had also conducted behavioral modification experiments from the 1950s until the early 1970s. These experiments, collectively known as Project MKULTRA, relied on mind-altering drugs, hypnosis, sleep deprivation and other forms of harassment.[222]

Claims have been made that the work done under Project MKULTRA may have been used in conjunction with EMF to create "psychotronic weaponry"[223] in the form of "Silent Sound" or "Voice to Skull" technology. Voice to Skull technology is based on what is known as the microwave auditory effect or "microwave hearing." Microwave hearing is caused by using pulsed EMF in the microwave frequency band to induce audible clicks or sounds described as buzzing, hissing, or knocking. The cause is thought to be thermoelastic expansion of portions of the ear.[224] The sounds are generated directly inside the human head without the need of any receiving electronic device and are not audible to other people, even if they are nearby. If the signal is modulated,[225] whole words can be produced.

The idea behind this technology was that the spoken words of a hypnotist could be conveyed through microwave hearing into an unknowing person's head. This would allow the hypnotist to control the actions of the targeted individual's subconscious mind. Some have speculated about another possibility - that a targeted individual who heard voices inside his head would be distressed over the notion of going insane or being viewed as such.

The microwave auditory effect was first reported by persons working in the vicinity of radar transponders during World War II. The effect was later discovered to be inducible by frequencies higher in the electromagnetic spectrum. American neuroscientist Allan H. Frey studied this phenomenon and first published information[226] on the nature of the microwave auditory effect.[227] At least one patent has been issued for "Voice to Skull" technology based on the material in Frey's studies - U.S. Patent 4,877,027.[228] Note that several

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[222] <http://upload.wikimedia.org/wikipedia/commons/0/01/ProjectMKULTRA_Senate_Report.pdf>.
[223] A psychotronic weapon is an alleged type of mind control device.
[224] <http://www.ncbi.nlm.nih.gov/pubmed/17495664>.
[225] In telecommunications, modulation is the process of varying one or more properties of a high-frequency periodic waveform: amplitude, phase, or frequency. The effective result is piggybacking a signal on top of the RF EMF.
[226] <http://jap.physiology.org/content/17/4/689>.
[227] <http://www.slavery.org.uk/Bioeffects_of_Selected_Non-Lethal_Weapons.pdf>.
[228] <http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&p=1&u=%2Fnetahtml%2FPTO%2Fsearch-bool.html&r=4&f=G&l=50&co1=AND&d=PTXT&s1=4,877,027&OS=4,877,027&RS=4,877,027>.

criteria must be met in order for a U.S. patent to be issued, but the existence of a functional device is not one of those criteria. There is no credible evidence to suggest that such a device exists.

While this may be an interesting phenomenon, it is not applicable to smart meters because:

- The energy intensity required to accomplish the microwave auditory effect would be greater than the output capability of the radio module in a smart meter – perhaps even above MPE levels;
- The frequencies involved (higher microwave bands) are outside the range emitted by smart meters;
- EMF is directional in nature. A device intended to produce these sounds would require a transmitting antenna that optimized this directionality, and the emitted energy would have to be aimed directly at a person's head. Studies performed by EPRI of emission patterns from smart meters show the transmitting antenna in a smart meter directs most of its RF energy outward, away from the wall on which it is mounted. The RF energy would be greatly attenuated inside the building. Also, meter antennas are not aimed at people's heads;
- The existence of psychotronic weapons as described above is merely speculative; and
- Smart meters are designed to measure a customer's overall electricity usage and deliver that data to the utility. They may also offer a limited set of information to an end user if he desires. Smart meters are not intended for, are not designed to, and do not have the capability to harm an individual or direct a person's thoughts or actions.

Other Material

Critics of wireless technology have called attention to various materials in order to further claims about adverse health effects of exposure to EMF, including non-thermal effects. Some people have made assertions that this material has been forgotten, hidden, or suppressed. One example of a paper that opponents of wireless technology characterize as neglected was originally written for the Naval Medical Research Institute (NMRI) in 1971 and updated six months later. The document is "Bibliography of Reported Biological Phenomena ('Effects') and Clinical Manifestations Attributed to Microwave and Radio-frequency Radiation, MF12.524.015-0004B, Report No 2 Revised."[229]

The first chapter of the document provides an outline of biological phenomena that had been reported in individual studies of biological exposure to microwave or RF radiation. The more than 120 reported phenomena are placed into 17 categories such as "changes in physiologic function," "central nervous system effects," "psychological disorders," and "endocrine gland changes." The remainder of the document makes up the bulk of its content and is a bibliography that identifies 2311 research papers, the oldest of which dates from 1925 and the most recent from 1972. The author stated that the paper was created to provide a listing of studies that may be "needed in the formulation and appraisal of criteria and limits of human exposure to non-ionizing radiation, and in the planning and conduct of future research."

The author noted that a few citations were of marginal and/or peripheral relationship but were nonetheless included so a reader could judge the applicability to his individual research needs. The author draws no conclusions and admits that the screening of the entries was limited to relevance of the topic, not the quality of the studies or the validity of their results:

> "Note: These effects are listed without comment or endorsement since the literature abounds with conflicting reports. In some cases the basis for reporting an "effect" was a single or a non-statistical observation, which may have been drawn from a poorly conceived (and poorly executed) experiment."

[229] <http://www.dtic.mil/cgi-bin/GetTRDoc?AD=AD0750271>.

While there may be people who believe that the listing in the NMRI paper of purported effects resulting from exposure to EMF reveals damning evidence of harm, the document is limited in value for the following reasons:

- The paper merely compiles a list of reported effects without assessing their validity or prevalence;
- The document is primarily intended as a bibliography, citing research performed;
- The material does not offer abstracts for the cited studies (no findings are given);
- The report does not provide conclusions or determine causality - no meta-analysis was performed;
- The list is no longer comprehensive - it is over 40 years old (research dates from 1925 – 1972); and
- The cited studies do not yield any new information - they have been a part of the extensive body of knowledge on RF EMF for many years.

Further, the stated purpose of the NMRI paper was for planning and to conduct future research. When the FCC established its exposure standards in 1996, the results of the studies listed in the bibliography of the paper had been available for decades, and the standards took this research into consideration. Research on the biological effects of EMF has continued and will continue for the foreseeable future.

Conclusion

RF EMF, a form of non-ionizing radiation, has been utilized for nearly a century to broadcast radio and television programs and for many other types of telecommunication. Smart meters, an upgrade to our electrical infrastructure, emit EMF at only low intensity and within a narrow part of the RF band, close to the ranges where UHF TV, cordless phones, and cellular phones operate.

Decades of scientific research have not provided any proven or unambiguous biological effects from exposure to low-level radio frequency signals. Further, after performing a review of all available material, Staff found no credible evidence to suggest that smart meters emit harmful amounts of RF EMF.

At higher intensities, RF EMF can heat living tissue. As a result, the FCC established a more restrictive MPE for the general population that is 2% of the level where thermal effects are known to occur. This lower limit was established for the general population because exposure typically results from a situation that the recipient cannot control and a maximum possible time of exposure (24 hours per day) was presumed.

For decades, much scientific research has been performed to investigate the potential health effects of exposure to many kinds of EMF, including RF. Governmental health agencies from around the world, including but not limited to the U.S., Canada, the UK, and Australia, as well as academic institutions and other researchers, have stated that there are no known *non-thermal* effects from exposure to RF EMF. In other words, tissue heating is the only known risk of exposure to RF EMF. Nonetheless, substantial medical research on any potential non-thermal effects of non-ionizing radiation will continue in the future, and will include studies on emissions that fall into the RF bands.

Those concerned about health will often refer to the results of an individual research study or sometimes several studies to draw conclusions. It is important to use great caution when relying on the results of individual research studies because other studies may have inconsistent or even conflicting results. One must also consider that not all studies hold equal value in the scientific community; all research has some amount of inherent bias, and some studies arguably have flaws or lack scientific rigor.

EPRI, Naperville, the Vermont Department of Health, the Victorian State Government of Australia, and the City of Richmond in British Columbia, Canada have conducted investigations of smart meter RF EMF, and found that smart meters complied with the governmental exposure limits in their respective jurisdictions.

When measurements were taken at relative close proximity to smart meters or groups of smart meters, the RF EMF emissions were several orders of magnitude below the established exposure limits. It is important to note that increasing distance will decrease the intensity of an EM field by the square of the distance (i.e. decrease exponentially).

In addition to distance, in-residence exposure to emissions is further decreased by:

- Shielding of the meter enclosure;
- Building construction materials;
- Antenna orientation of the meter; and
- Meter duty cycle – data is transmitted only 1 - 5% of the time.

Some smart meter opponents have raised the concern that the meters may interfere with other electronic devices including implantable medical devices. Smart meters communicate using unlicensed spectrum. The FCC has mitigated the potential for interference among electronic devices operating in unlicensed spectrum by

requiring these devices to be tested and certified as compliant with its rules before they can be marketed. Financial penalties can be assessed if one does not comply with the appropriate FCC equipment authorization procedure. Medical devices must also comply with EMI standards.

Some opponents of smart meters have raised the idea of electromagnetic hypersensitivity and cite anecdotes of having witnessed or experienced various afflictions. After reviewing a substantial body of evidence, the WHO concluded that there was no scientific basis to link EHS symptoms to EMF exposure. It has suggested that symptoms experienced by some individuals described as EHS might arise from environmental factors unrelated to EMF or that the symptoms may be due to pre-existing psychiatric conditions or stress reactions resulting from worrying about EMF health effects, rather than the EMF exposure itself. Further, scientific studies show that people who are ill are highly receptive to negative suggestion and may demonstrate a "nocebo response" as a result of these suggestions.

The notion that EMF can be used as a weapon to cause pain, disrupt thought, or alter or control human behavior might be interesting to some people, but smart meters do not have the capabilities to do these things. First, the output energy from a smart meter radio module is miniscule. Second, the module does not transmit at frequencies near those used in directed energy weapons systems or which have been purportedly used in physiological or psychological experiments. Further, smart meters are designed to measure a customer's overall electricity usage and deliver that data to the utility. A meter may also offer a limited set of information to an end user if he desires. Smart meters are not intended for, are not designed to, and do not have the capability to harm an individual or direct a person's thoughts or actions.

A large number of scientific studies regarding the biological effects of EMF on living organisms have been performed over a period of at least seven decades. These studies are part of an extensive body of human knowledge on the subject, and safety standards have been devised based on the body of knowledge. One must be cautious when individuals make claims about research being suppressed, and when individual studies are cited as evidence that hazards or illnesses are being ignored. Other studies may produce conflicting results. One must be cognizant of what adherence to scientific principles entails and how to decipher research. Laymen often may not recognize poorly executed studies, or they can misinterpret the results of properly conducted scientific research. Either of these circumstances may lead a casual observer to draw errant conclusions.

Acronyms and Abbreviations

AAEM	American Academy of Environmental Medicine
AAMI	Association for the Advancement of Medical Instrumentation
ABEM	American Board of Environmental Medicine
ACMA	Australian Communications and Media Authority
AEIC	Association of Edison Illuminating Companies
AGNIR	Advisory Group on Non-ionising Radiation
AM	Amplitude Modulated
ANSI	American National Standards Institute
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
BC	British Columbia
BCCA	BC Cancer Agency
BfS	German Federal Office for Radiation Protection
CCST	California Council on Science and Technology
CDC	Center for Disease Control and Prevention
cm	centimeter (0.01 meter)
CPUC	California Public Utilities Commission
CRT	Cathode Ray Tube
DDT	dichlorodiphenyltrichloroethane
EA	Equipment Authorizations
EC	European Commission
EEG	Electroencephalography
EEI	Edison Electric Institute
EHS	Electromagnetic Hypersensitivity
EIRP	Effective Isotropic Radiated Power
ELF	EMF Extremely Low Frequency electromagnetic fields
EM	Electromagnetic
EMF	Electromagnetic Field
EMI	Electromagnetic Interference
EMR	Electromagnetic Radiation
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
ERP	Effective Radiated Power
EU	European Union
eV	Electron Volt
FAQ	Frequently Asked Questions
FAS	Swedish Council for Working Life and Social Research
FCC	Federal Communications Commission
FDA	U.S. Food and Drug Administration
FM	Frequency Modulated
GAO	U.S. Government Accountability Office
GHz	Gigahertz (1 billion hertz)

GPS	Global Positioning System
HAN	Home Area Network
HHS	U.S. Department of Health and Human Services
Hz	Hertz (cycles per second)
IARC	International Agency for Research on Cancer
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IEEE	Institute of Electrical and Electronics Engineers
kg	kilogram (1000 grams)
kHz	kilohertz (1000 hertz)
LBNL	Lawrence Berkeley National Laboratory
Maine CDC	Maine Center for Disease Control & Prevention
MHz	megahertz (1 million hertz)
MPE	Maximum Permissible Exposure
MPSC	Michigan Public Service Commission
MPUC	Maine Public Utilities Commission
mW	milliwatt (0.001 watts)
NCI	National Cancer Institute
NCRP	National Council on Radiation Protection and Measurements
NEMA	National Electrical Manufacturers Association
NIEHS	National Institute of Environmental Health Sciences
NIH	National Institutes of Health
NMRI	Naval Medical Research Institute
NSGI	Naperville Smart Grid Initiative
OET	FCC Office of Engineering and Technologies
OPA	Maine Office of the Public Advocate
OSHA	U.S. Occupational Safety and Health Administration
PG&E	Pacific Gas & Electric
PUCT	Public Utility Commission of Texas
RF	Radio Frequency
RF EMF	Radio Frequency Electromagnetic Field
RSC	Royal Society of Canada
SAR	Specific Absorption Rate
SGTAP	Smart Grid Technical Advisory Project
TV	Television
UHF	Ultra-high Frequency
UK	United Kingdom
U.S.	United States of America
UTC	Utilities Telecom Council
VHF	Very High Frequency
W	Watt
WHO	World Health Organization
µW	microwatt (1 millionth of a watt)
$\mu W/cm^2$	microwatts per square centimeter

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