Health Fact Sheet

Advanced Metering Infrastructure

What is an Advanced Meter?

Advanced meters give customers more timely information on their energy use. After installation, customers will also be able to access a customized online dashboard that can help them track and compare their energy usage by day, week, month or year.

While most meters record a running total of the energy used, an advanced meter can record energy usage data in 15, 30 or 60 minute increments. Generally, the meter will only transmit the usage information for a few minutes each day.

When we build out this network of advanced meters over the next several years and install the necessary supporting infrastructure, these technologies will then work together and help us more quickly detect when an outage occurs and then communicate with our system to help identify its location.

Can Advanced Meters affect my health?

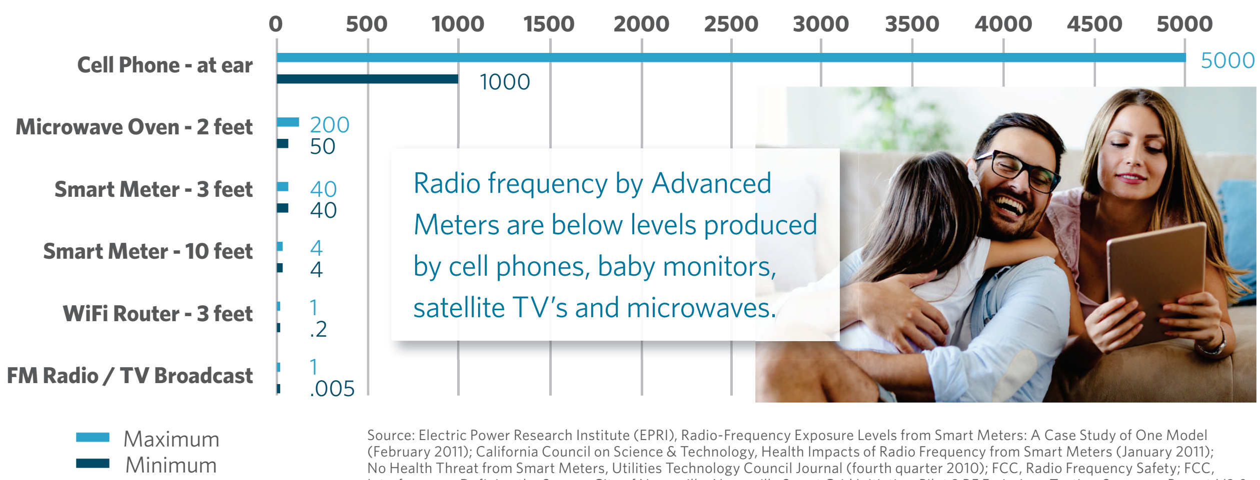
NO The World Health Organization (WHO) has concluded that **no adverse health effects have been demonstrated** from exposure to low-level radio frequency energy such as that produced by advanced meters†.

Radio frequency signals also weaken significantly as the distance between you and the device increases. The casing of an advanced meter, as well as wall construction materials, also decreases the level of RF energy in the vicinity.

Please note that advanced meters transmit RF energy only for short periods each day. In fact, an Electric Power Research Institute (EPRI) analysis of 47,000 advanced meters installed in southern California found that 99.5% of the meters were transmitting for approximately three minutes or less daily‡.

† Source: http://www.who.int/peh-emf/about/WhatisEMF/en/index1.html
‡ Source: Mezei, G. An Investigation of Radio Fields Associated with the Itron Smart Meter. Palo Alto: Electric Power Research Institute, 2010

Radio Frequency Power Density Levels of Common Devices (in microwatts/cm2)



The type of meter depicted in the table may or may not have been used in the studies cited.

Source: Electric Power Research Institute (EPRI), Radio-Frequency Exposure Levels from Smart Meters: A Case Study of One Model (February 2011); California Council on Science & Technology, Health Impacts of Radio Frequency from Smart Meters (January 2011); No Health Threat from Smart Meters, Utilities Technology Council Journal (fourth quarter 2010); FCC, Radio Frequency Safety; FCC, Interference – Defining the Source; City of Naperville, Naperville Smart Grid Initiative, Pilot 2 RF Emissions Testing-Summary Report-V2.0, Smart Meters, Household Equipment, and the General Environment (November 10, 2011); International Agency for Research on Cancer, IARC Monographs on the Evaluation of Carcinogenic Risks to Humans (January 2006)

Meter Upgrade Project

To empower our customers with detailed and personalized energy usage data, and to help the Companies better respond to and restore power outages, LG&E and KU will upgrade metering equipment at no additional cost to customers. For more information about Advanced Metering Infrastructure visit **lge-ku.com/meter-upgrade.**

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EPRI Comment: Sage Report on Radio-Frequency (RF) Exposures from Smart Meters

Electric Power Research Institute (EPRI)

Summary

A report by Sage Associates dated January 1, 2011 and entitled, "Assessment of Radiofrequency Microwave Radiation Emissions from Smart Meters" was posted on the internet. The "Sage Report" uses various approaches to characterize radio-frequency (RF) field levels and to compare them to the exposure limits published by the Federal Communications Commission (FCC) in FCC OET Bulletin 65, Edition 97-01, dated August 1997. The report concludes that, "FCC compliance violations are likely to occur under normal conditions of installation and operation of smart meters and collector meters in California." The report also compares field levels from smart meters to those from studies reporting biological and health effects. However, the research findings referred to in the Sage Report have not been replicated or are inconsistent with the results of other studies. Furthermore, virtually every recent mainstream expert scientific review of the RF health literature conducted in North America and Europe has not recognized the effects cited by the Sage Report as confirmed or definitive. This commentary deals with the engineering and source characterization aspects of the Sage Report.

The Sage Report misapplies the specifications in the FCC rule as follows:

Time averaging exposure: Exposures from smart meters may be time-averaged according to the FCC statement in OET Bulletin 65 that, "'source-based' time-averaging based on an inherent property or duty-cycle of a device is allowed." Clearly, smart meters fall into the "source-based" category of emitters. An extensive analysis of smart meter transmissions for almost 47,000 units in southern California was conducted for EPRI ("An Investigation of Radiofrequency Fields Associated with the Itron Smart Meter" EPRI Report 1021126 December 2010; available to the public at www.epri.com). The report estimated that 99.5% of the sample was operating at a duty cycle of about 0.22% or less, a value that translates to 3 minutes and 10 seconds of transmitting over a day; the maximum duty cycle in any residence did not exceed 5%. The duty cycle for cell relays (referred to as "collectors" in the Sage Report) within the same sample did not exceed 1%. The Sage Report defaults to compute exposures based on a 100% duty cycle, thus over-estimating exposure in the sample cited above by no less than 20-fold and more typically more than 400-fold.

Spatial averaging of exposure: The FCC states that to characterize a person's exposure properly, the RF power density should be averaged across the entire volume of an exposed body. An example in the EPRI Report indicates that power density averaged over the body of a 6-foot person situated one foot in front of a meter is less than approximately one-quarter of the emission at the point of the wavefront's peak at that distance. The Sage Report assumes a uniform field across the body that is equal to the peak power density within a body's cross-section, thus overestimating an individual's exposure.

Reflections: Radio frequencies "bounce" or reflect off of surfaces exactly the way light is reflected off the surface of a mirror. The level of a reflected wave that is present at any point is expressed as a percent of the electric field of the incident wave, which is the free-space wave in the absence of any reflection. The power density at that point is the incident power density multiplied by $[1+(\text{percent of reflection}/100)]^2$. The FCC's worst-case scenario is a 100% reflection (4-fold increase in power density), with a less conservative though more realistic value of 60% (2.56-fold increase in power density) used in many cases as an upper bound (e.g., see EPRI White Paper 1020798, "A Perspective on Radio-Frequency Exposure Associated With Residential Automatic Meter Reading Technology"). A key element to factoring reflections into an exposure calculation is that, for RF emitters like smart meters in real-world residential environments, the percent reflection diminishes as one approaches the meter. Thus, at the distance at which incident power density is maximal, the contributions of reflections to total power density are minimal. The Sage Report assumes that incident power density is enhanced by reflections uniformly throughout the space surrounding the meter. Furthermore, in adopting reflection values from one particular study (Hondou et al., 2006), it uses reflection factors that, in terms of power density, are between 30 and 110 times greater than the worst-case power density enhancement due to reflections identified by the FCC.

In addition, this commentary points out several other pertinent issues:

- The Sage report, in discussing exposure with relation to specific anatomic sites that include eyes and testes, referred to stipulations in an outdated 1999 IEEE standard. The current IEEE standard, published in 2005, with extensive documentation on the topic, removed any exceptions for such anatomic sites.
- In comparing field calculations to the FCC limits, the Sage Report did not frequency weight the contributions from the end-point meter (~900 MHz), the Home Area Network (HAN) antenna (~2,400 MHz) and the cell relay (~850 MHz). Because the FCC exposure limits are frequency dependent, a simple arithmetic addition of contributions from various sources is an inappropriate approach to compliance assessment.

Therefore, the Sage Report, for the reasons enumerated in this commentary, has over-estimated exposures from smart meters using assumptions and calculations that are inconsistent with the FCC's rule and that do not recognize the basic physical characteristics of RF emissions.

Section I: Background

A report by Sage Associates dated January 1, 2011 and entitled, "Assessment of Radiofrequency Microwave Radiation Emissions from Smart Meters" was posted on the internet; it will be referred to here as the Sage Report for short. The report's authorship was not specifically identified. The proprietor of Sage Associates, Ms. Cindy Sage, also coordinated the BioInitiative Working Group (BWG) report that was published in 2007. That report included chapters by about a dozen scientists known in the EMF research field. Ms. Sage and Dr. David Carpenter the report's other signatory concluded that health effects of various kinds result from low-level radio-frequency exposure, and:

> There may be no lower limit at which exposures do not affect us. Until we know if there is a lower limit below which bioeffects and adverse health impacts do not occur, it is unwise from a public health perspective to continue "business-as-usual" deploying new technologies that increase ELF [extremely-low-frequency] and RF exposures, particularly involuntary exposures.

The BWG report, which covered RF as emitted from various sources (cell phones, base stations) suggested that safety standards for RF exposures, as specified by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the U.S. Federal Communication Commission (**FCC**[1]), are not sufficiently conservative. EPRI's commentary (EPRI publication #1016233) on the BWG Report can be found at www.epri.com.

The recently issued Sage Report takes a two-fold approach. First, it uses a number of engineering assumptions to calculate presumed exposure levels from one or more smart meters with or with out a **cell relay** (referred to as "collectors" in the Sage Report) also present, and to then identify "violations" of FCC exposure limits for the general public. The Sage Report concludes that:

> FCC compliance violations are likely to occur under normal conditions of installation and operation of smart meters and collector meters in California. Violations of FCC safety limits for uncontrolled public access are identified at distances within 6" of the meter. Exposure to the face is possible at this distance, in violation of the time-weighted average safety limits. FCC violations are predicted to occur at 60% reflection (OET Equation 10 and 100% reflection (OET Equation 6) factors, both used in FCC OET 65 formulas for such calculations for time-weighted average limits. Peak power limits are not violated at the 6" distance (looking at the meter) but can be at 3" from the meter, if it is touched.

Secondly, it compares these exposure levels with those in selected studies that have reported biological or health effects resulting from RF exposures that are considered adverse. However, the research findings referred to in the Sage Report have not been replicated or are inconsistent with the results of other studies. Furthermore, virtually every recent mainstream expert scientific review of the RF health literature conducted in North America and Europe has not recognized the effects cited by the Sage Report as confirmed or definitive.

This commentary will not deal any further with the health aspect of the report, and will focus primarily on its technical assumptions, treatment of engineering factors, and source characterization. This commentary will also draw from

[1] Bolded terms are defined in the Glossary

measurement and modeling data published in an Electric Power Research Institute (**EPRI**) study of smart meters ("An Investigation of Radiofrequency Fields Associated with the Itron Smart Meter" EPRI Report 1021126, December 2010; available to the public at www.epri.com). In the commentary that follows, Section II deals with the Sage Report's understanding of the FCC rule governing RF exposures. Section III comments on how the FCC formula for computing RF field levels was used in the Sage Report, and Section IV provides conclusions.

Section II: Sage Report's Interpretation of the FCC Rule Specifying Exposure Limits for Radio-Frequency Electromagnetic Fields

The Federal Communications Commission established limits for exposure to radio-frequency electromagnetic fields, which are published in FCC OET Bulletin 65 (August 1997), and codified in the Code of Federal Regulations (47 CFR § 1.1310). The FCC rule was adopted from two previous guidelines, one published by the National Council on Radiation Protection and Measurements (NCRP Report No. 86) in 1986, and the other by the Institute for Electrical and Electronic Engineers (IEEE C95.1 1991) in 1991. Both had extensively reviewed the biological and health literature, concluding that the only established effects were associated with tissue heating and no confirmed effects below heating thresholds were identified. The effects associated with heating, so-called "thermal effects", concerned diminished response rates in food-motivated behavioral experiments in laboratory animal subjects (rhesus monkeys and rats) and were accompanied by a rise in body core temperature of about 1° C. Such behavioral changes are considered amongst the most sensitive indicators of potentially adverse effects. In the absence of heating, there have been no consistently demonstrated "non-thermal" mechanisms that could lead to adverse biological or health effects either acutely or chronically. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the IEEE have since developed guidelines very similar to the FCC's based on the same behavioral effects following for each a comprehensive review of the scientific literature. Prior to its publication, the FCC rule received endorsements from the U.S. Environmental Protection Agency (EPA), the U.S. Food and Drug Administration (FDA), and the U.S. Occupational Safety and Health Administration (OSHA). The EPA reaffirmed its opinion in letters written in 1999 and 2002.

There are four aspects of the Sage Report that are examined in the ensuing discussions within this section. The first three relate to the basis for the FCC rule, as follows: (1) averaging exposure over time (2) averaging exposure across space, and (3) **reflections**. The 4th item concerns the Sage Report's understanding of the most recent exposure standards as published by IEEE, as they relate to specific anatomic sites, namely the eyes and testes.

<u>Time Averaging</u>

FCC OET Bulletin 65 states:

> …exposures, in terms of **power density**…may be averaged over certain periods of time with the average not to exceed the limit for continuous exposure…the averaging time for occupational/controlled exposures is 6 minutes, while the averaging time for general population/uncontrolled exposures is 30 minutes. (page 10)

The OET further states:

> Time-averaging provisions may not be used in determining typical exposure levels for devices intended for use by consumers in general population/uncontrolled environments. However, "source-based" time-averaging based on an inherent property or duty-cycle of a device is allowed. (page 74)

In this context, smart meters fall into the "source-based" category, and time averaging is completely appropriate. The Sage Report claims that time averaging does not apply to assessing exposures from smart meters, and continuous operation should be assumed for compliance assessment, which represents a misinterpretation of the FCC rule. The applicability of time averaging to smart meters was reaffirmed in a letter dated August 6, 2010 to Ms. Sage from the FCC's Julius Knapp, Chief, Office of Engineering and Technology, stating:

> For exposure evaluations, however, the average power is relevant, which is determined by taking into account how often these devices [smart meters] will transmit.

To illustrate the amount of time a meter may actually transmit, data were collected from the transmitting records from almost 47,000 meters over a nearly three month period, amounting to more than four million readings in all. The capability to accomplish this was enabled by special software developed by the smart meter manufacturer (Itron) to acquire transmit data. The analysis enumerated the data

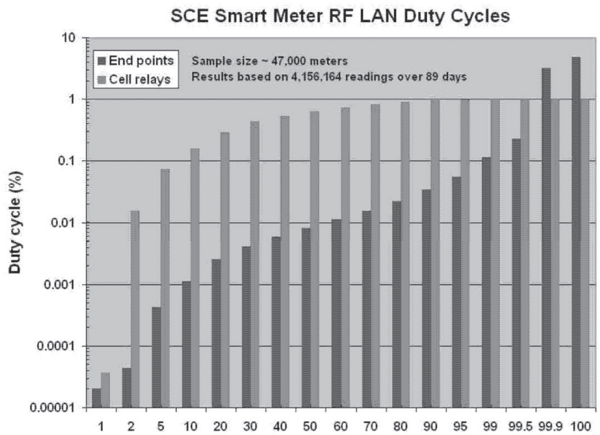

Figure 1

Analysis of SCE daily average duty cycle distribution for different percentiles based on 4,156,164 readings of transmitter activity from an average of 46,698 Itron Smart Meters over a period of 89 consecutive days. Analysis based on estimated transmitter activity during a day. (From EPRI Technical Report 1021126, December 2010)

"packets" associated with uplink and downlink communication to and from end-point and cell relay meters to serve as surrogates for transmission time. The study estimated (Figure 1) a maximum duty cycle of under 5%, with 99.5% of the sample operating at a duty cycle of about 0.22% or less, a value that translates to 3 minutes and 10 seconds of transmitting over a day (a 5% duty cycle, worst case in this study, translates to 72 minutes of transmitting). The duty cycle for cell relays within the same sample did not exceed 1%. Assuming these data are representative of smart meter function in general, the Sage Report using a 100% duty cycle, over-estimates exposure by no less than 20-fold and more typically more than 400-fold. In a smaller study of over 6,800 meters, end-point and cell relay meters were monitored for the number of bytes of data transmitted over an observation period of one day. This method provided a direct (exact) measure of time, and reported duty cycles even lower than those in the larger sample, with no one-day average duty cycle exceeding 1%.

Thus, as an example of examining smart meter duty cycle from the compliance perspective, the EPRI study estimated a nominal exposure of about 12 microwatts per square centimeter ($\mu W/cm^2$) for a person a foot from a 250-mW **end-point meter** while the meter is transmitting. Assuming the worst case duty cycle of 5% for that meter, the "source-based" time-averaged exposure would be 0.6 $\mu W/cm^2$, which is 0.1% of the FCC's **MPE** (maximum permissible exposure); for a 1% duty cycle, the average exposure would be 0.02% of the FCC limit. This value does not yet account for the FCC's stipulation for spatial averaging dealt with in the next discussion.[2]

Spatial Averaging

FCC OET Bulletin 65 states:

> Limits for General Population/Uncontrolled exposure: 0.08 W/kg as averaged over the whole-body and spatial peak **SAR** not exceeding 1.6 W/kg as averaged over any 1 gram of tissue (defined as a tissue volume in the shape of a cube). (page 75)

Exceptions are made for the extremities that have higher SAR permitted. Earlier in the document, FCC states as a general principle:

> A fundamental aspect of the exposure guidelines is that they apply to power densities or the squares of the electric and magnetic field strengths that are spatially averaged over the body dimensions. Spatially averaged RF field levels most accurately relate to estimating the

[2] The FCC rule is not specified to account for the fraction of transmitting time over the course of a day that a person would actually traverse the area within a given distance to the meter. Using the example in the text, a person doing yardwork for 2 hours and 24 minutes (one-tenth of a day) close, say a foot (30 centimeters) from a single meter operating with a 5% duty cycle mounted on the external wall of a residence, would nominally receive an exposure equivalent to 0.01% of the FCC exposure limit for the general public (one-ten thousandth of the exposure limit).

whole body averaged SAR that will result from the exposure and the MPEs … (page 10)

The Sage Report presumes a uniform exposure level across the volume of an exposed person that corresponds to the maximum level in the wavefront at a given distance. However, in fact, the exposure level varies across the dimensions of a body. Figure 2 depicts the general idea of averaging across a body's volume in which 10 or more measurements along the body's axis are averaged in terms of their power density (often measured as the electric field, which is then squared to represent power density).

According to measurements reported in the EPRI study, power densities vary across the measurements' angle of elevation. Figure 3 illustrates how the power density varies along a circular trajectory from above to below the meter. The color coded graphic on the right-hand panel of the figure indicates that, in the case of the meter characterized, power density may be lower at the top by roughly a factor of 3 (~5 dB), and at the bottom by up to a factor of about 10 (~10 dB). In a crude fashion, one could liken the variation of power to the beam from a flashlight, which is maximal head on and diminishes as one moves further from the center of the beam (Figure 4). Qualitatively, it is fairly apparent that the power density in the center of the beam can significantly overestimate the power density averaged over one's body dimensions. An example of a vertical profile measured 1 foot in front of a continuously transmitting 900-MHz, 250-mW end-point smart meter (i.e., transmitting to the **LAN**), as reported in the EPRI study cited above, is shown in Figure 5. Note that at its peak the emission is just below 2% of the FCC's MPE for 900 MHz, but the vertical average, which is the basis for the FCC rule is 0.44% of the FCC MPE, more than 4 times less than the peak.

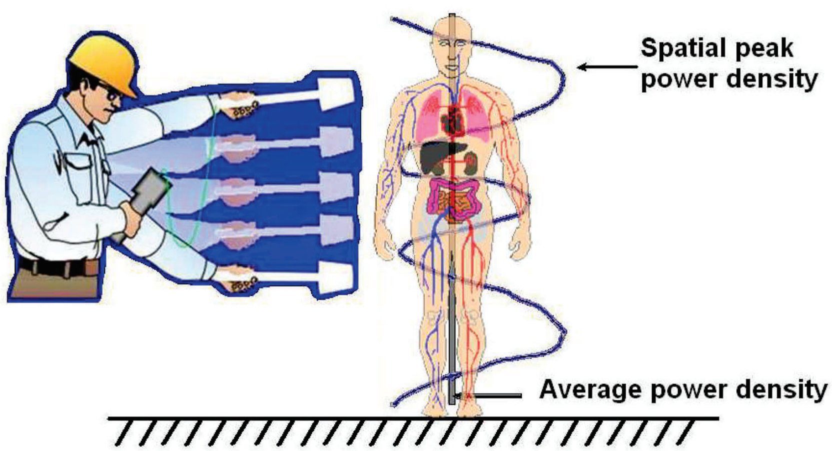

Figure 2
Estimating whole-body SAR with measurements of the power density along the axis of a person in the location to be occupied. (adapted from EPRI Resource paper 1014950, December 2007)

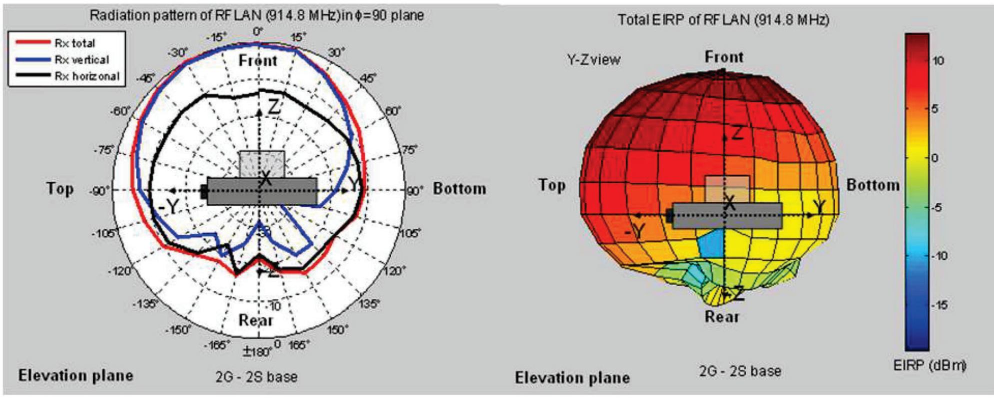

Figure 3
Left: Elevation plane pattern of the 900 MHz RF LAN transmitter in an end point meter showing the horizontal, vertical and total pattern. The scale is in dB with the maximum field at the outer edge of the pattern circle. Right: Elevation plane view of the total EIRP of the 900 MHz RF LAN transmitter in an end point meter. (From EPRI Technical Report 1021126, December 2010)

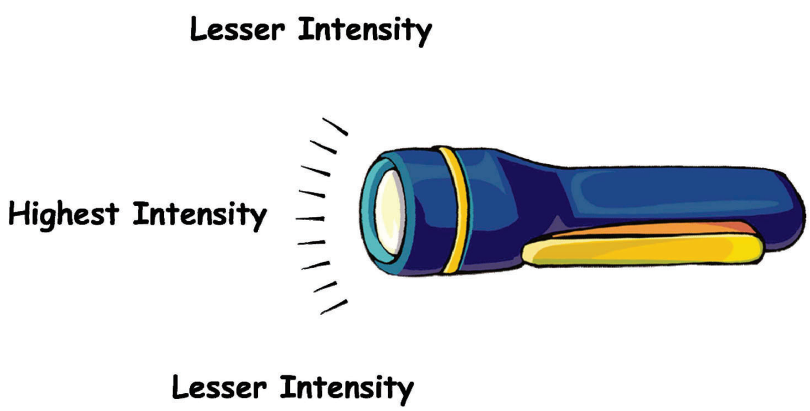

Figure 4
Depiction of beam from a flashlight as a crude analogy of the vertical gradient of the power density from a smart meter

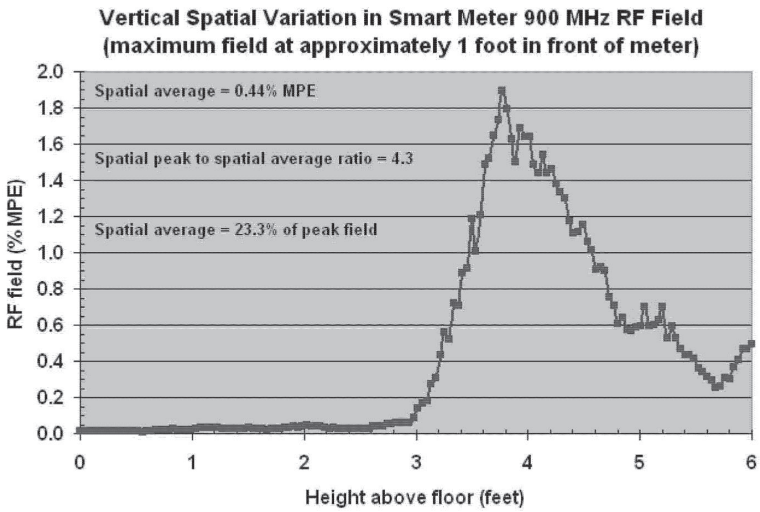

Figure 5

Vertical spatial variation in Smart Meter 900 MHz RF LAN field from 0 to 6 feet above the floor at a lateral distance from the Smart Meter of approximately 1 foot. (From EPRI Technical Report 1021126, December 2010)

Reflections

Electromagnetic waves may reflect off surfaces (Figure 6), which enables us to use rear- and side-view mirrors, which are highly reflective surfaces, to observe traffic traveling behind us. Though visible light is electromagnetic energy that propagates at frequencies 5 to 6 orders of magnitude greater than RF emissions from smart meters, the latter may likewise be reflected to some extent from floors, ceilings and walls depending on their reflective properties. However, most of the environments inhabited by people consist largely of indoor surfaces (wood or carpeted floors, plaster walls and ceilings, windows) and outdoor surfaces (exterior walls, lawns, sidewalks) of moderate reflectivity that may also absorb (and thus attenuate) or pass electromagnetic energy much as light passes through glass. Further, given that smart meters are very frequently on building exteriors facing open space (Figure 7), reflections in those cases would be very small contributors to overall exposure.

The extent of an added exposure due to reflection depends on the reflectivity of the surface (e.g., metallic surfaces are highly reflective; carpeted and wood floors are more absorptive and less reflective), the antenna's beam characteristics (e.g., its angular width and direction) the angle of reflection, and the distance traveled by the wave to an exposed person. For an analysis of RF fields that will result in a conservative estimate of the actual field, the FCC OET 65 Bulletin states:

> For a truly worst-case prediction of power density at or near a surface, such as at ground level or on a rooftop, 100% reflection of incoming radiation can be assumed, resulting in a potential doubling of predicted field strength and a four-fold increase in (far-field equivalent) power density. (Page 20)[3]

The Sage Report interpreted several studies to justify that a worst-case analysis would require increasing the power density of the free-space emissions to account for reflections. This approach was based primarily on a paper by Hondou et al. (J Phys Soc Jap 75:084801, 2006), which reported power density levels for an enclosure made entirely of perfectly reflective surfaces, as depicted in Figure 8 (right). Using the light analogy, this would be equivalent to an enclosed space whose walls, floor and ceiling were made entirely of mirrors. The Hondou et al. (2006) result adapted by the Sage Report is shown in Figure 8 (left), which shows the power density along a path leading away from the antenna.

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[3] Reflection values are expressed in terms of the electric field. Thus, as power density is proportional to the electric field squared, a 100% reflection at a particular point in space corresponds to an enhancement of the power density by a factor of $(1+100/100)^2 = 4$. A more common upper bound estimate of 60% for reflection results in a power density enhancement of $(1+60/100)^2 = 2.56$.

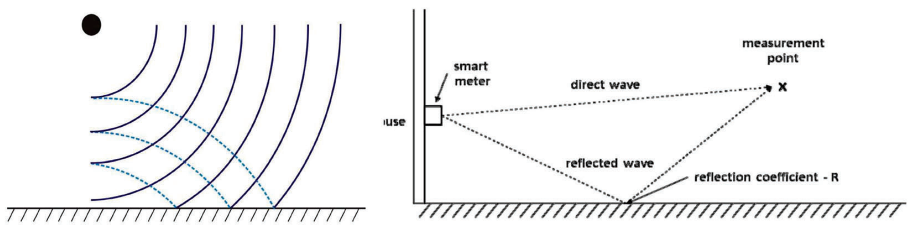

Figure 6
RF Reflections. Left: Wavefronts emitted (solid lines) by source (black dot) and reflected (dashed lines) from the ground. Far from the source (far field), these waves become nearly "plane waves." (From EPRI Technical Report 1014950, Dec 2007); Right: Exposure to incident and reflected wave as would occur at a measurement point; the two contributions may reinforce or cancel one another depending on their mutual phase relationships (Compliments of R.G. Olsen and R.A. Tell)

Figure 7
Measuring RF power densities in front of an outdoor bank of smart meters

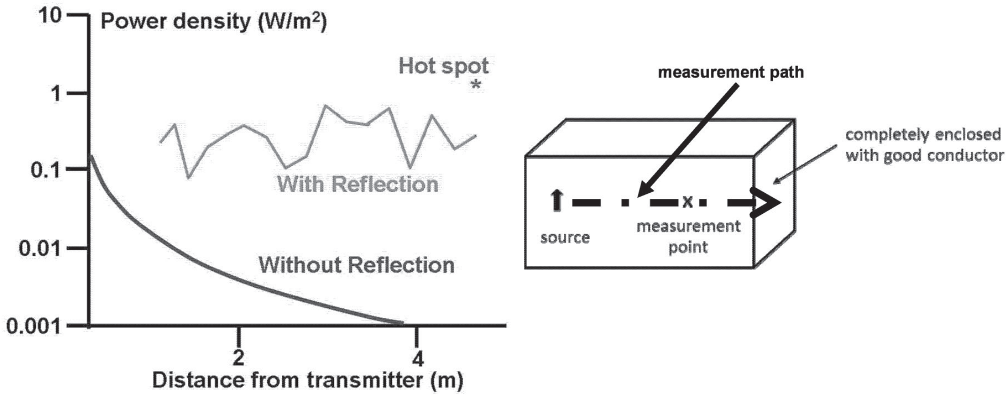

Figure 8
Right: Conceptualization of measurements conducted by Hondou et al. (Compliments of R.G. Olsen and R.A. Tell); Left: Measured power density in the conductive enclosure (red), and calculated free-space value (adapted from Hondou et al., 2006)

At a distance of about 4 meters the power density in this enclosure is between 100 to 1,000 times greater than would be the calculated free space value (blue curve), with a "hot-spot" noted with a power density about 2,000 times greater than the free space scenario. Also note in Figure 8 that as the distance to the antenna decreases, the discrepancy between the reflected and free-space values also decreases (see below for further discussion of reflections versus distance from an antenna). The Sage Report introduced enhancement factors of 1,000% and 2,000%, which translate to, respectively, 121- and 441-fold enhancements of the incident power density (see footnote 3). Despite the claim of adopting "conservative" reflection values based on Hondou et al., the Sage Report, nonetheless used power density enhancements roughly 30 to 110 times greater than the FCC's worst-case scenario, and, moreover, applied the enhancements uniformly to every point in space, which violates the laws of physics. In addition, there are no practical scenarios that simulate the conditions of the enclosure tested by Hondou et al. whereby an individual would be in a space occupied by a smart meter that was also entirely enclosed by conductive surfaces on all sides (floor, walls and ceiling).

Looking further at a realistic indoor case, one might consider rooms in the home (such as a bedroom) to be nearly fully enclosed; doors and windows do represent openings in the enclosure. But, even if this is said, there are two fundamental problems (see Figure 9). First, the source (i.e., the smart meter) is not within the room. It is possible for some of the RF electromagnetic waves to "leak" into the room, but only if the wall is partially transparent to electromagnetic waves from the meter on the exterior of the residence or in the garage. The leakage is small because a smart meter does not radiate much in the direction of the house; its radiation is intentionally directed away from the house. As an added note, though the HAN "Zigbee" antennas are designed to communicate to devices within a residence's interior, their transmission pattern measured in the EPRI study was also more heavily weighted outward much like the end-point meter's pattern. In addition, as the RF passes through the wall it is attenuated. The second problem is since the room is not completely enclosed and the enclosure is not a perfect (or nearly perfect) conductor, it will not behave nearly like the resonant cavity used by Hondou et. al. As a final note, if the wall is more transparent to RF so that attenuation of the RF into the room is small, then the room will look even less like a resonant cavity because its walls are more "leaky."[4]

Although the power density values in the Hondou paper in all likelihood correctly represent the experimental conditions they describe, the results were not utilized appropriately in the Sage Report. The Sage Report calculates the field at

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[4] It is worth noting that Hondou et al. reported another scenario simulating an elevator with a mounted antenna. The "elevator" enclosure used by Hondou et. al. also has metallic sides floor and ceiling. It does have an open door, but given the orientation of the source antenna, only smaller fields are radiated towards the door opening. Thus the door does not degrade the properties of the elevator as a resonant cavity as much as it could if the source was oriented in a different direction.

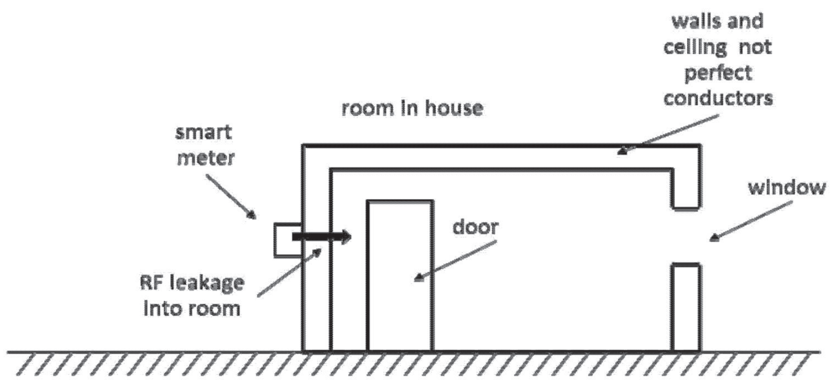

Figure 9
RF leakage into a room in a house which is not a good resonant cavity due both to openings in the walls and the imperfectly conducting enclosure. (Compliments of R.G. Olsen and R.A. Tell)

(for example) 0.15 meters (i.e., 6 inches) from the source and then increases the field by 1000% or 2000% to calculate an "actual" power density at that point. This is not a correct use of Hondou's data. The author of the Sage report incorrectly assumes that the factor of 1,000% or 2000% (10 or 20 fold enhancement of the electric field) may apply at every point in space as a multiplier to the "free space" value of the field. Based on fundamental laws of physics, it can be unequivocally stated that the closer the field point is to the source, the smaller any increase in the field due to reflections. In fact, this ratio approaches 1.0 as the field point becomes arbitrarily close to the source.

This aspect of exposure regarding reflections close to a source, included in the EPRI Technical Report, is illustrated in Figure 10 (left), which represents a calculated power density one foot from a smart meter placed at a height of 5 feet with and without a reflection. The values with reflections present (wavy blue curve) were calculated with a technique called "method of moments" that utilizes realistic characteristics of a ground surface to calculate reflected power density. With a reflection present in this model, the average power density over the vertical axis of a six-foot person standing one foot from the meter was 3.2% greater than the average with no reflections. Also, note how much smaller the exposure levels would be for a person shorter than 4-5 feet. Figure 10 (right) charts the contribution of reflections to the free space power density as distance from the meter increases. Though the relative contribution of reflection is shown to increase with distance from the meter, the total incident power density is simultaneously falling by a greater relative amount with increasing distance from a source. A key finding from this analysis of reflections is that for the distance range modeled, from 1 foot to 20 feet from the meter, the greatest enhancement in power density caused by reflections was only 65%, far smaller than the 256% value provided by FCC for conservatively estimating RF fields when reflections occur. Furthermore, these higher enhancements occurred for points furthest from the source for which the incident field is already smaller. A previous EPRI White Paper, "A Perspective on Radio-Frequency Exposure Associated With Residential Automatic Meter Reading Technology" (1020798), described 60% as a realistic upper bound reflection.

The Sage Report cites another paper (Vermeeren et al., Phys Med Biol 55:5541, 2010) in the context of supporting its enhancement factors which, in fact, it does not. This study models SAR resulting from a rooftop exposure to a base station antenna in the presence of a reflective rooftop (or ground plane) and wall. It reports that at 900 MHz – close to the frequency of the RF LAN (915 MHz) in the wireless smart meter under discussion here – the SAR (proportional to power density at any given frequency) could increase by as much as a factor of about 3.6 (5.5 dB) on a localized basis in 10 grams of tissue, and by a factor of about 2.8 (4.5dB) on a whole body basis, both of these values being consistent with the FCC OET 65 cited above (Figure 11, vertical blue bars). At the same time, reflections modeled at 900 MHz may also result in a reduction of SAR compared to the free-space scenario. At lower frequencies (300 and 450 MHz) reflections were slightly greater, and at higher frequencies, including 2,100 MHz, roughly a home area network's (**HAN**) operating frequency, the reflections were lower (vertical red bars).

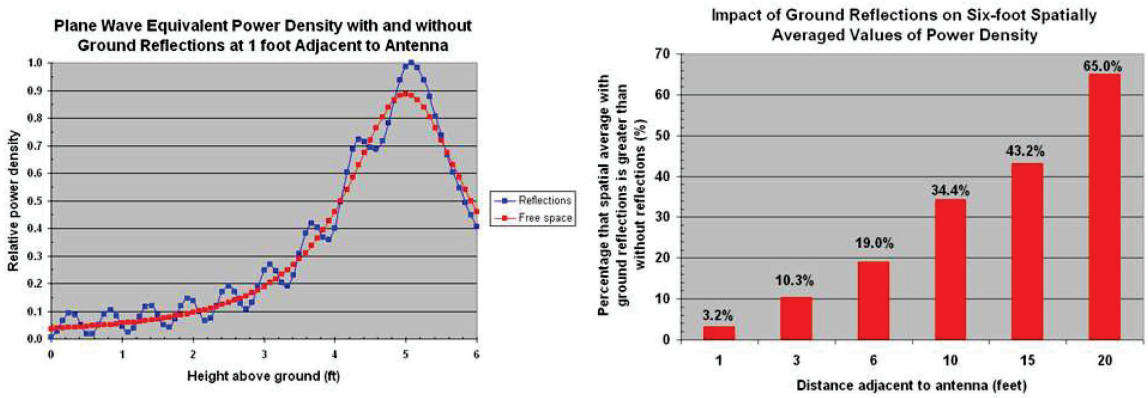

Figure 10
Left: Relative calculated plane wave equivalent power density along a six-foot vertical path, one foot adjacent from a 900 MHz half-wave dipole positioned at five feet above the ground. Power density values are compared with and without ground reflections. Right: Impact of ground reflections on six-foot spatial average of power density for different distances lateral to a 900 MHz dipole antenna mounted at five feet above ground. Vertical axis represents the percentage that the spatially averaged power density that includes any ground reflected fields is greater than the spatially averaged power density in free space (without any ground reflected fields). Ground reflection estimated by method of moments as described in the EPRI Report. (From EPRI Technical Report 1021126, December 2010)

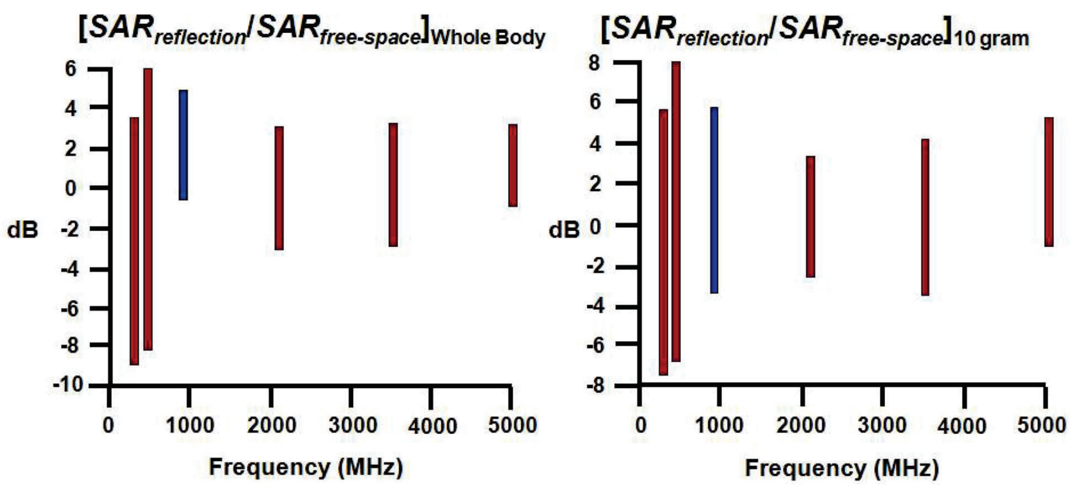

Figure 11
The range of whole-body and 10-gram SAR in the rooftop scenario with reflective ground and wall. Each frequency includes combinations of distance and reflective surface (ground, wall, ground + wall). The blue vertical bar corresponds to the power density range for 900 MHz. (adapted from Vermereen et al., 2010)

Worthy of note was that the Vermeeren et al. study modeled a vertical panel antenna that would intercept much of the body's dimension, leading to a much greater opportunity for whole body exposure than the case of the much smaller smart meter relative to the body's dimension.

<u>Sage Report Interpretation of IEEE Standard Concerning Eyes and Testes</u>

The Sage Report states the following:

> The ANSI/IEEE C95.1-1999 standard specifically excludes exposure of the eyes and testes from the peak power limit of 4000 uW/cm2* [asterisk is a reference to a footnote]. However, nowhere in the ANSI/IEEE nor the FCC OET 65 documents is there a lower, more protective peak power limit given for the eyes and testes.

However, in 2005, IEEE published a revised standard covering RF electromagnetic fields, "IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz (IEEE Std C95.1™-2005). The 2005 revision, working with additional research results available after the 1999 standard was published, removed the language and the intent of language in the 1999 standard regarding an exclusion for eyes and testes. IEEE Std C95.1™-2005 remains the current IEEE standard for RF exposures. The basis for the removal of the 1999 language regarding eyes and testes was extensively documented in the 2005 standard, with brief excerpts as follows:

> …localized exposure at the upper limit (10 W/kg averaged over 10 g of tissue) is protective against all adverse effects including those occurring in the fetus and testes, the two targets identified as most sensitive to thermal damage. (p. 86)
>
> In summary, adverse effects of RF exposure of the eye, i.e., cataracts, are associated with significant temperature increases due to the absorption of RF energy. The maximal permissible RF exposures in this standard are therefore protective against the significant temperature increases that can result in adverse effects on the eye, such as cataracts. There is no evidence of other significant ocular effects, including cancer, which would support a change in the adverse effect threshold of 4 W/kg. (p 60)

Thus, given that revised standards are designed to override their predecessors, the Sage Report relied on an outdated document to suggest an exclusion for eyes and testes.

Section III: Sage Report Calculation of Exposure Levels

The formula used by the FCC for estimating emission levels from an RF source is:

$$S = \frac{P_t \times G_{\max} \times \delta \times R}{4\pi r^2}$$

Where,

S is plane wave equivalent power density (W/m^2)
P_t is maximum transmitter output power (W)
G_{max} is the maximum possible antenna power gain (a dimensionless factor); this means that the transmission has directionality with maximum power transmitted in one particular direction.[5]
δ is the duty cycle of the transmitter (dimensionless)
r is the radial distance between the transmitter and the point of interest (meters)
R is a dimensionless factor that accounts for possible ground reflections that could enhance the resultant field. For a 60% reflection of the electric field, a value typically used for assessing compliance, the power density, S, would increase of $(1.6)^2$ or 2.56 in the power density since it is proportional to the square of the electric field.[6]

The Sage Report used this formula to calculate RF power density levels as they compare to the FCC general public compliance levels under the assumptions that:

---

[5] The power density transmitted in this direction at a given distance is greater – by a factor, G_{max} - than the power density at the same distance were it transmitted symmetrically in all directions (or omnidirectionally) in a spherical pattern as from an isotropic source. This also means that there are areas near the antenna with transmitted power density lower than the power density from an omnidirectional source.

[6] The inclusion of the ground reflection factor of 2.56 makes this formula conservative since it assumes that the meter's signal emitted by a power meter is also reflected from the ground causing an enhancement of the resultant RF field due to what is called phase addition of the direct and reflected signals. If this occurs, it will only happen at very specific points above the ground while at other points, the signals will add destructively, reducing the signal intensity. Hence, when considering the body as a whole, the ground reflection will generally not affect the body's average exposure. Nonetheless, it is common when performing FCC compliance analyses to include the possibility of ground reflections.

1. Duty cycle need not be taken into account, and that continuous exposure should be assumed.

2. Implicitly, space averaging across the volume of an individual is unnecessary, with a uniform exposure at the maximum value occurring across all exposure space.

3. Reflections that may range from 60% to 2000% are uniform across the entire exposure volume.

4. Power densities from multiple meters can be added to calculate a cumulative power density, which can then be compared to the FCC limit.

Taking these in sequence:
(1) The discussion above clarified that as a source-based exposure, incorporating the duty cycle into the estimate of average power density (and average SAR) is appropriate.

(2) Furthermore, the FCC OET 65 indicates that exposure levels should be averaged over the volume of a person presumed to occupy the space where exposure occurs.

(3) In estimating the potential effect reflections may play, 60% is a highly conservative estimate for smart meters, with 100% a worst-case estimate. The reflective enclosure case modeled by Hondou et al. (2006) does not apply to any practical real world situations yet identified (see footnote 3 above concerning Hondou et al.'s elevator model). Uniform enhancement cannot be assumed because close to and in front of an emitter, where the emission is maximum, is exactly where the effect of reflections is at a minimum.

(4) When one is very close to a bank of meters (the Sage Report uses exposure to four meters), one cannot be in the direct path of the maximum emission for each, because (again using the crude flashlight model), the power density decreases to some degree with the azimuthal angle from the center of a propagated field. At the very closest distance in front of one emitter, the azimuthal angle from other emitters predicts lower exposures than derived from simple addition. With respect to this point, it should be pointed out that the exposure level in the 4-meter scenario in the Sage Report was unexplainedly not the 4-fold value expected; rather it was less (for example, see Sage Report, Tables 2 & 3). In Sage Report, Table 1, upper panel, the author reports values at 9 inches, rather than the stated 6 inches, such that the 4-meter scenario in the bottom pane is over 7 times the 1-meter scenario, which is clearly not possible even under the report's assumptions.

In terms of compliance assessment, when more than one source is present, each is weighted according to its frequency dependent FCC limit, as shown below Table 1 on the following page Thus, the Sage Report's approach of reporting a simple sum of power densities from sources at different frequencies is inappropriate in terms of assessing compliance.

In fact, the RF field levels from smart meters, even when grouped together, are not expected to exceed FCC limits. The graph in Figure 12 shows expected exposure levels, in terms of the fraction of the FCC limits appropriately weighted by relative contributions from each source. The specifications for the meters in these calculations, shown here in Table 1, correspond to those used in the Sage Report. The graph considers four end-point meters and three end-point meters combined with a cell relay for 60% and 100% reflections. The smart meters include both the end-point LAN emitter, and the HAN transmitting at 2,405 MHz. The Cell Relay includes these two transmitters, as well as a third transmitter for communicating over a wireless wide area network (**WWAN**) back to the utility company. The calculation assumes a duty cycle of 1%, which was applicable to over 99.5% of the readings from the data shown in Figure 1. Furthermore, the graph is extremely conservative in applying the reflection factor at every distance, and assuming that the peak power density in the wavefront is uniform in space (neither of these applies in actuality). These factors more than compensate for the fact that a small fraction of meters may operate at duty cycles up to 5%. Even at a distance of 8 cm (~3 inches) the power density is well below the FCC MPE.

Section IV: Conclusion

In assessing potential RF exposure levels from smart meters, the Sage Report misapplied the practices prescribed by the FCC in "Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields" (OET Bulletin 65, Edition 97-01, August 1997). Both space and time-averaging are appropriate and reflections of 60% or even 100% may be included to provide conservative estimates. In addition, the Sage Report's author did not evaluate cumulative exposure weighted by MPE at the frequency of each source as instructed by the FCC. A more realistic estimate, even allowing for assumptions that overestimate exposure levels

Table 1
Antenna Values for Figure 12

Antenna	*TPO* (dBm)	*G* (dBi)	*EIRP* (dBm)	*EIRP* (mW)	*f* (MHz)	*MPE* (mW/cm^2)
RF LAN	24.27	2.2	26.47	443.6	915	0.610
Zigbee	18.71	1	19.71	93.5	2405	1.0
Cell Relay	31.8	-1	30.8	1202.3	850	0.567

Fraction of FCC Limit = $n_1 S_{LAN}/0.610 + n_2 S_{Zig}/1.0 + n_3 S_{CR}/0.567$
Within a residence:
n_1=number of LAN meters; n_2=number of Zigbee meters; n_3=1=number of cell relays

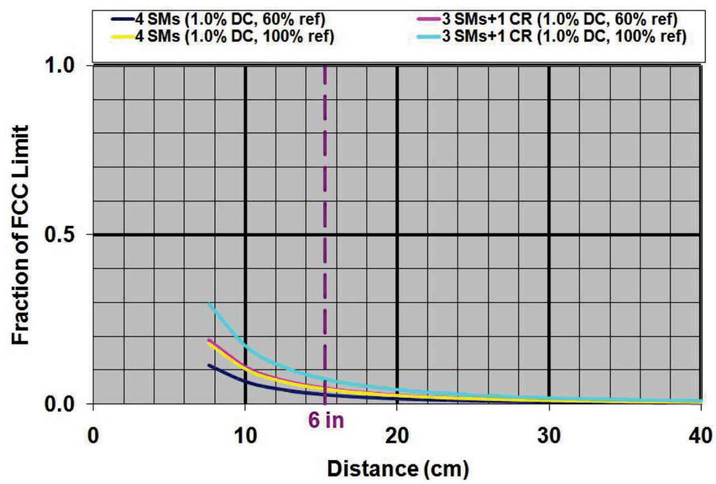

Figure 12
Calculated exposure levels from combinations of meters operating at 1% duty cycle with reflection values of 60% and 100% (see text)

by ignoring space averaging and declining RF levels at positions lateral to the center of a wavefront, reveals that FCC MPEs are very unlikely to be exceeded, even at distances very close to the source. This conclusion also applies to regions behind a meter bank owing to lower emissions in that direction and the attenuating properties of wall materials. These points were supported by measurements described in the EPRI Report, in which power density was measured in front of a rack of 10 ¼ watt (nominal power) continuously operating (i.e., 100% duty cycle) smart meters starting at a distance of 1 foot[7]. Under these circumstances, the frequency-weighted power density was 8% of the FCC MPE for the general public. For a realistic duty cycle of 1%, this would translate to 0.08% of the FCC MPE. For measurements taken immediately behind the rack, the field level for continuous transmission was 0.6% of the FCC MPE at a distance of 8 inches. It should also be pointed out that while the testing was conducted with end-point meters rated nominally at ¼-watt (~250 mW), the manufacturer's data illustrated in the EPRI Report allow one to estimate that, based on a sample of 200,000 meters, 99.9% operate at powers between 150 and 475 mW, with a possible maximum of 500 mW for no more than 0.05% of units. However, were all 10 meters rated at 1 W with the same spatial transmission pattern as the quarter-watt meters actually measured, the exposure at 1 foot would still be less than the FCC limit by a factor of three. Therefore, the Sage Report, for the reasons enumerated in this commentary, has over-estimated

[7] The meters were specially programmed to operate continuously for the measurement study. They do not operate in this manner when actually deployed, transmitting intermittently for very brief periods, as explained in the text.

exposures from smart meters using assumptions and calculations that are inconsistent with the FCC's rule and that do not recognize the basic physical characteristics of RF emissions.

Glossary

Cell relay: A form of Smart Meter that provides the normal function of an end point meter but also allows for data connectivity with the electric utility company via a wireless wide area network that functions in the cellular telephone or personal communications service (PCS) bands.

Duty Cycle: a measured of the percentage or fraction of time that an RF device is in operation. A duty cycle of 1.0, or 100%, corresponds to continuous operation. Also called duty factor. A duty cycle of 0.01 or 1% corresponds to a transmitter operating on average only 1% of the time.

End point meter: A term used to designate a Smart Meter that is installed on a home or business to record and transmit electric energy consumption but that does not provide access point features such as those provided by a cell relay.

EPRI, Electric Power Research Institute, Inc.: EPRI conducts research and development relating to the generation, delivery and use of electricity for the benefit of the public. An independent, nonprofit organization, EPRI brings together its scientists and engineers as well as experts from academia and industry to help address challenges in electricity, including reliability, efficiency, health, safety and the environment. EPRI also provides technology, policy and economic analyses to drive long-range research and development planning, and supports research in emerging technologies. EPRI's members represent more than 90 percent of the electricity generated and delivered in the United States, and international participation extends to 40 countries. EPRI's principal offices and laboratories are located in Palo Alto, Calif.; Charlotte, N.C.; Knoxville, Tenn.; and Lenox, Mass.

FCC, Federal Communications Commission: the Federal Communications Commission (FCC) is an independent agency of the US Federal Government and is directly responsible to Congress. The FCC was established by the Communications Act of 1934 and is charged with regulating interstate and international communications by radio, television, wire, satellite, and cable. The FCC also allocates bands of frequencies for non-government communications services (the NTIA allocates government frequencies). The guidelines for human exposure to radio frequency electromagnetic fields as set by the FCC are contained in the Office of Engineering and Technology (OET) Bulletin 65, Edition 97-01 (August 1997). Additional information is contained in OET Bulletin 65 Supplement A (radio and television broadcast stations), Supplement B (amateur radio stations), and Supplement C (mobile and portable devices).

Gain, antenna: a measure of the ability of an antenna to concentrate the power delivered to it from a transmitter into a directional beam of energy. A search light exhibits a large gain since it can concentrate light energy into a very narrow beam while not radiating very much light in other directions. It is common for cellular antennas to exhibit gains of 10 dB (dB is a form of expressing power density on a logarithmic scale) or more in the elevation plane, i.e., concentrate the power delivered to the antenna from the transmitter by a factor of 10 times (10 dB = 10x; 20 dB = 100x) in the direction of the main beam giving rise to an effective radiated power greater than the actual transmitter output power. In other directions, for example, behind the antenna, the antenna will greatly decrease the emitted signals. Gain is often referenced to an isotropic antenna, that is one that transmits uniformly in all directions (spherical wavefront).

HAN, Home Area Network: In the context of Smart Meters, a local area network for communication between a personal computer and various electrical appliances, equipment or systems to accomplish optimized electric energy consumption at the home. Small sensors with low power radio transmitters are attached to the various electrical appliances for communication in the HAN.

LAN, Local Area Network: The wireless mesh (see below) network that interconnects end-point meters, which transmit data to the cell relay (collection point) for transmittal to the local utility. (**Mesh Network**: A term describing a network, typically wireless, in which multiple nodes communicate among themselves and data can be relayed via various nodes to some access point. Mesh networks are self healing in that should a particular pathway become nonfunctional for some reason, alternative paths are automatically configured to carry the data. Mesh networks can expand beyond the normal range of any single node (Smart Meter) by relaying of data among the different meters.)

MPE, Maximum Permissible Exposure: The value of an exposure that should not be exceeded. These include the electromagnetic field, expressed in terms of power density, or as either the electric or magnetic field, and induced or contact currents.

Power Density: The power per unit area, denoted by the symbol *S*, of an RF electromagnetic field normal (perpendicular) to its direction of propagation, usually expressed in units of watts per square meter (W/m^2) or, for convenience, milliwatts per square centimeter (mw/cm^2) or microwatts per square centimeter ($\mu w/cm^2$). For plane waves (i.e., those beyond the immediate proximity of an antenna operating in the frequency range of a smart meter), power density, electric field strength, *E*, and magnetic field strength, *H*, are related by the impedance of free space, whose value is 120π (377) ohms. In particular, the power density, $S = E^2/120\pi = 120\pi H^2$ (where *E* and *H* are expressed in units of V/m and A/m, respectively).

Reflection: An electromagnetic wave (the "reflected" wave) caused by a change in the electrical properties of the environment in which an "incident" wave is propagating. This wave usually travels in a different direction than the incident wave. Generally, the larger and more abrupt the change in the electrical properties of the environment, the larger the reflected wave.

SAR, Specific Absorption Rate: The time derivative of the incremental energy absorbed by (dissipated in) an incremental mass contained in a volume of a given density. SAR is expressed in units of watts per kilogram, W/kg (or milliwatts per gram, mW/g). Guidelines for human exposure to radio frequency fields are based on SAR thresholds for potential adverse biological effects. When the human body is exposed to a radio frequency field, the SAR experienced is proportional to the squared value of the electric (or magnetic) field strength induced in the body.

WWAN, Wireless Wide Area Network: WWANs are provided by several cellular telephone companies for wireless connectivity directly to the Internet for data transmission. WWANs are different from so-called wireless "hot spots" such as found in cyber cafés and operate in either the 850 MHz cellular or 1900 MHz PCS bands.

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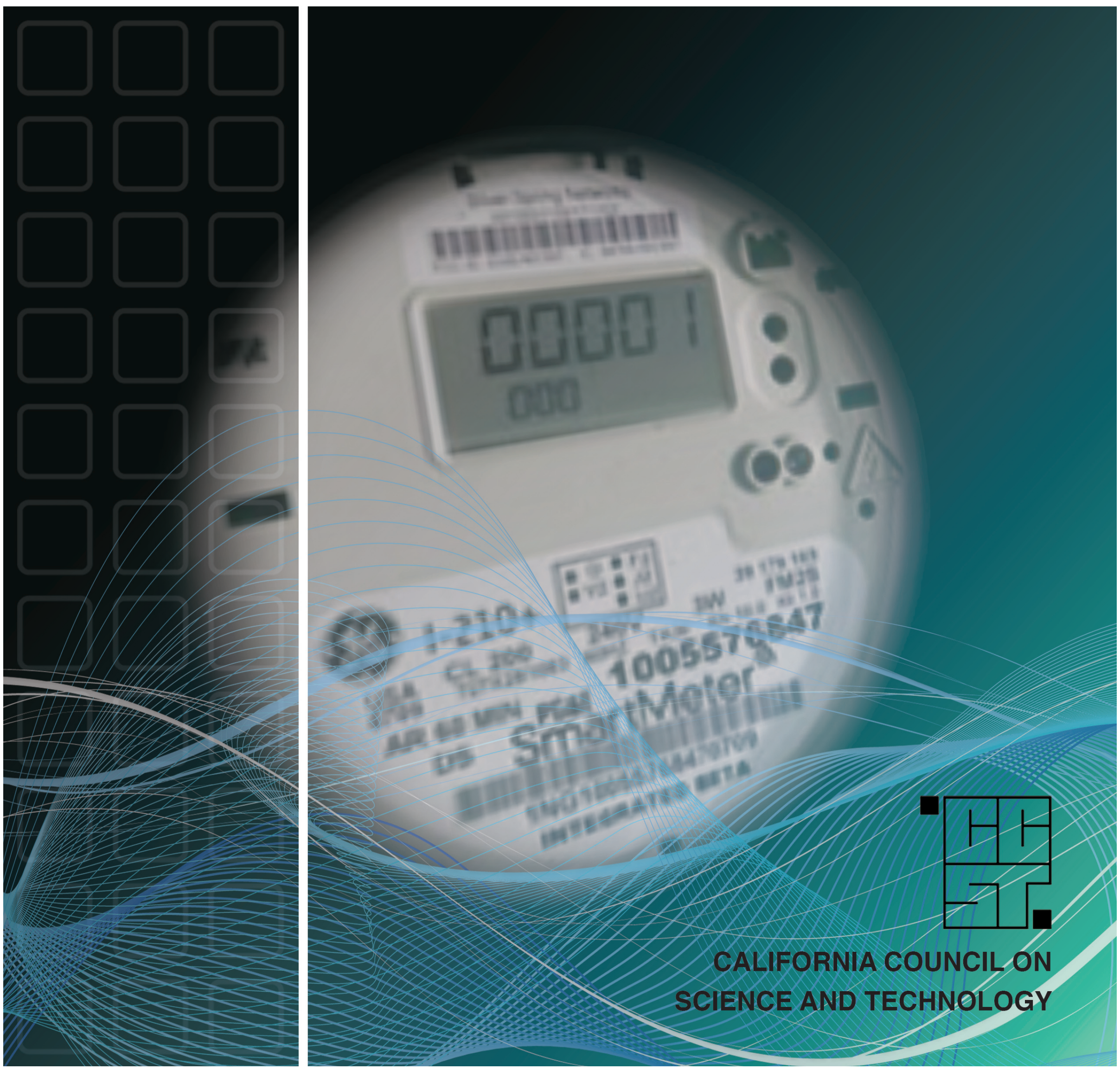
HEALTH IMPACTS OF RADIO FREQUENCY EXPOSURE FROM SMART METERS

APRIL 2011 - FINAL REPORT



CALIFORNIA COUNCIL ON SCIENCE AND TECHNOLOGY

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This report was conducted with the oversight of a CCST Smart Meter Project Team, whose members include: Rollin Richmond (Chair), Emir Macari, Patrick Mantey, Paul Wright, Ryan McCarthy, Jane Long, David Winickoff, and Larry Papay. We also thank J.D. Stack for his technical contributions and Lora Lee Martin for the overall coordination of this report response. We express gratitude to CCST's members and colleagues for their many contributions to the report. Comments on the January 2011 draft of this report were solicited from the public. Many very thoughtful and informed comments were received. All public comments were reviewed and taken into consideration as this final report was completed.

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CCST is a non-profit organization established in 1988 at the request of the California State Government and sponsored by the major public and private postsecondary institutions of California and affiliate federal laboratories in conjunction with leading private-sector firms. CCST's mission is to improve science and technology policy and application in California by proposing programs, conducting analyses, and recommending public policies and initiatives that will maintain California's technological leadership and a vigorous economy.

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Letter from CCST

With rapidly emerging and evolving technologies, lawmakers at times find themselves pressed to make policy decisions on complex technologies. Smart meters are one such technology.

Smart meters are being deployed in many places in the world in an effort to create a new generation of utility service based on the concepts of a smart grid, one that is agile, efficient and cost effective.

The electricity crisis of 2000 and 2001 helped force the issue here in California, lending significant urgency to the need for better management of power generation and distribution. In 2006, the California Public Utilities Commission authorized the Pacific Gas and Electric Company to implement a relatively new technology, smart meters, to gather much more precise information about power usage throughout the state. The process of installing the meters throughout the state is still underway.

As with any new technology, there are unknowns involved. Smart meters generally work by transmitting information wirelessly. Some people have expressed concerns about the health effects of wireless signals, particularly as they become virtually ubiquitous. These concerns have recently been brought to the attention of state legislators, with some local municipalities opting to ban further installation of the meters in their communities.

We are pleased that Assembly Members Huffman and Monning have turned to CCST for input on this issue. It is CCST's charge to offer independent expert advice to the state government and to recommend solutions to science and technology-related policy issues. In this case, we have assembled a succinct but comprehensive overview of what is known about human exposure to wireless signals and the efficacy of the FCC safety standards for these signals. To do so, we assembled a project team that consulted with over two dozen experts and sifted through over a hundred articles and reports, providing a thorough, unbiased overview in a relatively rapid manner.

In situations where public sentiment urges policy makers to make policy decisions with potentially long-term consequences, access to the best information possible is critical. This is the role that CCST was created to fulfill.

Susan Hackwood

Susan Hackwood
Executive Director, CCST

Rollin C. Richmond

Rollin Richmond
Project Team Chair, CCST

Health Impacts of Radio Frequency from Smart Meters
Response to Assembly Members Huffman and Monning

California Council on Science and Technology
April 2011

KEY REPORT FINDINGS
1. Wireless smart meters, when installed and properly maintained, result in much smaller levels of radio frequency (RF) exposure than many existing common household electronic devices, particularly cell phones and microwave ovens. 2. 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. 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. 4. Not enough is currently known about potential non-thermal impacts of radio frequency emissions to identify or recommend additional standards for such impacts

OTHER CONSIDERATIONS
Smart electricity meters are a key enabling technology for a “smart grid” that is expected to become increasingly clean, efficient, reliable, and safe at a potentially lower cost to the consumer. The CCST Smart Meter Project Team offers the following for further consideration by policy makers, regulators and the utilities. <u>We appreciate that each of these considerations would likely require a cost/benefit analysis</u>. However, we feel they should be considered as the overall cumulative exposure to RF emissions in our environment continues to expand. 1. As wireless technologies of all types increase in usage, it will be important to: (a) continue to quantitatively assess the levels of RF emissions from common household devices and smart meters to which the public may be exposed; and (b) continue to investigate potential thermal and non-thermal impacts of such RF emissions on human health. 2. Consumers should be provided with clearly understood information about the radiofrequency emissions of all devices that emit RF including smart meters. Such information should include intensity of output, duration and frequency of output, and, in the cases of the smart meter, pattern of sending and receiving transmissions to and from all sources. 3. The California Public Utilities Commission should consider doing an independent review of the deployment of smart meters to determine if they are installed and operating consistent with the information provided to the consumer. 4. Consideration could be given to alternative smart meter configurations (such as wired) in those cases where wireless meters continue to be concern to consumers.

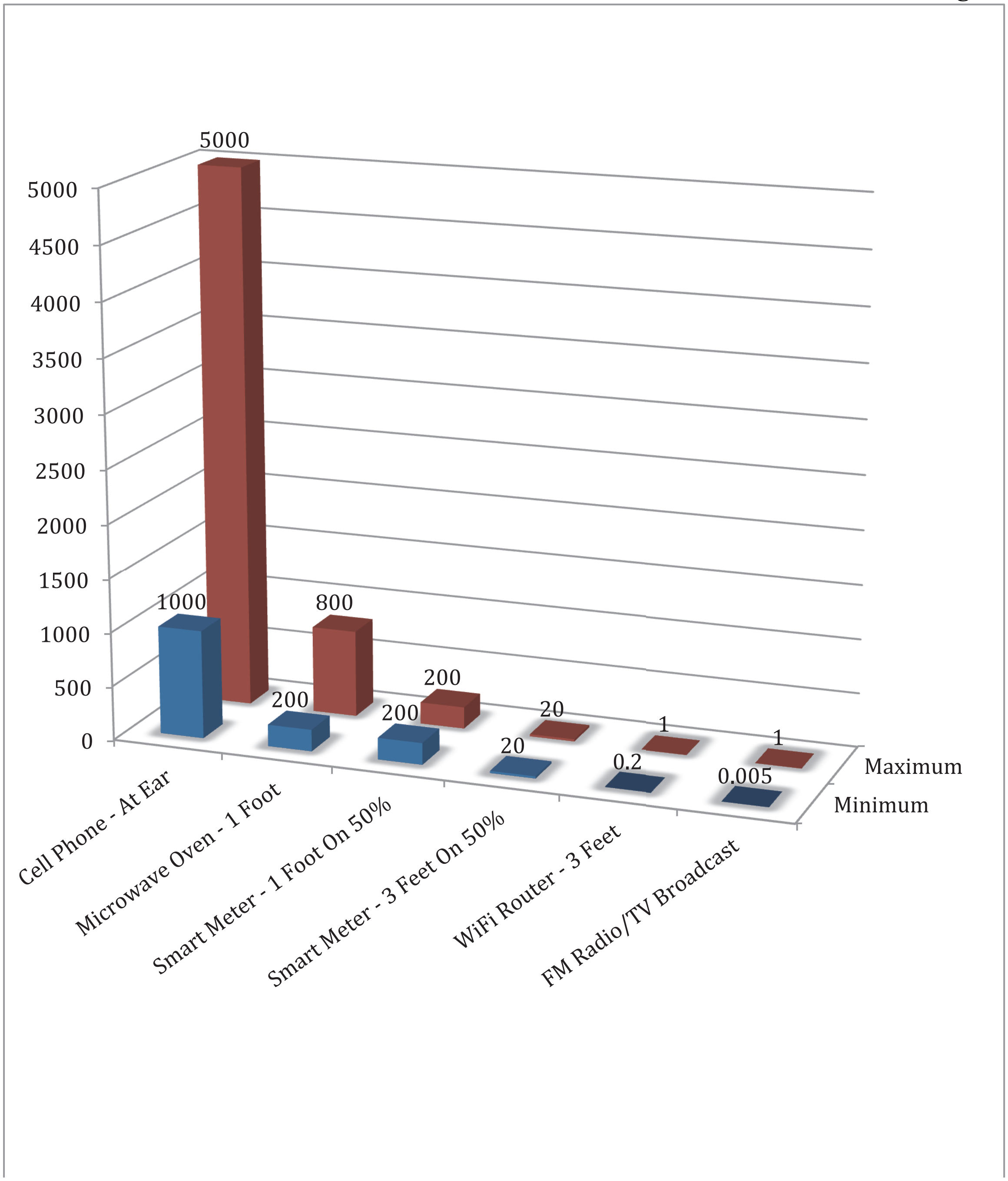

Figure 1. Instantaneous Radio Frequency Power Density Levels of Common Devices (in microWatts/cm^2)
About this figure**:** This figure was developed by the CCST project team**.** Quantities for different distances calculated using Inverse Square Law. Assumes distances in far-field, where power density reduces as the square of the distance from the source. Smart meter power scaled to obtain output for 50% duty cycle. The source for the various starting measurements came from Electric Power Research Institute (EPRI), Radio-Frequency Exposure Levels from Smart Meters: A Case Study of One Model (February 2011)

Legislative Request

On July 30, 2010, California Assembly Member Jared Huffman wrote to the California Council on Science and Technology (CCST) to request that the Council perform an "independent, science-based study…[that] would help policy makers and the general public resolve the debate over whether smart meters present a significant risk of adverse health effects." California Assembly Member Bill Monning signed onto the request with his own letter to CCST on September 15, 2010. The City of Mill Valley also sent a letter on September 20th supporting Assembly Member Huffman's request for the study.

Approach

Reflecting the requests of the Assembly Members, CCST agreed to compile and assess the evidence available to address:

> **1. Whether Federal Communications Commission (FCC) standards for smart meters are sufficiently protective of public health, taking into account current exposure levels to radiofrequency and electromagnetic fields.**
>
> **2. Whether additional technology-specific standards are needed for smart meters and other devices that are commonly found in and around homes, to ensure adequate protection from adverse health effects.**

CCST convened a Smart Meter Project Team composed of CCST Council and Board members supplemented with additional experts in relevant fields (see Appendix A for Project Team members). The Project Team identified and reviewed over 100 publications and postings about smart meters and other devices in the same range of emissions, including research related to cell phone RF emissions, and contacted over two dozen experts in radio and electromagnetic emissions and related fields to seek their opinion on the two identified issues.

It is important to note that CCST has not undertaken primary research of its own to address these issues. This response is 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 from electric appliances generally, and smart meters specifically. This report has been extensively reviewed by the Project Team, experts in related fields, and has been subject to the CCST peer review process (see Appendix B). It has also been made available to the public for comment.

Two Types of Radio Frequency Effects: Thermal and Non-thermal

Household electronic devices, such as cellular and cordless telephones, microwave ovens, wireless routers, and wireless smart meters produce RF emissions. Exposure to RF emissions may lead to thermal and non-thermal effects. Thermal effects on humans have been extensively studied and appear to be well understood. The Federal Communications Commission (FCC) has established guidelines to protect public health from known hazards associated with the thermal impacts of RF: tissue heating from absorbing energy associated with radiofrequency emissions. Non-thermal effects, however, including cumulative or prolonged exposure to lower levels of RF emissions, are not well understood. Some studies have suggested non-thermal effects may include fatigue, headache, irritability, or even cancer. *But these findings have not been scientifically established, and the mechanisms that might lead to non-thermal effects remain uncertain.* Additional research and monitoring is needed to better identify and understand potential non-thermal effects.

Findings

Given the body of existing, *generally accepted scientific knowledge* regarding smart meters and similar electronic devices, CCST finds that:

1. **The FCC standard provides an adequate factor of safety against known RF induced health impacts of smart meters and other electronic devices in the same range of RF emissions.**
   The potential for behavioral disruption from increased body tissue temperatures is the only biological health impact that has been consistently demonstrated and scientifically proven to result from absorbing RF within the band of the electromagnetic spectrum (EMF) that smart meters use. The Federal Communications Commission (FCC) has set a limit on the Standard Absorption Rate (SAR) from electronic devices, which is well below the level that has been demonstrated to affect behavior in laboratory animals. Smart meters, including those being installed by Pacific Gas and Electric Company (PG&E) in the Assembly Members' districts, if installed according to the manufacturers instructions and consistent with the FCC certification, emit RF that is a very small fraction of the exposure level established as safe by the FCC guidelines.

   FCC staff has recently confirmed that it "relied on the expert opinions of EPA, NCRP, and others to conclude that the RF exposure limits it adopted were adequately protective of human health from all known adverse effects, regardless of whether these effects were thermal or athermal in origin".[1]

   The FCC guidelines provide a significant factor of safety against known RF impacts that occur at the power levels and within the RF band used by smart meters. Given current

[1] Statement provide by Robert Weller regarding FCC regulations on February 3, 2011. Robert Weller, Chief, Technical Analysis Branch, Office of Engineering and Technology, Federal Communications Commission.

scientific knowledge, the FCC guideline provides a more than adequate margin of safety against known RF effects.

2. **At this time there is no clear evidence that additional standards are needed to protect the public from smart meters or other common household electronic devices.** Neither the relevant scientific literature nor our expert consultations support that there is a causal relationship between RF emissions and non-thermal human health impacts. Nor does the relevant evidence convincingly describe mechanisms for such impacts, although more research is needed to better understand and verify these potential mechanisms. Given the absence of evidence supporting a real hazard, the benefits of elevating existing standards are highly speculative. Further, there is not an existing basis from which to understand what types of standards could be helpful or appropriate. Without a clearer understanding of the biological mechanisms involved identifying additional standards or evaluating the relative costs and benefits of those standards cannot be determined at this time.

   Given the existing significant scientific uncertainty around non-thermal effects, there is currently no generally accepted definitive, evidence-based indication that additional standards are needed. Because of the lack of generally accepted evidence, there is also not an existing basis from which to understand what types of standards could be helpful or appropriate. Without a clearer understanding of the biological mechanisms involved identifying additional standards or evaluating the relative costs and benefits of those standards cannot be determined at this time.

   CCST notes that in some of the studies reviewed, contributors have raised emerging questions from some in the medical and biological fields about the potential for biological impacts other than the thermal impact that the FCC guidelines address. A report of the National Academies identifies research needs and gaps and recommended areas of research to be undertaken to further understanding of long-term exposure to RF emissions from communication devices, particularly from non-thermal mechanisms.[2] In our increasingly wireless society, smart meters account for a very small portion of RF emissions to which we are exposed. Concerns about human health impacts of RF emissions from smart meters should be considered in this broader context.

[2] National Research Council (2008) *Identification of Research Needs Relating to Potential Biological or Adverse Health Effects of Wireless Communication,* The National Academies Press, Washington, D.C.

THE SCIENTIFIC METHOD
"Scientifically established", "generally accepted scientific knowledge" and other such references throughout this document are referencing information obtained through the scientific method. A scientific method consists of the collection of data through observation and experimentation, and the formulation and testing of hypotheses. These steps must be repeatable in order to predict future results. Scientific inquiry is generally intended to be as objective as possible, to reduce biased interpretations of results. Another basic expectation is to document, archive and share all data and methodology so they are available for careful scrutiny by other scientists, giving them the opportunity to verify results by attempting to reproduce them. This practice, called full disclosure, also allows statistical measures of the reliability of these data to be established.

INTERPRETING THE SCIENTIFIC LITERATURE
In our review of the relevant scientific evidence, we privileged those studies that had as many of the following indicia of scientific reliability as possible: (1) Empirical testing; (2) Peer review and publication; (3) The use of accepted standards and controls; (4) Degree to which the finding is generally accepted by a relevant scientific community. These criteria of scientific reliability are broadly based on the standards of expert testimony and evidence in the US Federal Courts.

Health concerns surrounding RF from smart meters are similar to those from many other devices that we use in our daily lives, including cordless and cellular telephones, microwave ovens, wireless routers, hair dryers, and wireless-enabled laptop computers. As detailed in the report, a comparison of electromagnetic frequencies from smart meters and other devices shows that the exposure level is very low.

Standards of Proof or Certainty in Public Health
In this report, scientific evidence is the primary consideration. Upon consulting with the California Department of Public Health, it is noted that using scientific evidence to shape public policy is always challenging. The standards for declaring certainty within a scientific discipline, which are based on the results of statistical testing, may be unrealistic or inappropriate for making public policy decisions, particularly those with potential impacts on population health. Statistical tests usually rely on the convention of whether the results of a given study are sufficient to reject the null hypothesis of no effect (i.e., of a given exposure). This is effectively a standard of 95% certainty, analogous to the legal standard of proof "beyond a reasonable doubt."

In public health, five factors are generally considered when reviewing scientific evidence for policy decisions related to specified exposures:

1. Severity of potential effect(s): e.g., cancer or serious birth defects would be considered more severe than skin irritation;
2. Number of people with potential exposure;
3. Levels of likely and possible exposures;
4. Degree of certainty of the specific effect(s) at different exposure levels; certainty just above 50% might be characterized as "more likely than not."
5. Cost to mitigate potential effect(s), typically considered in light of the other factors.

Policy makers constantly weigh these factors consciously or unconsciously as they interact with stakeholders to craft good public policy. In one situation, they might consider high-cost mitigations for high-severity effects with high-certainty evidence. In another situation with high-severity effects and "more likely than not" certainty of those effects, they might choose low-cost mitigations. This report did not extend beyond the scientific evidence realm with which we were charged leaving those issues to the policy makers to whom this report has been delivered.

What are Smart Meters?

Smart meters measure attributes of electricity, natural gas, or water as delivered to consumers and transmit that information (e.g., usage) digitally to utility companies. Some smart meters are also designed to transmit real-time information to the consumer. These smart meters replace traditional, analog meters and meter readers with an automated process that is expected to reduce operating costs for utilities, and potentially, costs for customers (see Figure 2). Each of California's major electricity utilities has begun deploying smart meter infrastructure.

a. Analog Meter b. Digital Meter

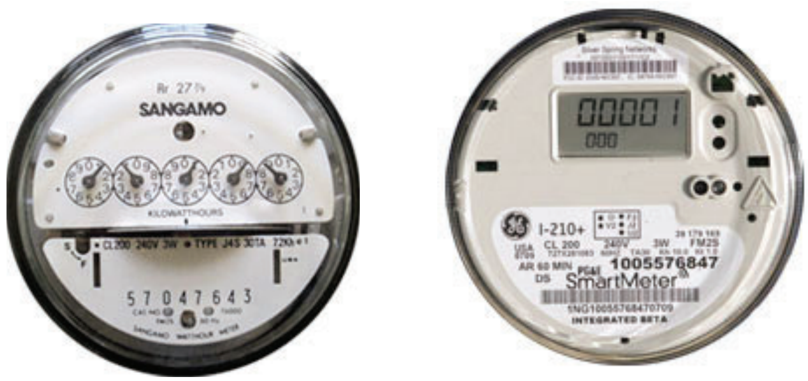

Figure 2. a) An analog, conventional meter and a (b) digital smart meter (Source: PG&E)

There are many kinds of smart meters manufactured by a variety of companies. The meter, including sensors and the housing or casing, may be manufactured by one company while the communications device (installed within the meter) is manufactured by another. Depending upon the internal communications device employed, meters are configured to operate in a wired or in wireless environment. The smart meters used by PG&E are made by General Electric and Landis + Gyr and use a wireless communications technology from Silver Spring Networks. Each of these PG&E meters has two transmitters to provide two different communications of data from these meters.[3] The first provides for the "automatic meter reading" (AMR) function of the meter (and for more detailed and real time monitoring of the characteristics of the

[3] Tell, R. (2008) "Supplemental Report on An Analysis of Radiofrequency Fields Associated with Operation of the PG&E Smart Meter Program Upgrade System," Prepared for Pacific Gas & Electric Company, Richard Tell Associates, Inc., October 27.

electrical energy delivered to the consumer) and sends this data to an access point, where it is collected along with data from many other customers and transmitted to PG&E using a wireless area network (WAN) (similar to the way cell phone communication works).

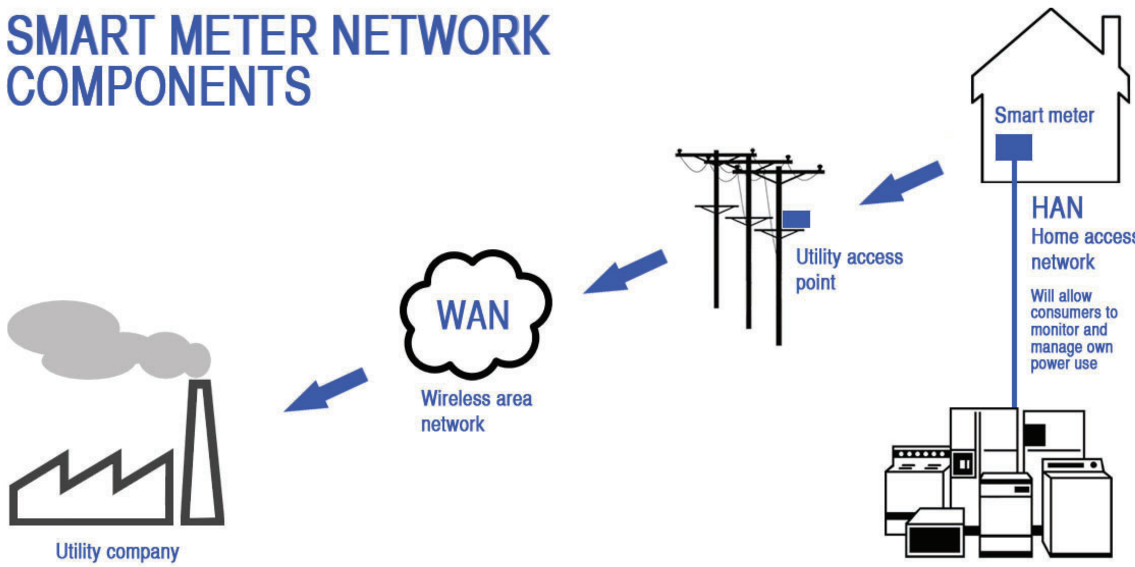

Figure 3. Simplified depiction of Smart Meter system network. Arrows show the use of radiofrequency (RF) signals for automated meter reading, communications among electric power meters, relays, access points, the company's enterprise management systems. The future home access network will operate within the house.

Smart meters have evolved from automatic meter reading (AMR; i.e., replacing meter readers) to a real time monitoring of power as delivered to the consumer by the utility company. CCST obtained from PG&E the Richard Tell Associates report, which describes the operation of the smart meter from the 2008 perspective of AMR, not a fully deployed real time smart grid. The Richard Tell Associates reports describe the use of the smart meter radios being deployed by PG&E as licensed by the FCC for a maximum power output of 1 W (watt) and within the 902-928 MHz (mega-hertz) frequency band. In its initial deployment, PG&E reports that it will configure the radios to transmit data from the meter to the access point once every four hours, for about 50 milliseconds at a time.[4] Accounting for this, the current duty cycles of the smart meter transmitter (that is, the percent of time that the meter operates) would then typically be 1 percent, or in some cases where the meter is frequently used as a relay, as much as 2-4 percent. *This means that the typical smart meter in this initial (AMR) use would not transmit any RF signal at least 96-98 percent of the time.*

It is important to note that any one smart meter is part of a broader "mesh" network and may act as a relay among other smart meters and utility access points. In addition, when the smart

[4] Tell, R. (2008) "Supplemental Report on An Analysis of Radiofrequency Fields Associated with Operation of the PG&E Smart Meter Program Upgrade System," Prepared for Pacific Gas & Electric Company, Richard Tell Associates, Inc., October 27. http://www.pge.com/includes/docs/pdfs/shared/edusafety/systemworks/rfsafety/rf_fields_supplemental_report_2008.pdf)

grid is fully functional the smart meters would be expected to be transmitting much more than once every four hours, providing data in near real-time, which will result in a much higher duty cycle. For purposes of this report we include a hypothetical scenario where the smart meter is transmitting 50 percent of the time (i.e., transmitting half the time and receiving half the time). Even in this 50% duty cycle situation the power output would be well below the FCC limits.

Smart meters are designed to transmit data to a utility access point that is usually 25 feet above ground, on utility or light poles. These access points are designed to transmit data from up to 5,000 smart meters to the utility company. Access points have a similar AMR transmitter as smart meters, as well as an additional *AirCard,* which communicates with utilities and is similar to wireless cards used in laptop computers. *AirCard*s typically operate at 0.25-1 W, in the 800-900 MHz or 1.9 GHz range.

In some cases, data is moved through the mesh network, relaying the data through other meters to the utility access point. This may occur when the topography or built environment interferes with the transmission of data from a smart meter to the access point. In these cases, the relaying of data may occur between one smart meter and another before the signal is sent to the utility access point (e.g., hops along a set of meters). Additionally, some non-meter data relays will also exist in the system to connect some smart meters to utility access points.

Many smart meters, including those from PG&E, also have a second transmitter that, at some future point in time, will allow customers to enable a home access network (HAN). The HAN will allow increased consumer monitoring of electricity use and communication among appliances and the future smart grid. This functionality is important to achieve the full potential of the smart grid. This second internal transmitter, for delivery of smart meter data to the consumer, reportedly will operate at a rated power of 0.223W, at frequency of about 2.4 GHz (again, similar to that of cell phones and wireless phones). The actual duty cycle of this transmitter will depend on the design and operation of the home area network.

Why are Smart Meters Being Installed Throughout California?

It is anticipated, when fully operational, that smart electricity meters are a key enabling technology for a "smart grid" that is expected to become increasingly clean, efficient, reliable, and safe (see Figure 3) at a potential lower cost to the consumer. (Digital meters are also being used for reading of natural gas and water consumption). Smart electrical meters allow direct two-way communication between utilities and customers, which is expected to help end users adjust their demand to price changes that reflect the condition of the electricity grid. These end user adjustments can help to protect the overall reliability of the electricity grid, cut costs for utility customers, and improve the operation and efficiency of the electricity grid. The smart grid will enable grid operators to better balance electricity supply and demand in real-time, which becomes increasingly important as more intermittent wind and solar generation resources are added to the grid.

Figure 4 depicts the potential operation of a smart grid.

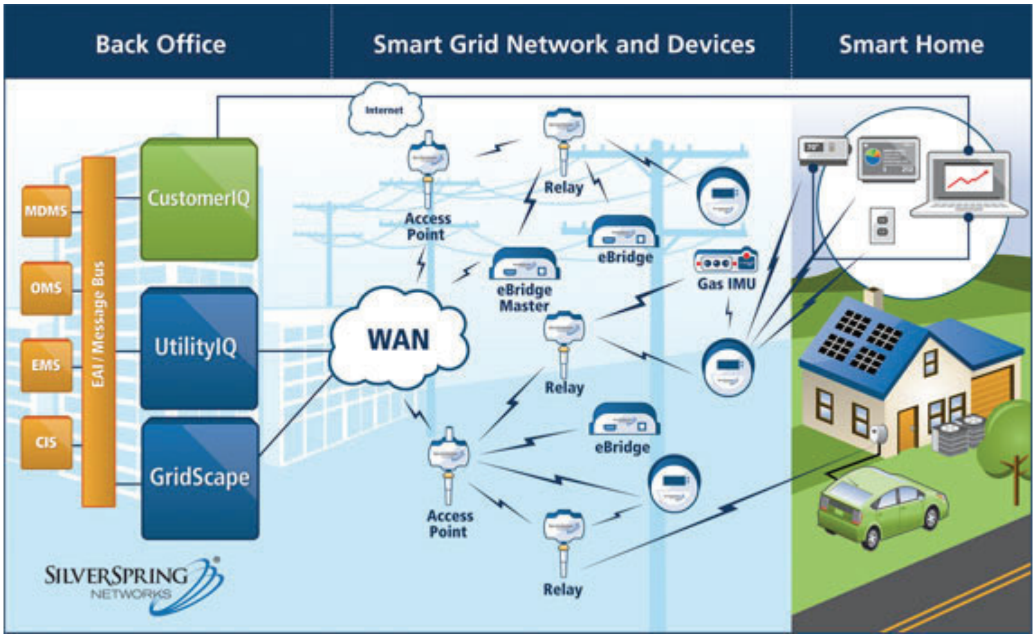

Figure 4. Illustration of components of the PG&E Smart Meter Program Upgrade showing the use of radiofrequency (RF) signals for communications among electric power meters, relays, access points and, ultimately, the company's enterprise management systems. (Source Silver Spring Network[5])

Smart meters will also allow utilities to communicate grid conditions to customers through price signals, so that consumers, via their HAN, can delay non-time sensitive demands (such as clothes drying) to a time when electricity is cheapest or has the most benefit to the reliability of the system. In some cases wireless signals interior to the structure will also be able to automatically adjust the heating and ventilation systems and to adjust heat or air conditioning units. This adaptation to price or reliability signals could reduce overall electricity costs for customers, improve the utilization of renewable and non-renewable power plants, and cut costs associated with adding intermittent wind and solar resources to the grid.

While such long-term value of smart meters will take years to fully realize, they are sufficiently promising that the federal government has required utilities to take steps to implement smart

[5] See http://www.silverspringnet.com/products/index.html for component descriptions. Network infrastructure includes the Silver Spring Access Points (APs) and Relays that forward data from endpoints across the utility's backhaul or WAN infrastructure into the back office.
The UtilityIQ application suite incorporates both utility applications such as Advanced Metering and Outage Detection as well as administrative programs for managing and upgrading the network. GridScape provides management for DA communications networks.
The CustomerIQ web portal enables utilities to directly communicate usage, pricing, and recommendations to consumers. Silver Spring works with each utility to customize the information portrayed and to import utility-specific information such as rate schedules.

grid networks, including the use of smart meters.[6] After review and authorization from the California Public Utilities Commission,[7] utilities in California have begun to install smart meters throughout the state. Some California utilities (such as Sacramento Municipal Utility District) have received significant federal funding for smart meter deployment from the American Recovery and Reinvestment Act (federal stimulus package). Many countries around the world are actively deploying smart meters as well. Digital smart meters are generally considered to be the fundamental technology required to enable widespread integration of information technology (IT) into the power grid (i.e., the smart grid). The following table (table 1) summarizes some potential societal benefits expected to result from the smart grid.

Table 1: Smart Grid Benefits

Consumers 1. Cost Savings Resulting from Energy Efficiency 2. Increased Consumer Choice and Convenience 3. More Transparent, Real-Time Information and Control for Consumers	**Environment** 1. Widespread Deployment of Renewable Energy (Solar, Wind, Biofuels) and Electric Vehicles (EVs) 2. Reduced Need to Build More Fossil Fueled Power plants 3. Reduced Carbon Footprint and Other Pollutants (via Renewables, Energy Efficiency, Electric Vehicles)
Utilities 1. Reduced Cost Due to Increased Efficiencies in Delivering Electricity and Reduction in Manpower to Read Meters. 2. Improved Reliability and More Timely Outage Response 3. Increased Customer Satisfaction Due to Cost Savings and Self-Control *Source: California Smart Grid Center*	**Economy** 1. Creates New Market for Goods and Services (i.e., New Companies, New Jobs) 2. Up-skilling Workforce to be Prepared for New Jobs 3. Reduced Dependence on Foreign Oil, Keeps Dollars at Home

[6] The federal Energy Independence and Security Act of 2007 directs states to encourage utilities to initiate smart grid programs, allows recovery of smart grid investments through utility rates, and reimburses 20% of qualifying smart grid investments. The American Recovery and Reinvestment Act of 2009 provided $4.5 billion to develop smart grid infrastructure in the U.S. For more information, see: Congressional Research Service (2007) "Energy Independence and Security Act of 2007: A Summary of Major Provisions," CRS Report for Congress, Order Code RL34l294, December 21. (http://energy.senate.gov/public/_files/RL342941.pdf)

[7] California Public Utilities Commission decision on Application 07-12-009 (March 12, 2009). Decision on Pacific Gas and Electric Company's Proposed Upgrade to the Smartmeter Program.

What Health Concerns are Associated with Smart Meters?

Human health impacts from exposure to electromagnetic frequency (EMF) emissions vary depending on the frequency and power of the fields. Smart meters operate at low power and in the RF portion of the electromagnetic spectrum. At these levels, RF emissions from smart meters are unlikely to produce *thermal effects; however it is not scientifically confirmed whether or what the non-thermal effects* on living organisms, and potentially, human health might be. These same concerns over potential impacts should apply to all other electronic devices that operate with similar frequency and power levels, including cell phones, computers, cordless phones, televisions, and wireless routers. Any difference in health impacts from these devices is likely to be a result of differences in usage patterns among them.

Thermal Effects

Electromagnetic waves carry energy, and EMF absorbed by the body can increase the temperature of human tissue. The scientific consensus is that body temperatures must increase at least 1^{o}C to lead to potential biological impacts from the heat. The only scientifically verified effect that has been shown to occur in the power and frequency range that smart meters are designed to occupy is a disruption in animal feeding behavior at energy exposure levels of 4 W/kg and with an accompanying increase in body temperature of 1^{o}C or more.[8] The exposure levels from smart meters even at close range are far below this threshold. The FCC has set limits on power densities from electronic devices that are well below the level where demonstrated biological impacts occur, and the limits are tens or hundreds of times higher than likely exposure from smart meters.[9]

Non-thermal Effects

There are emerging questions in the medical and biological fields about potential harmful effects caused by non-thermal mechanisms of absorbed RF emissions. Complaints of health impacts from "electromagnetic stress" have been reported, with symptoms including fatigue, headache, and irritability. Some studies have suggested that RF absorption from mobile phones may disrupt communication between human cells, which may lead to other negatives impacts on human biology.[10,11] While concerns of brain cancer associated with mobile phone usage persist, there is currently no definitive evidence linking cell phone usage with increased

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[8] D'Andrea, J.A., Adair, E.R., and J.O. de Lorge (2003) Behavioral and cognitive effects of microwave exposure, *Bioelectromagnetics* Suppl 6, S39-62 (2003).

[9] Tell, R. (2008) "Supplemental Report on An Analysis of Radiofrequency Fields Associated with Operation of the PG&E Smart Meter Program Upgrade System," Prepared for Pacific Gas & Electric Company, Richard Tell Associates, Inc., October 27. (http://www.pge.com/includes/docs/pdfs/shared/edusafety/systemworks/rfsafety/rf_fields_supplemental_report_2008.pdf)

[10] Markova, E., Malmgren, L., and I.Y. Belyaev (2009) Microwaves from mobile phones inhibit 53PB1 focus formation in human stem cells stronger than in differentiated cells: Possible mechanistic link to cancer risk. Environmental Health Perspectives, doi:10.1289/ehp.0900781.

[11] Nittby, H., Grafstrom, G., Eberhardt, J.L., Malmgren, L., Brun, A., Persson B.R.R., and L.G. Salford (2008) Radiofrequency and Extremely Low-Frequency Electromagnetic Field Effects on the Blood-Brain Barrier Electromagnetic Biology and Medicine, 27: 103–126, 2008.

incidence of cancer.[12] But due to the recent nature of the technology, impacts of long-term exposure are not known. Ongoing scientific study is being conducted to understand non-thermal effects from long-term exposure to mobile phones and smart meters, etc., especially the cumulative impact from all RF emitting devices including that of a network of smart meters operating throughout a community.[13]

There currently is no conclusive scientific evidence pointing to a non-thermal cause-and-effect between human exposure to RF emissions and negative health impacts. For this reason, regulators and policy makers may be prudent to call for more research while continuing to base acceptable human RF exposure limits on currently proven scientific and engineering findings on known thermal effects, rather than on general concerns or speculation about possible unknown and as yet unproven non-thermal effects. Such questions will likely take considerable time to resolve. The data that are available strongly suggest that if there are non-thermal effects of RF absorption on human health, such effects are not so profound as to be easily discernable.

FCC Guidelines

In 1985, the FCC first established guidelines to limit human exposure and protect against thermal effects of absorbed RF emissions. The guidelines were based on those from the American National Standards Institute (ANSI) that were issued in 1982.[14] In 1996, the FCC modified its guidelines,[15] based on a rulemaking process that began in 1993 in response to a 1992 revision of the ANSI guidelines[16, 17] and findings by the National Council on Radiation Protection and Measurements (NCRP).[18] The 1996 guidelines are still in place today.

> In its rulemaking process to set SAR and MPE limits, the FCC relied on many federal health and safety agencies, including the U.S. Environmental Protection Agency and the Food and Drug Administration.

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[12] Ahlbom, A., Feychting, M., Green, A., Kheifets, L., Savitz, D. A., and A. J. Swerdlow (2009) Epidemiologic evidence on mobile phones and tumor risk: a review. *Epidemiology* 20, 639-52 (2009).
[13] National Research Council (2008) *Identification of Research Needs Relating to Potential Biological or Adverse Health Effects of Wireless Communication,* The National Academies Press, Washington, D.C. (http://www.nap.edu/catalog/12036.html)
[14] American National Standards Institute (1982) "American National Standard Radio Frequency Radiation Hazard Warning Symbol," ANSI C95.2-1982, Institute of Electrical and Electronics Engineers, Inc.
[15] FCC (1997) "Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields," OET Bulletin 65 (Edition 97-01), Federal Communications Commission, August. (http://www.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet65/oet65.pdf)
[16] American National Standards Institute (1992) "Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz," ANSI/IEEE C95.1-1992 (previously issued as IEEE C95.1-1991), Institute of Electrical and Electronics Engineers, Inc.
[17] American National Standards Institute (1992) "Recommended Practice for the Measurement of Potentially Hazardous Electromagnetic Fields – RF and Microwave," ANSI/IEEE C95.3-1992, Institute of Electrical and Electronics Engineers, Inc.
[18] NCRP (1986) "Biological Effects and Exposure Criteria for Radiofrequency Electromagnetic Fields," NCRP Report No. 86 (1986), National Council on Radiation Protection Measurements.

While the FCC guidelines appear to provide a large factor of safety against known thermal effects of exposure to radiofrequency, they do not necessarily protect against potential non-thermal effects, nor do they claim to.[19] Without additional understanding of these effects, there is inadequate basis to develop additional guidelines at this time.

The FCC guidelines measure exposure to RF emissions in two ways. Specific absorption rate (SAR) measures the rate of energy absorption and is measured in units of watts-per-kilogram of body weight (W/kg). It accounts for the thermal effects on human health associated with heating body tissue and is used as a limiting measurement for wireless devices, such as mobile phones, that are used in close proximity to human tissue.[20] The FCC limits, as well as the underlying ANSI and NCRP limits, are based on a SAR threshold of 4 W/kg. At the time of the FCC rulemaking, and still today, behavioral disruption in laboratory animals (including non-human primates) at this absorption rate is the only adverse health impact that has been clearly linked to RF at levels similar to those emitted by smart meters. This finding is supported in scientific literature[21, 22] and by the World Health Organization and many health agencies in Europe.[23, 24] The FCC limit of 1.6 W/kg provides a significant factor of safety against this threshold.

Limits on SAR provide the basis for another measurement of exposure, maximum permissible exposure (MPE). MPE limits average exposure over a given time period (usually 30 minutes for general exposure) from a device and is often used for exposure to stationary devices and where human exposure is likely to occur at a distance of more than 20 cm. It is measured in micro (10^{-6}) watts-per-square-centimeter ($\mu W/cm^2$), and accounts for the fact that the human body absorbs energy more efficiently at some radiofrequencies than others. The human body absorbs energy most efficiently in the range of 30-300 MHz, and the corresponding MPE limits for RF emissions in this range are consequently the most stringent. In the frequency bands where smart meters operate, including PG&E's, namely the 902-928 MHz band and 2.4 GHz range, the human body absorbs energy less efficiently, and the MPE limits are less restrictive.

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[19] The U.S. EPA confirmed this in a letter to The Electromagnetic Radiation Policy Institute, dated March 8, 2002. (http://www.emrpolicy.org/litigation/case_law/docs/noi_epa_response.pdf)

[20] FCC (2001) "Additional Information for Evaluating Compliance of Mobile and Portable Devices with FCC Limits for Human Exposure to Radiofrequency Emissions," Supplement C (Edition 01-01) to OET Bulletin 65 (Edition 97-01), Federal Communications Commission, June. (http://www.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet65/oet65c.pdf)

[21] D'Andrea, J.A., Adair, E.R., and J.O. de Lorge (2003) Behavioral and cognitive effects of microwave exposure, *Bioelectromagnetics* Suppl 6, S39-62 (2003).

[22] Sheppard, A.R, Swicord, M. L., and Q. Balzano (2008) Quantitative evaluations of mechanisms of radiofrequency interactions with biological molecules and processes, *Health Phys* 95, 365-96 (2008).

[23] The World Health Organization has reviewed international guidelines for limiting radiofrequency exposure and scientific studies related to human health impacts and concludes that exposure below guideline limits don't appear to have health consequences. (http://www.who.int/peh-emf/standards/en/)

[24] Committee on Man and Radiation (COMAR) (2009) "Technical Information Statement: Expert reviews on potential health effects of radiofrequency electromagnetic fields and comments on The Bioinitiative Report," Health Physics 97(4):348-356 (2009).

The FCC limits on MPE are summarized in Figure 5.[25, 26] At 902 MHz, appropriate for operation of the AMR transmitter of the smart meter; the FCC limit is 601 μW/cm^2. At higher frequencies, the human body absorbs even less energy, and the threshold for the 2.4 GHz transmitter for home area network communications is consequently higher, 1000 μW/cm^2.

PG&E commissioned a 2008 study by Richard Tell Associates, "Supplemental Report on An Analysis of Radiofrequency Fields Associated with Operation of the PG&E Smart Meter Program Upgrade System." In this study of PG&E's proposed smart meter network it is noted that the FCC limits on MPE include a factor of safety, and the perceived hazardous exposure level is 50 times higher than the FCC limits.[27] The study estimates that the highest exposure from smart meters, if an individual were standing directly in front of and next to the meter, would be 8.8 μW/cm^2 transmitting at 2 to 4% of the time. The study notes that this is almost 70 times less than the FCC limit and 3,500 times less than the demonstrated hazard level. In all likelihood, individuals will be much farther away from smart meters and likely behind them, (within a structure) where power density will be much lower. The highest exposure from the entire smart meter system would occur immediately adjacent to an access point. It is very unlikely that an individual would be immediately adjacent to an access point, as they are normally located 25 feet above the ground on a telephone or electrical pole or other structure. The peak power density from an access point is estimated to be 24.4 μW/cm^2, or about 25 times less than the FCC limit. From the ground, exposure to power density from access points is estimated to be 15,000 times less than the FCC limit in great part due to the distance from the device.

The PG&E commissioned report by Richard Tell Associates is based only on an AMR duty cycle of transmitting data once every four hours which results in this very low estimated peak power. However, we are not aware of the justification for using averaging over a four-hour period. We do know the FCC[28] allows averaging of exposure over a designated period (30 minutes). To truly be a smart grid the data will be transmitted at a much more frequent rate than this. In this report we look at the worst-case scenario, a meter that is stuck in the "on" position, constantly relaying, at a 100% duty cycle. Even in this 100% scenario the RF emissions would be measurably below the FCC limits for thermal effects.

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[25] FCC (1997) "Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields," OET Bulletin 65 (Edition 97-01), Federal Communications Commission, August. (http://www.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet65/oet65.pdf)

[26] FCC (1999) "Questions and Answers about Biological Effects and Potential Hazards of Radiofrequency Electromagnetic Fields," OET Bulletin 56 (Fourth Edition), Federal Communications Commission, August. (http://www.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet56/oet56e4.pdf)

[27] Tell, R. (2008) "Supplemental Report on An Analysis of Radiofrequency Fields Associated with Operation of the PG&E Smart Meter Program Upgrade System," Prepared for Pacific Gas & Electric Company, Richard Tell Associates, Inc., October 27. (http://www.pge.com/includes/docs/pdfs/shared/edusafety/systemworks/rfsafety/rf_fields_supplemental_report_2008.pdf)

[28] http://www.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet56/oet56e4.pdf

Power Density (and Exposure Level) Declines Rapidly with Distance

The power density from smart meters, or other devices that emit RF, falls off dramatically with distance. Figure 6 illustrates this affect for an example smart meter. While the estimated maximum exposure level at 1 foot from the meter with a duty cycle of 50% is 180 $\mu W/cm^2$ (far below the FCC guidelines), at a distance of about 10 feet, the power-density exposure approaches zero.

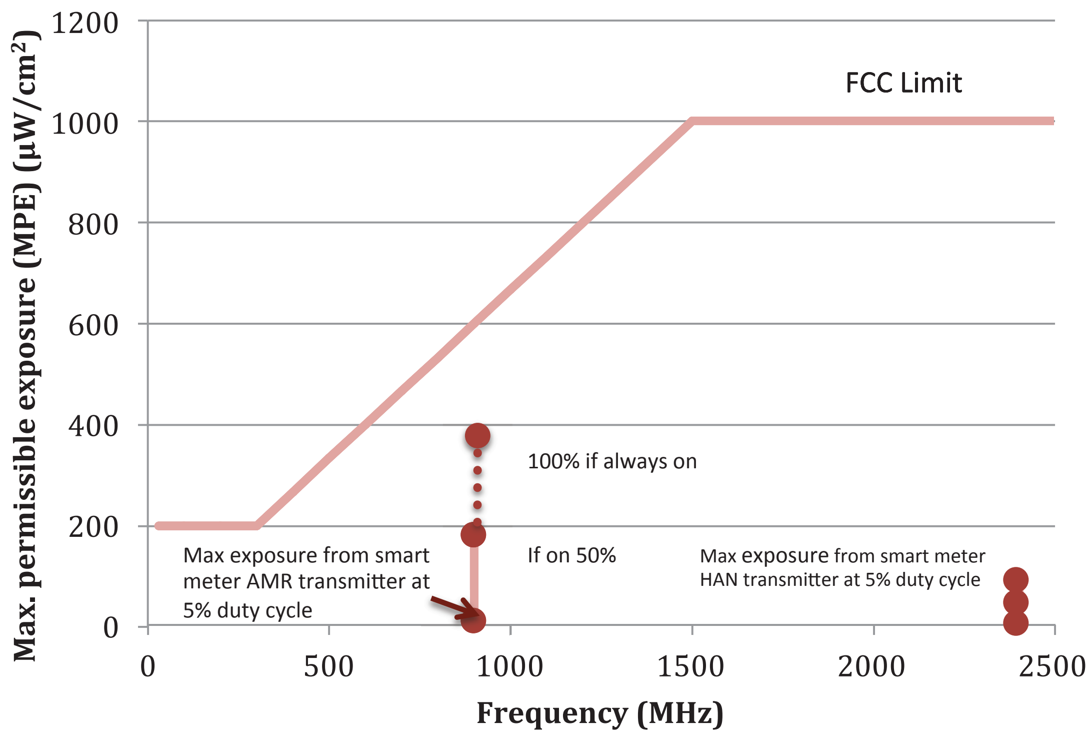

Figure 5. FCC maximum permissible exposure limits on power density rise with frequency because the human body can safely absorb more energy at higher frequencies. The estimated maximum exposure from a 1-Watt AMR transmitter at 5% duty cycle (i.e., 72 minutes/day) and one-foot distance is 18 $\mu W/cm^2$, or 3% of the FCC limit. Even if a meter malfunctioned and was stuck in the always-on transmit mode (i.e., 100% duty cycle), exposure levels would be 60% of the FCC limit for an AMR transmitter. For a 250mW HAN transmitter at a 5% duty cycle, the level would be .45% of the FCC limit and 9% of the FCC limit if the transmitter were on 100%. Exposure figures derived from February 2011 Electric Power Research Institute (EPRI) field measurement study entitled "Radio Frequency Exposure Levels from Smart Meters: A Case Study of One Model".[29]

[29] EPRI (2011) "Radio-Frequency Exposure Levels from Smart Meters: A Case Study of One Model," Electric Power Research Institute, February 2011.

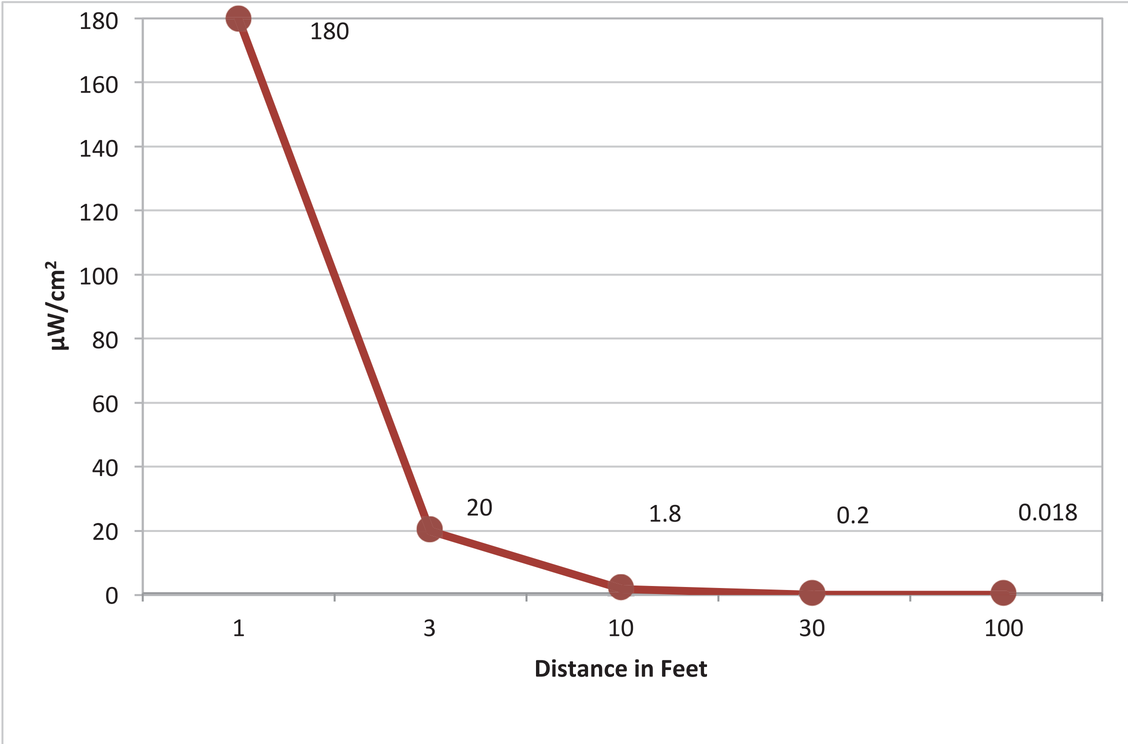

Figure 6. Power density from a sample smart meter versus distance;[30] 1-Watt emitter at 50% duty cycle. Typical smart meter AMR transmitter power density declines rapidly with distance. The rapid drop of power density with distance (inverse-square law) is similar for various duty cycles and different sets of source data.

Comparison of Electromagnetic Frequencies from Smart Meters and Other Devices

Health concerns surrounding RF from smart meters are similar to those from many other devices that we use in our daily lives, including cordless and mobile telephones, microwave ovens, wireless routers, hair dryers, and wireless-enabled laptop computers.

In addition to slight differences in frequency and power levels, which affect human absorption of RF from these devices, the primary difference among them is how they are used. Cell phones, for example, are often used for many minutes at a time, several times over the course of a day, and held directly next to one's head.

For perspective, microwave ovens operate at a similar frequency as the HAN transmitter of smart meters (2.45 GHz), and the U.S. Food and Drug Administration has set limits on leakage levels that are five times higher (5,000 μW /cm^2) than the FCC limit for smart meters and other

[30] EPRI (20110) "Radio- Frequency Exposure Levels from Smart Meters; A Case Study of One Model, "" Electric Power Research Institute, February 2011.

devices operating at 2.4 GHz.[31] Wireless routers and Wi-Fi equipment produce radiofrequency fields of about 0.2 – 1.0 µW /cm^2.[32, 33, 34] People in metropolitan areas are exposed to radiofrequency from radio and television antennas, as well, although for most of the population, exposure is quite low, around 0.005 µW /cm^2.[35]

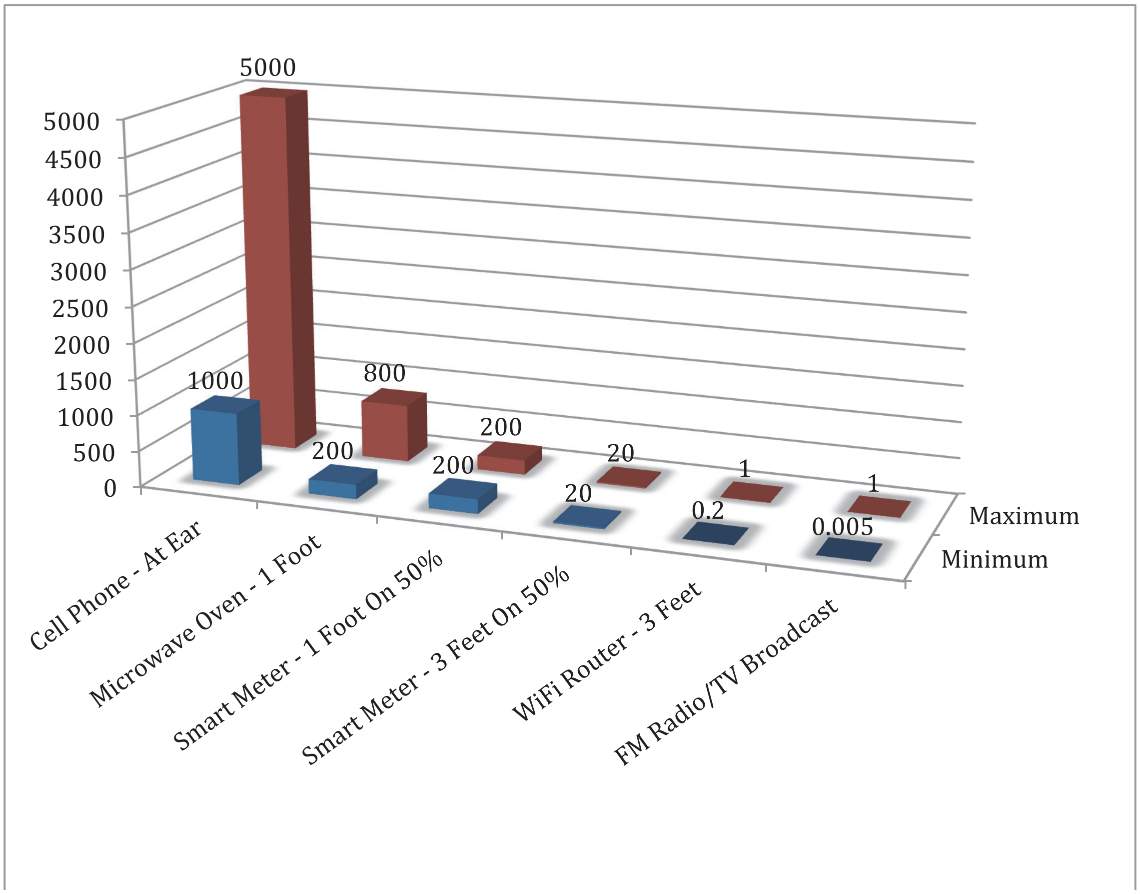

Figure 7. Instantaneous Radio Frequency Power Density Levels of Common Devices (in microWatts/cm^2)
About this figure**:** This figure was developed by the CCST project team**.** Quantities for different distances calculated using Inverse Square Law. Assumes distances in far-field, where power density reduces as the square of the distance from the source. Smart meter power scaled to obtain output for 50% duty cycle. The source for the various starting measurements came from Electric Power Research Institute (EPRI), Radio-Frequency Exposure Levels from Smart Meters: A Case Study of One Model (February 2011)

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[31] FDA, "Summary of the Electronic Product Radiation Control Provisions of the Federal Food, Drug, and Cosmetic Act," U.S. Food and Drug Administration. (http://www.fda.gov/Radiation-EmittingProducts/ElectronicProductRadiationControlProgram/LawsandRegulations/ucm118156.htm)

[32] EPRI (2011) "Radio-Frequency Exposure Levels from Smart Meters; A Case Study of One Model, "Electric Power Research Institute, February 2011.

[33] Foster, K.R. (2007) Radiofrequency exposure from wireless LANS utilizing WI-FFI technology. *Health Physics*, Vol. 92, No. 3, March, pp. 280-282.

[34] Schmidt, G. et al. (2007) Exposure of the general public due to wireless LAN applications in public Places, *Radiation Protection Dosimetry*, Vol. 123, No. 1, Epub June 11, pp. 48-52.

[35] EPA (1986) The Radiofrequency Radiation Environment: Environmental Exposure Levels and RF Radiation Emitting Sources, EPA 520/1-85-014, U.S. Environmental Protection Agency, July.

Table 2: Radio-Frequency Levels from Various Sources

Source	Frequency	Exposure Level (mW/cm^2)	Distance	Time	Spatial Characteristic
Mobile phone	900 MHz, 1800 MHz	1—5	At ear	During call	Highly localized
Mobile phone base station	900 MHz, 1800 MHz	0.000005—0.002	10s to a few thousand feet	Constant	Relatively uniform
Microwave oven	2450 MHz	~50.05-0.2	2 inches2 feet	During use	Localized, non-uniform
Local area networks	2.4—5 GHz	0.0002—0.001 0.000005—0.0002	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	900 MHz, 2400 MHz	0.0001 (250 mW, 1% duty cycle) 0.002 (1 W, 5% duty cycle)	3 feet	When in proximity during transmission	Localized, non-uniform
		0.000009 (250 mW, 1% duty cycle) 0.0002 (1 W, 5% duty cycle)	10 feet		

Source: Electric Power Research Institute (EPRI), Radio-Frequency Exposure Levels from Smart Meters: A Case Study of One Model (February 2011)

What is Duty Cycle and How Does it Relate to RF Exposure?

Duty cycle refers to the fraction of time a device is transmitting. For instance, a duty cycle of 1% means the device transmits RF energy 1% of a given time period. One percent of the time in a day is equivalent to 14.4 minutes per day. *The duty cycle, or signal duration is an often-overlooked factor when comparing exposures from different kinds of devices (e.g., mobile phones, Wi-Fi routers, smart meters, microwave ovens, FM radio/TV broadcast signals).*

Duty cycles of various devices vary considerably. The duty cycle of AM/FM radio/TV broadcasts, are 100%; in other words, they are transmitting continuously. Mobile phones usage varies widely from user to user, of course. However, the national average use is about 450 minutes per month. This usage equates to a 1% duty cycle for the "average" user.

From information that CCST was able to obtain we understand that the smart meter transmitter being used by PG&E operates with a maximum power output of 1 W (watt) and within the 902-928 MHz (mega-hertz) frequency band. Each smart meter is part of a broader "mesh" network and may act as a relay between other smart meters and utility access points. The transmitter at each smart meter will be idle some of the time, with the percent of time idle (not transmitting) depending on the amount and schedule of data transmissions made from each meter, the relaying of data from other meters that an individual meter does, and the networking protocol (algorithm) that manages control and use of the communications paths in the mesh network.

Theoretically the transmit time could increase substantially beyond today's actual operation level if new applications and functionality are added to the meter's communication module in the future. For a hypothetical illustration (i.e., the meter transmits half the time and receives half the time), an upper end duty cycle would be 50%,. The table below compares the effect of different duty cycles against the FCC guidelines for human exposure limits.

Typical Smart Meter Operation With Repeater Activity	**Scaled Hypothetical Maximum Use Case (i.e., always on)**
5% Duty Cycle	50% Duty Cycle
72 minutes/day	12 hours/day
3% of FCC limit	30% of FCC limit

Source data on operating duty cycles (i.e., first column) from Electric Power Research Institute (EPRI) actual field testing of smart meters, as reported in *Radio-Frequency Exposure Levels from Smart Meters: A Case Study of One Model*, February 2011. Second column hypothetical maximum case derived through extrapolation of first column data. Both exposure levels at 1-foot distance.

In summary, the duty cycles of smart meters in typical meter-read operation and added maximum-case repeater operation result in exposures that are 3% of the FCC exposure guidelines. Even in a hypothetical extreme and unusual case of half-transmit and half-receive scenario the maximum exposure would be about 30% of the FCC limit, which provides a wide safety margin from known thermal effects of RF emissions.

What About Exposure Levels from a Bank of Meters and from Just Behind the Wall of a Single Meter?

In a February 2011 study Electric Power Research Institute (EPRI)[36] field tested exposure levels from a bank of 10 meters of 250 mW power level at one foot distance in order to simulate a bank of smart meters located at a multifamily building, such as an apartment house. The exposure level was equivalent to 8% of the FCC standard.

In the same study EPRI measured exposure of one meter from eight inches *behind* the meter panel box in order to simulate proximity on the opposite site of the meter wall. At 5% duty cycle it yielded an exposure of only 0.03% of the FCC standard. Even at 100% duty cycle (i.e., always transmitting), exposure at eight inches behind the meter was 0.6% of the FCC limit.

Is the FCC Standard Sufficient to Protect Public Health?

The FCC guidelines do provide a significant factor of safety against thermal impacts the only currently understood human health impact that occurs at the power level and within the frequency band that smart meters use. In addition to the factor of safety built into the guidelines, at worst, human exposure to RF from smart meter infrastructure operating at even 50% duty cycle will be significantly lower than the guidelines. While additional study is needed to understand potential non-thermal effects of exposure to RF and effects of cumulative and prolonged exposure to several devices emitting RF, given current scientific knowledge the FCC guideline provides an adequate margin of safety against known RF effects.

Are Additional Technology-specific Standards Needed?

FCC guidelines protect against thermal effects of RF exposure. Many non-thermal effects have been suggested, and additional research is needed to better understand and scientifically validate them.

Given the scientific uncertainty around non-thermal effects of all RF emitting equipment, at this time there is no clear indication of what, if any, additional standards might be needed. Neither is there a basis from which to understand what types of standards could be helpful or appropriate**.** Without a clear understanding of the biological mechanisms at play, the costs and benefits of additional standards for RF emitting devices including smart meters, cannot be determined at this time.

[36] EPRI (2010) "A perspective on radio-frequency exposure associated with residential automatic meter reading technology," Electric Power Research Institute, February, 2011.

Public Information and Education

It is important that consumers have clear and easily understood information about smart meter emissions as well as readily available access to clear, factual information and education on known effects of RF emissions at various field strengths and distances from an array of devices commonly found in our world.

Equipped with this information, people can make knowledgeable judgments about how to prudently minimize possible risks to themselves and their families by utilizing standards-compliant devices at known safe distances. Also, people will be better able to gauge relative field strengths of various RF sources in our everyday environment (e.g., mobile phones, electric blankets, clock radios, TV and radio, computers, smart meters, power lines, microwave ovens, etc.). An ongoing regularly updated source of unbiased information on the state of scientific research, both proven and as-yet-unproven causal effects being studied, if presented by an independent entity, would provide consumers a credible and transparent source from which to obtain facts about RF in our environment.

CCST is not currently aware of a single website with up-to-date consumer information which we are able to endorse as impartial.

Alternatives to Wireless?

Assembly Member Huffman has inquired about potential alternatives to wireless communication with smart meters. There are currently several other methods of transmitting data from some smart meters to the utility company. These methods include transmitting over a power line or wired through phone lines, fiber-optic or coaxial cable. Each method has tradeoffs among cost and performance (e.g., how much data can be carried, how far, how fast). The ability to have a transmission protocol alternative to wireless depends upon the type and configuration of the meter used. Some existing smart meters can be hard-wired, while others would have to be modified or replaced. The communications board plugs into a digital meter. The current PG&E meters use a SilverSpring communications board that only supports wireless protocol. SilverSpring or another vendor could provide an alternative communications means if such were warranted and cost effective. The related costs of an alternative approach would need to be factored into the decision making process related to different options.

If future research were to establish a causal relationship between RF emissions and negative human health impacts, industries and governments worldwide may be faced with difficult choices about practical alternatives to avoid and mitigate such effects. This would greatly affect the widespread use of mobile phones, cordless phones, Wi-Fi devices, smart meters, walkie-talkies, microwave ovens, and many other everyday appliances and devices emitting RF. If such a hypothetical scenario were to occur, smart meters could conceivably be adapted to non-wireless transmission of data. However, retrofitting millions of smart meters with hard-wired technology could be difficult and costly. Perhaps more importantly, retrofitting smart meters would not address the significantly greater challenge presented by the billions of mobile phones in use globally.

Key Factors to Consider When Evaluating Exposure to Radiofrequency from Smart Meters

1. Signal Frequency	Compare to devices in the 900 MHz band and 2.4 GHz band	Frequency similar to mobile phones, Wi-Fi, laptop computers, walkie-talkies, baby monitors, microwave ovens
2. Signal Strength (or Power Density)	Microwatts/square centimeter ($\mu W/cm^2$)	Meter signal strength very small compared to other devices listed above
3. Distance from Signal	Signal strength drops rapidly (doubling distance cuts power density by four)	Example: 1 ft. – 8.8 $\mu W/cm^2$ 3 ft. – 1.0 $\mu W/cm^2$ 10 ft. – 0.1 $\mu W/cm^2$
4. Signal Duration	- Extremely short amount of time (2.0-5.0%, max.) - No RF signal 95-98% of the time (over 23 hours/day)	- Often overlooked factor when comparing devices. - Short duration combined with weak signal strength yields tiny exposures
5. Thermal Effects	- Scientific consensus on proven effects from heat at high RF levels	- FCC "margin-of-safety" limits 50 times lower than hazardous exposure level - Typical meter operates at 70 times less than FCC limit and 3,500 times less than the demonstrated hazard level
6. Non-thermal Effects	- Inconclusive research to date - No established cause-and-effect pointing to negative health impacts	Continuing research needed

Conclusion

The CCST Project Team, after carefully reviewing the available literature on the current state of science on health impacts of radiofrequency from smart meters and input from a wide array of subject matter experts, concludes that:

1. **The FCC standard provides a currently accepted factor of safety against known thermally induced health impacts of smart meters and other electronic devices in the same range of RF emissions. Exposure levels from smart meters are well below the thresholds for such effects.**

2. **There is no evidence that additional standards are needed to protect the public from smart meters.**

The topic of potential health impacts from RF exposure in general, including the small RF exposure levels of smart meters, continues to be of concern. This report has been developed to provide readers and consumers with factual, relevant information about the:

- Scientific basis underpinning current RF limits
- Need for further research into RF effects
- Relative nature of RF emissions from a wide array of devices commonly used throughout world (e.g., cellular and cordless phones, Wi-Fi devices, laptop computers, baby monitors, microwave ovens).

CCST encourages the ongoing development of unbiased sources of readily available and clear facts for public information and education. A web-based repository of written reports, frequently asked questions and answers, graphics, and video demonstrations would provide consumers with factual, relevant information with which to better understand RF effects in our environment.

Appendix A – Letters Requesting CCST

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SAN RAFAEL, CA 94903
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FAX (415) 479-2123

Assembly
California Legislature

JARED HUFFMAN
ASSEMBLYMEMBER, SIXTH DISTRICT

COMMITTEES
CHAIR, WATER, PARKS AND WILDLIFE
NATURAL RESOURCES
UTILITIES AND COMMERCE

SUBCOMMITTEE NO.3
ON RESOURCES

July 30, 2010

Karl Pister, Chair
Susan Hackwood, Executive Director
California Council on Science and Technology
1130 K Street, Suite 280
Sacramento, CA 95814-3965

Dear Chair Pister and Ms. Hackwood:

I am writing to request a study by the California Council on Science and Technology in response to the many concerns and questions that have been raised by constituents in my Assembly District including the Marin County Board of Supervisors, City of Sebastopol, City of Fairfax, and Marin Association of Realtors relating to potential negative health effects from SmartMeters, the electronic monitoring devices that Pacific Gas and Electric Company (PG&E) is installing statewide to continuously measure the electricity output from each household and business.

SmartMeters are currently being installed throughout the state under the authority of the California Public Utilities Commission (CPUC) pursuant to a series of decisions that span from 2006 through 2009. The authority for PG&E to deploy SmartMeters in its territory is embodied in two decisions: D.06-07-027 (the initial deployment) and D.09-03-026 (the upgrade). On the question of health effects of radiation from the devises, PG&E and CPUC maintain that electromagnetic fields emitted from these SmartMeters and the radio frequency power associated with the wireless radios fall within the Federal Communications Commission's (FCC) regulations, pointing out that SmartMeters emit fewer radio frequencies than the amount allowable for cellular telephones, microwave ovens, and wireless Internet Services.

Critics claim, among other things, that FCC standards are not sufficiently protective of public health and do not take into account the cumulative effect of radiation exposure from a growing number of sources and devices, including continuous exposure from some sources. For example, they cite a letter from the Radiation Protection Division of the Environmental Protection Agency (attached), they argue, ..."these standards were thermally based and do not apply to chronic, nonthermal exposure situations, ... and that ... the current exposure guidelines are based on the effects resulting from whole-body heating, not exposure of and effect on critical organs including the brain and the eyes." Therefore, they argue the "safety" standards were not designed to protect the public from health problems under the circumstances which the meters are being used.

An independent, science-based study by the California Council on Science and Technology would help policy makers and the general public resolve the debate over whether SmartMeters present a significant risk of adverse health effects. Toward that end, I request that the Council specifically determine whether FCC standards for SmartMeters are sufficiently protective of public health taking into account current exposure levels to radiofrequency and electromagnetic fields, and further to assess whether additional technology specific standards are needed for SmartMeters and other devises that are commonly found in and around homes, to ensure adequate protection from adverse health effects.

Thank you for your serious consideration of this important and time-sensitive request. Please do not hesitate to contact me if I can be of assistance going forward

Sincerely,

JARED HUFFMAN
Assemblymember, 6th District

COMMITTEES
CHAIR, HEALTH
ARTS, ENTERTAINMENT, SPORTS, TOURISM & INTERNET MEDIA
ENVIRONMENTAL SAFETY & TOXIC MATERIALS
JOINT LEGISLATIVE AUDIT COMMITTEE
JUDICIARY
LABOR AND EMPLOYMENT
WEBSITE: www.assembly.ca.gov/monning

Assembly
California Legislature

WILLIAM W. MONNING
ASSEMBLYMEMBER, TWENTY-SEVENTH DISTRICT

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MONTEREY, CA 93940
(831) 649-2832
(831) 649-2935

SANTA CLARA COUNTY DIRECT LINE
(408) 782-0647

September 15, 2010

Karl Pister, Chair
California Council on Science and Technology
1130 K Street, Suite 280
Sacramento, CA 95814-3965

Dear Chair Pister:

This letter is to formally request that I be included in the response from the California Council on Science and Technology (CCST) regarding the health safety evaluation of the new electronic metering devices, otherwise known as Smart Meters, currently being installed by Pacific Gas and Electric Company (PG&E) which will be available by October 15, 2010.

Numerous concerns and questions have been raised by PG&E customers throughout the state, as well as local government entities such as the County of Santa Cruz, the City of Capitola, City of Santa Cruz, City of Scotts Valley, and the City of Watsonville, relating to potential health effects of the radio frequency (RF) emitted from Smart Meters.

As you know, the federal Energy Independence and Security Act of 2007 required each state to initiate a smart grid system. In response to this federal mandate, the State of California enacted Senate Bill 17, Chapter 327, Statutes of 2009, granting the California Public Utilities Commission (CPUC) smart grid oversight authority. While the CPUC has authorized PG&E to install their current Smart Meter system, CPUC has not addressed the question of whether the RF emissions from Smart Meter devices have potential health impacts.

While PG&E maintains that Smart Meters comply with the Federal Communications Commission (FCC) safety standards, there is still public concern that the FCC standards do not sufficiently protect the public's health and do not take into account the cumulative effect of radiation exposure from the growing number of sources and devices emitting RF.

The scientific evaluation by the California Council on Science and Technology will help to inform both elected officials and the public about the safety of PG&E's Smart Meters and I appreciate the Council taking the time to assess this very important issue.

Thank you for your time and assistance on this issue.

Sincerely,

WILLIAM W. MONNING
Assemblymember, 27th District

WWM:rog

September 20, 2010

Karl Pister, Chair
Susan Hackwood, Executive Director
California Council on Science and Technology
1130 K Street, Suite 280
Sacramento, CA 95814-3965

Dear Chair Pistel and Ms. Hackwood:

On behalf of the Mill Valley City Council, I am writing to support Assemblymember Jared Huffman's request for a study by the California Council on Science and Technology (CCST) to specifically determine whether Federal Communications Commission (FCC) standards for Pacific Gas and Electric (PG&E) SmartMeters are sufficiently protective of public health.

This request is in response to the many concerns and questions that have been raised by Mill Valley residents relating to potential negative health effects from SmartMeters. Mill Valley residents have expressed their concerns that these devices, which are regulated by the California Public Utilities Commission (CPUC), emit levels of radiation that may be harmful to public health, especially with consideration to the long-term and cumulative impacts of the devices. The CPUC maintains that SmartMeters emit radiation well below the FCC-established safety standards, and have therefore not ordered PG&E to halt the installation of the advanced metering devices.

Critics argue that the safety standards determined by the FCC are not sufficient and specifically not designed to protect the public from health problems under the circumstances which the meters will be used. The FCC standards, they claim, do not take into consideration long-term and cumulative exposures to these devices.

The City of Mill Valley City Council therefore join Assemblymember Huffman in requesting the CCST undertake a study to specifically determine whether FCC standards for SmartMeters are sufficiently protective of public health, taking into account current exposure levels to radiofrequency and electromagnetic fields, and further to assess whether additional technology specific standards are needed for SmartMeters and other devices that are commonly found in and around homes, to ensure adequate protection from adverse health effects.

Thank you for your consideration.

Sincerely,

Stephanie Moulton Peters

Stephanie Moulton-Peters, Mayor
City of Mill Valley

Cc: Mill Valley City Council
Assemblymember Jared Huffman
Joshua Townsend, PG&E Public Affairs Manager
Marzia Zafar, CPUC Business and Community Outreach Division Manager

Appendix B – Project Process

CCST Smart Meter Project Approach
Assembly Member Huffman (Marin) (July 30, 2010 letter) and Assembly Member Monning (Santa Cruz) (September 17, 2010 letter) requested CCST's assistance in determining if there are health safety issues regarding the new SMART meters being installed by the utilities. In addition, the City of Mill Valley sent a letter to CCST (September, 2010) in support of Mr. Huffman's request. (Appendix A - letters)

The CCST Executive Committee appointed a Smart Meter Project Team that oversaw the development of a response on the issue (Appendix C):

- Rollin Richmond (Chair), President Humboldt State University, CSU
- Jane Long, Associate Director at Large, Global Security Directorate Fellow, Center for Global Security Research Lawrence Livermore National Laboratory
- Emir Macari, Dean of Engineering and Computer Science, California State University, Sacramento and Director of the California Smart Grid Center
- Patrick Mantey, Director, CITRIS @ Santa Cruz
- Ryan McCarthy, 2009 CCST Science and Technology Policy Fellow
- Larry Papay, CEO, PQR, LLC, mgmt consulting firm
- David Winickoff, Assistant Professor of Bioethics and Society, Department of Environmental Science, Policy and Management, UC Berkeley
- Paul Wright, Director, UC Center for Information Technology Research in the Interest of Society (CITRIS)

In addition to those on the project team, CCST approached over two dozen technical experts to contribute their opinion to inform CCST's response. The experts were referred from a variety of sources and were vetted by the Smart Meter Project Team. Efforts were made to include both biological and physical scientists and engineers to help provide broad context and perspective to the response. Many of the experts approached indicated they did not time to provide a written response however they provided references to additional experts and/or literature for review. A few experts identified were not asked to contribute due to affiliations that were felt to be a conflict of interest. Experts were asked to provide written comment on two issues, to provide referral to other experts, and to suggest literature that should be reviewed. Appendix D provides a list of those experts who provided written comment.

Smart Meter Project Team members and the experts providing written technical input completed a conflict of interest disclosure form to reveal any activities that could create the potential perception of a conflict.

In addition to written and oral input from technical experts, CCST identified relevant reports and other sources of information to inform the final report. This material can be found listed in Appendix E and on a CCST website: http://ccst.us/projects/smart/.

Peer Review: After the draft report was vetted in great detail by the Smart Meter Project Team, it was forwarded to the CCST Board and Council for peer review.

Public Comment: Comments on the January 2011 draft of this report were solicited from the public. The report was posted to the CCST website to allow the general public to easily comment. Many very thoughtful and informed comments were received. All public comments were reviewed and taken into consideration as this final report was completed.

Appendix C – Project Team

The California Council on Science and Technology adheres to the highest standards to provide independent, objective, and respected work. Board and Council Members review all work that bears CCST's name. In addition, CCST seeks peer review from external technical experts. The request for rigorous peer review results in a protocol that ensures the specific issue being addressed is done so in a targeted way with results that are clear and sound.

In all, this report reflects the input and expertise of nearly 30 people in addition to the project team. Reviewers include experts from academia, industry, national laboratories, and non-profit organizations.

We wish to extend our sincere appreciation to the project team members who have helped produce this report. Their expertise and diligence has been invaluable, both in rigorously honing the accuracy and focus of the work and in ensuring that the perspectives of their respective areas of expertise and institutions were taken into account. Without the insightful feedback that these experts generously provided, this report could not have been completed.

Rollin Richmond, Smart Meter Project Chair, CCST Board Member
President Humboldt State University, CSU

Prior to Richmond's appointment at Humboldt State University in 2002, he had a distinguished career as a faculty member, researcher in evolutionary biology and academic administrator. Richmond received a Ph.D. in genetics from the Rockefeller University and a bachelor's degree in zoology from San Diego State University. Dr. Richmond's career has included: Chairperson of biology at Indiana University, founding Dean of the College of Arts and Sciences at the University of South Florida, Provost at the State University of New York at Stony Brook, and Provost and Professor of Zoology and Genetics at Iowa State University. He was named the sixth President of Humboldt State University in July of 2002. Dr. Richmond is a fellow of the American Association for the Advancement of Science and a member of Phi Beta Kappa. His research interests are in evolutionary genetics.

Jane Long, CCST's California's Energy Future Project Co-Chair and CCST Sr. Fellow
Associate Director at Large, Global Security Directorate Fellow, Center for Global Security Research Lawrence Livermore National Laboratory

Dr. Long is the Principal Associate Director at Large for Lawrence Livermore National Laboratory working on energy and climate. She is also a Fellow in the LLNL Center for Global Strategic Research. Her current interests are in reinvention of the energy system in light of climate change, national security issues, economic stress, and ecological breakdown. She holds a bachelor's degree in engineering from Brown University and Masters and Ph.D. from UC Berkeley.

Patrick Mantey
Director, UC Center for Information Technology Research in the Interest of Society (CITRIS) @ Santa Cruz, University of California, Santa Cruz

Mantey holds the Jack Baskin Chair in Computer Engineering and was the founding Dean of the Jack Baskin School of Engineering. He is now the director of CITRIS at UC Santa Cruz and of ITI, the Information Technologies Institute in the Baskin School of Engineering. In 1984, he joined the UCSC faculty to start the engineering programs, coming from IBM where he was a senior manager at IBM Almaden Research. His research interests include system architecture, design, and performance, simulation and modeling of complex systems, computer networks and multimedia, real-time data acquisition, and control systems. Mantey is a Fellow of the Institute of Electrical and Electronics Engineers. His current projects at CITRIS include the Residential Load Monitoring Project and work on power distribution system monitoring and reliability. Mantey received his B.S. (magna cum laude) from the University of Notre Dame, his M.S. from the University of Wisconsin-Madison, and his Ph.D. from Stanford University, all in electrical engineering. He is a Fellow of the Institute of Electrical and Electronics Engineers (IEEE).

Emir José Macari
Dean of Engineering and Computer Science, California State University, Sacramento and Director of the California Smart Grid Center

Prior to his appointment as dean at CSU Sacramento, Macari was dean of the College of Science, Mathematics and Technology at the University of Texas at Brownsville. Prior to that, he served as the program director for the Centers of Research Excellence in Science and Technology at the National Science Foundation. From 1999-2001 he served as the Chair and Bingham C. Stewart Distinguished Professor in the Department of Civil and Environmental Engineering at Louisiana State University. At the Georgia Institute of Technology he taught both engineering and public policy and at the University of Puerto Rico he was a professor and director of Civil Infrastructure Research Center. He has also worked as a civil engineer in private industry and has been a fellow at NASA. Macari holds both a doctorate and a master's degree in civil engineering geomechanics from the University of Colorado. He has a bachelor's degree in civil engineering geomechanics from Virginia Tech University.

Larry Papay CCST Board Member
CEO, PQR, LLC, mgmt consulting firm

Papay is currently CEO and Principal of PQR, LLC, a management consulting firm specializing in managerial, financial, and technical strategies for a variety of clients in electric power and other energy areas. His previous positions include Sector Vice President for the Integrated Solutions Sector, SAIC; Senior Vice President and General Manager of Bechtel Technology & Consulting; and Senior

Vice President at Southern California Edison. Papay received a B.S. in Physics from Fordham University, a M.S. in Nuclear Engineering from MIT, and a Sc.D. in Nuclear Engineering from MIT. He is a member of the National Academy of Engineering and served on its Board of Councilors from 2004-2010. He served as CCST Council Chair from 2005 through 2008, after which he was appointed to the Board.

David E Winickoff
Associate Professor of Bioethics and Society, Department of Environmental Science, Policy and Management, UC Berkeley

David Winickoff (JD, MA) is Associate Professor of Bioethics and Society at UC Berkeley, where he co-directs the UC Berkeley Science, Technology and Society Center. Trained at Yale, Harvard Law School, and Cambridge University, he has published over 30 articles in leading bioethics, biomedical, legal and science studies journals such as The New England Journal of Medicine, the Yale Journal of International Law, and Science, Technology & Human Values. His academic and policy work spans topics of biotechnology, intellectual property, geo-engineering, risk-based regulation, and human subjects research.

Paul Wright
Director, UC Center for Information Technology Research in the Interest of Society (CITRIS)

As Director of CITRIS Wright oversees projects on large societal problems such as energy and the environment; IT for healthcare; and intelligent infrastructures such as: public safety, water management and sustainability. Wright is a professor in the mechanical engineering department, and holds the A. Martin Berlin Chair. He is also a co-director of the Berkeley Manufacturing Institute (BMI) and co-director of the Berkeley Wireless Research Center (BWRC). Born in London, he obtained his degrees from the University of Birmingham, England and came to the United States in 1979 following appointments at the University of Auckland, New Zealand and Cambridge University England. He is also a member of the National Academy of Engineering.

Ryan McCarthy
Science and Technology Policy Fellow, California Council on Science and Technology

McCarthy recently completed the CCST Science and Technology Policy Fellowship in the office of California Assembly Member Wilmer Amina Carter, where he advised on issues associated with energy, utilities, and the environment, among others. McCarthy holds a master and doctorate degree in civil and environmental engineering from UC Davis, and a bachelor’s degree in structural engineering from UC San Diego. His expertise lies in transportation and energy systems analysis, specifically regarding the electricity grid in California and impacts of electric vehicles on energy use and emissions in the state.

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Biologists/medical
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Asher Sheppard, Ph.D., Asher Sheppard Consulting, trained in physics, environmental medicine, and neuroscience
Magda Havas, B.Sc., Ph.D., Environmental & Resource Studies, Trent University, Peterborough, Canada
Cindy Sage, MA, Department of Oncology, University Hospital, Orebro, Sweden and Co-Editor, BioInitiative Report

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Appendix F – Glossary

Access point - A term typically used to describe an electronic device that provides for wireless connectivity via a WAN to the Internet or a particular computer facility.

Duty cycle – A measure of the percentage or fraction of time that an RF device is in operation. A duty cycle of 100% corresponds to continuous operation (e.g., 24 hours/day). A duty cycle of 1% corresponds to a transmitter operating on average 1% of the time (e.g., 14.4 minutes/day).

Electromagnetic field (EMF) - A composition of both an electric field and a magnetic field that are related in a fixed way that can convey electromagnetic energy. Antennas produce electromagnetic fields when they are used to transmit signals.

Far-field - A distance which extends from about two wavelengths distance from the antenna to infinity, is the region in which the field acts as "normal" electromagnetic radiation. The power of this radiation decreases as the square of distance from the antenna. By contrast, the **near-field**, which is inside about one wavelength distance from the antenna, is a region in which there are effects from the currents and charges in the antenna, which do not behave like far-field radiation. These effects decrease in power far more quickly with distance, than does the far-field radiation power.

Federal Communications Commission (FCC) - The Federal Communications Commission (FCC) is an independent agency of the US Federal Government and is directly responsible to Congress. The FCC was established by the Communications Act of 1934 and is charged with regulating interstate and international communications by radio, television, wire, satellite, and cable. The FCC also allocates bands of frequencies for non-government communications services (the NTIA allocates government frequencies). The guidelines for human exposure to radio frequency electromagnetic fields as set by the FCC are contained in the Office of Engineering and Technology (OET) Bulletin 65, Edition 97-01 (August 1997). Additional information is contained in OET Bulletin 65 Supplement A (radio and television broadcast stations), Supplement B (amateur radio stations), and Supplement C (mobile and portable devices).

Gigahertz (GHz) - One billion Hertz, or one billion cycles per second, a measure of frequency.

Hertz - The unit for expressing frequency, one Hertz (Hz) equals one cycle per second.

Maximum permissible exposure (MPE) limit. An exposure limit or guideline for RF energy exposure published by a recognized consensus standards organization.

Megahertz (MHz) - One million Hertz, or one million cycles per second, a unit for expressing frequency.

Mesh network - A network providing a means for routing data, voice and instructions between nodes. A mesh network allows for continuous connections and reconfiguration around broken or blocked data paths by "hopping" from node to node until the destination is reached.

Milliwatt per square centimeter (mW/cm^2) - A measure of the power density flowing through an area of space, one thousandth (10^{-3}) of a watt passing through a square centimeter.

Microwatt per square centimeter (µW/cm^2) - A measure of the power density flowing through an area of space, one millionth (10^{-6}) of a watt passing through a square centimeter.

Radiofrequency (RF) - The RF spectrum is formally defined in terms of frequency as extending from 0 to 3000 GHz, the frequency range of interest is 3 kHz to 300 GHz.

Repeater unit - A device that can simultaneously receive a radio signal and retransmit the signal. Repeater units are used to extend the range of low power transmitters in a geographical area.

Router - An electronic computer device that is used to route and forward information, typically between various computers within a local area network or between different local area networks.

Smart meter - A digital device for measuring consumption, such as for electricity and natural gas, and sending the measurement to a utility company. Automated meter reading (AMR) meters send information one-way only. Automated meter infrastructure (AMI) meters are capable of two-way communications.

Specific absorption rate (SAR) - The incremental energy absorbed by a mass of a given density. SAR is expressed in units of watts per kilogram (or milliwatts per gram, mW/g).

Transmitter - An electronic device that produces RF energy that can be transmitted by an antenna. The transmitted energy is typically referred to a radio signal or RF field.

Wide area network (WAN) - A computer network that covers a broad area such as a whole community, town, or city. Commonly, WANs are implemented via a wireless connection using radio signals. High-speed Internet connections can be provided to customers by wireless WANs.

Wi-Fi - An name given to the wireless technology used in home networks, mobile phones, and other wireless electronic devices that employ the IEEE 802.11 technologies (a standard that defines specific characteristics of wireless local area networks).

Appendix G – CCST 2011 BOARD MEMBERS

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Appendix I – Report Credits

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