BEFORE THE STATE CORPORATION COMMISSION
OF THE STATE OF KANSAS

In the Matter of the Consolidated Complaints filed Against Kansas City Power & Light and Westar Energy Regarding the Required Use of Advanced Metering Infrastructure Digital Electric Meters.	)))))	Docket No. 15-WSEE-211-COM Docket No. 15-KCPE-265-COM Docket No. 15-KCPE-474-COM Docket No. 16-WSEE-066-COM

NOTICE OF FILING OF STAFF'S
REPORT AND RECOMMENDATION

COMES NOW, the Staff of the State Corporation Commission of the State of Kansas (Staff and Commission, respectively), and hereby files its Report and Recommendation in the above consolidated complaints regarding the required use of Advanced Metering Infrastructure Digital Electric Meters. Staff provides recommendations regarding the protection of utility customers' Personally Identifiable Information, as well as customer-selected electric meter reading programs. Staff recommends the Commission require jurisdictional utilities to modify their respective general terms and conditions tariffs to include an obligation to protect a customer's Personally Identifiable Information. Staff does not recommend the Commission require jurisdictional utilities to establish programs that allow customers to select the type of meter reading service used on a customer's account. However, Staff believes requiring such a program would be within the Commission's discretion and provides recommendations to aid in the implementation of such a program should the Commission so order.

WHEREFORE, Staff submits its Report and Recommendation for Commission review and consideration, and for such other relief as the Commission deems just and proper.

Respectfully Submitted,

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REPORT AND RECOMMENDATION
UTILITIES DIVISION

TO: Chair Shari Feist Albrecht
Commissioner Jay Scott Emler
Commissioner Pat Apple

FROM: Leo M. Haynos, Chief of Energy Operations and Pipeline Safety
Jeff McClanahan, Director of Utilities

DATE: December 23, 2015

SUBJECT: 15-WSEE-211-COM; 15-KCPE-265-COM; 15-KCPE-474-COM; and 16-WSEE-066-COM: In the Matter of the Consolidated Complaints filed Against Kansas City Power & Light and Westar Energy Regarding the Required Use of Advanced Metering Infrastructure Digital Electric Meters

EXECUTIVE SUMMARY:

Over the course of the last 12 months, the Commission has received a total of seven Complaints from residential customers of Westar Energy (Westar) and Kansas City Power & Light (KCPL), (or collectively referred to as "the Utilities") regarding the Utilities' mandated use of Advanced Metering Infrastructure Digital Meters ("AMI meters" or "Smart meters"). Three of the Complaints were dismissed because of procedural errors in filing.[1] The remaining four Complaints were consolidated into one Docket. In the Consolidated Complaint, the Complainants allege the following:

1. It is an unreasonable practice of the Utilities to require its customers to use AMI meters because the radio transmitters associated with the meters emit radio frequency (RF) and electromagnetic fields (EMF) which cause harmful health effects to the customers.
2. It is an unreasonable practice of the Utilities to require its customers to use AMI meters because the automated functions and wireless transmissions of the AMI meters risk the security of the Complainants' Personally Identifiable Information (PII).
3. Given the above concerns, the Utilities' respective tariffs impose an unreasonable requirement on the Complainants by not allowing them to select the type of meter through which they desire to receive electric service.

The Complainants proposed remedy recommends the Commission require the Utilities to allow its customers the option of either an AMI meter or a non-transmitting meter. The

[1] 15-KCPE-515-COM, 15-WSEE-543-COM, and 15-WSEE-598-COM were dismissed by the Commission with the provision the Complainant could file an amended Complaint within 30 days. In these cases, the Complainants did not make an amended filing. Although dismissed, the Complaint allegations may be viewed from the Commission's Docket filings.

Complainants also proposed the Commission allow little or no additional charges for customers that select the non-transmitting meter option.

In response, the Utilities argue the Complainants have not produced any evidence that RF radiation has or will harm their health. Likewise, the Utilities argue the Complainants offer no proof that customers' PII is at risk from wireless data transmissions. The Utilities note that customers must have meters in place to measure electric usage, and there is no provision in the Utilities' respective tariffs that prevent the Utilities from installing AMI meters. Further, the Utilities argue the Complainant's request for an opt-out provision would reduce the benefits of the AMI meter program and introduce additional costs for manual meter reading and data entry.

While Staff does not question the Complaints' concerns regarding the health impact of RF exposure, we note that scientific studies regarding this topic have not been able to establish a direct link between properly installed AMI meters and any ill effects on human health. Staff has also reviewed the security practices of the Utilities and concludes there is minimal risk to a Customer's PII from the use of AMI meters. While any wireless device is at risk of being "hacked", Staff believes the voluntary safeguards put in place by the Utilities to prevent unauthorized access to customer data are acceptable. Therefore, Staff agrees with the Utilities that the use of AMI meters are a reasonable application of technology in providing electric service and the Consolidated Complaint should be dismissed. In order to assure the Utilities' customers that PII are secure, Staff recommends the Commission order the Utilities to amend their tariffs to include a requirement to protect and monitor security measures controlling access to customer PII.

Although Staff believes the health and privacy concerns of the Complainants are unproven, we note the desire of utility customers to opt-out of the use of AMI meters is a popular topic that has been raised in various public utility commissions across the nation. And Staff believes it is within the Commission's prerogative to allow the customer to choose to receive utility service through a meter that does not provide wireless transmission of usage data. To date, Westar has placed 190,000 AMI meters in service in the Wichita area and has only had 70 customers refuse Westar access to install the meter. Acknowledging the possibility the number of customers would probably be higher if Westar allowed the type of meter installed to be optional, Staff still believes those customers electing to have meters without radio transmitters would be a very small minority of Westar's customer base.

Staff does not believe it is in the public interest to create a special metering program that caters to unproven concerns of a minority of ratepayers. However, if the Commission decides it is good public policy to offer utility customers the choice of selecting their meter type (as many public utility commissions have done), Staff recommends those customers choosing a meter that is not the standard offering of the Utility should pay the incremental costs associated with the Utility providing such service. This Report and Recommendation includes a brief summary of charges assigned by other utility commissions regarding this option.

BACKGROUND:

Description of AMI Metering Systems: Similar to a conventional analog meter, an AMI meter records the cumulative amount of electricity that is used by a customer. In both cases, the meter only records parameters related to the amount of electric energy flowing past the

meter and the time at which the electricity is used. Both meters have no ability to discern how a customer's purchased electricity is consumed by the customer's electric powered appliances. The difference between the two devices relates to how the recorded usage information is relayed to the utility. While the analog system requires a meter reader to manually read and record the usage data, the AMI meter uses a radio transmitter to deliver the usage data to the Utility. Because manually reading meters is manpower-intensive, meters conventionally have been read only once per month. Using a radio transmitter and data aggregation technology, an AMI meter transmits cumulative usage data upon request from the operator. In the case of the Utilities, the AMI system requests data transmission four times per day to the Utility with a total daily transmission time of less than 15 seconds.[2] The radios are capable of transmitting data on a more frequent basis, but four times per day appears to be the most cost effective data transmission frequency. Using radios to transmit usage data allows the Utility to perform the same data acquisition as the analog meters for a fraction of the cost while also providing the added benefits of near real-time monitoring of the electric distribution system's load profile. Other benefits gained from automation include alarms that will report any abnormal operating conditions regarding the individual meter operation, the meter's communication system, or other unusual conditions that may occur on the distribution system. A majority of the AMI meters operated by the Utilities[3] have the ability to also receive remote commands to disconnect service to the customer. All of Westar's AMI meters and a portion of the KCPL AMI meters are also equipped with a ZigBee communications card that, if activated, will allow customers to enable a home access network (HAN). The HAN would allow the consumer to remotely coordinate electric use as read from the meter with the operation of appliances. If activated, the radio transmitter associated with the HAN would operate at power rating of 0.223 watts and a radio frequency of 2.3 gigahertz similar to a wireless phone. It should be noted that while some of the AMI meters of the utilities are equipped with a ZigBee radio, neither Westar nor KCPL have activated this feature.

Description of AMI Meter Radio Transmitters: The radios used by AMI meters operate in a frequency bandwidth of approximately 900 megahertz (MHz).[4] As noted, the radio in each meter transmits data approximately four times per day for a total daily transmission time of 15 seconds. As a transmitting radio, its operations are subject to the oversight of the Federal Communications Commission (FCC) which establishes emissions limits for a given transmission frequency. For a frequency of 900 MHz, the FCC sets the Maximum Permissible Exposure (MPE) limits on power density at approximately 590 microwatts per square centimeter (uW/cm^2).[5] The MPE values set by the FCC are based on the point at which thermal effects from RF become harmful to humans, and the maximum values include a significant safety factor. Additionally, the MPE values assume the thermal radiation is applied on average of 30 minutes at a distance of eight inches.[6] The Maximum Power density from the Utilities' AMI meters is calculated to be 222 uW/cm^2. In the event the ZigBee radio contained in the meters is activated in the future, the maximum power density

[2] Response of KCPL to Staff Data Request 6.
[3] All of Westar's AMI meters that provide 200 amp service and a small portion of KCPL's AMI meters are capable of receiving remote commands to disconnect a customer's electric service.
[4] Response of KCPL to Staff Data Request 5.
[5] See Appendix 1, Page 16, April 2011, California Council on Science and Technology, Health Impacts of Radio Frequency Exposure from Smart Meters.
[6] ibid. Appendix 1, Page 14.

increases to 315 uW/cm^2 at a 100% duty cycle.[7] It must be noted the power density decreases exponentially with distance from the source. The distance a meter would typically be from a homeowner and the fact that the meter housing and building wall provide additional shielding would make the amount of theoretical RF from an AMI meter present inside a residential home to be an order of magnitude smaller than the meter's maximum power density at eight inches, even if it was continually operating.[8]

Description of Data Transmission Network: As depicted in Attachment 1, the AMI meters form a mesh network which allows the meters to communicate with each other or with a router. The router aggregates data from up to 3,000 devices. The router then connects through a radio link to a data collector that aggregates up to 14,000 endpoints. The collector then communicates via a cellular connection with the Utilities' third party service provider's facilities before being forwarded to the Utility through a virtual private network for billing purposes. Beginning at the meter, all data is encrypted and no direct customer PII –encrypted or otherwise- is transmitted. The meter number associated with the data transmission can be linked to the account number and customer PII through other Utility records and processes which are also kept secure by the Utilities' internal operating procedures. The primary means used by the Utilities to ensure accurate and secure data transmission is data encryption that is specific to the Utility. The Utilities also have provisions in their contracts with third party service providers that require the service provider to also meet certain cybersecurity standards. Although there is no requirement of the Utility to assure the service provider's performance in this regard, the Utilities perform tests on a regular basis to assure both their internal security measures and those of their service providers are up to date and meet industry standards.

Description of Westar AMI meters: In its AMI meter replacement program, Westar is deploying the Elster REX2 meter and the Landis&Gyr Gridstream RF Focus AXR or AXR-SD meter. Both brands of meters are equipped with 900MHz two-way radio transmitters and 2.4GHz ZigBee radio for a future application in a home area network. The Elster meters support advanced demand limiting and lockout functionality that may be operated remotely or at the meter. The Landis&Gyr AXR-SD also supports remote lockout functionality. Using the radio communication, the meters also allow software to be updated remotely.[9] Attachments 2 and 3 provide data specification sheets for each meter.

Description of KCPL AMI meters: In the case of KCPL, the AMI meter is replacing an earlier version of a meter equipped with a wireless data transmitter that has been used by KCPL since the mid-1990s. The earlier vintage meter is known as an Automated Meter Reading meter (AMR) which allowed the utility to remotely request usage data to be transmitted by radio to a receiver. The typical AMR meter was not equipped to receive any remote data transmission other than a request to transmit. In its meter replacement program, KCPL is deploying the Landis&Gyr Gridstream RF Enhanced Integrated Focus AX Meter which will have the capabilities outlined above for Westar AMI meter program (See Attachment 3). However, KCPL is only equipping a small percentage of its meters with ZigBee communications cards and remote disconnect technology.

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[7] Response of KCPL to Staff Data Request 5. A 100% duty cycle would assume the radio operated continuously.
[8] op. cit. Appendix 1, Page 17.
[9] Westar Response to Staff Data Request 1.

ANALYSIS:

Health Effects of RF Emissions from AMI Meters: As noted in the Consolidated Complaint, the radio transmissions associated with data acquisition from AMI meters are a source of RF emissions that may cause negative health effects on the public. A report prepared by the California Council on Science and Technology (CCST) on the health impact of radio frequency exposure from AMI meters is attached to this Report and Recommendation as Appendix 1. In its report, the CCST discusses AMI or "Smart" Meters in general and the health concerns associated with their operation. The study notes the FCC has established guidelines for the thermal effects of RF but not for any other potential health impacts. As discussed above in the description of radio transmissions, the MPE limits set by the FCC are based on a 30 minute exposure within eight inches of the transmission source. For AMI meters, the radio transmitters are expected to have a duty cycle of less than 2%.[10] During the short intermittent radio transmission from an AMI meter, the customer inside a home would be at least several feet from the transmission source as well as behind the meter housing and house walls. The shielding effects of the structure, combined with the distance from living areas, reduce the anticipated effect of RF exposure to much lower than that received from cell phones, wireless phones, or microwave ovens.[11] The Complainants raise allegations of other health concerns that can be generally characterized as RF sensitivity or Electromagnetic Hypersensitivity (EHS). EHS is defined as a variety of non-specific symptoms which afflicted individuals attribute to exposure to electromagnetic fields.[12] Although EHS is widely discussed on the internet, Staff is unable to discover any scientific studies with peer reviewed empirical data that correlate EHS as the result of RF emissions from AMI meters.

Based on the limited duty cycle, the low power output of the radios, their distance from typical living areas, and the maximum power density of the radio transmissions being well below the FCC thresholds, Staff does not believe the installation of AMI meters represent any unreasonable hazard related to thermal effects to customers. Regarding the unproven health effects that may be related to EHS, Staff agrees with the CCST Study that additional research is needed to validate these concerns.[13] Again, the low power density and distance from the transmitter would also be expected to dramatically minimize EHS experienced from AMI meters. In this case, Staff agrees with the Utilities that the Complainants provide no evidence of health effects that can be attributed to AMI meters.

Privacy Concerns Related to Wireless Data Transmission from AMI Meters: In the Consolidated Complaint, the Complainants express their concerns that security of PII may be compromised by the wireless transmission of their electric usage data. They also express concern regarding the privacy of their electric usage habits. In this case, the AMI meter only records the electric usage of the residential home. Similar to conventional analog meters, the AMI meter is unable to record how electricity is used by the customer's appliances. While the AMI meter has some remote control potential, it is limited to only the remotely controlling (disconnecting) at the metering point. Because custody transfer of electric energy from the Utilities to the Customer occurs at the meter, any activity upstream and through the meter is well within the purview of the Utilities. In the future, if the Utilities activate the ZigBee chip installed in the meters and offer a service where a HAN can be used by the

[10] op. cit. Page 8.
[11] op. cit. Page 18.
[12] http://www.who.int/peh-emf/publications/facts/fs296/en/
[13] Op. cit. Page 22.

customer to control appliances, the customer may use the AMI data to control its appliances through a remote software solution. But such a solution would be at the discretion of the Customers and not within the control of the Utilities. Under the current operating scenario where remote recording or operations is limited to the meter point, Staff does not consider installation of an AMI meter to be an invasion of customer privacy.

Security Concerns Related to Wireless Data Transmission from AMI Meters:
The mesh network used by an AMI system depends upon radio transmitters to send usage data and to receive commands from the Utilities regarding meter operations. The wireless communications among the various meters, other end devices, routers, and collectors are encrypted with computer code that is specific to the Utility. From the collector to the third party service provider, the encrypted electronic transmissions use standard cellular service. From the service provider to the Utility, the data remains encrypted and is transmitted via a Virtual Private Network connection. Within the third party service provider's operation, the data security is subject to contractual agreements with the Utility to assure the up-to-date cyber security protocols are operational. In Staff's opinion, this data pathway provides minimal risk of unauthorized access to customer meter numbers and usage data. In the unlikely event that a meter number and the associated usage data were retrieved by a cyber hacker, Staff notes there would be additional hurdles for the hacker to correlate the meter number to a Utility account number and then to any meaningful customer PII.

In the discovery process of this Docket, the Utilities provided Staff with insight into how cybersecurity is maintained for their respective operations. In Staff's opinion, cybersecurity is of the utmost concern to the Utilities and they demand similar efforts in their contracts with their third party providers. However, Staff recommends the Utilities institute formal procedures to test on a regular basis the security of the third party providers to assure they are meeting their contractual obligations to the Utility. Furthermore, in order to assure Customers that PII and cybersecurity are a serious obligation of the Utilities, Staff recommends the Utilities modify the general terms and conditions of their respective tariffs to codify the obligation to protect customers' PII.

Utility Authority to Require AMI Meter Installations: In the Consolidated Docket, the Complainants requested the Commission to allow electric customers to have the option of receiving service through an AMI meter or through a meter that does not have radio transmission capabilities. Their reasons for this request are summarized earlier in this Report. The Utilities argue there is no provision in their tariffs that require them to offer a choice of electric meters. The Utilities also point out the AMI meter program offers benefits to the Utilities and ratepayers by reducing the Utilities' manpower costs associated with reading meters and servicing meters. Through November of 2015, Westar has installed 236,945 AMI meters which correlates to monthly meter reading decreases in the same amount. Also, Westar has avoided 77,247 truck rolls to service accounts that are directly attributable to the AMI program. All in all, Staff believes the program is reducing or at least controlling a portion of Westar's operating costs while providing accurate and timely usage data. On the other hand, special reading routes to read the few meters for customers that do not want radio transmission of usage data will require the Utilities to incur costs to provide monthly meter reading personnel and any administrative overhead costs associated with billing. After deploying over 200,000 AMI meters, only 70 Westar customers have refused to allow the AMI meter to be installed. Undoubtedly more customers would have selected non radio transmitting meters if given the choice, but it is Staff's opinion that a very small

minority of customers is concerned with AMI meters. Given the fact that the health concerns regarding RF emissions from AMI meters are unproven, and the small minority of customers that wish to opt-out of having AMI installed at their residence, Staff does not believe it is in the public interest to create a special metering program that caters to unproven concerns of a minority of ratepayers. Therefore, Staff does not recommend the Commission require the Utilities to establish a program that allows customers to select the type of meter reading service they wish to have for their accounts.

We note, however, it is within the Commission's authority to require a utility to offer customer choice regarding the type of meter service. Although health effects directly correlated to the use of AMI meters remains unproven, Staff does not dismiss the health concerns of the Complainants, and we note many state public utility commissions consider it an acceptable policy to allow customer choice in selecting a meter that limits the customer's perceived risk to RF emissions. Therefore, Staff believes an opt-out program would be an acceptable alternative solution to this Complaint. If the Commission determines such an approach is in the public interest, Staff recommends the Commission require the customers desiring such nonstandard metering service to bear the full cost of implementation and operation of the metering process. Such an approach can be achieved by installing AMI meters without activating the meter's communication capabilities or by installing analog meters. Whichever approach is selected, any costs associated with modifying the existing AMI meter or installing an analog meter must be borne by the customer desiring such service. Similarly, the customer must pay all incremental costs associated with the reading and billing for electric usage from a nonstandard metering system. Although somewhat dated, a review of rates for opt-out programs set in other states is included as Attachment 4.[14] An internet search of more current opt-out rates is as follows:

State/Utility	Installation Charge	Monthly Charge
Oklahoma	$183-$261	$28
Nevada	$53	$9
Vermont	$0	$0
Portland, Oregon	$254	$51
Illinois	$70	$20
San Antonio, Texas	$175	$20

CONCLUSIONS

In conclusion, the Complainants expressed their concerns of potential health effects from RF emission but presented no evidence of health impact directly associated with AMI meters. Staff believes the meter configuration and the low power capabilities of the meter's radio significantly reduce the chance of harmful effects from RF emissions from AMI meters. AMI meters only record electric usage at the meter and do not have the capabilities to control a customer's appliances. While there is a small risk that meter usage data transmission can be intercepted, Staff believes the cybersecurity efforts put in place by the Utilities to prevent unauthorized access to customer data are appropriate. We also note that even if the meter usage data is hacked, the meter number does not directly link to a customer's PII which offers another layer of security to the customer.

[14] http://bv.com/docs/articles/the-opt-out-challenge.pdf

RECOMMENDATIONS

In order to assure customers their PII is protected, Staff recommends the Commission require the Utilities to modify the general terms and conditions of their respective tariffs to include the Utilities' obligations to protect its customers' PII. The obligations should provide for Company routine testing an updating of cybersecurity efforts of the Company's automation and communication systems. The obligations should also include a requirement for the Company to provide routine testing and verification of any terms regarding cybersecurity that are contained in its contracts with third party service providers that may have access or interaction with the Company's data systems.

Staff recommends the Commission not require the Utilities to establish a program that allows customers to select the type of meter reading service they wish to have for their accounts. However, we believe it is entirely within the Commission's discretion to require the Utility offer an opt-out program and such programs have been required of various electric utilities across the nation. If the Commission decides to require an opt-out program, Staff recommends the customer selecting the nonstandard method of meter reading, pay for the cost of such a program. To accomplish this, Staff recommends the Commission require the Utilities file an addition to their respective tariffs to establish an appropriate rate for such a service.

ATTACHMENT 1

Functional Elements of Gridstream RF System

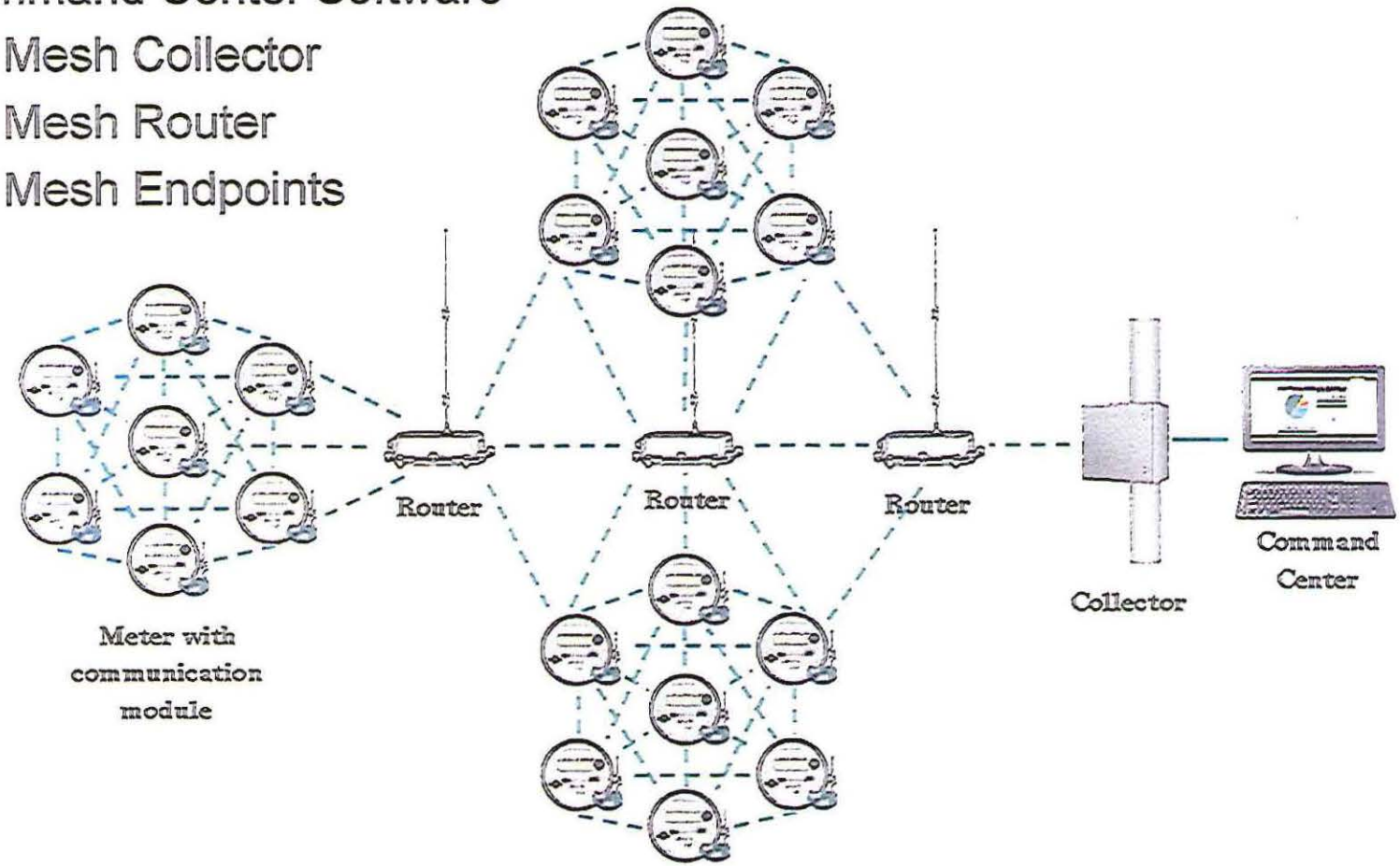
Landis+Gyr

Command Center Software

RF Mesh Collector

RF Mesh Router

RF Mesh Endpoints



All messages are encrypted using 256 Bit AES Encryption and a single System Wide Encryption Key specific to Westar Energy.

elster
Vital Connections

REX2™ meter

The robust features and flexible architecture of the REX2 meter provides a solid foundation for implementing the smart grid of the future. The REX2 meter brings to the REX® meter family many enhancements designed to support emerging needs of smart grid initiatives. REX2 meters include enhanced memory, greater security, remote upgradeability, and additional capabilities to support smart grid needs such as outage and voltage monitoring.

Developed with technology and communications flexibility in mind, the REX2 meter provides communication to the two-way Elster 900 MHz EA_LAN and to the ZigBee 2.4 GHz network. It also provides an open architecture framework for third party technology innovation supporting the Advanced Grid Infrastructure Initiative. The REX2 meter supports both ANSI C12.19 and C12.22 for communications.

Internal service control switch

REX2 meters are available with an optional 200 A integrated service control switch. Based on significant field experience, the REX2 service control switch has been optimized to provide low contact resistance for increased life. REX2 meters with service control switches are externally indistinguishable from REX2 meters without switches, thereby protecting utilities from consumer concerns about deployment. REX2 meters support advanced demand limiting and lockout functionality, and switches may be operated by authorized utility personnel through the network or locally at the meter.

Over-the-air upgrades

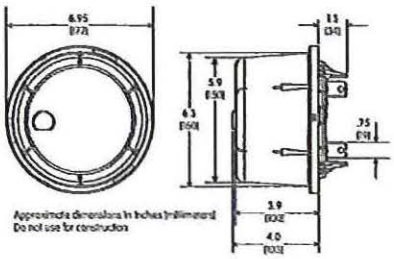
Using proven code management architecture, REX2 technology allows remote upgrade of meter and communications firmware while ensuring endpoint network functionality remains intact without loss of metering data. Remote upgradeability of the entire firmware image protects your AMI investment and allows you to meet future requirements of the smart grid without concern of technology obsolescence. In addition to remote firmware upgradeability, the meter also supports remote reconfiguration of many metering parameters.

Optimal functionality

- On-request energy, demand, status, and instrumentation data
- 2 configurable metered quantities for real and reactive bidirectional metering, ideal for net metering and co-generation applications
- 3 demand quantities with 5-, 15-, 30-, or 60-minute block demand, including remote demand reset and demand limiting
- 4-tier, 4-season, TOU energy and demand with critical tier pricing
- 4 channel interval data collection with EOI energy snapshot for improved data validation
- Flexible voltage profiling support
- Flexible water, gas, and third party device support through integrated or add-on communication modules
- Advanced energy theft and meter tampering detection technology
- Status, warning, and error conditions reportable through the network
- Separately upgradeable meter firmware and radio firmware
- Advanced security with full 128-bit AES encryption
- Nonvolatile memory rated for 1 million write cycles, ensuring data integrity for the life of the meter
- All data calculated and stored in meter for full auditability
- Optimized for very low burden on utility distribution system

Available styles

REX2 meters are available in standard residential metering form factors (1S, 2S, 3S, 4S, and 12S).



Outage restoration and restoration functionality

The REX2 meter provides advanced outage and restoration support, enhancing the utility's ability to more quickly identify the scope of outages and to receive positive restoration messages to validate that power has been restored to every endpoint. Information needed to determine important outage indices is also available.

Instrumentation profiling

The REX2 meter provides the ability to record up to two channels of voltage profile data with up to 5-minute resolution. Voltage data may include snapshot, minimum, maximum, or average voltage values.

Technical specifications

Operating ranges			
Voltage	Nameplate nominal	Operating	Switch control range[1]
Forms 1S and 2S	120 V	96 V to 144 V	108 V to 144 V
Form 2S	240 V	192 V to 288 V	216 V to 288 V
Forms 3S and 4S	120 V	96 V to 144 V	108 V to 144 V
	240 V	192 V to 288 V	216 V to 288 V
Current	0 to Class ampere rating		
Frequency	Nominal 50 Hz or 60 Hz ± 5 %		
Temperature	-40 °C to +85 °C (inside meter cover)		
Humidity	0 % to 100 % (noncondensing)		
General performance characteristics			
Starting current	Forms 1S, 2S, and 12S	100 mA for Class 200 160 mA for Class 320	
	Forms 3S and 4S	10 mA for Class 20	
Creep 0.000 A (no current)	No more than 1 pulse measured per quantity, conforming to ANSI C12.1 requirements		
Burden	Less than 1.5 W		
Primary time base	Relative time maintained by a crystal; real time is provided by the EnergyAxis network		
Communication frequency	902 MHz to 928 MHz (unlicensed)		

[1]The switch control voltage range is the voltage range required to change the state of the service control switch.

Elster
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United States

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D542-10170

TCB

GRANT OF EQUIPMENT AUTHORIZATION

TCB

Certification
Issued Under the Authority of the
Federal Communications Commission
By:

TUV Rheinland of North America, Inc.
Product Safety Division 762 Park Avenue
Youngsville, NC 27596

Date of Grant: 03/10/2010

Application Dated: 02/24/2010

Elster Solutions, LLC
208 S. Rogers Lane
Raleigh, NC 27610

Attention: John Holt , Principal Engineer

NOT TRANSFERABLE

EQUIPMENT AUTHORIZATION is hereby issued to the named GRANTEE, and is VALID ONLY for the equipment identified hereon for use under the Commission's Rules and Regulations listed below.

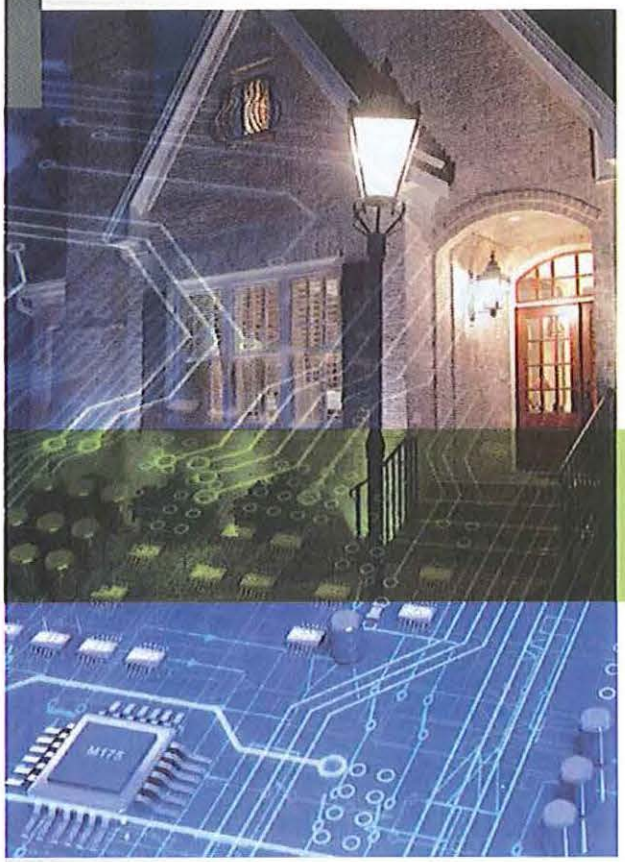
Rex - Residential

FCC IDENTIFIER: QZC-RX2EA4
Name of Grantee: Elster Solutions, LLC
Equipment Class: Part 15 Spread Spectrum Transmitter
Notes: Spread Spectrum Modular Transmitter
Modular Type: Limited Single Modular

Grant Notes	FCC Rule Parts	Frequency Range (MHZ)	Output Watts	Frequency Tolerance	Emission Designator
	15C	902.8 - 927.6	0.25		323KG1D

Note 1: Limited Modular Approval: Power listed is conducted. This Module is approved only for installation in devices under control of the grantee and only for models indicated in this filing. Only antenna(s) documented in this filing may be used with this transmitter. The antenna(s) used for this transmitter must be installed to provide a separation distance of at least 20 cm from all persons and must not be co-located or operating in conjunction with any other antenna or transmitter. OEM integrators and End-users and installers must be provided with antenna installation instructions and transmitter operating conditions for satisfying RF exposure compliance.

Product Specifications



Gridtream RF Mesh
Residential Endpoints

Landis+Gyr
manage energy better

Meter Platforms

FOCUS® AL
FOCUS AX/AX-SD
FOCUS AXe/AXe-SD
Elster REXU/REXU-SD

Secure Intelligence Meets Residential Metering for Optimum Revenue and Greater Efficiencies

Overview

More options. More security. Landis+Gyr's Gridstream® RF Mesh Residential Endpoints deliver. Here's why: Delivering future-ready advanced metering automation solutions and enabling consumer energy management programs—you can expect optimized revenue and more efficiencies in a long-lasting solution.

The endpoint leverages its integrated design and advanced functionality to work with the meter and provide a direct, meter register read. The endpoint transmits and receives data via Gridstream's robust and self-healing mesh network, utilizing the 902 to 928 MHz FHSS unlicensed frequency. Our premier single- or poly-phase digital endpoints prioritize application-based messages, expand to millions of endpoints, and offer control through the intuitive, browser-based interface for streamlined network and data management.

In addition to kWh, kW and voltage readings, the endpoints report load profile, time-of-use periods and up to 5-minute interval data for billing, engineering and customer service applications. With the exception of the FOCUS AL platform, endpoints may be ordered with integral service disconnect and built-in, SEP certified, ZigBee® Home Area Network (HAN) interface.

FEATURES & BENEFITS:
Why Landis+Gyr makes a difference.

- Enhanced security – tilt/vibration tamper detection, magnetic/DC detection and complete optical port lockout
- Full two-way communication – on-demand or routine
- Scheduling of metrology available data
- Remote upgradeable application – eliminates on-site firmware and hardware changes
- Integral service disconnect with load limiting (AX-SD, AXe and REXU platforms)
- Advanced data support – demand, TOU, load profile, and voltage
- Voltage monitoring and reporting capabilities

Gridstream RF

Product Specifications: Gridstream RF Mesh Residential Endpoints

	FOCUS AL	FOCUS AX	FOCUS AXe	Elster REXU
Electrical				
Voltage	120 or 240 V depending on form	9-16 V (From meter's power supply)	9-16 V (From meter's power supply)	Nominal (+/- 20%)
Power	Max: 2.8W Typical: 2W	Max: 1.0W Typical: 0.6W	Max: 1.0W Typical: 0.6W	Max: 3.0VA Typical: <1VA
RF 900 MHz				
Output Power	+26 dBm +/- 1 dBm	+26 dBm +/- 1 dBm	+26 dBm +/- 1 dBm	+26 dBm +/- 1 dBm
Adjacent Channel Power	+39 dBc Nominal	+39 dBc Nominal	+39 dBc Nominal	+39 dBc Nominal
Transmit Frequency	902 to 928 MHz ISM unlicensed	902 to 928 MHz ISM unlicensed	902 to 928 MHz ISM unlicensed	902 to 928 MHz ISM unlicensed
Receive Sensitivity	-108 dBm minimum	-108 dBm minimum	-112 dBm (typical, 9.6 kbps)	-112 dBm (typical, 9.6 kbps)
			-110 dBm (typical, 19.2 kbps)	-110 dBm (typical, 19.2 kbps)
RF ZigBee®				
Output Power	N/A		+20 dBm +/- 2 dBm	
Adjacent Channel Power			40 dBc Nominal	
Transmit Frequency			2405-2480 MHz	
Receive Sensitivity			-104 dBm Minimum	
Communications Protocol			ZigBee Protocol	
Standards Compliance				
FCC Title 47 CFR Part 15	Radiated and Conducted Emissions (including intentional radiators)			
IEC 61000 4-2, 3, 4, 5, 11, 12	Electromagnetic Compatibility			
ANSI C12.19	Compatible with Utility Industry End			
ANSI C12.20-2002	National Standard for Electricity Meters - 0.2 and 0.5 accuracy class			
ANSI C12.1-2008	Code of Electricity Metering			
ANSI C37.90.1-2002	Standard Surge Withstand Capability (SWC) Tests			

Compatibility

Class	1S	2S	2SE	2K	3S	4S	9S(8)	12S(25)	12SE(25)	16S	16SE	36 S(6)	45S(5)
100	AL AX* AXe												
200	AXe* REXU*	AL AX* AXe*						AL AX* REXU*		AX			
320		REXU	AL AX AXe					AXe* REXU	AX		AX		
480				AL AX AXe									
10/20					AL AX AXe	AL AX AXe							
20					REXU	REXU	AX					AX	AX

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REGULATORS REACT

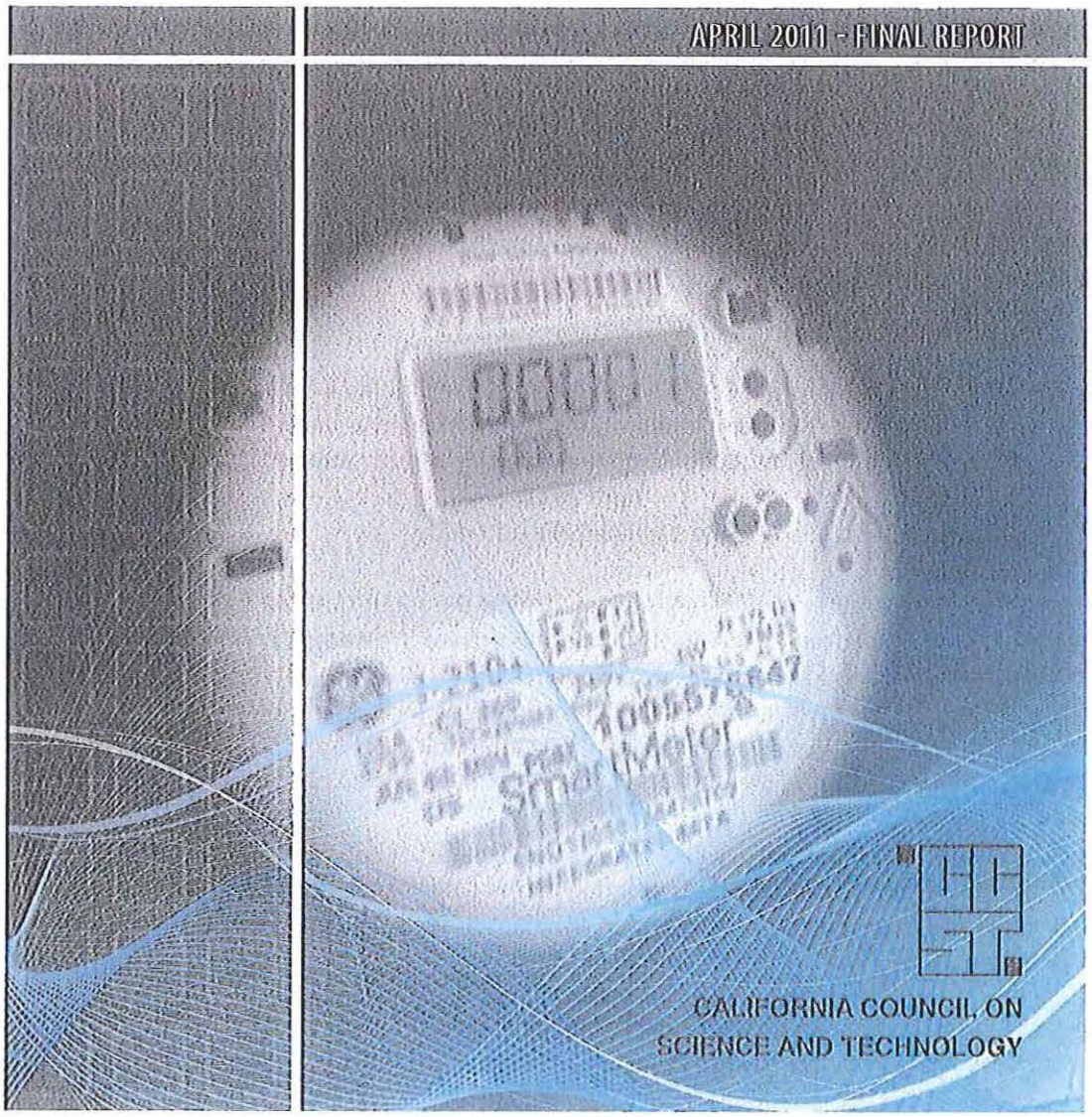
As a result of growing consumer concerns, there is a growing surge of state and local agencies requiring utilities to offer opt-out options to customers who refuse to receive AMI meters. Table 2 highlights current state regulatory activity and resulting utility opt-out programs.

Table 2

STATE COMMISSION	REGULATORY ACTIVITY AND UTILITY OPT-OUT PROGRAMS
Maine Public Utilities Commission	▪ MPUC requires state's utilities to implement opt-out programs. ▪ Central Maine Power (www.cmpco.com) provides two opt out options (1) installation of an electro-mechanical meter for a one-time charge of $40 and an ongoing monthly fee of $12, (2) installation of a smart meter with the internal communications module in non-transmit mode for a one-time charge of $20 and a monthly fee of $10.50.
Oregon Public Utility Commission	▪ Oregon PUC requires state's utilities to implement opt-out programs. ▪ Portland General Electric provides one opt-out option that allows for the installation of a non-network-based meter for a one-time cost of $254 and a monthly charge of $51.
California Public Utilities Commission	▪ CPUC has ordered the initiation of a postponement list. Customers who request that a smart meter not be installed are added to this list. ▪ On 2/1/2012, the CPUC ordered Pacific Gas & Electric to implement an analog meter opt-out option (application 11-03-014). The CPUC order includes a one-time charge of $75 and a monthly fee of $10.
Public Utilities Commission of Nevada	▪ PUCN opened a docket considering the implementation of four opt-out alternatives: analog meter, non-AMI digital meter, radio-off AMI meter, and reduced communications AMI meter. ▪ NV Energy filed its cost proposal for each option – with one-time costs ranging from $110 to $280 and monthly charges ranging from $0.90 to $13.30. (Investigation Regarding NV Energy's Advanced Service Delivery Program aka Smart Meter and its Implementation, 12/28/2011, Docket 11-10007) ▪ The PUCN conducted a workshop on January 18, 2012 to discuss the opt-out options and is expected to rule in the near future. ▪ NV Energy has also implemented a postponement list.
Other States	▪ Michigan Public Service Commission opened case no. U-17000 in January 2012 requiring the investigation of, among other things, opt-out options. ▪ Regulators in Vermont and Arizona are informally investigating opt-out options but have not formally initiated dockets.

APPENDIX 1

HEALTH IMPACTS OF RADIO FREQUENCY EXPOSURE FROM SMART METERS



ACKNOWLEDGMENTS
We would like to thank the many people who provided input and feedback towards the completion of this report. Without the insightful feedback that these individuals generously provided, this report could not have been completed. We would like to give special thanks to the California Smart Grid Center, College of Engineering and Computer Science at the California State University, Sacramento and to the University of California's Center for Information Technology Research in the Interest of Society (CITRIS).

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.

Note: The California Council on Science and Technology (CCST) has made every reasonable effort to assure the accuracy of the information in this publication. However, the contents of this publication are subject to changes, omissions, and errors, and CCST does not accept responsibility for any inaccuracies that may occur.

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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
Executive Director, CCST

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.

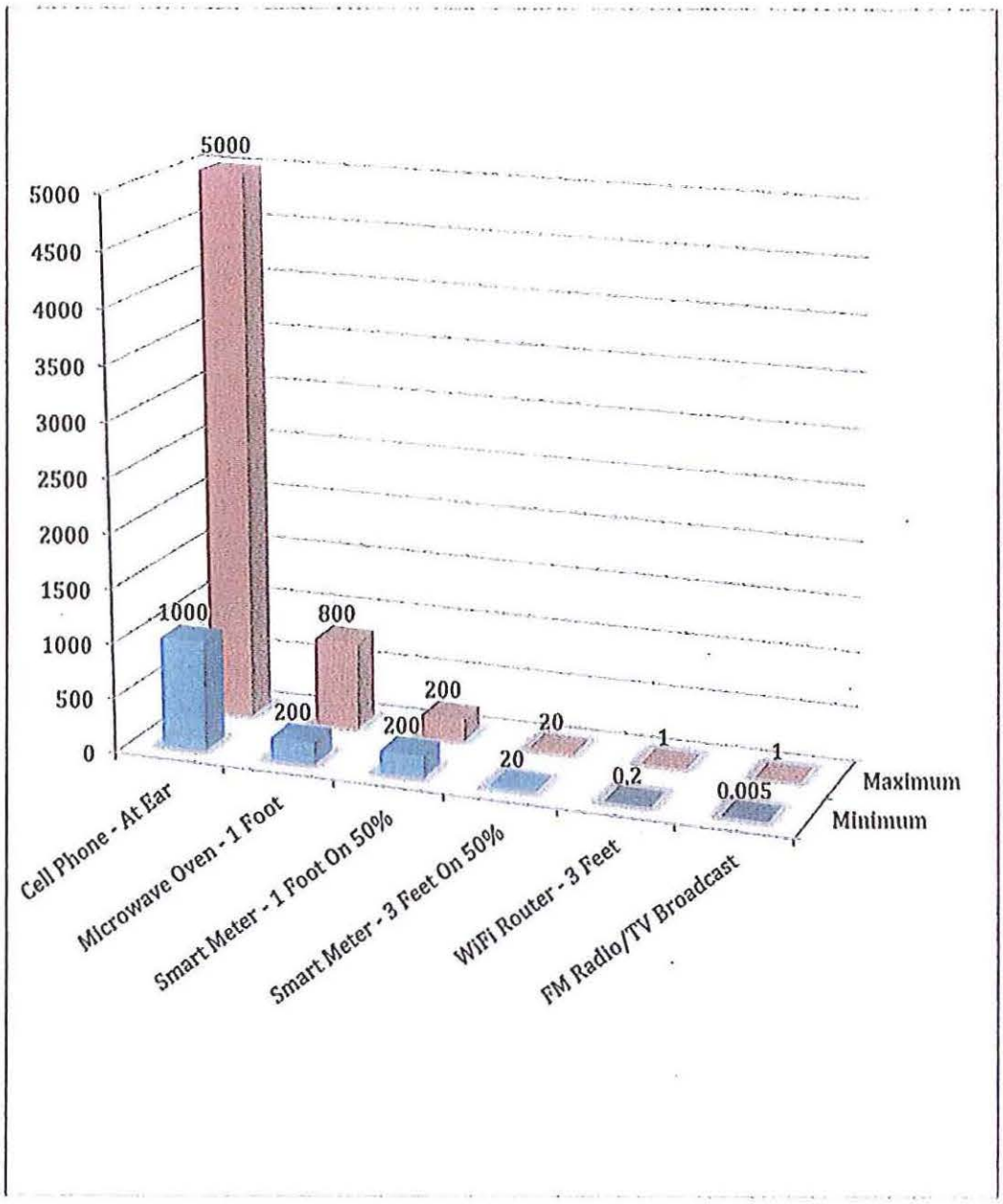

Figure 1. Instantaneous Radio Frequency Power Density Levels of Common Devices (in microWatts/cm^2)
About this figure: This figure was developed by the CCST project team. Quantities for different distances calculated using Inverse Square Law. Assumes distances in far-field, where power density reduces 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

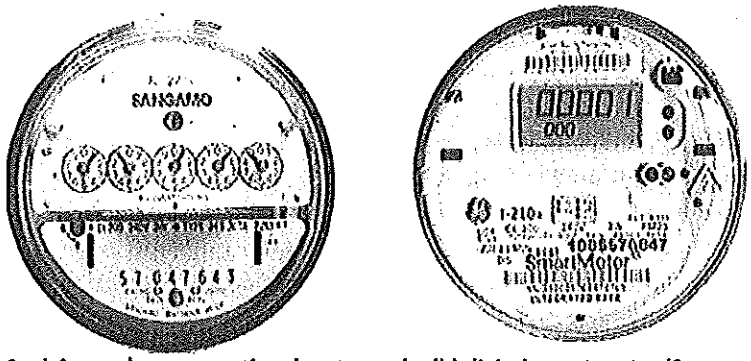

Figure 2. a) An analog, conventional meter and a (b) digital smart meter (Source: PG&E)

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).

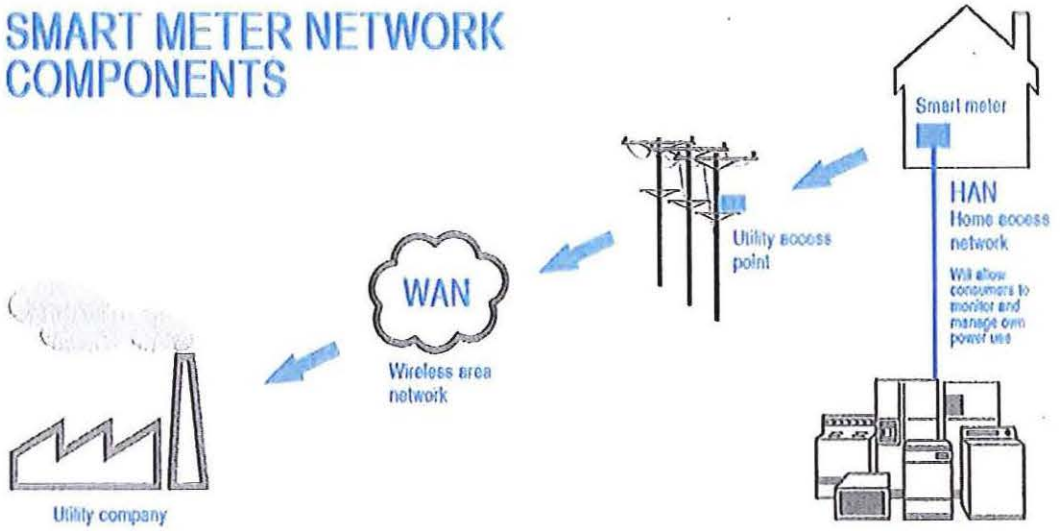

Figure 3. Simplified depiction of Smart Meter system network. Arrows show the use of radiofrequency (RF) signals for automated meter reading, communications among electric power meters, relays, access points, the company's enterprise management systems. The future home access network will operate within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

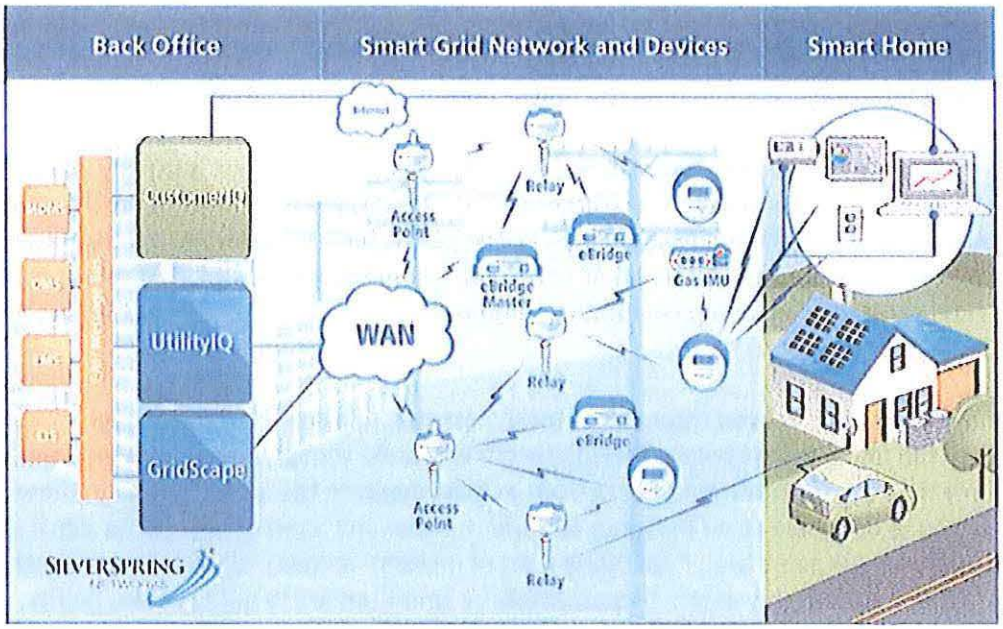

Figure 4. Illustration of components of the PG&E Smart Meter Program Upgrade showing the use of radiofrequency (RF) signals for communications among electric power meters, relays, access points and, ultimately, the company's enterprise management systems. (Source Silver Spring Network[5])

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	Environment
1. Cost Savings Resulting from Energy Efficiency 2. Increased Consumer Choice and Convenience 3. More Transparent, Real-Time Information and Control for Consumers	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	**Economy**
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	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
Source: California Smart Grid Center	

[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 RL341294, 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°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°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 $\mu W/cm^2$. 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 $\mu W/cm^2$.

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 $\mu W/cm^2$ 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 $\mu W/cm^2$, 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.

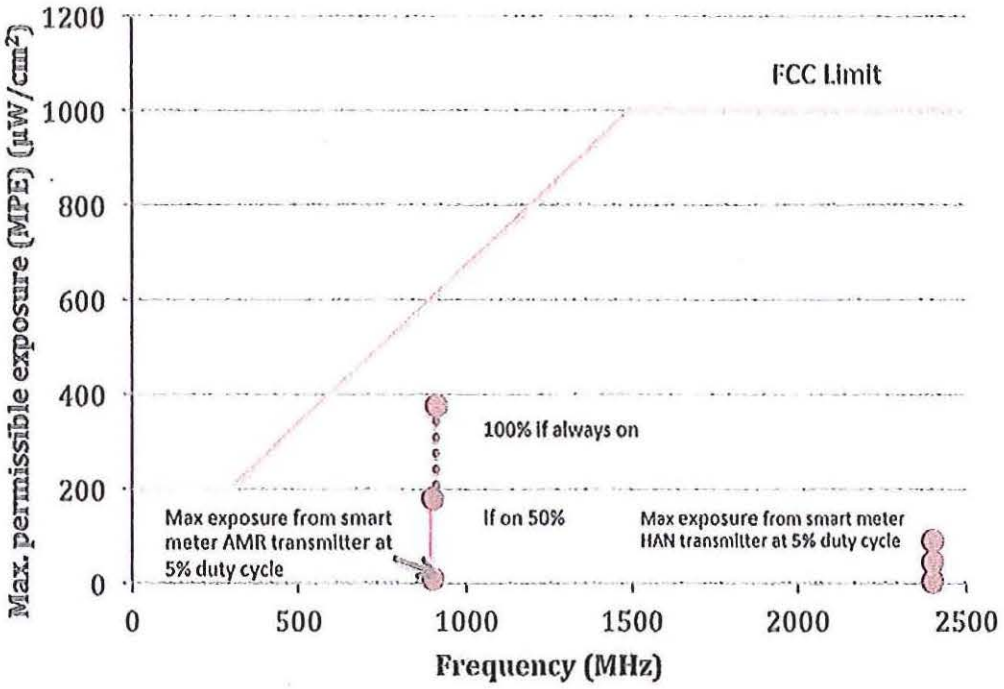

Figure 5. FCC maximum permissible exposure limits on power density rise with frequency because the human body can safely absorb more energy at higher frequencies. The estimated maximum exposure from a 1-Watt AMR transmitter at 5% duty cycle (i.e., 72 minutes/day) and one-foot distance is 18 $\mu W/cm^2$, 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.

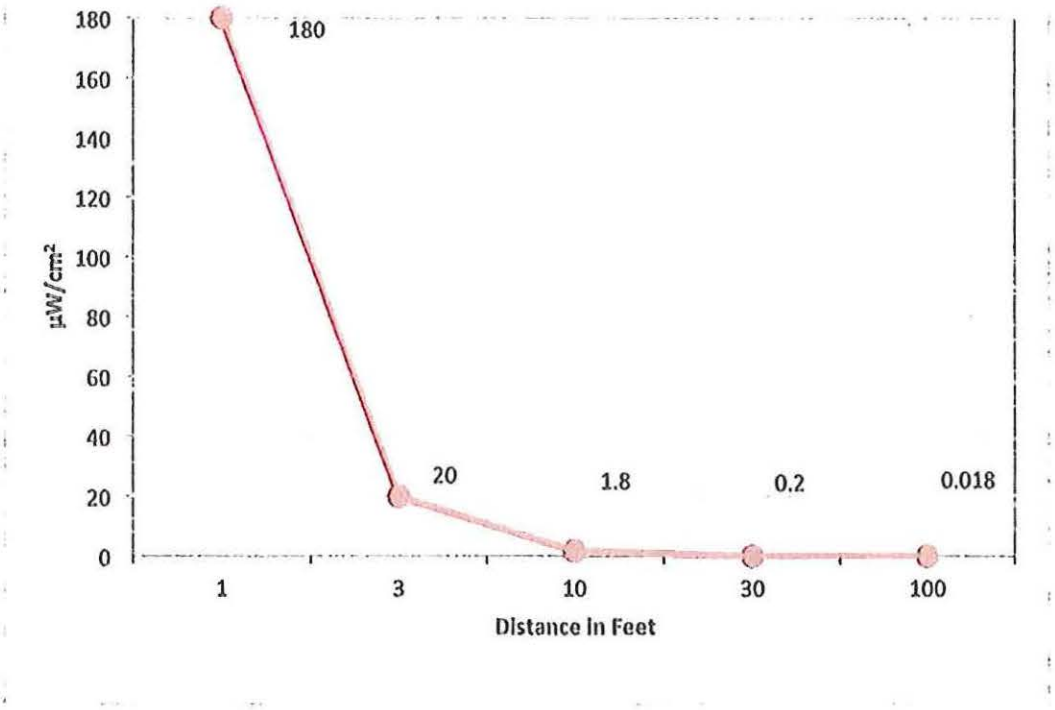

Figure 6. Power density from a sample smart meter versus distance;[30] 1-Watt emitter at 50% duty cycle. Typical smart meter AMR transmitter power density declines rapidly with distance. The rapid drop of power density with distance (inverse-square law) is similar for various duty cycles and different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

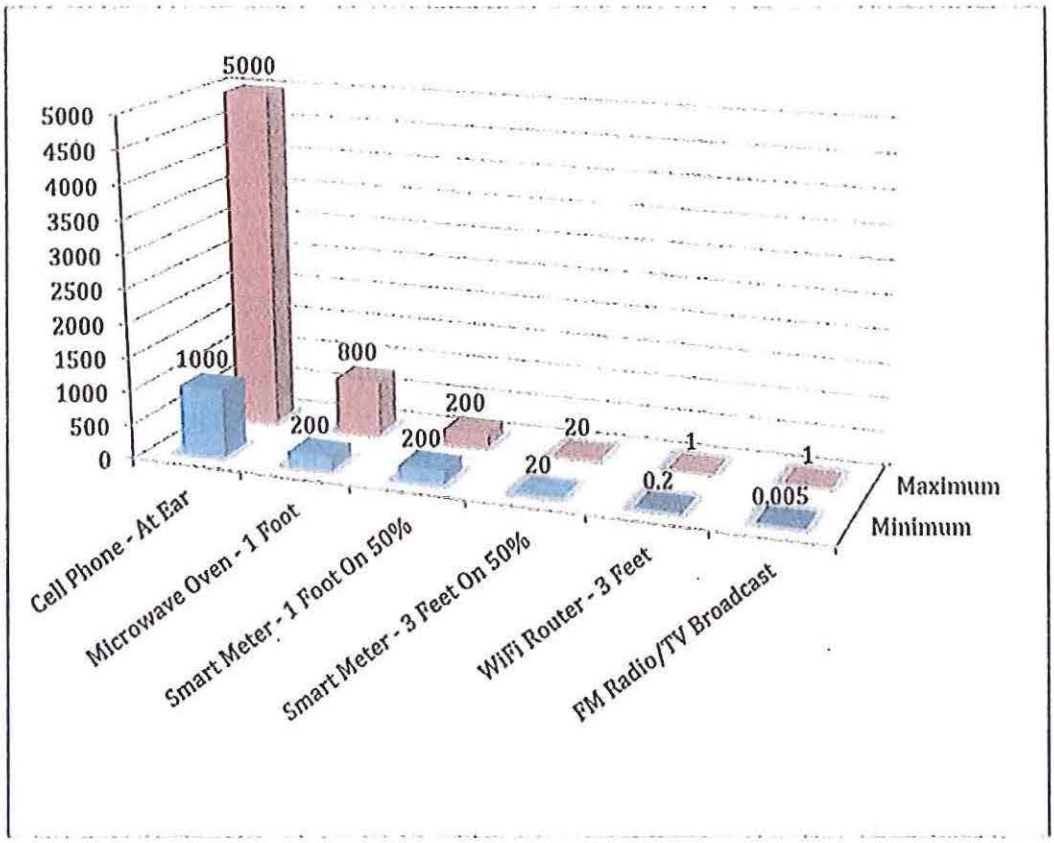

Figure 7. Instantaneous Radio Frequency Power Density Levels of Common Devices (in microWatts/cm^2)
About this figure: This figure was developed by the CCST project team. Quantities for different distances calculated using Inverse Square Law. Assumes distances in far-field, where power density reduces 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) 0.000009 (250 mW, 1% duty cycle) 0.0002 (1 W, 5% duty cycle)	3 feet 10 feet	When in proximity during transmission	Localized, non-uniform

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.

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[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

STATE CAPITOL
P.O. BOX 942849
SACRAMENTO, CA 94249-0006
(916) 319-2006
FAX (916) 319-2106

DISTRICT OFFICE
3501 CIVIC CENTER DRIVE, SUITE 412
SAN RAFAEL, CA 94903
(415) 479-4920
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 significent 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
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
WEBSITE [illegible]

Assembly
California Legislature

WILLIAM W. MONNING
ASSEMBLYMEMBER, TWENTY-SEVENTH DISTRICT

STATE CAPITOL
[illegible]
SACRAMENTO, CA 95814-0027
(916) 319-2027
FAX (916) 319-2127

DISTRICT OFFICES
701 OCEAN STREET, SUITE 318 E
SANTA CRUZ, CA 95060
(831) 426-3503
FAX (831) 425-2240

99 PACIFIC STREET, SUITE 555 D
MONTEREY, CA 93940
(831) 649-2800
(831) 649-2335

SANTA CLARA COUNTY DIRECT LINE
(408) 222-0047

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:tog

MILL VALLEY

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

City of Mill Valley, 26 Corte Madera Avenue, Mill Valley, California 94941 • 415-388-4033

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, 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.

Appendix D – Written Submission Authors

Written Input Received from:

Physical Sciences/Engineers
Kenneth Foster, Professor, Department of Bioengineering, University of Pennsylvania
Rob Kavet, Physiologist/Engineer, Electric Power Research Institute (EPRI)

Biologists/medical
De-Kun Li, MD, Ph.D., Senior Reproductive and Perinatal Epidemiologist, Division of Research, Kaiser Foundation Research Institute, Kaiser Permanente
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

Appendix E – Additional Materials Consulted

All sources can be accessed through the CCST website at http://ccst.us/projects/smart/

American Academy of Pediatrics

- The Sensitivity of Children to Electromagnetic Fields American Academy of Pediatrics (August 3, 2005)

Australian Radiation Protection and Nuclear Safety Agency (ARPANSA)

- www.arpansa.gov.au Australian Radiation Protection and Nuclear Safety Agency (ARPANSA)
- Radiation Protection - Committee on Electromagnetic Energy Public Health Issues (Fact Sheet)
  Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) (May 2010)
- Radiation Protection - Mobile Telephones and Health Effects
  Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) (June 25, 2010)

Bushberg, Jerrold – Written Submission

- Background on the Thermal vs. Non-thermal Exposure and Health Issue
  Jerrold Bushberg

Documents From the California Department of Public Health (CDPH)

- Correspondence Provided by Rick Kreutzer, California Department of Health
  Rick Kreutzer, California Department of Public Health (March 10, 2011)
- Mixed Signals About Cellphones' Health Risks Hang Up Research
  The Chronicle (September 26, 2010)
- Summary of the Literature: What do we Know About Cell Phones and Health? (July 20, 2010)
- Brain Tumor Risk in Relation to Mobile Telephone Use: Results of the INTERPHONE International Case - Control Study
  Oxford University Press (March 8, 2010)
- Mobile Phones and Health
  U.K. Department of Health
- Late Lessons from Early Warnings: Towards Realism and Precaution with EMF?
  David Gee, European Environment Agency, (January 30, 2009)
- Statement of Finnish Radiation and Nuclear Safety Authority (STUK) Concerning Mobile Phones and Health
  Radiation and Nuclear Safety Authority - STUK (January 7, 2009)
- Fact Sheet: Children and Safe Cell Phone Use
  Toronto Public Health (July 2008)
- Children and Mobile phones: The Health of the Following Generations in Danger
  Russian National Committee on Non-Ionizing Radiation Protection (April 14, 2008)
- AFSSE Statement on Mobile Phones and Health
  French Environmental Health and Safety Agency - AFSSE (April 16, 2003)

Committee on Man and Radiation (COMAR)

- IEEE Engineering in Medicine and Biology Society Committee on Man and Radiation (COMAR)
- COMAR Technical Information Statement the IEEE Exposure Limits for Radiofrequency and Microwave Energy
  IEEE Engineering in Medicine and Biology Magazine (April 2005)

Commonwealth Club of California

- Commonwealth Club of California - The Health Effects of Electromagnetic Fields (Video) (November 18, 2010)

Electric Power Research Institute (EPRI)

- emf.epri.com EMF/RF Program at EPRI
- Radio-Frequency Exposure Levels from Smart Meters: A Case Study of One Model
  Electric Power Research Institute (EPRI) (February 2011) Final Report
- Radio-Frequency Exposure Levels from SmartMeters Draft
  Electric Power Research Institute (November 2010) Draft Report - accessed via the Internet December 2010
- Perspective on Radio-Frequency Exposure Associated With Residential Automatic Meter Reading Technology
  Electric Power Research Institute (EPRI) (February 22, 2010)
- Testing and Performance Assessment for Field Applications of Advanced Meters
  Electric Power Research Institute (EPRI) (December 4, 2009)
- Overview of Personal Radio Frequency Communication Technologies
  Electric Power Research Institute (EPRI) (September 9, 2008)
- Characterizing and Quantifying the Societal Benefits Attributable to Smart Metering Investments
  Electric Power Research Institute (EPRI) (July 2008)
- Metering Technology
  Electric Power Research Institute (June 20, 2008)
- The BioInitiative Working Group Report
  Electric Power Research Institute (EPRI) (November 23, 2007)
- An Overview of Common Sources of Environmental Levels of Radio Frequency Fields
  Electric Power Research Institute (EPRI) (September 2002)

Environmental Protection Agency

- United States Environmental Protection Agency's Response to Janet Newton (March 8, 2002)
- United States Environmental Protection Agency's Response to Jo-Anne Basile (September 16, 2002)

Epidemiology

- Prenatal and Postnatal Exposure to Cell Phone Use and Behavioral Problems in Children

Epidemiology July 2008 - Volume 19 - Issue 4 - pp 523-529

European Journal of Oncology - Ramazzini Institute

- Non-Thermal Effects and Mechanisms of Interaction between Electromagnetic Fields and Living Matter
  (2010)

Federal Communications Commission

- Radio Frequency Safety FAQ's
- RF Safety Page
- Statement Provided by Robert Weller Regarding FCC Regulations
  Robert D. Weller, Chief, Technical Analysis Branch, Office of Engineering and Technology, Federal Communications Commission (February 3, 2011)
- Federal Communications Commission Response to Cindy Sage
  (August 6, 2010)
- FCC Certifications
  - FCC Certification for the Silver Spring Networks Devices - September 28, 2009
  - FCC Certification for the Silver Spring Networks Devices - September 28, 2009
  - FCC Certification for the Silver Spring Networks Devices - September 4, 2007
  - FCC Certification for the Silver Spring Networks Devices - July 6, 2007
- Questions and Answers about Biological Effects and Potential Hazards of Radiofrequency Electromagnetic Fields
  Federal Communications Commission Office of Engineering & Technology (August 1999)
- Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields
  Federal Communications Commission Office of Engineering & Technology (August 1997)

Food and Drug Administration

- No Evidence Linking Cell Phone Use to Risk of Brain Tumors
  U.S. Food and Drug Administration (May 2010)

Health Protection Agency

- Wi-Fi
  Health Protection Agency (Last reviewed: October 26, 2009)
- Cordless Telephones - Digital Enhanced Cordless Telecommunications (DECT) and other Cordless Phones
  Health Protection Agency (Last reviewed: September 4, 2008)

International Commission on Non-Ionizing Radiation Protection (ICNIRP)

- www.icnirp.de International Commission on Non-Ionizing Radiation Protection (ICNIRP)

- International Commission on Non-Ionizing Radiation Protection (ICNIRP) on the Interphone Publication
  International Commission on Non-Ionizing Radiation Protection (May 18, 2010)
- ICNIRP Statement on the "Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields (up to 300 GHz)"
  International Commission on Non-Ionizing Radiation Protection (September 2009)
- Epidemiologic Evidence on Mobile Phones and Tumor Risk
  International Commission on Non-Ionizing Radiation Protection (September 2009)
- Exposure to High Frequency Electromagnetic Fields, Biological Effects and Health Consequences (100 kHz - 300 GHz)
  International Commission on Non-Ionizing Radiation Protection (2009)

National Academies Press

- Identification of Research Needs Relating to Potential Biological or Adverse Health Effects of Wireless Communication
  National Academies Press (2008)
- An Assessment of Potential Health Effects from Exposure to PAVE PAWS Low-Level Phased-Array Radiofrequency Energy (9.9MB PDF)
  National Academies Press (2005)

National Cancer Institute

- Cell Phones and Cancer Risk (Fact Sheet)
  National Cancer Institute
- Cell Phones and Brain Cancer: What We Know (and Don't Know)
  National Cancer Institute (September 23, 2008)

National Institute of Environmental Health Sciences

- Electric and Magnetic Fields
  National Institute of Environmental Health Sciences

Neutra, Raymond – Materials Submitted

- www.ehib.org/emf The California Electric and Magnetic Fields (EMF) Program
- Should the World Health Organization (WHO) Apply the Precautionary Principal to Low and High Frequency Electromagnetic Fields?
  Raymond Richard Neutra

PG&E

- Understanding Radio Frequency (RF)
  PG&E
- Supplemental Report on An Analysis of Radiofrequency Fields Associated with Operation of PG&E SmartMeter Program Upgrade System
  Richard A. Tell, Richard Tell Associates, Inc. (October 27, 2008)
- Smart Grid: Utility Challenges in the 21st Century (7.4MB PDF)
  Andrew Tang, Smart Energy Web, Pacific Gas and Electric Company (September 18, 2009)
- Summary Discussion of RF Fields and the PG&E SmartMeter System

Richard A. Tell, Richard Tell Associates, Inc. (2005 Report and 2008 Supplemental Report)

- Analysis of RF Fields Associated with Operation of PG&E Automatic Meter Reading Systems
  Richard A. Tell, Richard Tell Associates, Inc. and J. Michael Silva, P.E. Enertech Consultants (April 5, 2005)

Society for Risk Analysis

- Risk Governance for Mobile Phones, Power Lines and Other EMF Technologies
  Society for Risk Analysis (2010)

Swedish State Radiation Protection Authority (SSI)

- The Nordic Radiation Safety Authorities See no Need to Reduce Public Exposure Generated by Mobile Bas Stations and Wireless Networks
  Swedish State Radiation Protection Authority (SSI) (2009)

University of Ottawa

- Wireless Communication and Health - Electromagnetic Energy and Radiofrequency Radiation FAQ's
  University of Ottawa, RFcom

World Health Organization

- Database of Worldwide EMF Standards
- WHO - Electromagnetic Fields
- Electromagnetic Fields and Public Health - Base Stations and Wireless Networks (Fact Sheet N°304)
  World Health Organization (May 2006)
- Electromagnetic Fields and Public Health - Electromagnetic Hypersensitivity (Fact Sheet N°296)
  World Health Organization (December 2005)
- Electromagnetic Fields and Public Health - Mobile phones (Fact Sheet N°193)
  World Health Organization (May 2010)

Unsolicited Submissions

Documents Provided by Alexander Blink, Executive Director of the DE-Toxics Institute, Fairfax CA

- Points and Sources Submitted for Consideration by Alexander Blink 2
- Points and Sources Submitted for Consideration by Alexander Blink 1
- Public Health Implications of Wireless Technologies, Cindy Sage
- Memory and Behavior, By Henry Lai, Bioelectromagnetics Research Laboratory, University of Washington

Sage Consulting

- Assessment of Radiofrequency Microwave Radiation Emissions from Smart Meters
  Sage Associates (January 2011)
- Cindy Sage Letter to Julius Knapp (FCC)

(September 22, 2010)

- Response Letter to Cindy Sage from Julius Knapp (FCC) (August 6, 2010)
- Cindy Sage Letter to Edwin D. Mantiply (FCC) (March 15, 2010)
- Bioinitiative Report: A Rational for a Biologically-based Public Exposure Standard for Electromagnetic Fields (ELF and RF) (3.1MB PDF)
- Bioinitiative Report: What is the BioInitiative Report?
- Bioinitiative Report: Myocardial Function Improved by Electromagnetic Field Induction of Stress Protein hsp70 (1.1MB PDF)
- Bioinitiative Report: The Interphone Brain Tumor Study (1.6MB PDF) Cindy Sage, Editorial Perspective
- Bioinitiative Report: Steps to the Clinic with ELF EMF (1.0MB PDF)
- Mobile Phone Base Stations - Effects on Wellbeing and Health Pathophysiology (August 2009)
- Increased Blood-Brain Barrier Permeability in Mammalian Brain 7 Days after Exposure to the Radiation from a GSM-900 Mobile Phone Pathophysiology (August 2009)
- Public Health Implications of Wireless Technologies Pathophysiology (August 2009)
- Genotoxic Effects of Radiofrequency Electromagnetic Fields Pathophysiology (August 2009)
- Epidemiological Evidence for an Association Between Use of Wireless Phones and Tumor Diseases Pathophysiology (August 2009)
- Public Health Risks from Wireless Technologies: The Critical Need for Biologically-based Public Exposure Standards for Electromagnetic Fields (2.9MB PDF) BioInitiative Briefing for President-Elect Obama Transition Team
- The BioInitiative Report: A Rationale for A Biologically-based Public Exposure Standard for Electromagnetic Fields (ELF and RF) (3.6MB PDF) Cindy Sage PowerPoint Presentation (November 2007)

Wilner & Associates

- SmartMeters and Existing Electromagnetic Pollution Wilner & Associates (January 2011) - **This report was not commissioned by CCST**
- Application for Modification Before the California Public Utilities Commission (3.5MB PDF)

Other Documents

- Health Canada Safety Code 6 and City of Toronto's Proposed Prudent Avoidance Policy (2010)
- Transmitting Smart Meters Pose A Serious Threat To Public Health

(2010)

- RF Safety and WiMax FAQ's: Addressing Concerns About Perceived Health Effects (April 2008)

Relevant Websites

- EMF - Portal
- emfacts.com
- emfsafetynetwork.org
- lbagroup.com
- NIOSH Program Portfolio Centers for Disease Control and Prevention (CDC)
- Radio Frequency RF Safety and Antenna FAQs
- Smart Grid Information Clearinghouse (SGIC)
- stopsmartmeters.org

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 ($\mu W/cm^2$) - 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).

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