

Low Cost Wireless Electric Energy Meter Specification

DRAFT—Version 2.4

- 1. Background.** Prioritizing building energy efficiency projects is essential to responsible fiscal management whether in the private sector or government. Understanding what systems within a building consume what types and amounts of energy is essential to identifying areas for efficiency improvement. This is especially true in the federal sector, where agencies are required to meet specific metering requirements (e.g., the metering of buildings for electricity use per the Energy Policy Act of 2005); meet aggressive energy efficiency goals established in the Energy Independence and Security Act of 2007, where meters can be applied to manage energy use and diagnose energy efficiency opportunities; and support the overall sustainable buildings and communities goals as established in Executive Order 13514 (October 5, 2009). This project would support both government and private sector energy efficiency improvements through the development and delivery of low cost wireless energy meters. This specification is intended to be performance-based and is aimed at a low-cost electric energy sub-metering system. The metering system addresses measuring three-phase electric energy consumption in commercial buildings and includes wireless communication of the measured data to a central data collection point (base station).
- 2. Introduction and Purpose.** This document recommends minimum performance requirements for a wireless electric energy metering system. The metering system shall perform electrical measurements, as specified in Section 4 of this document, and communicate the results wirelessly to a central data collection point (base station), where measurements are collected and may be communicated by a variety of means (wired or wirelessly) to other points of potential use on-site and/or off-site, as specified in Section 4. The energy meters required for this system are not utility revenue grade meters. The intent of this metering system is to provide adequate data that can be used to improve building systems performance. Although it is expected that all electric energy metering systems will comply fully with this specification, any designs that meet the technical measurement requirements (accuracy, data collected, safety, etc.) but vary in installation and/or communication methods, (wireless), will be considered if the low cost (overall) intent is satisfied.

This metering system is defined as a measurement device measuring three-phase true RMS¹ electric energy flow and a wireless method of data transfer to a central base station located remote to the location of the metering device. The data measurement and/or data transmission and collection will be open protocol. The metering system shall collect Watt-hour energy for a three-phase circuit. Such a meter could be applied to a whole-building, individual panel, or individual circuit within an electric panel.

Compliance with the specification will be determined by verification of the required performance in a specified “real” building used as the performance testing environment (in-building test). Details

¹ Root-mean square

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are provided in the Appendices. The “rated” cost of each “meter” per measured point (an individual three-phase measurement) will be calculated.

3. Definitions.

Metering system – A system that measures electric energy consumption and communicates the measurements to a central base station. The wireless metering system consists of multiple measurement devices (sub-meters), multiple current sensors, a base station, and possibly other devices (such as wireless signal repeaters).

Measurement device – An electric sub-metering device (meter), measuring true RMS three-phase energy, located at or near an electrical conductor that measures the characteristics of the electrical energy flow during a specified time interval and communicates that information wirelessly to the base station.

Base station – A device, located remotely from the measurement devices, that wirelessly receives the data from all measurement devices, stores it, and makes it available to user devices via a variety of means (e.g., Universal Serial Bus connections, Ethernet connections, etc.).

Other devices – Any additional devices required to make the metering system fully functional (with the exception of the user device, defined below), such as remote antennae and wireless signal repeaters.

User devices – Devices generally having displays on which users access, analyze, and view/monitor the measured data, aggregations of it, and results from processing it, such as a personal computer (PC). These devices run software that performs functions such as mathematical and logical processing to produce derived results of importance to users. User devices are **not** considered part of the wireless metering system in this specification.

Measurement point – a location in an electric circuit (inside the user facility, downstream of the utility meter) at which true RMS three-phase electric energy consumption is measured by the measurement device (meter).

4. **Specifications.** The metering systems shall comply with the following specifications. Each specification is considered a requirement unless otherwise stated. In addition to the required specifications, additional options are also listed. Offering options is not a requirement in response to this Challenge, but may be considered as additional features (with an associated additional cost).

4.1 Electrical

Source of electric power for measurement device	120, 208, 240, 277, or 480 volt source within the panel or power scavenged from the circuit being measured
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Source of electric power for the base station and other devices	120 to 240 volt, 50 to 60 Hz (plug power)
Power loss response	Automatic resumption of operation after power loss
Safety	Measurement device must have ground connection whether the measurement device is designed to measure a WYE, or DELTA circuit configuration

4.2 Electrical measurements

Electric energy measurement	The measurement device (meter) must measure electricity Watt-hour energy consumption, true RMS energy, for a three-phase circuit.
Electrical service application	The measurement device (meter) must support measurement of: <ul style="list-style-type: none"> • 208 V to 600 V three-phase • WYE and DELTA configurations • Different meter models may be used for different voltage applications and/or circuit configuration
Measurement parameters	The following measurement parameters shall be measured with the output communicated to the base station. Required Output: <ul style="list-style-type: none"> • Watt-hour true RMS energy for a three-phase circuit Optional Outputs: <ul style="list-style-type: none"> • Watt-hour true RMS energy per phase • Phase-to-neutral voltages (WYE) • Phase-to-phase voltages (DELTA) • Current (amps) per phase
Ranges of measured parameters	The measurement device shall be applicable to the following ranges. Voltage: 0 to 600 volts AC, 50 to 60-Hz <ul style="list-style-type: none"> • The voltage may be different for model application and circuit configuration • 80% to 120% of normal line voltage Current: 5 to 2400 amps <ul style="list-style-type: none"> • The current ranges may be covered by selection of current transformers (CT)/current sensors. • 1.5% to 100% of rated current

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Data collection interval	<p>Recorded data interval must have user-selectable options.</p> <p>Required:</p> <ul style="list-style-type: none"> • Three user-selectable options: 1-, 15-, and 60-minute data intervals <p>Optional:</p> <ul style="list-style-type: none"> • Multiple (more than three) user-selected data interval options from 1-minute to 60-minutes. <p>NOTE: The data collection interval is for recording time-series data and is NOT meant to imply a sampling frequency.</p>
Accuracy of measurements	<p>Required:</p> <ul style="list-style-type: none"> • 1% of reading measurement accuracy (metering device) • 1% of reading measurement accuracy (current sensors) <p>Optional:</p> <ul style="list-style-type: none"> • The energy meter shall be deliverable with a NIST traceable certificate documenting accuracy of 1% or better • The current transformers (CTs)/current sensors shall be deliverable with a NIST traceable certificate documenting accuracy of 1% or better
Data log record	<p>Measurement data to include date and time stamp.</p> <p>Measurement device shall include a method to synchronize internal clock with the base station</p>

4.3 Mechanical and environmental

Operating environment	<p>Required:</p> <ul style="list-style-type: none"> • Temperature: -20°C to 50°C • Humidity: 10% to 90% relative humidity (RH), non-condensing <p>Optional:</p> <ul style="list-style-type: none"> • Extended temperature range -55°C to 85°C
Enclosure (if necessary)	<p>Measurement devices: Preference will be made for metering devices that are designed to fit inside a typical panel box. However, metering devices accessible through a separate NEMA (National Electrical Manufacturers Association) enclosure, located near the panel to be metered, is also acceptable.</p> <p>Other devices: Other devices (wireless transmitters, repeaters, base station) are to be designed for indoor use and do not require separate NEMA safety enclosures.</p>

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Weight	There is no weight specification for the measurement device (meter), base station or other devices (such as wireless signal repeaters). Manufacturers are required to include weight of all devices in the specification submittal.
Dimensions	There is no physical size specification for the measurement device (meter), base station or other devices (such as wireless signal repeaters). Manufacturers are required to include physical dimensions of all devices in the specification submittal.

4.4 Communications

Architecture	No specific wireless architecture or topology is required.
Frequency band	Radio frequency communications must be compliant with FCC Part 15 for unlicensed operation in the United States.
Simultaneous operation of multiple metering systems	Multiple independent wireless metering systems must be able to coexist within communications range of each other.
Communication success rate	If data record communication is dropped, base station shall try to recover the dropped record. Required: <ul style="list-style-type: none"> • Communication success rate $\geq 99\%$ (See Appendix I, Section 8)
Data communication interval	Required: <ul style="list-style-type: none"> • Data from each measurement device must be communicated to the base station no less than once per 24 hours. Preferred Option: <ul style="list-style-type: none"> • The time interval for communication of data from a measurement device to the base station shall be user selectable from a minimum of the following values: 15 minutes, 1 hour, 4 hours, 6 hours, 12 hours, or 24 hours. Option: <ul style="list-style-type: none"> • Vendors can provide other values from which users can select.

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Data storage— measurement device	<p>Required:</p> <ul style="list-style-type: none"> • In the event of loss of communications between a measurement device and the base station, the measurement device shall continue to measure and store data without interruption. Internal data storage for at least 128 measurements • Measurement devices shall store all measured data after a loss of communication event has occurred until communication of the measurement device with the base station is successfully restored • Manufacturer must identify internal storage capability in terms of the number of measurements stored. • For losses of communications exceeding the backup storage capabilities, the most recent data shall be stored. <p>Options:</p> <ul style="list-style-type: none"> • Extended internal data storage for 14 days (1344 measurements assuming 15-minute data intervals). For losses of communications exceeding the backup storage capabilities, the most recent data shall be stored. • Extended internal memory for 30 days (2880 measurements assuming 15-minute data intervals). For losses of communications exceeding the backup storage capabilities, the most recent data shall be stored.
Data Storage—base station	<p>Required:</p> <ul style="list-style-type: none"> • Internal data storage memory of at least 4 GB. • Internal clock with independent battery back up
Response to loss of communication	Automatic resumption of communication after power loss or loss of communication
Security mechanism	All data sent wirelessly shall be encrypted using 128-bit (or greater) Advanced Encryption Standard (AES-128).
Use of existing networks	Wireless metering system must be stand-alone system from the metering device to the base station. Metering networks shall not require connection to any wired network for any purpose, including passing communication testing in the test building, determining the cost per measurement point, installation, or routine use for metering or sub-metering. No “piggybacking” of this sort on networks in a building will be permitted by this specification for any purpose.

4.5 Remote transmission or remote antenna

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Wireless devices are prohibited in many secure areas in federal facilities. To enable measurement of electric energy (e.g., for electrical panels) in such areas, the metering device must include the ability to remotely locate the wireless transmission component. This may include either separating the metering device from the wireless transmitter (with a hard-wired connection in between) or remotely locating the broadcast antenna from the metering device via extended cable option. The remote device must support communication over wire or solid optical media having a length of at least 150 feet.

4.6 Safety and certifications

UL	All units in the metering system must be UL certified. Prototype units not yet UL approved will be considered by DOE for use in the in-building test on a case-by-case basis.
FCC	All radio frequency transmission capabilities must comply with all applicable FCC regulations (e.g., Part 15 – ISM Band - Unlicensed operation)

4.7 User equipment compatibility

Base station ports/communications connections	<p>The base station must provide a means to connect to a personal computer or network server for the purpose of transferring (output) measured data file.</p> <p>Required:</p> <ul style="list-style-type: none"> • USB (minimum USB 2.0 or later compliant) • Ethernet (minimum 100Base-TX) <p>Optional:</p> <ul style="list-style-type: none"> • Additional ports/connections may be provided by the vendor
Required data file formats from the base station	File export from the base station to user device must be CSV file

4.8 Installation and configuration

The system should have a design for simple, user-friendly installation, registration and communication. As an example, once installed, configuration of the system should consist essentially of the user pressing an auto-configure button, which configures the base station, attempts to connect all nodes, and then provides indication(s) to the user that the system is set up and ready to use. Only assignment of a label for each measurement point that identifies the circuit on which it is installed should require user input. Addition of measurement devices after the initial set up should be similarly simple and follow a similar procedure.

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4.9 Operational

<p>Visual indicators for measurement devices (minimum)</p>	<p>LED to indicate unit status LED to indicate successful power-on self-test LED to indicate successful communication LED to indicate strength of communication signal LED(s) to indicate correct/incorrect phase connections or a visual display providing all of the above indications on the device</p>
<p>Automatic self-tests</p>	<p>On start-up and restart after power outage, measurement devices and base station shall go through a self-test process to confirm functionality. Required:</p> <ul style="list-style-type: none"> • Power-on self-test <p>Option:</p> <ul style="list-style-type: none"> • Periodic execution of self-test to ensure proper operation. Self-test includes checks of both upstream and downstream communication. A notification report is generated upon detection of a failure/problem.

4.10 Other requirements

<p>Cost</p>	<p>The cost of the metering system is desired at \$100 or less per metered point, excluding options. Price point to include all hardware (metering device, CTs, base station, software) but not design, installation, or operation labor. The cost of systems will be determined during product performance testing in the in-building test (see Appendix I). DOE seeks input from all stakeholders on this cost target as part of the process of identifying an appropriate and reasonable cost range.</p>
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5. Verification of Compliance.

Compliance with the requirements of this specification shall be performed through a combination of: 1) system and device visual inspection, 2) laboratory measurements, and 3) performance testing in a real-building performance testing environment. Compliance with all requirements will be tested at DOE's discretion. Details of the performance testing process and environment and submission requirements are provided in the Appendices I through III.

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Appendix I: In-Building Testing

1. Introduction

The testing process described in the appendices to the specification focus on validating that wireless sensing systems proposed by manufacturers in response to the DOE Challenge adequately meet the requirements of the specification. Testing is divided into two categories: 1) in-building tests and 2) laboratory tests. The in-building tests involve testing primarily the communication capabilities of the wireless metering systems submitted but will also provide information essential for evaluating the system cost per measurement point (see specification Section 4.10). The laboratory tests, which are described in Appendix II, concern validating conformance of the submitted systems with other requirements of the specification. The cost evaluation procedure is described in Appendix III. The remainder of this appendix describes the in-building test process and the associated expectations of participating manufacturers.

2. Overview of In-Building Test Approach

The purpose of the in-building testing is to measure the success of each candidate wireless metering system in collecting measurements at a specified measurement time interval at designated measurement points and communicating the measurement results successfully to the system's base station. Each candidate wireless metering system will be tested in a demonstration facility (hereafter referred to as "*the test facility*") designated by the DOE with metering points distributed throughout *the test facility*. The designated metering points will include both total electrical panels (*whole panel*) and designated individual electrical circuits (*individual circuit*) within an electrical panel. Each candidate wireless metering system will measure the same points for a period of 2 weeks (336 hours). The success of each system will be characterized by the fraction of total expected measurement points that are actually received at the system's base station during the test period. Only one candidate wireless metering system will be installed and tested at a time.

The in-building test will be used to characterize the communication capability of each candidate wireless metering system. The communication range commonly specified for wireless hardware, which involves open-air straight-line unobstructed communication between a data-source device and a receiver, will not be used. The relationship of this communication range to the real-world performance of wireless systems inside buildings is difficult to generically quantify other than that longer communication ranges usually correspond to the ability to communicate over longer distances indoors. Communication ranges vary from building to building and with the communication path in any specific building. Building construction, the location of wireless devices, the kinds and locations of furnishings, and the types and locations of equipment operating in a building all affect communications of wireless devices indoors. The test specified in this appendix performed in a federal building will be used to characterize the metering systems relative to each other and the requirements of the specification. Specifically, the in-building test will characterize the ability of each candidate wireless metering system to measure electrical characteristics identified in the Specification (Section 4.2) for all of the designated electrical

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circuits identified in the in-building test (Appendix IV: In-Building Testing Supplement²) at the specified time interval and to communicate the resulting data reliably to the system base station.

The results of testing will be evaluated relative to the maximum data loss as described in Appendix I, Section 8.

The primary steps in the in-building testing process are shown in Figure 1. Sections 4 through 8 of this appendix describe this process and provide information relevant to it.

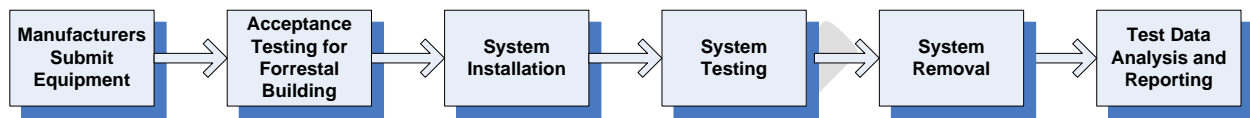


Figure 1. Primary steps of the in-building test process.

3. The Test Facility

The DOE's James A. Forrestal Building at 1000 Independence Avenue, Washington, DC, will be used as *the test facility*. This office building complex, constructed in 1970, has eight occupied floors, basements, and 1,754,800-square feet of floor space. It consists of three interconnected buildings; the North Building, South Building and West Building (see Figure 2).

Electrical panels are located in electrical closets throughout the facility. Specific locations of electrical panels on which metering will be installed for testing will be communicated to the manufacturers interested in participating in the Challenge (refer to the Low-Cost Wireless Metering Challenge web page for information regarding manufacturer participation requirements). The opportunity for a walkthrough of the building will also be provided to participating manufacturers as part of the Challenge after submission of a letter of intent and signing the NDA.

² Appendix IV: In-Building Testing Supplement will be provided to manufacturers confirming an interest in participating in the Challenge.

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Figure 2. Aerial view of the Forrestal Building showing the South Building (A), the North Building (B) and the West Building (C).

4. Pre-Test Evaluation: Manufacturer Equipment Submission and Reporting of Evaluation Results

All wireless equipment that will potentially be installed in *the test facility* must be approved for purposes of ensuring adequate cybersecurity for the facility. The approval process involves laboratory tests performed by the DOE Office of the Chief Information Officer (CIO).

Manufacturers must submit four pieces of each type of component of their candidate wireless metering systems by a date to be specified by DOE. Operation instructions and technical information on safe operation of the components and systems must be submitted along with the hardware components. Additional information, including the address for submitting equipment will be provided to participating manufacturers in advance of the date for submission.

Upon completion of the pre-test evaluation, DOE will inform each manufacturer regarding approval for installation. Manufacturers of systems not approved will be provided feedback on the primary reasons for denial of approval.

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5. System Installation

After approval of the hardware for installation, dates for installation of each approved candidate wireless metering system will be scheduled by DOE with the respective manufacturers. Prior to installation, manufacturers must resubmit technical information sheets on safe operation of the equipment. They must also submit a price for each component that is part of the candidate wireless metering system. If prices depend on purchase quantities, the prices submitted should be the price corresponding to the number that will be installed in *the test facility* for testing. The manufacturer can submit a revised price within 2 weeks after completion of the installation if the actual number installed differs from the number anticipated before installation (if the difference affects component pricing). In some cases, manufacturers may install prototype equipment; in those cases, the manufacturer must submit a best estimate of the likely price when the prototype is offered commercially as a product.

Installation of the candidate wireless metering system for the in-building test shall be performed by a DOE contractor qualified for electrical installations in DOE facilities. The DOE contractor will install the candidate metering system according to the manufacturer instruction and be observed by the manufacturer. Set up of the base station and commissioning of the entire candidate wireless metering system shall be performed by the manufacturer. All installation work shall be performed during non-business hours to minimize occupant disruptions. Each manufacturer shall provide for all necessary materials and equipment for complete installation, set up, and commissioning. Only technically qualified personnel will be permitted to perform installation work. All electrical work shall be performed by licensed electricians and in accordance with National Electric Code (NEC) and Occupational Safety and Health Administration (OSHA) regulations. At the time of scheduling the installation, DOE will inform the manufacturer and installation subcontractor of any documentation that must be completed prior to coming on site to install the candidate wireless metering system. This documentation will include design lay-out submittals and a DOE Headquarters on-site work permit that outlines the work to be accomplished and identifies safety hazards and associated measures to mitigate those hazards.

For any system components that transmit radio signals, only the types (manufacturer, model, and version) that have been approved by DOE in advance will be permitted for installation. No substitutions of untested transmitting equipment will be permitted.

DOE and national laboratory staff will observe the installation of the candidate wireless metering systems. In addition to general observations, these staff will inventory the number of each system component installed and measure the time and level of effort used to install the system.

6. Testing

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For the in-building test, candidate wireless metering systems will be configured for 15-minute measurement time intervals. Measurements from different meter devices should be time synchronized; further, each data-series record must be labeled with a time stamp.

Measurement data will be collected by the base station for transfer to the connected computer. A data record for a specific time must include values for all measurements plus a time stamp and a field that identifies the specific metered device name. Values for all of these variables are required for a data record to be considered successfully received.

The 2-week testing period will begin within 1 day of the installation of the metering system being completed.

7. System Removal

Upon completion of the 2-week test, the candidate wireless metering system shall be removed by the DOE installation subcontractor. Removed metering equipment may be collected by the manufacture, at their own expense, once removed by the DOE contractor. Timely completion of removal is essential to enable testing of other candidate metering systems. Manufacturers will be aware of the completion date of the test as the date 2 weeks following completion of the installation and DOE will verify the testing completion date by phone or email.

8. Test Data Analysis and Reporting

Analysis of the test data will be performed by a national laboratory for DOE. The national laboratory will transmit to DOE a report summarizing the testing results along with the comma separated value (CSV) file of all data records for each wireless meter system tested. DOE will then communicate the results to the individual participating manufacturers.

The metric for determining the rate of success in measuring and communicating data to the base station is the communication success rate (CSR).

$$\text{Communication success rate (CSR)} = \sum_{n=1}^N I_n / N ,$$

where N is the total number of data record sets possible (which is equal to the total number of measurement intervals during the test evaluation period), n is an index for the measurement time interval, which takes a value of 1 for the first measurement interval and N for the last interval, $I_n = 1$ when the data record set (i.e., time stamp, average electric power during the interval, and any additional data collected as part of the interval data set) for measurement time interval n is successfully communicated to the computer connected to the base station and $I_n = 0$ when communication of the full data record is unsuccessful. The total number of data record sets, N, is equal to (2 weeks)*(7

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days/week)*(24 hours/day)*(60 minutes/hour)*(1 data set/15 minutes) = 1344 data sets. Therefore, when CSR is evaluated for the full 2-week testing period,

$$\text{Communication success rate (CSR)} = \sum_{n=1}^{1344} I_n / 1344.$$

The CSR is the fraction of the expected total number data record sets that are successfully received. No loss of data over the 2-week test period corresponds to CSR = 1.0; complete failure to communicate data corresponds to a value of 0.0. The target CSR is ≥ 0.99 . CSR values < 0.99 do not meet the targeted CSR specification.

In addition to reporting the value of CSR for the 2-week period, the analysis team will evaluate CSR defined for each day (sequential 24-hour period after the test start time) and values for each of the 2 individual weeks. Further, CSR for individual meters may also be assessed for the 2-week period. These values will provide insight into whether system behavior varied over time during the 2-week period. The analysis will also identify repeated problems associated with specific components of data record sets (e.g., the time stamp, average power measurement, or other data in the intended data set). A CSV file of the data collected during the test period will be attached to the report for each candidate wireless metering system.

-- END of APPENDIX I --

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Appendix II: Laboratory Compliance Testing

All candidate wireless metering systems submitted in response to the DOE Industry Challenge must be verified to comply with the Specification (see Section 4). Manufacturers are requested to perform tests to measure each pertinent parameter or metric for which a requirement is given in this specification. In cases where an existing commercial component that has been previously tested is used in the system, the finding of tests completed previously on the product can be submitted in support of verifying compliance. All new components must be tested to quantify the values of the performance metrics for the system. A copy of the documentation showing compliance to the specification must be submitted by the manufacturer to DOE prior to the in-building test. A national laboratory will review the test submittals for compliance with the specification.

The requirements for which tests are to be performed are (organized by the section of the specification in which the requirements are specified):

Section 4.2 Electrical measurements

- Electric energy measurements
- Measured parameter(s)
- Accuracy of measurement required

Section 4.3 Mechanical and environmental

- Operating environment

Section 4.4 Communications

- Simultaneous operation of multiple metering systems
- Communication success rate

All other requirements must be met and compliance with these requirements must be verified by a statement signed by an authorized manufacturer's representative. The statement must explicitly identify compliance with each of the requirements for which tests are not required. The statement must, also, identify each requirement that is not compliant (if any) and include an explanation of why the requirement was not satisfied.

These requirements are (organized by the sections of the specification in which the requirements are specified):

Section 4.1

- Sources of electric power for meter system components
- Power loss response

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- Proper grounding of metering system components

Section 4.2

- Electrical service configurations
- Measurement time interval period configurations
- Parameters to measure
- Data log record

Section 4.3

- Enclosure – state if a separate enclosure is required
- Dimensions and weights – provide dimensions and weights of individual metering system components

Section 4.4

- Communication architecture
- Frequency band
- Data communication interval
- Data storage for measurement device and base station
- Response to loss of communication
- Security mechanism
- Use of existing networks

Section 4.5

- Remote transmission

Section 4.6

- UL
- FCC

Section 4.7

- Base station ports for communication connections
- Required data file format from the metering system base station

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Section 4.8

- All requirements identified related to installation and configuration.

Section 4.9

- Visual indicators for measurement devices
- Automatic self-tests during start up or restart

Section 4.10

- Cost – provide breakdown of individual components costs

Note: Manufacturers are encouraged to submit their candidate wireless metering systems, even if they do not fully meet all the specifications, if by relaxing some requirements a significant reduction in cost is achieved. Manufacturers are encouraged to submit test results that document performance, even if the results do not fully satisfy some of the specifications, especially if the result is associated with significantly lowering the cost of the system.

-- END of APPENDIX II --

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Appendix III: System Cost Determination

Prior to installation of the candidate metering system in *the test facility*, the manufacturer must submit a price for each component of its wireless metering system. The prices submitted will be used to determine the cost of the system equipment per metered point as installed in *the test facility*.

The system cost per metered point will be determined using the relation

$$C(\$/\text{point metered}) = \sum_{i=1}^{N_{\text{component types}}} N_i P_i / N_{\text{points}},$$

where N_i is the number of components of type i (e.g., metering devices, current transformers, repeaters, base unit, software, etc.), P_i is the price of component i in \$ per piece, $N_{\text{component types}}$ is the number of different component types, N_{points} is the total number of points metered in *the test facility* (30), and C is the system cost per point metered in (\$ per point metered).

The result of this cost evaluation will be reported by the national laboratory responsible for the data analysis to DOE, which will report the result to the manufacturer along with the results of the in-building testing.

The purpose of this cost determination is to assess the average cost of the metering system components that a future candidate facility would need to purchase from the manufacturer on a cost per metered point to achieve a fully functional wireless metering system. The cost determination specifically excludes costs that are site and installation specific or that may be included by labor learning curves or local labor rates.

-- END of APPENDIX III --