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Metering Best Practices: A Guide to Achieving Utility Resource Efficiency, Release 3.0

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March 2015

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Metering Best Practices

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Preface

This release updates and modifies the content provided in Release 2.0 of the Metering Best Practice Guide issued in August 2011, developed under the direction of the U.S. Department of Energy's Federal Energy Management Program (FEMP). The mission of FEMP is to bring technical expertise to enable Federal agencies to meet energy-related goals and provide energy leadership to the country. FEMP's mission is directly related to achieving requirements set forth in the *Energy Policy Acts of 1992 and 2005, the Energy Independence and Security Act (EISA) of 2007*, and Executive Order 13693: *Planning for Federal Sustainability in the Next Decade* – and also those practices that are inherent in sound management of Federal financial and personnel resources.

The learning objectives of this guide are to:

- Highlight the benefits of using metered data to identify opportunities and drive cost-effective, energy management and investment practices.
- Understand and be able to outline the key elements of a metering plan, including prioritization.
- Illustrate how to use metered data to identify energy and cost saving opportunities.
- Achieve a high-level understanding of metering technologies, equipment, and applications.
- Describe the methods and approaches for building-level, distribution-level, and end-use metering.
- Explain the different data communication options for metered data.

The focus of this guide is to provide energy, water and facility managers and practitioners with information that facilitates using metering to achieve potential savings and benefits.

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The first chapter of this guide is an introduction and overview. Chapter 2 provides the rationale for metering. Chapter 3 discusses metering planning, providing key issues and highlighting their importance and covers metering economics. Chapter 4 provides an overview of different metering technologies by major utility type: electricity, natural gas, steam, water, and heated and chilled water circulation systems. Chapter 5 describes various data analysis techniques used by energy information systems and uses for metered data. Chapter 6 is a list of the references used to create the guide.

Acknowledgements

This guide is the result of numerous people working to achieve a common goal of highlighting the importance of metering and the resulting opportunities for energy efficiency. The authors wish to acknowledge the contribution and valuable assistance provided by the staff of the Federal Energy Management Program (FEMP). Specifically, we would like to thank Saralyn Bunch, FEMP program manager for metering and water, for her leadership and support in the development of this third edition. The authors would also like to thank the energy and facility staff members of the Federal agencies who have provided their input regarding metering needs and practices.

Acronyms

A	ampere (also amp)
ACEEE	American Council for an Energy-Efficient Economy
acf	actual cubic feet
AEC	Architectural Energy Corporation
AMI	advanced metering infrastructure
AMR	automated meter reading
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning
BACnet	building automation and control networks
BAS	building automation system
BMP	Best Manufacturing Practices Center of Excellence
Btu	British thermal unit
CEC	California Energy Commission
CEQ	Council for Environmental Quality
CIPEC	Canadian Industry Program for Energy Conservation
cfm	cubic feet per minute
CMMS	computerized maintenance management system
CRAC	computer room air conditioning
CPUC	California Public Utility Commission
CT	current transformer
dc	direct current
DC Pro	Data Center Energy Profiler
DHW	domestic hot water
DOE	U.S. Department of Energy
ECAM	Energy Charting and Metrics
ECIA	Electronics Components Industry Association
ECM	energy conservation measure
EIS	energy information system
EISA	Energy Independence and Security Act of 2007
EPA	U.S. Environmental Protection Agency
EPAct	Energy Policy Act of 2005
EPRI	Electric Power Research Institute
ESCO	energy service company
ESPC	energy savings performance contract
EUI	energy-use intensity (also energy-use index)
F	foot
FCC	Federal Communications Commission
FEMP	Federal Energy Management Program
FRPS	Federal Real Property Statistics

ft^2	square feet
gpm	gallons per minute
gsf	gross square feet
h	hour
HART	highway addressable remote transducer
HDD	heating degree days
HVAC	heating, ventilation, and air conditioning
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronic Engineering
IES	Illuminating Engineering Society
IESO	Independent Electricity System Operator
IREC	Interstate Renewable Energy Council
IRP	integrated resource planning
ISO	International Organization for Standards
IT	information technology
kBtu	thousand British thermal units
kVA	thousand volt-amperes
kW	kilowatt (1,000 Watts)
kWh	kilowatt-hour (1,000 Watt-hours)
kWh/h	kilowatt-hour per hour (equates to average kW)
L-L	line-to-line
L-N	line-to-neutral
LAN	local area network
LBNL	Lawrence Berkeley National Laboratory
LonWorks	local operating network
M&V	measurement and verification (also monitoring and verification)
Mcf	thousand cubic feet
MW	megawatt (million Watts)
MWh	megawatt-hour (million Watt-hours)
NBI	New Buildings Institute
NEEA	Northwest Energy Efficiency Alliance
NEMA	National Electric Manufacturers Association
NFPA	National Fire Protection Association
NIST	National Institute of Standards and Technology
NSTC	National Science and Technology Council
O&M	operations and maintenance
PF	power factor
PIER	Public Interest Energy Resource Program (California)
PKI	public key infrastructure
PNNL	Pacific Northwest National Laboratory
Portfolio Manager	ENERGY STAR Portfolio Manager
PECI	Portland Energy Commission, Inc.

pph	pounds per hour
psia	pounds per square inch – absolute
psig	pounds per square inch – gage
PT	potential transducer
PUE	power usage effectiveness
PURPA	Public Utility Regulatory Policies Act of 1978
PV	photovoltaic
RF	radio frequency
RMS	root mean square
SCADA	supervisory control and data acquisition
scf	standard cubic feet
scfh	standard cubic feet per hour
scfm	standard cubic feet per minute
SSWC	Standard Surge Withstand Capability
TCP/IP	transmission control protocol/internet protocol
THD	total harmonic distortion
TOU	time-of-use (pricing)
UESC	utility energy service contract
UPS	uninterruptible power supply
USC	U.S. Code of Federal Regulations
USGBC	U.S. Green Building Council
V	voltage (also volt)
VA	volt-ampere
VAR	volt-ampere reactive
VEE	validating, estimation, and editing
W	Watt
w.c.	water column
W-h	Watt-hour
WAN	wide-area network
yr	year
XML	extensible markup language

Contents

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Tables

Chapter 1 Introduction and Overview

The purpose of this guide is to provide information on effective energy and water metering strategies, relevant metering technologies and communications, how to collect and use metered data, and how to develop a metering plan. This guide is designed to serve as a resource for facility, energy, and water management and technical staff. It does not try to represent the universe of metering-related material. Rather, it attempts to:

- Provide background information on why metering is important.
- Provide guidance on the structure of an effective metering program.
- Provide information on metering and communications technologies.
- Highlight common uses of metered data.

1.1 Target Audience

Facility, energy, and water resource managers, practitioners, and technical staff represent the prime audience of this document. The benefits of a comprehensive metering program extend from the site-level, up through to the national headquarters' level. A comprehensive metering program requires the participation of staff from key areas within the overall facilities organization including operations, maintenance, engineering, procurement, training, and administration. While a given site may not have all of these areas as separate entities, these functions are provided for within the organization. These staff members are also part of the target audience of this guide.

A successful metering program requires cooperation, dedication, and participation at all levels and cannot succeed without everyone involved understanding the basic principles and supporting the efforts to acquire technically sound data regarding resource use within buildings or associated with delivery of an energy resource.

1.2 Organization and Maintenance of the Document

This document represents Release 3.0 of *Metering Best Practice Guide: A Guide to Achieving Utility Resource Efficiency*. The initial release of this document occurred in October 2007. Some of the detailed information provided in previous versions of the guide has been replaced with summary tables.

The first chapter of this guide is an introduction and overview. Chapter 2 provides the rationale for metering. Chapter 3 discusses metering planning, providing key issues and highlighting their importance and covers metering economics. Chapter 4 provides an overview of different metering technologies by major utility type: electricity, natural gas, steam, water, and heated and chilled water circulation systems. Chapter 5 describes various data analysis techniques used by energy information systems and uses for metered data. Chapter 6 is a list of the references used to create the guide. A glossary of terms is presented in Appendix A. Appendix B provides a copy of Section 103 of the *Energy Policy Act of 2005* and Section 434(b) of the *Energy Independence and Security Act of 2007*. Appendix C includes select applicable codes and standards as related to metering equipment and installations.

Chapter 2 Why Meter?

Energy and water managers have long known the value of metered data. With recent advances in energy and water metering and information systems resulting in increased functionality at lower costs, obtaining these data in a cost-effective manner is now a standard practice. Whether energy and water resource managers are trying to comply with legislated and mandated metering requirements, or looking to apply accepted building management best practices, such as utility bill verification or benchmarking, today's metering technologies can provide the information needed to meet energy and water goals, save money, and improve building operations.

> The importance of metering can be summed up in the Energy Manager's maxim:
>
> You can't manage what do don't measure.
> If you don't measure it, you can't improve it.

Metering of energy and water utilities has seen an increase in interest, application, and technology advancement in both the private and the public sectors. One significant driver of this heightened interest is the ongoing modernization of the nation's electric infrastructure with the move toward the smart grid and smart meters. Another significant driver, specific to the Federal sector, includes the legislative mandates for metering of Federal buildings. See Appendix A, Glossary of Common Terms, for additional advanced metering terms and definitions.

2.1 Business Case for Metering

The application of meters to individual buildings and energy-intensive equipment provides facility managers and operators with real-time information on how much energy has been or is being used. This type of information can be used to assist in optimizing building and equipment operations, in utility procurements, and in building energy budget planning and tracking.

It is important to keep in mind that meters are not an energy efficiency/energy conservation technology per se; instead, meters and their supporting systems are resources that provide building owners and operators with data that can be used to:

- Reduce energy and water use
- Reduce energy and water costs
- Improve overall building operations
- Improve equipment operations.

> *How the metered data are used is critical to a successful metering program.*

How the metered data are used is critical to a successful metering program. Depending on the type of data collected, these data can enable the following practices and functions:

- Verification of utility bills
- Comparison of utility rates
- Proper allocation of costs or billing of reimbursable tenants
- Demand response or load shedding when purchasing electricity under time-based rates
- Measurement and verification of energy project performance

- Benchmarking building energy use
- Identifying operational efficiency improvement opportunities and retrofit project opportunities
- Usage reporting and tracking in support of establishing and monitoring utility budgets and costs, and in developing annual energy reports.

Most of the metered data uses listed above will result in a reduction in energy and water costs. The degree of cost reduction realized will depend on the unit cost of the energy and water being saved and on the effectiveness with which the site analyzes the data and acts upon its findings and recommendations. Examples of additional metering benefits can include:

- Supporting efforts to attain ENERGY STAR and/or green building certifications
- Promoting tenant satisfaction by providing information that tenants find useful in managing their operations
- Prolonging equipment life (and reducing capital investment requirements) and improving its reliability by verifying the efficient operation of equipment
- Assessing the impact of utility price fluctuations prior to or as they happen, allowing sites/agencies to address budget shortfalls on a proactive basis.

Metering options will change in response to new material, electronic, and sensor development, as well as new and additional requirements for real-time data information. Future expansion of a metering system should be considered, as well as introduction of new metering and sensor technologies, based on the best available information, but be careful not to overdesign a system, thus unnecessarily increasing its cost.

2.2 Metering Drivers

Increasing meter functionality, declining costs of meters, and a growing recognition of the value of metered data contribute to the expanded use of energy and water metering. For example, the smart grid provides electrical energy from suppliers to consumers accompanied by two-way digital communication. It is this communication ability that affords the grid its intelligence. While there are many potential applications for the smart grid, the near-term relevance is in the form of economic pricing of the commodity through “real-time pricing” programs and the potential for demand limiting (also known as demand response) activities. Legislative drivers, the building energy code and voluntary standards are additional drivers for using metered data.

2.2.1 Legislative Drivers

There are several legislative acts that require metering of energy and water resources at Federal facilities. The specific metering requirements in these acts are based on the idea that the data provided by the meters (and its subsequent analysis and actions) will greatly help sites (and therefore agencies) reduce their energy use and costs. Beyond legislation, motivation to consider the application of meters is also provided in organization policy for energy efficiency and/or sustainable operations, as well as through the efforts of the local utility companies looking to better manage or reduce their customer loads on an increasingly constrained electric grid.

Table **2-1** presents a summary of Federal metering requirements by establishing authority. Appendix B provides additional details on the legislative requirements.

Table 2-1. Federal Metering Legislative Drivers

	Establishing Authority		
	Energy Policy Act of 2005	Energy Independence and Security Act of 2007	Executive Order 13693: Planning for Federal Sustainability in the Next Decade March 19, 2015
Metering Requirements Section	Section 103: Energy Use Management and Accountability	Section 434 (b): Metering	Section 3: Sustainability Goals for Agencies
Applicability	All agencies	All agencies	All agencies
Key Requirements	- All buildings - Where practicable - By October 1, 2012 - Meter electricity - Hourly interval data (minimum) collected at least daily	- Not later than October 1, 2016 - Each agency shall provide for equivalent (as to Section 103 EPAct 2005) metering of natural gas and steam - Metering of water is encouraged to obtain data to support water intensity reduction goals	- By fiscal year 2018, all data centers will have advanced energy meters installed and the data will be monitored (as to Section (a)(ii)(B)) - Install water meters and collect and use building and facility water balance data to improve water conservation and management (as to Section (f)(ii))

2.2.2 ANSI/ASHRAE/IES Standard 90.1-2013[1]

The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) publishes guidelines and standards for building system design, energy efficiency, sustainability, and other related topics. The standards are frequently codified by states and influence requirements for new construction, major building system projects, and equipment replacement projects. The most recent version of ANSI/ASHRAE/IES Standard 90.1-2013, *Energy Standard for Buildings Except Low-Rise Residential Buildings*, incorporates a number of sub-metering-related requirements for all buildings or building additions over 25,000 ft^2. Buildings with multiple tenants have some more restrictive requirements. The new standard states that measurement devices shall be installed to monitor the electrical energy use for total electric energy; heating, ventilating, and air-conditioning (HVAC) systems; interior lighting; exterior lighting; and receptacle circuits *separately*. In addition to sub-metering electrical energy, the ASHRAE standard requires measurement devices be installed to monitor the building use of other energy resources supplied by a utility, energy provider, or plant that is not within the building, including natural gas, fuel oil, propane, steam, chilled water and hot water. The electrical energy usage for all separate loads shall be recorded a *minimum* of every 15 minutes. Other fuel sources shall be recorded a minimum of every 60 minutes (ANSI/ASHRAE/IES 2013).

2.2.3 ANSI/ASHRAE/USGBC/IES Standard 189.1-2011[2]

ANSI/ASHRAE/USGBC/IES Standard 189.1-2011, *The Standard for the Design of High-Performance Green Buildings* (ANSI/ASHRAE/USGBC/IES 2011) incorporates additional metering and sub-metering requirements for building energy (see Table 7.3.3.1A) and water (see Table 6.3.3A) resources that extend beyond the ASHRAE Standard 90.1-2013, including electricity, natural gas, district energy, geothermal energy, onsite renewable electric energy, onsite renewable thermal energy, potable water, municipally

[1] ANSI refers to the American National Standards Institute and IES refers to the International Electrotechnical Commission.
[2] USGBC refers to the U.S. Green Building Council.

reclaim water, and alternative water. Within the building, ASHRAE Standard 189.1-2011 identifies a number of sub-metering requirements for various energy (Table 7.3.3.1B) and water (Table 6.3.3B) end uses and tenants.

2.2.4 ISO 50001 – Energy Management

The International Organization for Standards' (ISO) ISO 50001 is based on the ***Plan – Do – Check – Act*** management system model of continual improvement of the energy management system (EMS). The purpose of this standard is to enable organizations to establish the systems and processes necessary to improve energy performance. The ISO 50001 model provides a framework for organizations to:

- Develop a policy for more efficient use of energy
- Fix targets and objectives to meet the policy
- Use data to better understand and make decisions about energy use
- Measure the results
- Review how well the policy works, and
- Continually improve energy management.

In the context of energy management, the Plan – Do – Check – Act approach is illustrated in

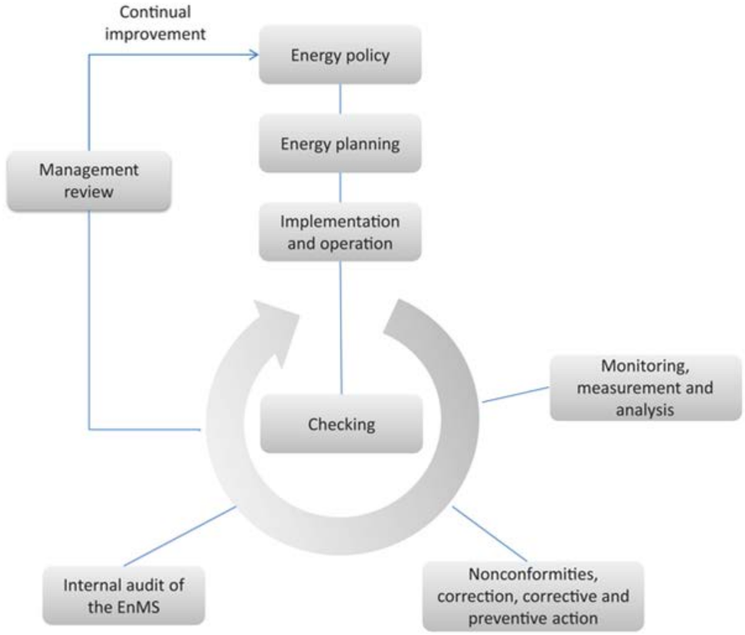

Figure 2-1:

- Plan: Conduct the energy review and establish the baseline, energy performance indicators, objectives, targets and action plans necessary to improve energy performance in accordance with the organization's energy policy.
- Do: Implement the energy management action plans.
- Check: Monitor and measure processes and the key characteristics of operations that determine energy performance against the energy policy and objectives, and report the results.

- Act: Take actions to continually improve energy performance and the energy management system.

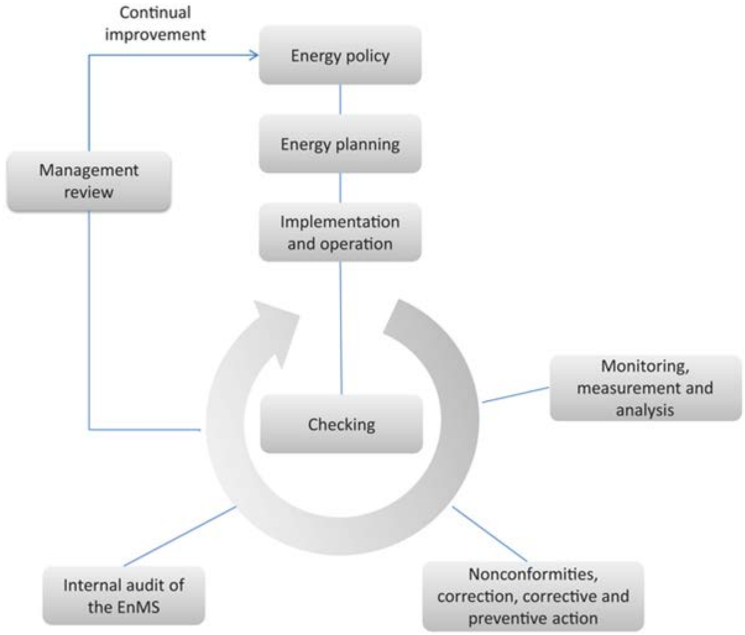

Figure 2-1. Energy Management System Model for ISO 50001

Metering plays a critical role in the Check portion of the ISO 50001 Plan – Do – Check – Act model. Energy metering should be fully integrated into the overall energy management system, including energy policy, energy planning, implementation, and operation. Metered data provides a foundation of support throughout the ISO 50001 continual improvement cycle. For example:

- How can the metering system be improved to further identify energy saving opportunities or prevent losses?
- Do the current energy performance indicators need to be updated to identify further energy savings?
- Are local site staff aware of the benefits achieved through metering? Are headquarter staff aware of the benefits realized?
- Is there a way to better share the metered data that will drive additional staff engagement, resulting in more savings?
- Are we taking advantage of lessons learned from other metering programs? Are we sharing our lessons learned to the benefit of others?

Similar to other ISO management system standards, certification to ISO 50001 is possible but not a requirement.

Chapter 3 Metering Planning

When managing multiple buildings, metering planning is essential to ensure the metering, data management, and data analysis investments are made where they can offer the greatest impact. A successful metering program will:

- Provide appropriate and accurate data in a timely manner
- Complete data analysis in a timely manner
- Provide data and analysis results to users in a format that leads to actions
- Identify funding resource requirements necessary to establish and maintain an effective metering system
- Operate continually and effectively on a daily basis.

The effective analysis of data from a metering program and the subsequent actions that follow, will lead to utility use and/or cost savings.

The application of the data, or, more correctly, the effective analysis of data and the subsequent actions that follow, will lead to utility use and/or cost savings and continued effective operation of the metering system and program.

3.1 Metering Plan

Metering implementation plans offer a planning mechanism to assist organizations with metering decisions. Developing a metering plan establishes a metering framework for building and site energy and water utility managers to follow. Five-year metering plans should include all of the required elements identified in the Federal Building Metering Guidance, paraphrased below. These elements can be adapted to plan for any portfolio of buildings:

- Metering implementation plan for each individual major function within its jurisdiction
- Prioritization and locations of metering implementation efforts that consider the resources required to meter the *appropriate* buildings and a path forward for buildings that are not expected to be metered within the planning cycle
- Anticipated milestones and timeline for the five-year planning cycle
- Estimated funding and personnel required for implementation
- Description of energy tracking systems that are made available to facility managers
- Identify titles of personnel responsible for analyzing the meter data
- Description of how standard meter data will be incorporated into energy tracking and benchmarking systems on a monthly basis, including how it will be entered into Energy Star Portfolio Manager
- Explanation of how Green Button data will be used where available
- Description of how known information technology and cyber security barriers are being addressed
- Description of how known implementation barriers are being addressed (e.g., a risk management plan)
- Documentation of ownership by management via signatures of key personnel.

Metering plans can be used to:

- Document metering program objectives
- Describe the training and retraining requirements for metering and data analysis
- Document the metering system design
- Identify data collection, processing and analysis needs
- Define performance validation strategy including recovery procedures for when a meter stops working or is deemed out of calibration and data are lost or considered questionable.

3.2 When to Meter

The first step in developing a metering plan for a portfolio of buildings is to identify which buildings and end uses need to be metered. Some buildings are expected to use such a small amount of energy or water that metering may not offer any opportunities to reduce resource use. Every building is different and thus setting a standard for metering will not address every conceivable situation. Federal buildings are considered "appropriate" for energy or water metering unless identified for exclusion within the Federal Building Metering Guidance. The criteria were developed based on likelihood of the use of energy or water meters offering cost-effective energy and water efficiency opportunities and may be useful to other building portfolio managers. Questions to ask before installing meters include:

- Will the building continue to be part of the portfolio in five years?
- For leased properties, do you pay the utility bills or are they embedded in the rent?
- Does the building have an energy-consuming heating or cooling system or significant process loads?
- Based on the building size and function requirements set forth in the guidance is the building appropriate for metering?

The decision to meter is easier the more a building manager knows about the building operations, but when in doubt add it to the list of building to meter and prioritize when the investment can be made and will be useful.

3.3 Metering Prioritization

In recognition that organizations may have resource constraints and that not all meters can be installed and connected instantaneously, prioritization criteria are needed that take into account the unique utility uses and costs of a building and any requirements applicable to the building. The Federal Building Metering Guidance outlines a prioritization approach that can be used for any organization's buildings portfolio. At the highest level, the guidance recommends the following priorities for energy and water meters:

1. New construction and major renovations [Energy & Water]
2. Covered facilities[3]
    a) Self-generation of electricity and steam [Energy]

[3] In the Federal sector a "covered facility" is one that has been identified as one that contributes significantly to an agency's total energy use. See Appendix A for the official definition.

b) Data centers [Energy]

c) Internal/Well supply lines [Water]

d) Distribution lines – largest first [Water]

e) Energy/Water-intensive buildings/facilities [Energy & Water]

f) Buildings greater than 10,000 ft^2 [Energy & Water]

g) High Performance and Sustainable Buildings[4] [Energy & Water]

h) Remainder of buildings – largest first [Energy & Water]

3. All other buildings (same priority as above).

Developing an organization-level building list with key building characteristics could facilitate tracking the priority for buildings that are deemed appropriate for metering. Building characteristics of interest include the criteria for determining whether a building is appropriate for metering, the recommended prioritization criteria described above, and additional information related to an organization's metering program objectives. Figure 3-1 offers an example of a Federal agency building building list assessed for appropriateness to meter. In this example, five buildings are deemed not appropriate to meter for water and four buildings are deemed not appropriate to meter for energy.

Function	Location (City, State)	Razed or Conveyed before 2020	Owned or Leased	Pay the Utility Bill?	HVAC System	Sells Electricity Commercially	Size (Square Footage)	Water Use (gal/day)	Water Meter Appropriate ?	Energy Meter Appropriate?
Office	Richland, WA	No	Owned	Yes	Yes	No	**4,500**	N/A	**No**	**No**
Laboratory	Berkeley, CA	No	Owned	Yes	Yes	No	25,750	N/A	**Yes**	**Yes**
Office	Richland, WA	No	Owned	Yes	Yes	No	55,250	N/A	**Yes**	**Yes**
Laboratory	N. Chelmsford, MA	No	Owned	Yes	Yes	No	250,455	N/A	**Yes**	**Yes**
Office	Fernald, OH	No	Owned	Yes	Yes	No	150,750	N/A	**Yes**	**Yes**
Warehouse	Albuquerque, NM	No	Leased	Yes	**No**	No	19,560	**650**	**No**	**No**
Dormitories	Randolph, TX	**Yes**	Leased	Yes	Yes	No	10,500	N/A	**No**	**No**
School	Fernald, OH	No	Owned	Yes	Yes	No	20,150	N/A	**Yes**	**Yes**
Service	Berkeley, CA	No	Leased	Yes	Yes	No	7,500	**900**	**No**	**Yes**
Steam Plant	Dayton, OH	No	Owned	Yes	N/A	No	N/A	N/A	**Yes**	**Yes**
Hospital	Chicago, IL	No	Owned	Yes	Yes	No	75,890	N/A	**Yes**	**Yes**
Chilled Water Plant	Offutt, NE	No	Owned	Yes	N/A	No	N/A	N/A	**Yes**	**Yes**
Data Center	Grand Junction, CO	No	Owned	Yes	Yes	No	175,650	N/A	**Yes**	**Yes**
Office	Grand Junction, CO	No	Leased	**No**	Yes	No	15,000	N/A	**No**	**No**
Food Service	San Antonio, TX	No	Owned	Yes	Yes	No	1,585	N/A	**Yes**	**Yes**

Figure 3-1. Example Building List

The next step would be to prioritize the remaining eleven buildings for meter installation. When considering selected prioritization criteria for energy, Figure 3-2 provides an example of how an organization could document its metering prioritization. The highest energy meter priority is the office building planned for a major renovation. The second highest priority is the steam plant because it generates power and is a "covered facility". The third highest priority is the data center. There are

[4] In the Federal sector, High Performance and Sustainable Buildings are ones that are complying with defined green building requirements. See Appendix A for the official definition.

multiple energy intensive buildings that are also "covered facilities". The priority for those buildings was set by looking at building size and whether the buildings were aiming to be High Performance and Sustainable Buildings. The final two buildings on the list are not part of the "covered facilities" list and are prioritized based on building size.

Function	Location (City, State)	Major Renovation	Covered Facility	Self-Generation	Data Center	Energy Intensive	>10,000 square feet	HPSB	Size (Square Footage)	Meter Installation Priority
Laboratory	Berkeley, CA	No	Yes	No	No	Yes	Yes	No	25,750	6
Office	Richland, WA	Yes	No	No	No	No	Yes	Yes	55,250	1
Laboratory	N. Chelmsford, MA	No	Yes	No	No	Yes	Yes	No	250,455	4
Office	Fernald, OH	No	Yes	No	No	No	Yes	Yes	150,750	9
School	Fernald, OH	No	No	No	No	No	Yes	No	20,150	10
Service	Berkeley, CA	No	No	No	No	No	No	No	7,500	11
Steam Plant	Dayton, OH	No	Yes	Yes	No	N/A	N/A	N/A	N/A	2
Hospital	Chicago, IL	No	Yes	No	No	Yes	Yes	No	75,890	5
Chilled Water Plant	Offutt, NE	No	Yes	No	No	Yes	N/A	N/A	N/A	8
Data Center	Grand Junction, CO	No	Yes	No	Yes	Yes	Yes	No	175,650	3
Food Service	San Antonio, TX	No	Yes	No	No	Yes	No	No	1,585	7

Figure 3-2. Example of Energy Meter Prioritization

Organizations may have a greater number and more diverse set of buildings to prioritize. It may be beneficial to have additional criteria to further differentiate the priorities such as:

- Facilities, buildings, or sub-systems that have a high likelihood of immediate energy and water savings to create a positive impression of the metering program and to generate funds for reinvestment
- Facilities, buildings, or sub-systems with the highest energy or water costs
- Facilities, buildings, or sub-systems being charged the high rate tariffs
- Facilities, buildings, or sub-systems located closest to the central data acquisition receive the first meters, which allows for the communication pathway to grow and hopefully remain stable.

Metering program objectives may reveal other potential prioritization criteria.

3.4 Metering Program

While the ultimate objective of a metering program is to reduce utility use and/or costs, how this is done will depend on how the metered data are used. Some of the more typical uses include cost allocation among tenants, bill verification, demand side management, and energy use diagnostics.

3.4.1 Establish Program Objectives

Metering objectives should reflect an organization's requirements and specific interests. Examples of possible objectives include:

- Identify system-specific operational efficiency opportunities, e.g., upgrade fume hoods in all laboratory space or downsize irrigated landscape at all buildings by 50%

- Fully enable energy and water bill allocation throughout an entire facility
- Effectively manage electric loads to minimize costs under a time-based rate schedule
- Identify equipment malfunction or impending malfunction, such as in critical use facilities like hospitals or data centers.

Table 3-1**Error! Reference source not found.** has example questions to facilitate identifying organization metering program objectives.

Table 3-1. Example Questions for Developing Metering Objectives

Cost				
	What are the annual utility costs for your facility?	**Low**	**Med**	**High**
	Has utility price volatility been, or could it be, an issue?	**Yes**	or	**No**
	Are there operations actions that can help reduce utility costs?	**Yes**	or	**No**
	Are there utility rate opportunities that would reduce costs?	**Yes**	or	**No**
	Does demand response impact energy cost?	**Low**	**Med**	**High**
Age				
	Is the building or equipment in need of replacement of major upgrade?	**Yes**	**or**	**No**
Ease of Replication				
	Are there local, regional, national, or agency initiatives to address specific utility usage issues (e.g., water management)	**Yes**	or	**No**
	Do like building types use similar amounts of energy?	**Yes**	or	**No**
	Do buildings have unique operating requirements?	**Yes**	or	**No**
	How many energy and water utilities are involved?		**#**	
	What resources are required to analyze and benefit from the energy data?		**$**	

The organizations metering implementation plan should be a living document for planning, budgeting and implementation. Agencies should consider updating the organization's metering implementation plan at least every five years or more frequently if there is a need to revisit assumptions as data are analyzed and actions are taken.

3.4.2 Identify Staffing, Funding, Information Technology, and Data Needs

Staffing resources needed to install, maintain and, operate a metering system, as well as analyze the metered data, are critical to a successful metering program. Staffs need to be appropriately trained and afforded the necessary time to operate and maintain the metering equipment and system. Training and time need to be allotted for analysis of the metered data in order to gain the benefits of the metering system.

To develop a metering program, an organization needs to understand what funds are available, when they will be available, how additional funds can be attained, and how the funds can be used. Funds are needed to prioritize the building inventory, specify the equipment needed, purchase and install the equipment, connect the equipment to a data collection and management system, purchase or develop analysis tools, and develop and maintain the staffing resources described above.

The value of a metering program lies in communicating data so that action can be taken. Security requirements vary widely across organizations and are becoming more rigid. In general, information technology (IT) staff should be asked to participate in the development of the metering plan to determine whether there are limitations on the type of metering and communication equipment that can be used. Cyber security concerns will likely need to be addressed regarding whether the data can be transmitted over existing network systems, or if a separate communication system will be required.

Starting with the end in mind is useful in metering planning, particularly when considering anticipated data needs. By considering desired outputs and actionable information at the outset of metering planning, the system development and planning will become more focused. Table 3-2 presents the types of data required to support various water metering approaches.

Table 3-2. Example Water Data for Analysis

Goal	Metering Points	Data Interval	Minimum Update Rate
Cost Allocation	Water and wastewater for each tenant or organization to be billed	As frequent as required to support utility rate/billing requirements	Monthly
Utility Rate Analysis	Water and wastewater	As frequent as required to support the utility rate analysis	Monthly
Site-level Water Consumption Tracking	Water at the master-meter level	Daily or as frequent as required to support the analysis	Monthly
Building Benchmarking/Performance	Water for each facility to be included in the analysis	Daily or as frequent as required for the analysis	Monthly
Water System Diagnostics	Water at the system level (e.g., irrigation, cooling tower)	Suggestion: • 15 minutes	Daily More frequently for real-time analysis and reporting
Monitoring and Verification (M&V)	Water at the system level	As frequent as required to support M&V requirements; hourly may be sufficient	Monthly
Leak Detection	Water at zones in the distribution system	Hourly or as frequent as required to support the analysis (at low water use times, e.g., night-time)	Daily
Management Reporting Requirements	Water: potable and non-potable	Depends on reporting requirements	As required for reporting frequency

Table 3-3 presents the types of data required to support various building electricity metering approaches. Not included in this table are the data needs for onsite load shedding and utility-sponsored demand-response programs. In both of these programs, metering should be provided to accurately quantify energy use at the system level or at the point of use being affected.

Table 3-3. Example Electric Data for Analysis

Goal	Metering Points	Data Interval	Minimum Update Rate
Cost Allocation	Demand and energy for each tenant or organization to be billed	As frequent as required to support utility rate	Monthly
Load Aggregation	Demand and energy for each facility to be included in the aggregation	As frequent as required to support utility rate structures	Monthly
Utility Rate Analysis	Demand and energy	As frequent as required to support utility rate structure	Monthly, or as required to support analysis
Power Quality – typically appropriate to critical equipment requirements	Suggested: Amps, volts, reactive power, harmonic data	As frequent as required for waveform capture	Daily
Energy System Diagnostics	Depends on types of diagnostics, use demand and energy for consumption-related diagnostics	Suggestions: • 15 minutes • Shorter intervals for end-use diagnostics involving cycling analysis	Daily More frequently for real-time analysis and reporting
Monitoring and Verification (M&V)	Demand and energy	As frequent as required to support M&V requirements; hourly may be sufficient	Monthly
Design Information	Demand and energy	Hourly or daily	As required for design projects
Management Reporting Requirements	Depends on reporting requirements; demand and energy for consumption-related reporting	Depends on reporting requirements	As required for reporting frequency
Reference: AEC 2003			

3.4.3 Estimate Staffing and Resource Requirements

To achieve any value from metering systems there needs to be well-defined commitments in the areas of data usage and system maintenance. Each of these entails a different skill set and resulting resource requirements; both necessitate a commitment of time and resources for the program to be successful. Assessing the costs to perform data analysis and system maintenance is difficult and highly dependent on the specifics of the system. The number and type of meters used will impact maintenance requirements, and decisions on how to receive and process data will impact analysis costs.

Data Analysis. Prior to receiving metered data, it is recommended that a meter data management system be in place. These systems can be site-generated spreadsheet/database tools or commercially available software packages. Whatever the mode, it is important to automate as much of the data access and analysis functions as possible to minimize future data management costs.

Once the metering system is in place, data will accumulate very quickly. For example, a site with 50 meters, reporting 15-minute energy data, will result in 4,800 data points per day, 33,600 data points per week, and over 1.7 million data points per year.

To estimate resource commitments for data analysis, consider the following example:

- **System assumption**: A total of 50 building-level and end-use meters serving electric, natural gas, and steam loads.
- **System analytical outputs**: Daily plots of energy use presented as times-series metrics in engineering units in a dashboard environment.
  - Daily time series electric, natural gas, and steam plots
  - Alarm sets enabled to highlight out-of-range values
  - Exception report comparisons, day-of-the week, month-of-the year
  - Drill-down capability to 15-minute reporting
- **Resource commitments**: System training (one time)
  - Staff training on system design, access, and applications: 1-2 days
  - Staff access and system navigation mastery: 1 week
  - Daily access for system review and assessment: 2 hours
- **Resource commitment**: System use (weekly for 50-meter system)
  - Commitment for data access, review, and assessment: 10 hours/week

Notes: The initial set-up of the analytical outputs will take additional time to develop and make useful for your organizations analysis needs. Once developed, the analytical outputs can be re-used. Actions resulting from data assessments will require additional time/resources.

System Maintenance. With the advent of solid-state components and meters, routine system maintenance has been reduced – but not eliminated. Maintenance requirements will vary with meter type and should be included in standard preventive maintenance routines.

- **Resource commitments**: System training (one time)
  - Staff training on metering technology and function: 2-4 hours per meter type
- **Resource commitment**: Functional inspections (monthly for 50-meter system)
  - Monthly commitment for preventive maintenance activities: 5 hours/month

Note: Monthly inspections do not include manufacturer-recommended calibration activities.

3.4.4 Special Metering Considerations

The Federal Building Metering Guidance recommended prioritization method emphasizes the need to meter data centers, onsite energy generation, and other energy and water intensive buildings/facilities. This section uses data centers and onsite energy generation as examples of special metering considerations that may exist within an organization.

Data Centers – The energy use associated with data centers has increased markedly since 2000. That increase will continue in the future as a result of expanding facility automation and equipment upgrades that add new capabilities and create the need for additional servers and the space to house them. Power density and the effective cooling are fast becoming defining issues for the data center operators and energy managers. Thus, the need to improve energy efficiency can no longer be ignored.

While equipment manufacturers are responding to these concerns with equipment that has greater computing capability with less power input and more efficient cooling systems, the need for additional cooling capacity will still be required. This will require more concerted effort to meter energy consumption and ensure available cooling capability will be available. While some data centers are stand-alone buildings, a majority of data centers are distributed through existing buildings to meet individual user needs; others are a major portion of a larger building that serves the entire site.

Onsite Generation – There has been an increased emphasis on the need for onsite generation of power and solar thermal energy to both reduce the nation's dependence on foreign oil and increase energy security. As a result, there has been an increase in the assessment, design, and implementation of various onsite generation resources, including, but not limited to, fuel cells, renewable technologies (solar hot water, solar photovoltaic (PV), wind power, geothermal power, biomass, and methane gas), and siting of combined heat and power systems. This will require that advanced metering systems are used to capture time-interval data on the amount of energy being generated.

3.5 Metering System Costs

Metering system costs vary widely for a number of reasons: equipment specifications and capabilities, existing infrastructure, site-specific design conditions, local cost factors, etc. For this reason, this guide does not present specific cost estimates. Instead, we identify the main cost components that should be addressed when developing a metering cost estimate.

The metering cost estimate can be separated into three main categories: capital, labor, and recurring costs.

- **Capital** refers to the cost of the meters and all materials required to support their installation:
  - ***Meter purchase cost***. The purchase price depends on the required features selected such as accuracy, memory, and mounting.
  - ***Ancillary devices***. Electric meters require current transformers (CTs), potential transformers (PTs) and safety switches. These devices may be built into the meter or can be specified separately. Natural gas and steam meters may require filters or strainers, temperature and pressure compensators, flow straighteners, and straight pipe runs. These devices affect design, practicality, cost, and may influence the type of meter that can be specified for a given application.

How Much Do Meters Really Cost?

Meter costs cover a range and are affected by a number of variables including the type of metering, functionality, accuracy, communications, storage requirements, unique applications and installation requirements. Coupled with the rapid evolution of metering products available in the marketplace, it is not practical to provide cost estimates in this guide; instead, system planners and designers are encouraged to contact metering equipment vendors, as well as network with other system planners and designers to tap into their experiences.

Of particular interest is the cost of an advanced electric metering system and the on-going cost to maintain it. Reported information indicates the cost of a meter, associated communication equipment, required software, and installation activities range between $1,900 and $5,400. On-going cost for a single meter could range from $10 per month to almost $50 per month (Heller 2005). More recent information regarding installation of electrical meters at Federal sites indicates an average cost of $2,000 per meter. Other information indicates a range of $1,500 to $2,500 per meter based on installed costs (Lewis 2010).

  - ***Communications module***. There are a number of types of communication methodologies that can be incorporated into meters. Communication may be wired or wireless, analog or digital, one-way or two-way, periodic or continuous. The meter's communication module may include a handheld reader communicator, telephone modem, cellular modem, radio transceiver, power line carrier modem, Ethernet modem, Wi-Fi, hard wire (RS232 or RS485), or supervisory control and data acquisition (SCADA) interface. Communications modules are usually specified with the meter.
  - ***Miscellaneous supplies***. Small compared to other hardware line-item costs, miscellaneous supplies include items such as wire, conduit, junction boxes necessary to complete the installation. Also consider the power supply to the meter and data transmission system.

- **Labor** covers the time involved for a crew to install all of the hardware, connect the communications module, perform operational testing, and inspect the functionality of the metering system. Examples of variables in the labor costs include the type of meter being installed (utility being metered and if the meter is intrusive or non-intrusive), service shutdowns that may need to be accomplished during off-hours, and trenching requirements for running cable.

- **Recurring costs**: Recurring costs are planned regular costs that support the ongoing operation of the meter/metering system.
  - ***Monthly communications fees***. These fees will vary based on the communications method selected.
  - ***Data collection and storage***. Computer hardware and software will require some level of maintenance and upkeep.
  - ***Data analysis***. Data needs to be analyzed on a regular basis (daily and/or weekly) with findings and recommendations issued.
  - ***Operation and maintenance***. Meters require periodic calibration and testing.

3.6 Metering Savings Potential

The use of energy and water data has been shown to result in changes to operations and maintenance practices, and the identification of projects that improve the energy efficiency of building equipment and systems. By implementing these changes, buildings have shown efficiency improvements of 10-20%. Table 3-4 presents metering-related savings ranges based on different uses for metered data. Typically only success stories are published, thus the published metering savings ranges may not be representative of the typical result. Savings for a specific building will vary based on the current health of the building's systems and the ability to successfully implement, measure, and sustain a positive change. If no action is taken as a result of the metered data analysis, then no lasting energy reduction would be expected.

Table 3-4. Metering Savings Ranges

Summary	Metering-Related Savings
A pilot program from the California Energy Commission on 25 California campuses (greater than 40 buildings) demonstrated energy use reduction through the identification and correction of faulty system operations with the use of permanent monitoring data-streams.	10% - *Reduced energy use* 5% - *Peak-period demand*
EnerNOC found that expert building management combined with sufficient building technology can lead to significant savings opportunities.	11-20% - *Reduction in the energy consumption visible from the monitoring data-stream*
According to Portland Energy Conservation, using the measurements of energy use to diagnose equipment malfunctions and upgrades, yields savings in mission critical and commercial office buildings.	12-20% - *Reduced energy use*
Shortly after implementation, the Army's Meter Data Management System identified simultaneous heating and cooling in the same building. Once corrected, the finding demonstrated significant energy reduction.	60% - *Reduced energy use*

Even greater savings can be realized when the data are used to support actions to optimize building operations. This includes:

- Verifying or re-tuning building and/or equipment startup and shutdown times.
- Actively managing electric demand to minimize the impacts of time-based demand charges.
- Determining existing and on-going operating conditions for use in building commissioning studies.
- Continued verification of implemented building commissioning activities.

3.7 Interval Data and Energy Profiles

Utility interval data is time-stamped utility usage values recorded at regular periods. The value of interval data is the consistent recording of incremental use (e.g., 15 minute) offering increased resolution and diagnostic capability. Advanced meters and smart meters are capable of at least hourly intervals and many record data at the utility-standard 15-minute interval. Chapter 5 on data analysis and use offers a variety of time-series data analysis tools that can further support the understanding of energy and water use.

Building-level interval data contain a wealth of information on building energy use, both real-time and over a duration (e.g., seasonally, monthly, weekly, or daily). Interval data can be graphically represented and used to identify energy use peaks and spot trends that indicate problems such as equipment coming online earlier or running longer than expected. (Better Bricks 2011)

Figure 3-3 presents a daily demand profile for a commercial office building generated from the analysis of hourly interval data. The daily profile is divided into three regimes of energy use:

- Energy use that occur 24-hours per day, with a similar pattern each day (some variation on weekends) is defined as ***base load*** energy use. This minimum energy use occurs when the building is both occupied and unoccupied and is usually made up of security lighting, ventilation, and plug loads that operate continually.
- Energy use that tracks occupancy is referred to as the ***variable load***. These loads are typically proportional to occupancy or occupancy schedules and are made up of lighting, computers, office equipment, and other plug loads and convenience equipment (e.g., coffee makers and other cooking equipment).
- The final regime of energy use is the ***weather-dependent load***. This energy use is proportional to outside air temperature and humidity, solar heat gain, and has notable seasonal variability.

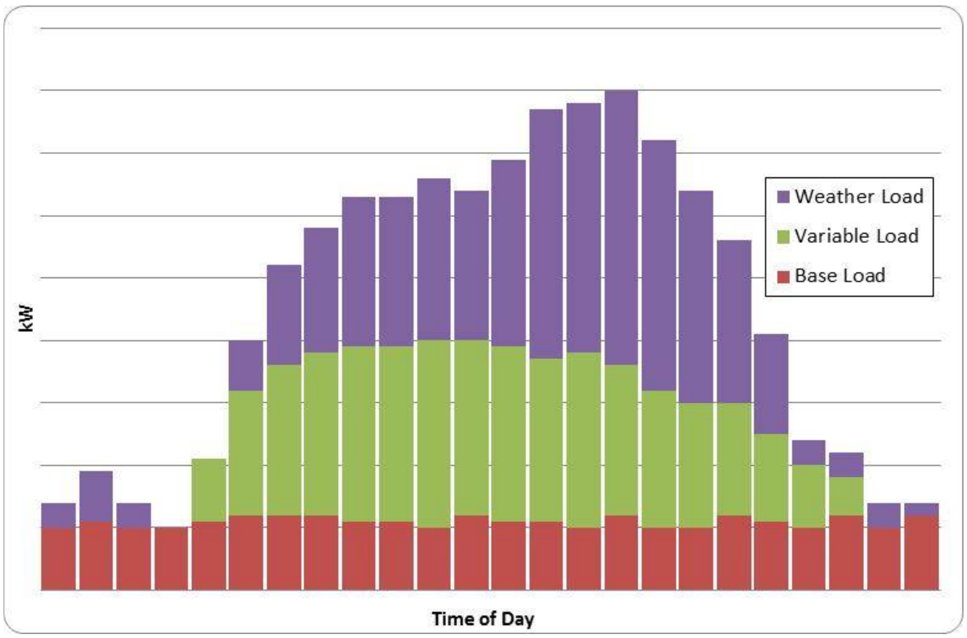

Figure 3-3. Hypothetical Commercial Building Daily Energy Load Profile

Daily, weekly, and monthly interval load data graphs can be generated to identify operational issues. These graphs are useful in verifying expected profiles of weekday versus weekend and holiday energy use; heating, cooling, and shoulder season energy use; and validating the relative shares of base load, variable load, and weather-dependent loads. It is recommended that load profiles be analyzed by relevant practitioners on a regular basis. Questions to be asked with these data include:

- When do peak loads occur?
- Is the base load energy use within expectation?
- Does the overall profile match operating hours?
- How does weather affect total energy use?
- Are HVAC controls set properly to take advantage of conditions and temperature reset opportunities?
- Are seasonal variances within expectation?

- Is trending data over time drifting higher?
- What are the causes of out-of-range values?
- What opportunities are there to reduce or change the shape of the profile?
- How does this profile and energy use compare with similar buildings?

Seasonal loads will have characteristic shapes depending on the building type, age, hours of operation, and fuels used. If natural gas is used as a heating fuel, similar interval data should be obtained and profiles developed. Seasonal comparisons should be made with knowledge of variance in weather conditions; weather normalization is recommended if seasonal comparisons are to be made.

3.8 Data Collection, Loss, Tracking, and Security

A metering plan should address data collection (e.g., how, how frequent, quality control), data loss (e.g., how to minimize and mitigate), project tracking, and data security.

3.8.1 Data Collection

Daily collection (with review) assures that any communication and/or metering issues are identified within that 24-hour period, thus minimizing the loss of data beyond that window. A daily data window is a convenient way to perform various processing and benchmarking routines for which energy/facility managers can review and make decisions. For hourly data retrieval (recommended where possible), these data can be aggregated-up to present the daily statistics and benchmarks. Data quality checks (data receipt, within range, and complete) are easily implemented within the daily window. For systems reporting hourly data, it is recommended that these checks be implemented at the reporting interval.

3.8.2 Data Loss

Whether by communications issues, metering equipment malfunction, or data processing error, data loss is an inevitable outcome for any reporting system. Typical causes of data loss include:

- ***Data transfer interruption***. Lapses in data transmissions can emanate from a number of causes and will depend on the mode of data transmission. Common causes are:
  - Loss of power to building/meters, communications nodes, or data processing end-point
  - Loss of phone connection (service loss, advertent/inadvertent disconnect)
  - Radio frequency (RF) interference (numerous potential sources) on wireless transmissions
- ***Data corruption***. While less common than interruption, data corruption is also mode dependent. Corruption can be manifest as no data, partial data, or irrational/suspicious data. Causes of corrupt data can be metering/sensor errors, communications interference (noise on lines or RF), or data receiving errors.
- ***Data interception***. In today’s world of encrypted data transfer, the concept of successful malicious data interception of standard building energy-use information is improbable. However, acknowledging best practices for data transfer security, it is recommended that all transfers be encrypted and system “hardness” is commensurate with perceived value and uses of these data.

To mitigate the impacts of data loss, it is recommended that all automated data posting systems and/or database processing functions be alarmed to identify lapses or out-of-range values. These alarms should continuously operate and be forwarded to relevant parties and/or highlighted on system dashboards.

Once identified and corrected, the focus shifts to understanding the magnitude of data loss and any corrective action necessary to the data set. ASHRAE Guideline 14-2002 offers two methods for handling missing data:

- ***Substitution***. This method requires additional information or data specific to the lost points. Missing data can be substituted with rational fixed values, calculated average values, or values interpolated from known points.
- ***Omission***. If missing data are more significant than substitution procedures will reasonably accommodate, these points and the resulting analysis can be omitted. While data gaps can be challenging, large data-set substitution may introduce unintended biases and other inaccuracies far more problematic than the missing data.

There are many methods that can be taken to address data loss. Regardless of the method chosen, it is important to document the modified records and the assumptions used to address the data gaps.

3.8.3 Data Security

Metered data security is currently being driven by the proliferation of smart meters and developments with the smart grid. Building off the data security and transfer protocols developed for financial and other internet transactions, metered data security is best implemented at the point of data collection (i.e., at the meter).

While there are a number of evolving data encryption protocols and technologies for secure data transfer such as public key infrastructure (PKI), which were developed to both protect data and authenticate the sender, this field is largely vendor driven. The National Institute of Standards and Technology (NIST) Computer Security Division has developed a special publication series focused on information technology security and its collaborative activities with industry, government, and academic organizations.

To help evaluate metering equipment security offerings, consider asking the following questions of prospective vendors:

- How does the meter handle data encryption? What technologies/protocols are used?
- What security features are integral to the meter versus software add-ons?
- How is data security handled between auxiliary components such as radios, routers, and collectors?
- What happens in the event of a security breach?
- How are security upgrades handled?
- How is your system certified?

Ultimately, data security will be a function of the meter and communications system selected. Site IT staff need to be part of this decision to assure any solution is appropriate, relevant, and compatible with existing IT security systems.

Chapter 4 Metering Technologies

At the most basic level, all meters track and provide some output related to the amount of resource passing through the meter – electricity, natural gas, steam, water, etc. More sophisticated meters take advantage of additional capabilities including peak demand tracking, power quality measurements, pressure and temperature compensation, or multiple-meter communication for leak detection applications. Appendix C of this guide provides a list of some of the codes and standards that are relevant to metering, metering systems, and communications.

At the most basic level, all meters track and provide some output related to resource use – electricity, steam, water, natural gas, etc.

Metering provides the data that ***when analyzed*** allows the building operations staff to make informed decisions on how to best operate mechanical/electrical, gas, and steam systems and equipment. These decisions will ultimately affect energy and water costs, equipment costs, and overall building performance. Metering can take place at a variety of points within an electrical, mechanical, or water system and can encompass the collection of electricity, natural gas, water, steam or other utility data. The priority of where and what to meter is determined by your metering objectives and should be a focus in your metering plan.

Metering in and of itself saves no energy, water, or dollars. In fact, it costs money to meter, including the purchase and installation of the metering, the communications or meter-reading expense, and the time necessary to process and interpret data analysis. The key to a successful metering program lies in the ability to make use of the metered data.

4.1 Generic Metering Approaches

The four predominant levels of resource metering are one-time or spot measurement (system/sub-system), run-time measurement (system/sub-system), short-term monitoring (system/sub-system/building-level), and long-term monitoring (system/building-level). (EPRI 1996) One-time measurements are useful to understand instantaneous power, short-term energy use, equipment performance, or loading. Run-time measurements are made in situations where hours-of-operation are the critical variable. These measurements are prevalent where an energy-efficiency project has impacted the use (i.e., hours of operation) of a device. Appropriate applications for run-time measurements include the run times of fans and pumps, or the operational characteristics of heating, cooling, or lighting systems. Short-term monitoring is used to verify performance, initiate trending, or validate efficiency improvement. Long-term or permanent monitoring makes use of time-series recording of energy or resource use with the measurements used in long-term trending or performance verification. Long-term measurements can be used for reimbursable resource allocation and tenant billing activities; to measure persistent utility savings; to address variances in weather, occupant behavior, or other operating conditions; or to benchmark the resource use of the building over time. Table 4-1provides a summary of the differences between these different levels of metering. Each level has its own unique characteristics – no one monitoring approach is appropriate for all sensor or meter activities.

The decision of where and what to meter is determined by your metering objectives and should be a focus in your metering plan.

Table 4-1. Summary of Metering Levels

Criteria	One-Time/Spot Measurements	Run-Time Measurements	Short-Term Measurements	Long-Term Measurements
Meet EPAct 2005 & EISA 2007 Requirements?	No	No	No	Yes
Unique Application	• Measure instantaneous power, short-term energy use, equipment performance, or loading	• Measure run times of fans and pumps, or the operational characteristics of heating, cooling, or lighting systems	• Verify performance, initiate trending, or validate efficiency improvement	• Measure variances in weather, occupant behavior, or other operating conditions. • Benchmark the resource use of the building over time
Advantage(s)	• Ease of use • Non-intrusive • Fast results	• Relatively easy of use • Non-intrusive • Useful for constant-load devices	• Can quantify magnitude and duration • Relatively fast results	• Highest accuracy • Can quantify magnitude and duration • Captures most variance
Disadvantage(s)	• Low accuracy • Limited application • Measures single operating parameter	• Limited application • Measures single operating parameter • Requires additional calculations/assumptions	• Mid-level accuracy • Limited application • Seasonal or occupancy variance deficient • More difficult to install	• Most difficult to install and monitor • Time duration for result availability
Cost	Lowest	Low	Mid	High

4.2 The Metering Hierarchy

In many cases, the objective of end-use monitoring is equipment performance, whether to identify inefficiency or validate savings estimates.

Given possible monitoring approaches, there is a hierarchy to consider as you look to maximize your metering value while minimizing your metering cost. Figure 4-1 presents this concept as a function of level of effort and diagnostic capability. This proposed hierarchy starts at the most aggregate level of data collection and processing – the building-level meter. Assuming access to interval data, this meter and resulting data can be diagnostic in identifying trends and variance in building-level performance. These data can be useful in understanding the operation and efficiency of major building systems (e.g., chillers, boilers, air handlers). While the resolution of building-level data may not be fine enough to identify specific operational or efficiency issues, it can often be used to "frame the question" of what equipment/system is performing inconsistently and in need of further exploration.

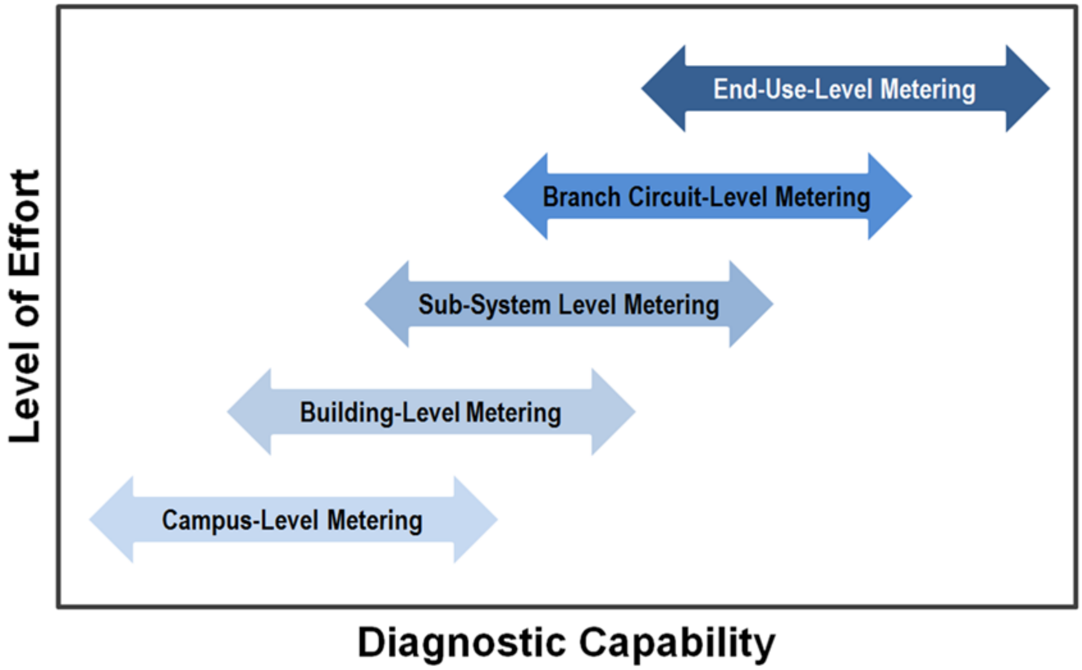

Figure 4-1. Metering Hierarchy

The campus-level meter presents the most aggregate level. A campus-level meter would have multiple buildings associated with it. At the building-level the meter represents the total use for that building for that particular utility. The sub-system level focuses on load centers and aggregations of specific loads. Examples of sub-system monitoring include lighting panels, central boiler plants, or central chiller plants where these systems are to be tracked more closely.

Branch circuit-level metering is within the panel or sub-distribution system and focuses on the monitoring of a specific area of interest. If electrical, this metering level may be to monitor specific electric load panel or group of circuits of interest such as those serving plug loads or other equipment. For natural gas, it may be to segregate individual boiler fuel consumption within a central plant. For water, it may be to segregate the cooling tower or irrigation system from the building-level metering system.

Chillers, boilers, cooling towers, pumps and motors are often end-use metered for performance metrics.

End-use monitoring serves to isolate a particular system or equipment type for detailed study. In many cases, the objective of end-use monitoring is equipment performance, whether to identify inefficiency or validate savings estimates. Chillers, boilers, cooling towers, pump motors, and even lighting are often end-use metered for performance metrics.

4.3 Meter Performance Criteria

Advanced meters measure flow or rate of flow over a pre-determined interval (e.g., gal/h) or for energy they can integrate the rate of energy flow (or power) over a predetermined interval (e.g., kW) to provide time-interval data. Recorded time intervals can be 15 minutes–to match common utility billing meter intervals–or may be other user-specified time intervals (e.g., 1 minute, 5 minute), which can be useful for examining system or equipment performance, trending, and start/stop characteristics. The advanced meters have the capability to use remote or automated meter reading (AMR). Depending on the need, these meters will vary in size, type, output configuration, accuracy, and price.

Common to most meters are rated levels of performance; some of the more universal performance metrics include accuracy, precision/repeatability, turndown ratio, resolution, ease of installation, straight pipe run requirements, on-going operations and maintenance, and costs.

Accuracy – Accuracy is the difference between a measured value and the actual value. No meter is 100% accurate and most manufacturers provide a range of accuracies in their product line—tighter accuracy requirements are typically more expensive and may also be more restrictive to specific applications. Accuracy may be stated in different ways, for example: percentage of scale, percentage of reading, or some other reference. Figure 4-2 illustrates the difference in reading error between accuracy stated as percentage of reading and percentage of scale. Published accuracies often will be referenced to specific calibration procedures (preferably documented through an American National Standards Institute (ANSI) accredited standard) including equipment-traceability to National Institute of Standards and Technology (NIST 2010) equipment and procedures. Within the realm of electric meters, there are multiple accuracy classes for electric meters defined by the National Electrical Manufacturers Association (NEMA) and approved by ANSI (ANSI/NEMA C12.1, ANSI/NEMA C12.20).

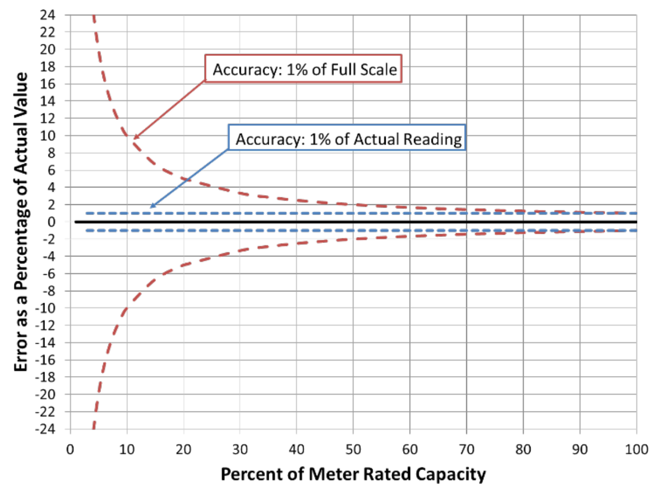

Figure 4-2. Accuracy Statement Comparison

Precision/Repeatability – the precision or repeatability of a measurement entails the ability to reproduce the same value (e.g., temperature, power, flow rate) with multiple measurements of the same parameter, under the same conditions.

No meter is 100% accurate—tighter accuracy requirements are typically more expensive and may also be more restrictive to the application

Turndown ratio – the turndown ratio refers to the flow rates over which a meter will maintain a certain accuracy and repeatability. For example, a steam flow meter that can measure accurately from 1,000 pounds per hour (pph) to 25,000 pph has a turndown ratio of 25:1. The larger the turndown ratio, the greater the range over which the meter can measure the parameter within the accuracy stated.

Resolution – the resolution is the smallest increment of energy consumption or flow that can be incrementally registered by the meter. For example, a water meter designed for a small diameter pipe may be able to provide a resolution of 100 pulses per gallon (or more) as a signal output, but a meter designed for a larger pipe or higher maximum flow may only be able to provide 1 pulse per 100 gallons. Further, a very large flow meter may only be able to provide 1 pulse per 1000 gallons. The metering system may have limitations with regard to peak signal frequency or minimum time between pulses to properly register the data signal. Greater resolution can be useful when recording higher frequency (e.g., 1-minute time interval) data, whereas higher resolution may be completely unnecessary for lower frequency (e.g., 60-minute time interval) data.

The uses for metered electricity data are numerous – ranging from totalized monthly kilowatt hours (kWh) to very sophisticated studies of power quality and harmonics.

Ease of installation – select make-and-model decisions considering size and weight constraints, specific electrical and communications needs, and the overall environment the meter will operate in.

Straight-pipe run requirements – applicable to some types of fluid (gas, liquid and steam) flow meters, straight-pipe run requirements relate to the length of unobstructed straight pipe required leading up to and immediately following the flow meter's location. Obstructions in the fluid flow (such as elbows, tees, filters, valves, and sensor fittings) cause changes in the flow pattern (flow regime and velocity profile). Straight-pipe runs allow the flow pattern to normalize/stabilize making measurements by velocity-type and differential-pressure-type flow meters less prone to measurement error. Straight-pipe run requirements are usually expressed in terms of the number of pipe diameters. The straight pipe requirement is in addition to the length of the meter itself. The straight-pipe run requirements can be reduced with the addition of flow straightening or flow conditioning devices installed upstream.

Ongoing operations and maintenance – the lowest cost metering technology may not be the best choice if it has high associated maintenance costs (e.g., frequent service, calibration and recalibration, sensor replacement). As with most capital purchases, a life-cycle cost approach (including all capital and recurring costs) is recommended for decision making.

Installation versus capital cost – in some situations, the cost to install a meter can be greater than the capital cost; this can be true where system shutdowns are necessary for meter installations, or where significant redesign efforts are needed to accommodate a meter's physical size, weight, or required connection. In these cases, decision makers should consider alternative technologies that may have a higher capital cost but a much lower installed cost. A good example of this is the use of non-intrusive metering technologies (e.g., ultrasonic flow meters) that typically have a high capital cost but often a significantly reduced installed cost. It is recommended that meters be installed with isolation valves or switches making it easier to remove, replace, or service the meter in the future.

4.4 Electricity Metering Technologies

The measure for *energy* consumption of electricity is the watt-hour (W-h), with kilowatt-hour (kWh, equal to 1,000 W-h) and Megawatt-hour (MWh equal to 1,000 kWh) more commonly used. The measure of *power* is the Watt (W), with the common higher magnitude terms being kilowatt (kW, equal to 1000 Watts) and megawatt (MW, equal to 1,000 kW). Power is the rate of energy consumption.

The lowest cost metering technology may not be the best choice if it has high associated maintenance costs.

The measurement of electricity can be accomplished in many ways, using a variety of instrumentation, with varying degrees of accuracy and reliability. The uses for metered electricity data are numerous – ranging from relatively simple totalized monthly kilowatt hours (kWh) to very sophisticated studies of power quality and harmonics. This section discusses the most common electrical metering parameters with the focus on those parameters offering the greatest potential for energy and operational efficiency improvements. Electricity metering can be a complicated and dangerous endeavor; the equipment and procedures discussed here should only be attempted by qualified staff and in compliance with the National Electric Code (NFPA 70 2008) and any local- or agency-specific codes or requirements. There are three major types of utility electricity meters:

Mechanical Meters: This meter type measures electricity use from the movement of a mechanical dial. It is the most mature and has the largest fraction of the installed base. A significant limitation to mechanical meters is the lack of data storage and an ability to electronically communicate. Mechanical meters are accumulators where data are read manually and energy use is calculated as the delta between the current and previous readings.

Electro-Mechanical Meters: The electro-mechanical meter has the same basic operation as the mechanical meter with the addition of some type of optical encoder measuring electricity use as an electronic or pulse output. The electro-mechanical meter is not designed for interval data storage and communication, but can have that function by adding the ancillary communication equipment and AMR system.

Advanced (solid state/digital) Electric Meters: Advanced meters require no moving parts; rather they rely on integrated circuits with current and voltage transformers, on-board memory, and communication technology. Advanced meters have the capability to measure and record interval data and communicate the data to a remote location in a format that can be easily integrated into an advanced metering system. These meters measure and record average electrical demand (kW) over a pre-determined interval—commonly every 15 minutes to match utility billing intervals. With availability and versatility of advanced meters increasing and capital costs falling, these meters are quickly gaining market share and acceptance.

Table 4-2 summarizes the criteria to consider with selecting an electricity metering technology.

Table 4-2. Common Electricity Metering Technologies and Key Criteria

Goal	Mechanical	Electro-mechanical	Advanced
Accuracy	Good	Good	Good
Data Storage	No	Possible	Yes
Data Communication	No	Possible	Yes
Installation Ease	Easy	Easy	Moderate
Diagnostic Capabilities	No	No	Yes
Recalibration Needs	Infrequent	Infrequent	Infrequent
Capital Cost	Low	Low	Medium-High
Installed Cost	Low	Low	Medium-High
Maintenance Cost	Low	Low	Low

Meters should be selected by the professionals that are going to maintain the meters and manage the utility data. When selecting an electricity meter, resist the temptation to purchase a more expensive meter that can capture more data than you are able to process and use. Consider standardization on communication between meters and other data acquisition systems to allow for interoperability. Also consider whether the metering equipment vendor offers a potentially useful data processing capability along with the equipment.

4.4.1 Electric Metering Maintenance

As the world of electronics has shifted from analog to solid state to digital, maintenance of the electronics has been substantially reduced and reliability has increased.

As the world of electronics has shifted from analog to solid state and finally to digital, maintenance of the associated electronics has been substantially reduced and reliability has increased. Environmental conditions play a key part in the longevity and reliability of the components (e.g., temperature, vibration). The current and potential transformers are generally maintenance free, provided they are originally designed for the operational and environmental conditions. The integrity of electrical connections should be checked periodically in accordance with National Fire Protection Association (NFPA), National Electric Code, NFPA 70 (NFPA 70-2008), and manufacturer guidance.

4.4.2 Electric Meter Data Output/Communications Considerations

For the building-level meters, a common energy data output is the calibrated pulse (e.g., pulses/kWh). For more advanced features and data collection, a more advanced communication protocol, such as Modbus, LonWorks, or BACnet may be required. These data are usually stored at the meter in the prescribed time-series format or may be real-time communicated to a data acquisition system that assigns a time stamp. At periodic intervals (at least daily), the data are accessed through one of a variety of communications options. These data are then downloaded to a database for future processing.

4.5 Fluid Metering Technologies – Natural Gas

Energy is contained in the mass and chemical composition of natural gas. Natural gas is a hydrocarbon gas mixture consisting primarily methane, but includes a host of other chemical components. The chemical energy is released when the natural gas is burned. In energy metering, this understanding is important for several reasons: the energy content of natural gas is a function of the mass of the component composition, the component composition will vary, gas is compressible, and fluid meters generally measure volume or velocity rather than mass. Therefore, (volumetric) energy content varies with composition, temperature, and pressure. Accurate natural gas flow measurement usually requires the measurement of the fluid’s temperature and pressure in addition to flow. The energy content of the natural gas consumed should be obtained from the commodity provider periodically because it can change over time.

Additional constraints on natural gas metering may include the physical space available or possibly configuration and weight of the metering system. Some of the fluid metering technologies require specific lengths of pipe, both upstream and downstream of the meter for proper function. Before any technology decisions are made, discussions with equipment vendors and/or design engineers are recommended to ensure proper technology selection and installation design.

Depending on the application, flow rate, installation access, and desired accuracy, there are a number of technology options for natural gas metering. In general, measurement of natural gas volumetric flow rate is represented in standard cubic feet per hour (scfh) or per minute (scfm).[5] The actual mass of gas flowing past a point of measurement changes with its temperature and pressure. Density changes resulting from temperature and pressure differences can result in differences between the energy content of similar volumes of the gas. To equalize the effect of density variations when metering gas, conditions are referenced against standard temperature and pressure conditions, hence standard cubic feet (scf) instead of actual cubic feet (acf). Gas meters must compensate for density differences between standard conditions and actual conditions to accurately define standard flow rates. The most common volumetric gas metering devices fall into one of the following categories: (1) positive displacement, (2) differential pressure, and (3) velocity. In most applications, gas meters are installed downstream of pressure regulation devices and the meters are then calibrated to that pressure. Natural gas meters may include options for temperature and pressure compensation.

Accurate natural gas flow measurement usually requires the measurement of the fluid's temperature and pressure in addition to flow.

Positive Displacement: A positive displacement meter functions by the fluid physically displacing the measuring mechanism and this displacement becomes the metered value. Of relevancy to natural gas measurement, the two predominant technologies are the diaphragm meter (most common) and the rotary meter. In each case, the volume of gas for measurement physically impinges on a measuring element (flexible diaphragm or rotary blower) to increment a recording dial or other output. The primary advantage of positive displacement flow meters is there are no straight-run piping requirements to establish a flow pattern that can be accurately metered. The primary disadvantage of positive displacement meters is higher pressure drops experienced across the meter at peak flow rates.

There are multiple types of differential pressure meters: orifice flow meter, venture flow meter, and annubar flow meter. All differential pressure meters rely on the velocity-pressure relationship of flowing fluids for operation.

Benefits of orifice flow meters should be traded off against the potential decrease in pressure at the end use.

Differential Pressure – Orifice Flow Meter. The orifice element is typically a thin, circular metal disk held between two flanges in the fluid stream. The center of the disk is formed with a specific-size and shape hole, depending on the expected fluid flow parameters (e.g., pressure and flow range). As the fluid flows through the orifice, the restriction creates a pressure differential upstream and downstream of the orifice proportional[6] to the fluid flow rate. This differential pressure is measured and a flow rate calculated based on the differential pressure and fluid properties.

[5] For the natural gas industry in North America, standard conditions for temperature and pressure are 60°F and 14.73 psia. Care should be taken as the "standard" conditions may vary between definitions; therefore, they should always be confirmed.

[6] The flow may be proportional to the pressure differential but the math is rather sophisticated. The equation is based on the Bernoulli equation. To see the flow equation and how it is derived, see the Engineering ToolBox at http://www.engineeringtoolbox.com/orifice-nozzle-venturi-d_590.html.

Differential Pressure – Venturi Flow Meter. The venturi flow meter takes advantage of the velocity-pressure relationship when a section of pipe gently converges to a small-diameter area (called a throat) before diverging back to the full pipe diameter. The benefit of the venturi flow meter over the orifice flow meter lies in the reduced pressure loss experienced by the fluid.

Differential Pressure – Annubar Flow Meter. The annubar flow meter (a variation of the simple pitot tube) also takes advantage of the velocity-pressure relationship of flowing fluids. The device causing the change in pressure is a pipe inserted into the natural gas flow.

There are multiple types of velocity meters: turbine flow meter, vortex-shedding flow meter, and fluid oscillation flow meter. Velocity meters determine fluid flow by measuring a representation of the flow directly. Because the fluid's velocity is measured (i.e., not the square-root relationship to determine velocity as with differential pressure meters), velocity meters can have better accuracy and usually have better turndown ratios than other meter types.

Velocity – Turbine Flow Meter. A multi-blade impellor-like device is located in, and horizontal to, the fluid stream in a turbine flow meter. As the fluid passes through the turbine blades, the impellor rotates at a speed related to the fluid's velocity. Blade speed can be sensed by a number of techniques including magnetic pick-up, mechanical gears, and photocell. The pulses generated as a result of blade rotation are directly proportional to fluid velocity, and hence flow rate.

Velocity – Vortex-Shedding Flow Meter. A vortex-shedding flow meter senses flow disturbances around a stationary body (called a bluff body) positioned in the middle of the fluid stream. As fluid flows around the bluff body, eddies or vortices are created downstream; the frequencies of these vortices are directly proportional to the fluid velocity.

Velocity – Fluid Oscillation Flow Meter. A fluid oscillation flow meter uses sensor technology to detect gas oscillations, which corresponds to the flow rate through the meters internal throat design.

Table 4-3 summarizes the key criteria to consider with selecting one of the common natural gas metering technologies.

Table 4-3. Common Natural Gas Flow Meter Technologies and Key Criteria

Goal	Positive Displacement	Orifice	Venturi	Annubar	Turbine	Vortex Shedding	Fluid Oscillation
Accuracy	Good	Moderate	Good	Good	Good	Good	Good
Turndown Ratio	10:1	<5:1	< 5:1	10:1	10:1	20:1	100:1
Repeatability	Good	Good	Good	Very Good	Low	Very good	Good
Installation Ease	Easy	Easy	Moderate	Easy	Challenging	Moderate	Easy
Pressure loss	Medium	Moderate	Low	Low	Moderate	Low	Low
Recalibration Needs	Infrequent	Frequent	Infrequent	Infrequent	Frequent	Infrequent	Infrequent
Capital Cost	Low	Low	Moderate	Low	Moderate	Moderate	High
Installed Cost	Moderate	Low	Moderate	Low	Moderate	Moderate	Low
Maintenance Cost	Low	High	Moderate	Low	Moderate	Low	Low

4.5.1 Natural Gas Meter Maintenance

Depending on the meter technology, installation, and quality of gas delivered, natural gas meters generally require limited maintenance. Generally during monthly inspections there is a need to check for gas leaks, noisy operations within the meter, and cleanliness of the equipment. The annual inspections should include calibration according to manufacturer's recommendation or as needed if trended data indicate miscalibration. For Positive Displacement Meters monthly inspections should look for consistent and smooth register operation. For Differential Pressure Meters monthly inspections check for properly connected and sealed pressure taps. During the annual inspections check orifice diameter and edges for wear, roughness, or material buildup, clean and smooth all internal surfaces, and check for well-connected and sealed pressure taps. For Velocity Meters annual inspections check impeller blades and bearings wear or damage.

Depending on the meter technology, installation, and quality of gas delivered, natural gas meters generally require limited maintenance.

4.5.2 Natural Gas Metering Data Output/Communications Considerations

At the building-level, where positive displacement diaphragm and rotary meters are common, calibrated pulses are common data output signals. While other output options are available (4 to 20 milliamp, 0 to 5 volt, Modbus, etc.), calibrated pulses are the most common and are relatively easy to work with.

When specifying the natural gas flow meter, the pulse calibration is a critical parameter.

When specifying the natural gas flow meter, the pulse calibration is a critical parameter. It is important in this specification to understand the range of expected flow and necessary resolution of output. There are situations where too high of a pulse count (i.e., too high of a frequency) can result in saturation of the data collection device. A saturation condition usually results in data loss and erroneous pulse counts. Vendors for the metering equipment, the data communication, and data collection system technology should be consulted when determining the appropriate pulse rate (resolution) and calibration.

4.6 Fluid Metering Technologies – Steam

For steam, energy is primarily contained in the latent heat[7] and, to a lesser extent, the sensible heat[8] of the fluid. The latent heat energy is released as the steam condenses to water. Additional sensible heat energy may be released if the condensate is further lowered in temperature. In steam metering, the energy content of the steam is a function of the steam mass, temperature and pressure. Even after the steam releases its latent energy, the hot condensate still retains considerable heat energy, which may or may not be recovered (and used) in a constructive manner. The energy manager should become familiar with the entire steam cycle, including both the steam supply and the condensate return.

When compared to other liquid flow metering, the metering of steam flow presents one of the most challenging metering scenarios. Most steam meters measure a velocity or volumetric flow of the steam and, unless this is done carefully, the physical properties of steam will impair the ability to measure and define a mass flow rate accurately.

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[7] Latent heat energy refers to the energy absorbed or released with the change in state, or phase, of mass at constant temperature. For example, the energy released when water changes from steam to liquid.
[8] Sensible heat energy refers to the energy absorbed or released with the change in temperature of mass.

Steam is a compressible fluid; therefore, a reduction in pressure results in a reduction in density. Temperature and pressure in steam lines are dynamic. Changes in the system's dynamics, control system operation and instrument calibration can result in considerable differences between actual pressure/temperature and a meter's design parameters. Accurate steam flow measurement generally requires the measurement of the fluid's temperature, pressure, and flow. This information is transmitted to an electronic device or flow computer (either internal or external to the flow meter electronics) and the flow rate is corrected (or compensated) based on actual fluid conditions.

The temperatures associated with steam flow measurement are often quite high and can affect the accuracy and longevity of metering electronics.

The temperatures associated with steam flow measurement are often quite high. These temperatures can affect the accuracy and longevity of metering electronics. Some metering technologies use close-tolerance moving parts that can be affected by moisture or impurities in the steam. Improperly designed or installed components can result in steam system leakage and impact plant safety. The erosive nature of poor-quality steam can damage steam flow sensing elements and lead to inaccuracies and/or device failure.

The challenges of metering steam can be simplified measuring the condensed steam, or condensate. The metering of condensate (i.e., high-temperature hot water) is an accepted practice, often less expensive and more reliable than steam metering. Depending on the application, inherent inaccuracies in condensate metering stem from unaccounted for system steam losses. These losses are often difficult to find and quantify and thus affect condensate measurement accuracy.

Volumetric metering approaches used in steam metering can be broken down into two operating designs: (1) differential pressure and (2) velocity metering technologies. For steam three differential pressure meters are highlighted: orifice flow meter, annubar flow meter, and spring-loaded variable area flow meter. All differential pressure meters rely on the velocity-pressure relationship of flowing fluids for operation.

Differential Pressure – Orifice Flow Meter. Historically, the orifice flow meter is one of the most commonly used meters to measure steam flow. The orifice flow meter for steam functions identically to that for natural gas flow (see previous section). For steam metering, orifice flow meters are commonly used to monitor boiler steam production, amounts of steam delivered to a process or tenant, or in mass balance activities for efficiency calculation or trending.

Differential Pressure – Annubar Flow Meter. The annubar flow meter functions the same way for steam flow as it does for natural gas flow.

Differential Pressure – Spring-Loaded Variable Area Flow Meter. The spring-loaded variable area flow meter is a variation of the rotameter. There are alternative configurations but in general, the flow acts against a spring-mounted float or plug. The float can be shaped to give a linear relationship between differential pressure and flow rate. Another variation of the spring-loaded variable area flow meter is the direct in-line variable area flow meter, which uses a strain gage sensor on the spring rather than using a differential pressure sensor.

Turbine meters can be susceptible to wear and resulting inaccuracies because of the mechanical elements in the fluid stream.

The two main type of velocity meters for steam flow, turbine and vortex shedding, both sense some flow characteristic directly proportional to the fluid's velocity.

Velocity – Turbine Flow Meter. The turbine flow meter functions the same way for steam flow as it does for natural gas flow.

Velocity – Vortex-Shedding Flow Meter. The vortex-shedding flow meter functions the same way for steam flow as it does for natural gas flow.

Table 4-4 presents some common steam metering technologies and key criteria for selection decisions.

Table 4-4. Common Steam Metering Technologies and Key Criteria

Goal	Orifice	Annubar	Turbine	Vortex Shedding
Accuracy	Moderate	Good	Good	Good
Turndown Ratio	<5:1	5:1	10:1	20:1
Repeatability	Good	Good	Low	Very good
Installation Ease	Easy	Easy	Challenging	Moderate
Pressure loss	Moderate	Low	Moderate	Low
Recalibration Needs	Frequent	Infrequent	Frequent	Infrequent
Capital Cost	Low	Low	Moderate	Moderate
Installed Cost	Low	Low	Moderate	Moderate
Maintenance Cost	High	Low	Moderate	Low

4.6.1 Steam Meter Maintenance

Depending on the meter technology, installation, and quality of steam generated, steam meters can require a significant amount of maintenance.

Depending on the meter technology, installation, and quality of steam generated, steam meters can require a significant amount of maintenance. Procedures followed should be those recommended by the manufacturer. For monthly inspections check all connections for steam leakage, listen for abnormally loud or discontinuous sounds internal to the meter, and inspect for general meter cleanliness. Annually the meters need calibration of differential pressure sensors/transmitters according to manufacturer's recommendation or as needed if trended data indicate miscalibration. For differential pressure meters monthly inspections check for properly connected and sealed pressure taps. During annual inspections check orifice diameter, orifice edges, and pressure parts for wear, roughness, or material buildup, and check for properly connected and sealed pressure taps. For velocity meter annual inspections check impeller blades and bearings for wear or damage.

4.6.2 Steam Metering Data Output/Communications Options

The most common outputs of steam metering devices are scalable analog signals of either 4 to 20 mA or 0 to 5 volts dc. In more sophisticated systems, HART™ (Highway Addressable Remote Transducer) protocol systems can be found.[9] The meter outputs are collected and processed using a flow computer/analysis device integral to the meter. The flow computer/analysis device takes the measurement signals (pressure, differential pressure, and temperature) and converts these values to a compensated steam flow rate.

The most common outputs of steam metering devices are scalable analog signals.

When specifying a steam flow meter, the flow computer/analysis device is typically an option with some array of alternatives for analysis and presentation. The output of the flow computer/analysis device is typically a scalable signal or pulse that can be transferred to a data acquisition or energy information system for collection and further analysis or trending.

4.7 Fluid Metering Technologies – Water

Because the metering of water is generally concerned with the quantification of flow volume, lower-cost metering options can be used.

Water is commonly measured and sold in volumetric measurements, which allows for lower-cost metering options. The specific metering option chosen will depend on a number of factors including, but not limited to, current design, budget, accuracy requirements, resolution, minimum flow rate, potable versus non-potable (or at least filtered versus non-filtered water), range of flow rates, and maximum flow rate.

Volumetric water metering designs can be broken down into three general operating designs: (1) positive displacement, (2) differential pressure, and (3) velocity.

Positive Displacement – Nutating-Disk Flow Meter. Nutating-disk flow meters are the most common meter technology used by water utilities to measure potable-water consumption for service connections up to 3-inch. The nutating-disk flow meter consists of a disk mounted on a spherically shaped head and housed in a measuring chamber. As the fluid flows through the meter passing on either side of the disk, it imparts a rocking or nutating motion to the disk. This motion is then transferred to a shaft mounted perpendicular to the disk. It is this shaft that traces out a circular motion – transferring this action to a register that records flow.

There are a variety of differential pressure devices useful for water metering; three of the more common devices include orifice flow meters, venture flow meters, and

Differential Pressure – Orifice Flow Meter. The orifice flow meter functions the same way for water flow as it does for natural gas flow.

Differential Pressure – Venturi Flow Meter. The venturi flow meter functions the same way for water flow as it does for natural gas flow.

[9] HART is a bi-directional communication protocol that provides data access between intelligent field instruments and host systems.

The velocity meter types described in this section include the turbine flow meter, vortex-shedding flow meter, and ultrasonic flow meters.

Velocity – Turbine Flow Meter. The turbine flow meter functions the same way for water flow as it does for natural gas flow.

Velocity – Vortex-Shedding Flow Meter. A vortex-shedding flow meter functions the same way for water flow as it does for natural gas flow.

Velocity – Ultrasonic Flow Meters. There are two different types of ultrasonic flow meters, transit-time and Doppler-effect. The two technologies use ultrasonic signals very differently to determine fluid flow and are best applied to different fluid applications. Transit-time ultrasonic flow meters require the use of two signal transducers. Each transducer includes both a transmitter and a receiver function. As fluid moves through the system, the first transducer sends a signal and the second receives it. The process is then reversed. Upstream and downstream time measurements are compared. With flow, sound will travel faster in the direction of flow and slower against the flow. Transit-time flow meters are designed for use with clean fluids, such as water.

Doppler-effect ultrasonic flow meters use a single transducer. The transducer has both a transmitter and receiver. The high-frequency signal is sent into the fluid. Doppler-effect flow meters use the principal that sound waves will be returned to a transmitter at an altered frequency if reflectors in the liquid are in motion. This frequency shift is in direct proportion to the velocity of the liquid. The echoed sound is precisely measured by the instrument to calculate the fluid flow rate.

Because the ultrasonic signal must pass through the fluid to a receiving transducer, the fluid must not contain a significant concentration of bubbles or solids. Otherwise the high frequency sound will be attenuated and too weak to traverse the distance to the receiver. Doppler-effect ultrasonic flow meters require that the liquid contain impurities, such as gas bubbles or solids, for the Doppler-effect measurement to work. One of the most attractive aspects of ultrasonic flow meters is they are non-intrusive to the fluid flow. An ultrasonic flow meter can be externally mounted to the pipe and can be used for both temporary and permanent metering.

Determining the accuracy requirements over the flow range is one of the considerations for selecting a meter for water.

Table 4-5 presents some common water metering technologies and key criteria for selection decisions.

Table 4-5. Common Water Flow Meter Technologies and Key Criteria

Goal	Positive Displacement	Orifice	Venturi	Turbine	Vortex Shedding	Ultrasonic Dop/TT
Accuracy	Good	Moderate	Good	Good	Good	Moderate
Turndown Ratio	10:1	<5:1	< 5:1	10:1	20:1	10:1/20:1
Repeatability	Good	Good	Good	Low	Very good	Good
Installation Ease	Easy	Easy	Moderate	Challenging	Moderate	Very easy
Pressure loss	Medium	Moderate	Low	Moderate	Low	None
Recalibration Needs	Infrequent	Frequent	Infrequent	Frequent	Infrequent	Moderate
Capital Cost	Low	Low	Moderate	Moderate	Moderate	High
Installed Cost	Moderate	Low	Moderate	Moderate	Moderate	Low
Maintenance Cost	Low	High	Moderate	Moderate	Low	Low

4.7.1 Water Meter Maintenance

Depending on the meter technology, installation, and quality of water delivered, water meters generally require limited maintenance. Maintenance procedures followed should be those as recommended by the manufacturer. Monthly inspections for all meter types should include examining connections for water leakage, identifying abnormally loud operations internal to the meter, check filters or strainers for blockage, and look for general meter cleanliness. The annual inspections should include calibration according to manufacturer's recommendation or as needed if trended data indicate miscalibration. Positive displacement meters should be check monthly for consistent and smooth register operation. Differential pressure meters should be checked monthly for properly connected and sealed pressure taps, and annually check the orifice diameter and edges for wear, roughness, or material buildup, and check the venturi for cleanliness and corrosion at throat. Annually velocity meters need the impeller blades and bearings check for wear or damage. Monthly inspections for ultrasonic meters include checking the transducer positions and attachment to piping, looking at the cleanliness of transducer/piping interface, inspecting the integrity of the sonic coupling fluid between the transducer and the piping, and verifying piping isolation (i.e., no vibration).

Depending on the meter technology, installation, and quality of water delivered, water meters generally require limited maintenance.

4.7.2 Water Metering Data Output/Communications Considerations

At the building-level, the meter's data output is frequently calibrated pulses. When specifying water flow meters, the pulse calibration is a critical parameter. Important in this specification is an understanding of the range of expected flow and necessary resolution of output. There are situations where too high of a pulse count (i.e., too high of a frequency) can result in saturation of the data acquisition system or other collection device. A saturation condition usually results in loss of data and erroneous pulse counts; therefore, it needs to be avoided. Vendors for metering equipment, as well as the data

When specifying the water flow meter, the pulse calibration is a critical parameter.

communications and data collection system technology, should be consulted when determining the appropriate pulse rate, resolution, and calibration.

4.8 Fluid Metering Technologies – Heated-Water and Chilled-Water Circulation Systems

Common applications of high-temperature heated-water metering include high-temperature hot-water (heating) distribution systems and metering of condensate-return systems. Central energy plants may also meter both chilled-water and heated-water distribution systems. When metering of heated- and chilled-water circulation systems, energy is determined as the product of the fluid's mass flow and the corresponding temperature differential through the system being metered. For hot-water delivery systems (such as potable hot water or service hot water), energy is determined basically the same way, but because there is no return system to consider, the temperature differential component is typically the difference between the supply and make-up water temperatures. The energy content is a function of the mass flow rate of the fluid being measured, as well as the corresponding change in fluid temperature across the system (e.g., inlet and outlet, supply and return, or delivered and make-up). The temperature differential refers to the direction of the energy flow. The primary metering devices discussed in this section focus on quantifying the fluid flow but to get energy flow, a flow computer—either integral to the meter or as a separate system component— is required to integrate the flow meter reading along with the two temperature readings to calculate the incremental energy flow over the time interval.

In-line flow meters should be sized based on the expected flow range and never be based on the pipe size.

Heated water will require selecting metering equipment designed to be used in the application's environmental conditions. For applications where the fluid is above 80°F, be sure the meter is designed for use with hot water. For higher-temperature applications, additional considerations may be required. To ensure the accuracy of most volumetric metering, high-temperature fluids must be maintained below the saturation temperature to prevent cavitation (a form of flash steam formation) within the metering equipment. In hot-water delivery systems, it is more common to see flow meters on the (cold) make-up water line, rather on the hot-water delivery line, because the operating environment is less abrasive and the metering equipment can be less expensive.

Fluid meters are volumetric measurement devices and energy is based on mass. Density, as well as specific heat of the fluid, varies with fluid temperature. The energy measurement is further complicated when glycol, or other anti-freeze component, is added to the fluid. The flow computer will generally include these parameters when performing the energy flow calculations.

Making sure the meter you have selected is applicable for the operating temperature range is critical to its performance and accuracy.

Positive displacement, differential pressure and velocity meters can be used to heated and chilled water circulation systems.

Positive Displacement – Nutating-Disk Flow Meter. The nutating-disk meter is appropriate on a hot-water system's make-up water line; however, for heated-water or chilled-water circulation systems, nutating-disk flow meters are rarely used. The nutating-disk flow meter functions the same way for a hot-water system's make-up water flow as it does for water flow.

The benefit of the venturi meter over the orifice meter lies in the reduced pressure loss experienced by the fluid.

There are a variety of differential pressure devices useful for high-temperature/chilled-water metering; three of the more common devices are described below.

Differential Pressure – Orifice Flow Meter. The orifice flow meter functions the same way for heated and chilled water flow as it does for natural gas flow.

Differential Pressure – Venturi Flow Meter. The venturi flow meter functions the same way for heated and chilled water flow as it does for natural gas flow.

Differential Pressure – Annubar Flow Meter. The annubar flow functions the same way for heated and chilled water flow as it does for natural gas flow.

Three types of velocity meters are described for use in metering water circulation systems.

Velocity – Turbine Flow Meter. A turbine flow meter functions the same way for heated and chilled water flow as it does for natural gas flow.

Velocity – Vortex-Shedding Flow Meter. A vortex-shedding flow meter functions the same way for heated and chilled water flow as it does for natural gas flow.

One of the most attractive aspects of ultrasonic flow meters is that they are completely non-intrusive.

Velocity – Ultrasonic Flow Meters. There are two different types of ultrasonic flow meters: transit-time and Doppler-effect. The two technologies use ultrasonic signals very differently to determine fluid flow and are best applied to different fluid applications, as described in previous section on water metering technologies. Caution is advised for higher-temperature applications, the sonic coupling fluid (gel) applied between the transducer and pipe surface is critical for signal strength and therefore for accuracy and repeatability. The coupling fluid needs to be rated for the applied temperature or, at higher temperatures, it may lose viscosity and melt away. Some manufacturers are now offering gel packs, which can alleviate this concern, as well as reduce longer-term maintenance requirements.

Table 4-6 presents some of the more common water metering technologies and key criteria for selection decisions.

Table 4-6. Common Flow Meter Technologies and Key Criteria

Goal	Positive Displacement	Orifice	Venturi	Turbine	Vortex Shedding	Ultrasonic Dop/TT
Accuracy	Good	Moderate	Good	Good	Good	Moderate
Turndown Ratio	10:1	<5:1	< 5:1	10:1	20:1	10:1/20:1
Repeatability	Good	Good	Good	Low	Very good	Good
Installation Ease	Easy	Easy	Moderate	Challenging	Moderate	Very easy
Pressure loss	Medium	Moderate	Low	Moderate	Low	None
Recalibration Needs	Infrequent	Frequent	Infrequent	Frequent	Infrequent	Moderate
Capital Cost	Low	Low	Moderate	Moderate	Moderate	High
Installed Cost	Moderate	Low	Moderate	Moderate	Moderate	Low
Maintenance Cost	Low	High	Moderate	Moderate	Low	Low

4.8.1 High-Temperature/Chilled-Water Meter Maintenance

Depending on the meter technology, installation, and quality of water delivered, these types of meters generally require limited maintenance. Procedures followed should be those as recommended by the manufacturer. The monthly and annual inspection expectations are the same as those described in the water section. Monthly inspections for all meter types should include examining connections for water leakage, identifying abnormally loud operations internal to the meter, check filters or strainers for blockage, and look for general meter cleanliness. The annual inspections should include calibration according to manufacturer’s recommendation or as needed if trended data indicate miscalibration. Positive displacement meters should be check monthly for consistent and smooth register operation. Differential pressure meters should be checked monthly for properly connected and sealed pressure taps, and annually check the orifice diameter and edges for wear, roughness, or material buildup, and check the venturi for cleanliness and corrosion at throat. Annually velocity meters need the impeller blades and bearings check for wear or damage. Monthly inspections for ultrasonic meters include checking the transducer positions and attachment to piping, looking at the cleanliness of transducer/piping interface, inspecting the integrity of the sonic coupling fluid between the transducer and the piping, and verifying piping isolation (i.e., no vibration).

4.8.2 Heated-Water and Chilled-Water Metering Data Output/Communications Considerations

Standardization on communication between meters and other data acquisition systems needs to be considered.

While other output options are available (e.g., 4 to 20 milliamp, 0 to 5 volt, Modbus, HART), calibrated pulses are easy to use. When specifying the flow meter, the pulse frequency and resolution are critical parameters. Important in this specification is an understanding of the range of expected flow and necessary resolution of output. There are situations where too high of a pulse frequency (i.e., too many pulse counts in a time interval) can result in saturation of the data acquisition system or other meter-reading device. A saturation condition usually results in loss of data and erroneous pulse counts; therefore, it needs to be avoided. Vendors for metering equipment and the data communication and data collection system technology should be consulted when determining the appropriate pulse rate, resolution and calibration.

Chapter 5 Data Analysis and Use

Meters provide data and these data generally do not constitute information or knowledge. Data need to be processed and analyzed to create information.

The purpose of metering is to collect and analyze the data to improve operations. Depending on the interval and collection frequency, metered data can accumulate quickly and become overwhelming unless automated data processing is implemented. Meters provide data which do not constitute information or knowledge. Data need to be processed and analyzed to create information before any proactive actions can be taken. Success comes from analyzing the metered data to create information, which, in turn, is used to create an action, which, as a result, will result in a reduction in energy and/or water consumption and cost.

Time-interval data are consumption data collected at regular time intervals. Different time interval data has different usefulness. Table 5-1summarizes the different applications of the different time intervals.

Table 5-1. Summary of Time Interval Data Uses

Time Interval	Uses
Annual	• Compare multiple buildings • Compare to benchmarks • Track progress toward goals • Prioritize future activities
Monthly	• Compare to monthly temperature/weather data • Track performance changes
Daily	• Assess energy consumption from heating and cooling systems • Assess impact of major changes in building equipment use • Examine weekday, weekend, and holiday use patterns • Compare to daily temperature/weather data • Examine seasonal differences • Track performance changes
Hourly	• Assess building operating schedule using daily load profile • Compare occupied to unoccupied use • Examine seasonal differences • Track performance changes • Compare to monthly temperature/weather data
15-minute	• Assess building operating schedule using daily load profile • Compare occupied to unoccupied use • Evaluate equipment or system functionality • Evaluate specific operational issues • Track performance changes
More Granular	• Evaluate equipment or system functionality • Evaluate specific operational issues • Assess equipment fault detection and diagnostics

5.1 Working With Interval Data – Data Analysis Tools

Interval data can be analyzed by any number of software tools—from a basic spreadsheet analysis using Microsoft Excel™, to more sophisticated statistical analysis software, such as MatLab™ or R (a free implementation of the S language). A number of specialty software tools are also available, many designed by metering companies and EIS companies, designed specifically for working with interval metered energy data. This guide will not discuss every tool available. For more information, see the building energy software tools directory compiled by the DOE Buildings Technologies Office at http://apps1.eere.energy.gov/buildings/tools_directory/subjects_sub.cfm. Better Bricks, a commercial building initiative of the Northwest Energy Efficiency Alliance, provides a list of software tools that can be used for benchmarking, utility bill tracking, and trend logging including interval metered data analysis at http://www.betterbricks.com/building-operations/software. Additional EIS vendor software tools and their capabilities are discussed in more detail in Kramer et al. (2013) and NSTC (2011).

5.1.1 Energy Charting and Metrics (ECAM+) Tool

Interval energy data can be assessed by any number of software tools—from a basic spreadsheet to more sophisticated software.

The ECAM+ tool is an add-on for Microsoft Excel™-developed to facilitate the analysis of time-interval energy data. The ECAM+ tool was developed to facilitate the examination of energy information from buildings, while reducing the time spent analyzing interval meter data. The tool is intended to help building owners, energy managers, and operators look at interval energy data by automating the generation of a wide variety of charting and analysis functions used to analyze interval metered energy and other trend data, as illustrated in Figure 5-1.

The tool makes extensive use of Excel™ pivot tables. A common use of ECAM+ is to assist in the comparison of pre- and post-energy efficiency project regression analysis of advanced metered time-interval energy data in conjunction with local weather data. Such comparisons can be in support of energy saving projects, re-tuning efforts, and recommissioning projects. ECAM+ has additional applications that can be used independently. Some other key features of ECAM+ include:

- creation of charts to help re-tuning and recommissioning projects
- creation of schedules and day-type information to time series data
- filtering data by month, year, day, day type, day of week, day of month, occupancy, temperature-binned weather data
- normalizing data and creating metrics based on user-entered data
- creation of various building or equipment load profiles or scatter charts for energy data selected by the user
- modeling and verification for metered data.

These applications can ultimately be used to better understand a building's energy-use patterns and inform the selection of energy-efficiency measures with the highest potential for savings. ECAM+ is useful for anyone who would like to expedite the processing and analysis of interval energy data. Commissioning providers, energy auditors, energy service companies (ESCOs), energy consultants, and building engineers will find ECAM+ useful in translating raw interval data into meaningful and highly flexible charts.

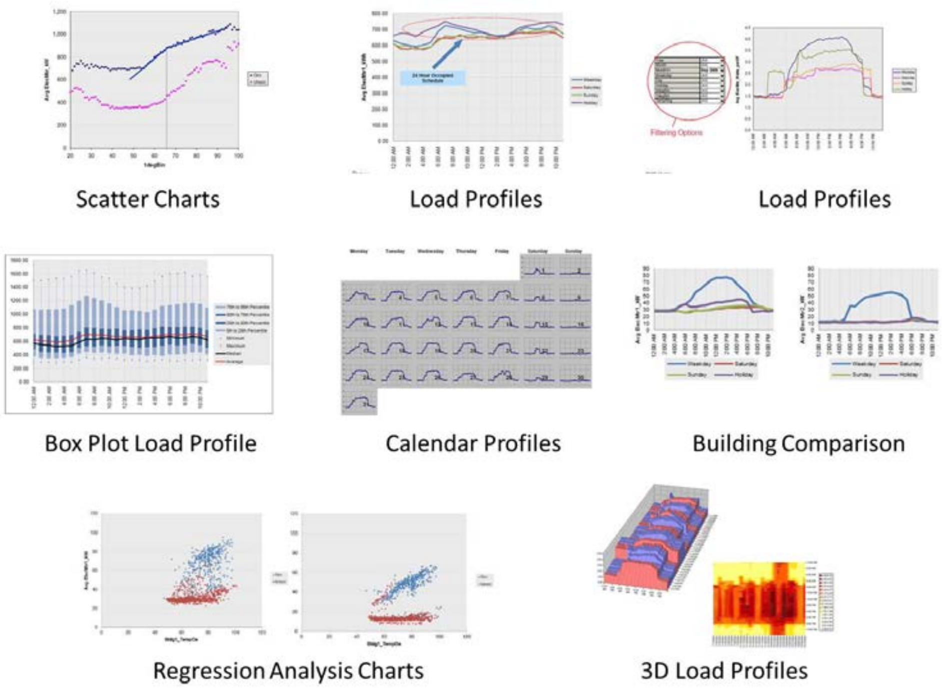

Figure 5-1. ECAM+ Assists in Developing a Wide Variety of Charts Using Pivot Tables

The Excel add-on tool was originally developed by William Koran and is available at no cost from PNNL (http://buildingretuning.pnnl.gov/ecam.stm) and NorthWrite (http://www.northwrite.com/ecam.asp). A number of free web-based training tools are available for users to learn how to use and benefit from ECAM+. ECAM was initially developed by NorthWrite with later assistance from PNNL. Support for the development of the ECAM tool has come from the DOE, Northwest Energy Efficiency Alliance (NEEA), New Buildings Institute (NBI), and the California Energy Commission's (CEC) Public Interest Energy Research (PIER) program.

5.2 Working with Energy Data – Examples from the Field

Interval energy data offer many benefits in identifying efficiency and operational opportunities. The data are likely to require active viewing to search for variability and trends. [10] The following is a collection of building-level and end-use data for which some sort of variance was noted. Most of the case study examples presented are illustrated using commonly available software tools to illustrate that basic analysis and charting does not need to be difficult.

[10] Agency names and locations are withheld to protect the innocent. The authors, however, would like to thank the agencies involved for allowing us to share the data and the lessons learned.

5.2.1 Annual Facility Energy Data—Glide Path Comparisons

Objective: Use annual facility data to assess energy program progress and prioritize opportunities.

Situation: The Federal energy index reduction goals are assessed at the agency level when reported to Congress, but the energy utilization index (energy intensity, Btu/gsf) data can also be useful at the departmental, regional, installation, and even the facility level in terms of prioritizing program actions.

> A common normalization technique is the energy-use index (EUI) metric, whereby the annual or monthly energy consumption is divided by the facility area in gross square feet.

Findings: Figure 5-2 illustrates the glide path for reduction in energy-use intensity (EUI) for an agency. The agency level EUI constitutes an average of all agency facilities. Being an average for the agency implies that several facilities are more energy intensive (above the agency line) and several facilities are less energy intensive (below the agency line). The figure also shows the energy data for four local buildings (each are the same building use category and each are in the same local weather region). The data illustrates that the four local facilities are below the overall agency energy index. This does not imply there is no opportunity for further energy reduction at these four facilities.

Outcome: Facility D and Facility A are potential targets for prioritization. Facility D has historically had the highest energy intensity of the four facilities. In recent years, the energy intensity of Facility A has been increasing rather than decreasing. The reason for the increase in energy intensity at Facility A requires further investigation. In terms of prioritization, Facility A and D likely have more reduction opportunities than either Facility B or C.

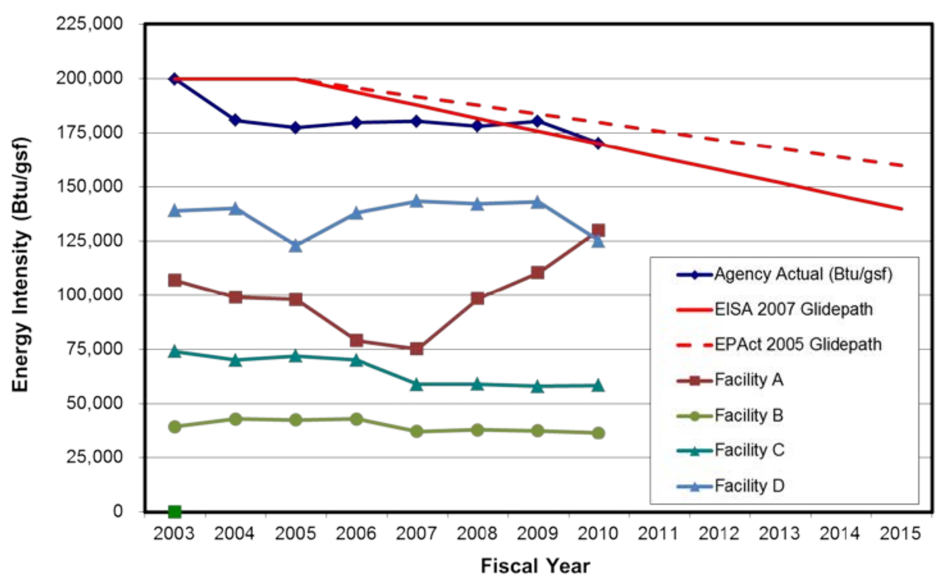

Figure 5-2. Agency Glide Path Chart with Addition of Individual Facility Data to Assist in Prioritization

5.2.2 Annual Building Energy Data—Prioritizing Covered Facilities

Objective: Use relative energy-use intensity (EUI, Btu/ft^2) and relative building area (gross square feet) to develop a visual heat map for a large portfolio of buildings.

Situation: An organization wanted to assess a portfolio of 75 buildings to prioritize energy management.

Findings: Viewing the data in the form of a heat map, as illustrated in Figure 5-3, can assist in visually processing large amounts of data. Each box represents one of the 75 buildings, labeled by building number. The relative size of each box in the figure represents the individual building's floor area relative to the total facility floor area. For example, Building 1 represents about 10% of the total facility area because it represents about 10% of the total figure area. The shade of each box represents the relative EUI for the individual building. Dark red represents a high EUI, dark green represents a low EUI, and the light neutral color represents an average EUI.

Outcome: In this example, the site used the EUI heat map to prioritize further investigate buildings 1 and 7. Building 1 is the largest facility and has a high EUI—identifying cost-effective energy improvement opportunities were needed to reduce overall energy consumption and lower the building EUI. Building 7 has one of the lowest EUIs on site. The goal of investigating Building 7 is to identify best practices, which should be learned and replicated at the other facilities.

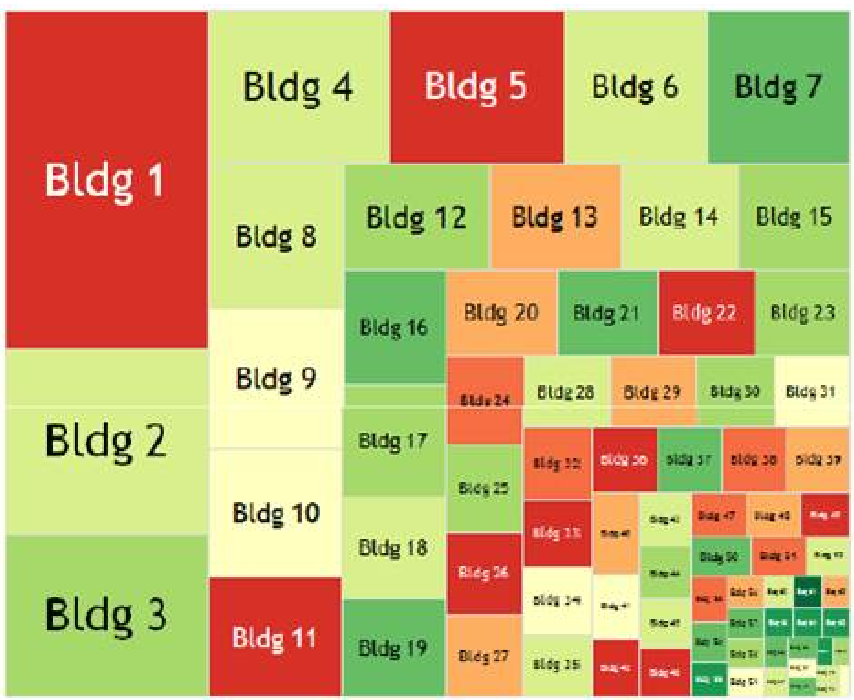

Figure 5-3. Building Energy-Use Intensity Heat Map
(Image source: Schneider Electric, Inc., used with permission)

5.2.3 Monthly Building Energy Data—Comparing Benchmarking Data for Trends

Benchmarking data allows you to compare multiple facilities, which can be useful in identifying trends and establishing priorities.

Objective: Use benchmarking energy data to compare building energy performance.

Situation: Two small, co-located training facilities with similar occupancy and hours of operation with building-level interval electric meters are installed.

Findings: Viewing the monthly benchmark data, illustrated in Figure 5-4, shows Building A using roughly 20% more energy per square foot, each month, compared to Building B. While there are a number of factors that could contribute to this, including occupancy variance, materials of construction, age, operation of equipment, and hours of operation – this type of variance is worthy of further exploration. The buildings had a similar energy utilization index in June but as time passed, the energy consumption of Building A increased relative to Building B. The cause of this trend should be investigated and corrective action taken if necessary.

Outcome: Further exploration identified high nighttime lighting loads in Building A as part of the variance. Corrective action was planned. The energy consumption of two buildings should continue to be tracked to verify if corrective action was successful.

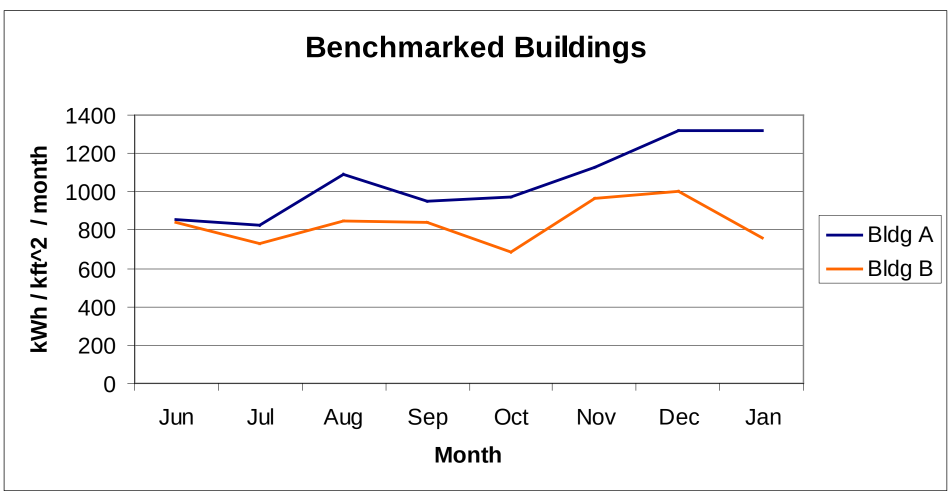

Figure 5-4. Building Benchmarking

5.2.4 Monthly Building Energy Data—Comparing Benchmarking Data for Prioritization

Objective: Use benchmarking to compare building performance and prioritize targets of opportunity.

Situation: Two facilities on the same campus with similar occupancy and hours of operation.

Findings: Benchmarking data allows you to compare multiple facilities, which can be useful in establishing priorities. Figure 5-5 illustrates benchmarking data for two individual buildings. The chart shows the benchmarking data for the organization's regional average facility. Plus, the chart shows the organization's average facility at the national level. The benchmarking data could be the traditional energy per square feet (Btu/ft^2), or—to reduce the impact of geographic diversity—the benchmarking data could be energy per degree day per gross square feet (Btu/ft^2/degree day).

Outcome: Examination of the data shows that Facility A stands out with a higher energy index than the other facility and the two average indices. For this reason, Facility A should become a priority of focus when looking for energy reduction opportunities.

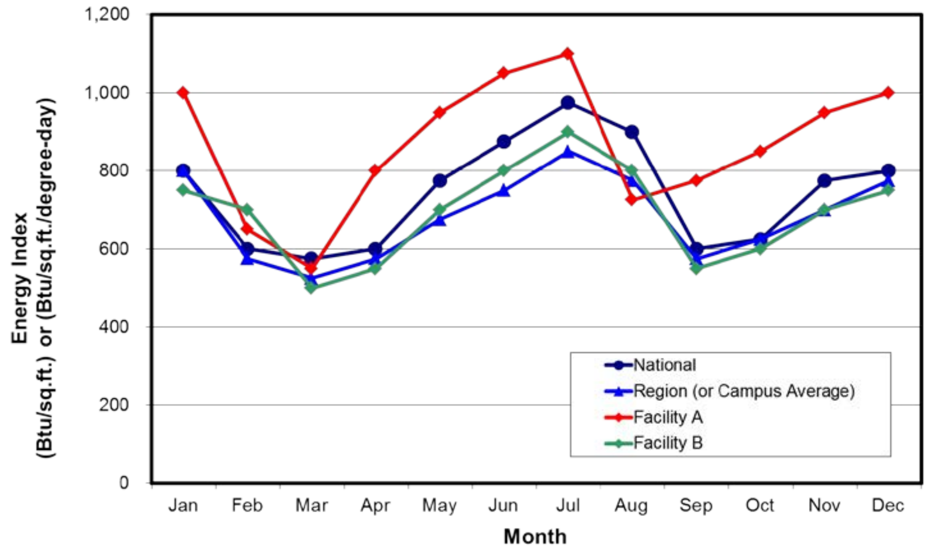

Figure 5-5. Using Benchmark Energy Data to Prioritize Efforts

5.2.5 Interval Data—Using the Daily Profile for Efficiency Opportunity Identification

Objective: Use interval data to identify project opportunities.

Situation: Small administrative building had standard hours of operation, typical occupancy density, and a building-level interval electric meter installed.

Findings: Viewing the daily demand profile, notice relative "flatness" of profile from day to night. Flat demand profiles are indicative of buildings with 24-hour operation, occupancy, or a disabled nighttime setback control feature. The setback control had been disabled to accommodate a series of night meetings held in the building and was never reset. Figure 5-6 and**Figure 5-7** present the data as found and corrected.

Outcome: Once the nighttime setback control feature is re-enabled, there was a significant decrease in the nighttime electrical load – predominantly fan loads which are observed in the early morning (~1:00 AM) and late evening (~10:00 PM). The relatively high base load (6 to 8 kW) compared to the peak load (16 to 18 kW) may indicate the building is a candidate for further energy reduction via lighting control or plug load controllers.

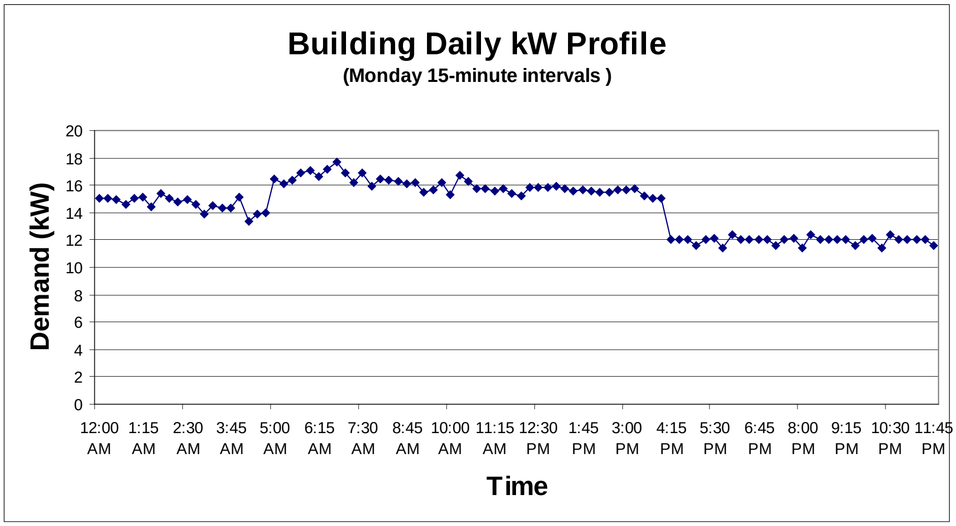

Figure 5-6. Daily Demand Profile – Nighttime Temperature Setback Disabled

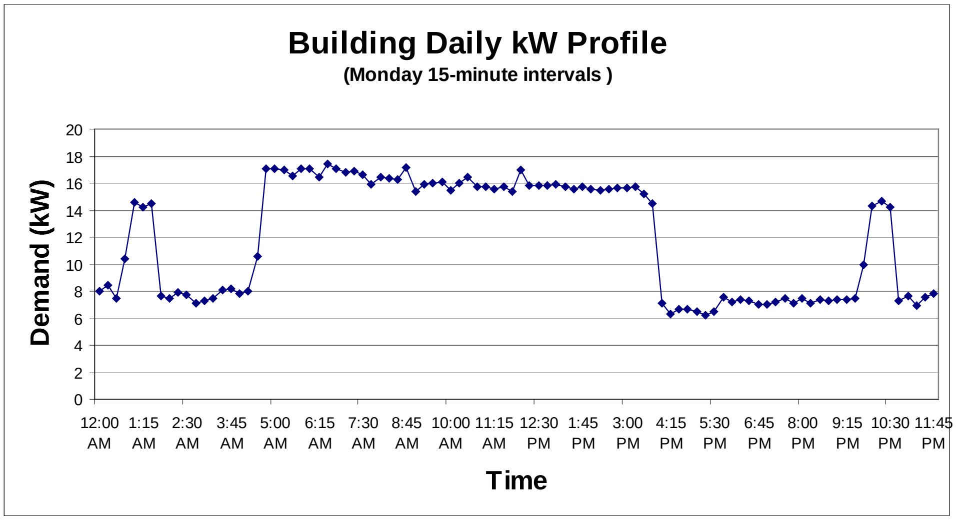

Figure 5-7. Daily Demand Profile – Nighttime Setback Enabled

5.2.6 Interval Data—Using the Daily Profile for Measurement and Verification

Objective: Use electrical panel level (lighting circuit) demand (kW) data to verify manufacturer's claim of energy savings from new lighting technology (spectrally enhanced fluorescent lighting).

Processing of the lighting panel data shows significant reduction in demand (kW) by the retrofit technology.

Situation: Measurement and verification of retrofit lighting installed at large administrative space. Panel-level interval metering installed.

Findings: Processing of the lighting panel data shows significant reduction in demand (kW) by the retrofit technology (spectrally enhanced fluorescent lighting) compared to the baseline technology (existing T-8 fluorescent lighting) with a clear presentation of savings. Figure 5-8 presents the time-interval metered electrical data for the lighting circuits in the form of a daily profile.

Outcome: Savings validates the performance improvement of the new lighting system.

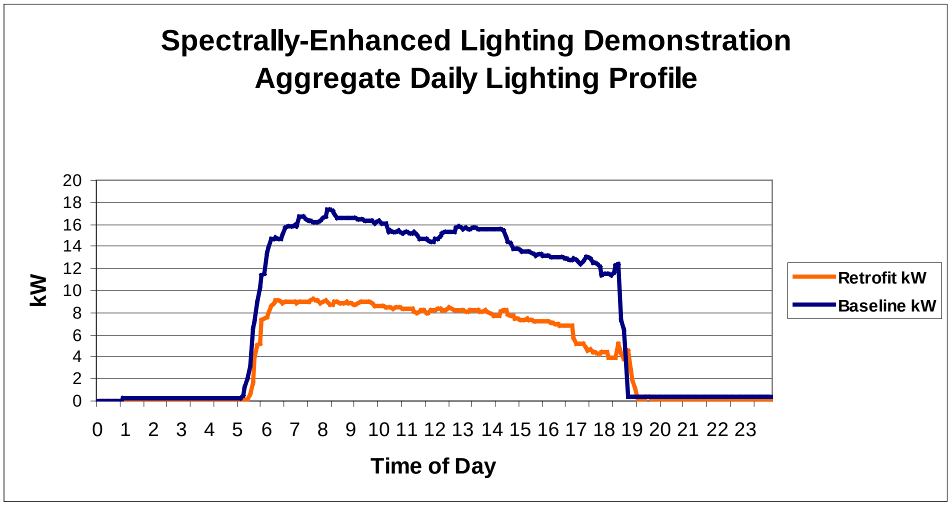

Figure 5-8. Measurement and Verification of Lighting Demonstration

5.2.7 Interval Data—Identifying Operational Concerns in Water Resource Management

Objective: Use interval water-use data to identify water inefficiency.

Viewing the daily interval water-use data highlights suspicious use pattern, particularly during off-hours.

Situation: Trending of water use in an administrative building where a building-level interval water meter is installed.

Findings: Viewing the interval water-use data shown on the daily plats in Figure 5-9 and Figure **5-10**, illustrates a suspicious use pattern, particularly during the period when the building is supposed to be unoccupied.

Outcome: The interval flow data observed during Saturday, when the building is unoccupied, raised the suspicion of a small but continuous water leak. Visual inspection of the fixtures in the men's restroom confirmed the leak's location. The meter has a resolution of 1 pulse per gallon. However, this leak only registered 1 pulse every 1½ hours. Leaks can be difficult to recognize during the day when water normally flows but during unoccupied periods when no flow is expected, regular pulses of the same magnitude and frequency are a common sign that there is a leak in the system.

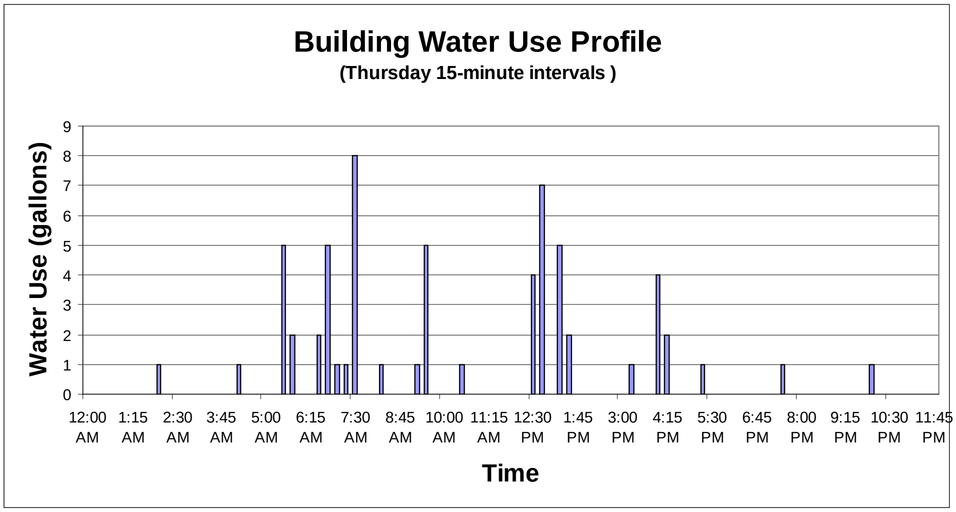

Figure 5-9. Building Water-Use Interval Data – Suspicious Pattern

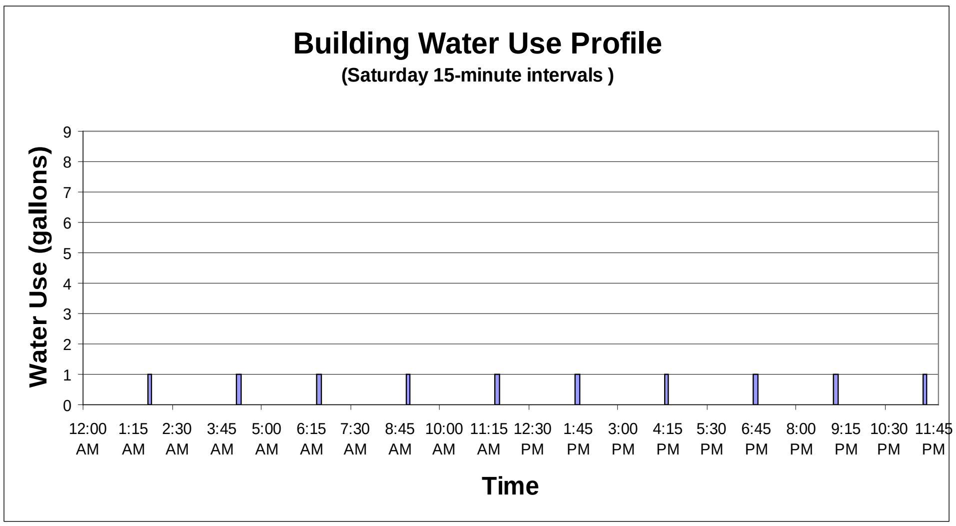

Figure 5-10. Building Water-Use Interval Data – Verification of Water Leak

5.2.8 Interval Data—Assessing Weekly Profiles for Energy Reduction Opportunity

Objective: Use interval energy data to identify unusual events that may be an energy reduction opportunity.

Situation: A child development center is occupied Monday through Friday and closed during the weekends and holidays. Figure 5-11 illustrates a sample of 3 weeks of building-level interval electric data.

Findings: Viewing the interval data, the facility follows a relatively normal and expected profile. The facility has a minimum load, occurring at night, of about 21 kW. The daytime profile, Monday through Friday follows an expected pattern. The 3 weeks illustrated are late July and cooling is a notable portion of the daytime load. Cooling is set back significantly at night and during the weekends when the facility is not occupied. During the night, Wednesday July 28, however, the interval electric data clearly shows that a significant electrical system did not turn off at night as usual because power only dropped to between 60 and 80 kW rather than down to the usual 21 kW. This raises the questions, what control was in override? What did not turn off and why? Was this a scheduled event? Could this have been prevented? Is this a problem that should be solved before more energy is wasted?

Outcome: Further investigation will be required. Trend data from the building automation system could provide useful information leading to the cause of the unusual high overnight power draw. Luckily, the data from the following night, Thursday July 29, indicates the problem (high overnight power demand) did not recur. If the problem did recur and was not caught and corrected, nighttime facility energy consumption could increase 250%. Of course, the August 1st weekend data now shows high energy consumption again. Maybe the override control was not properly reset, time for further investigation.

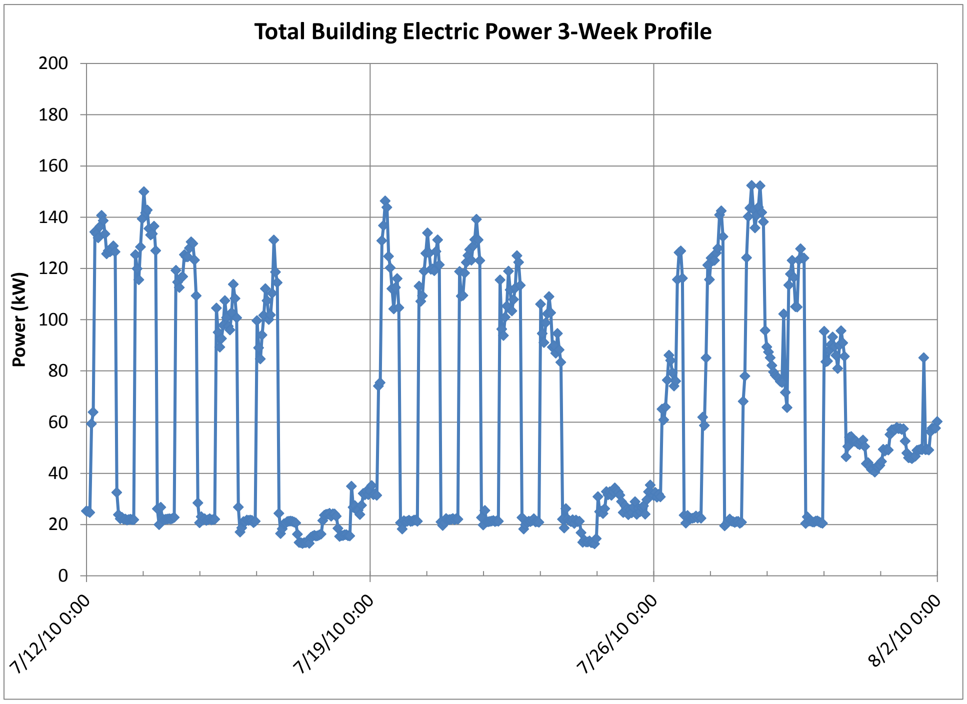

Figure 5-11. Weekly Power Profiles—Nighttime Investigation

5.2.9 Interval Data—Assessing Profiles to Identify Wrong-Way Trends

Objective: Use time-interval metered data to identify a significant increase in facility daily energy consumption and power requirements.

Reviewing interval data load profiles will reveal changes in load and energy consumption patterns.

Situation: A retail store at a site (military exchange facility) is open 7 days per week and closed on holidays. Electric power serves lights, ventilation, cooling equipment, office equipment, and miscellaneous plug loads. Natural gas serves the building heating system and a small water heater for the restroom sinks. Figure 5-12 illustrates the interval power data recorded for a series of days in November 2013.

Findings: Many buildings tend to have energy consumption patterns that follow predictable patterns. Reviewing the interval electrical data, this monitored facility had a daily power profile that followed a repetitive pattern—right up to when it changed. Daily power levels used to peak around 24 kW during the day when the facility was occupied and dropped off to around 8 kW at night when the facility was unoccupied. Daily average energy consumption ranged between 350 and 400 kWh/day, excluding air conditioning. During November 22, 2013, there was a brief power outage. Afterwards, the buildings power levels increased substantially and the increase continues unabated. Daytime peak demand measurements increased to the range of 30 to 32 kW—an increase of 25 to 33%—and nighttime loads rose to 12 kW—an increase of 50%. Daily electricity consumption now ranges between 525 and 550 kWh/day—an increase of 37% to 50%.

Outcome: Concerned that the power outage may have disabled building energy controls, the energy manager visited the facility to investigate. Building controls appeared to be functioning properly but the inspection revealed the tenant had installed new equipment in the building, which accounts for the load increase.

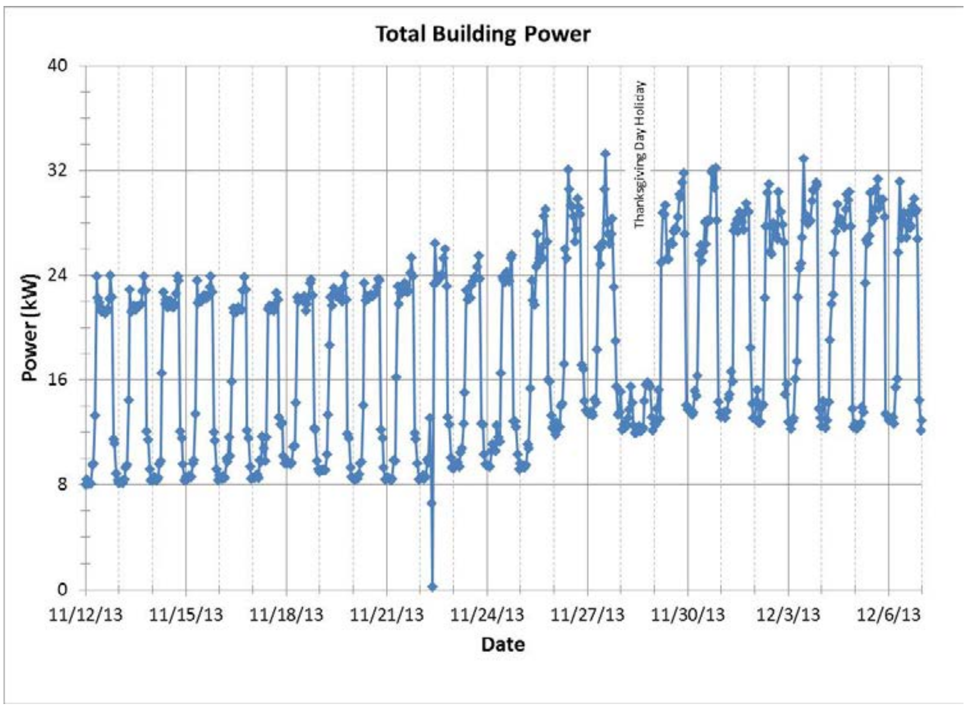

Figure 5-12. Building-Level Energy Meter Records Significant Load Increase

5.2.10 Interval Data—Using Unusual Weekend Profiles to Identify Opportunities

Objective: Use interval data to identify nighttime energy reduction opportunity.

Situation: A child development center is occupied Monday through Friday and closed on the weekends. Figure 5-13 illustrates a typical week of interval electric data (dates shown are Tuesday through Monday).

Findings: Viewing the weekly interval data, the facility follows a relatively normal and expected profile. The facility has a minimum load, occurring at night, of about 20 to 21 kW. The daytime profile, Monday through Friday follows an expected pattern. The week is during August and cooling is a notable portion of the daytime load. Cooling is set back significantly at night and during the weekends when the facility is not occupied.

During the weekend, however, the interval electric data follows an unusual inverted pattern. When the facility transfers from night-mode to day-mode, power drops to around 12 kW from 21 kW. This raises the questions, if weekend daytime unoccupied power can be as low as 12 kW, then why is nighttime unoccupied power still 21 kW, even during the weekend? What is running at night, during the week that does not run during the day over the weekend? More to the point, can this 9 kW load be turned off during the night (both during the week and weekends), since it is not operating during the day over the weekend?

Outcome: Further investigation will be required to identify the ~9-kW load that turns on around 8:00 PM Saturday night and turns off around 6:00 AM Sunday morning. A runtime meter may also be useful in determining how the component equipment cycles through the week leading to a better understanding of if the equipment can also be turned off at night, when the facility is unoccupied.

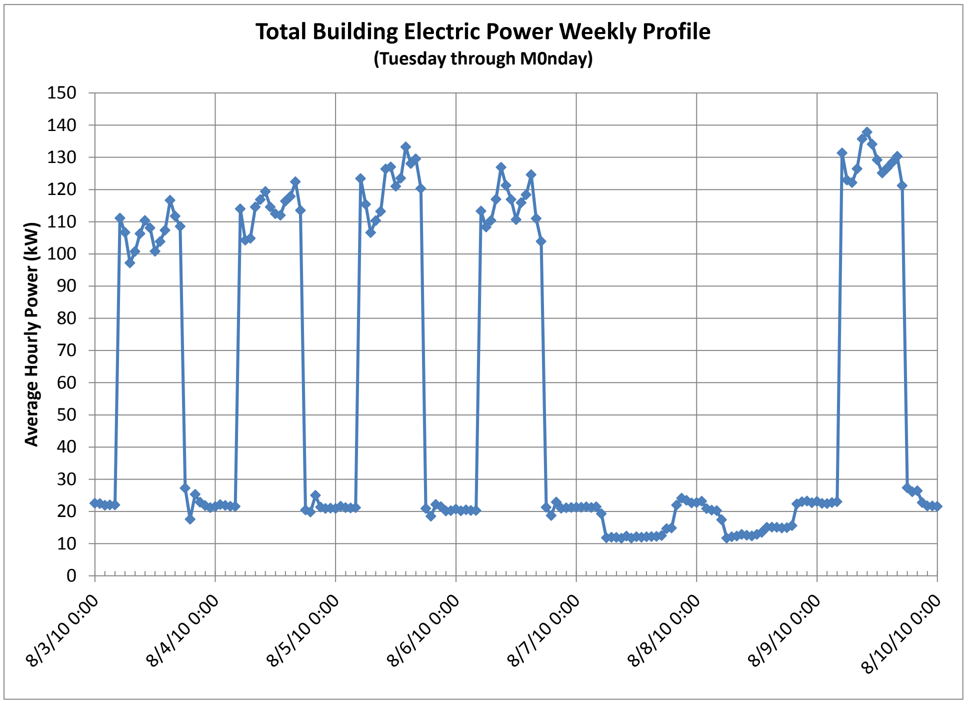

Figure 5-13. Weekly Power Profile—Weekend Investigation

5.2.11 Interval Data—Identifying an Energy Reduction Opportunity from an Unusual Increase in Natural Gas Consumption

Objective: Use interval metered data to identify unusual increase in natural gas consumption.

Situation: A dormitory at a military facility houses temporary duty visitors but is known for having a steadily high occupancy rate. Electric power serves lights, ventilation, cooling equipment, a small office, laundry facilities, and miscellaneous plug loads. Natural gas serves the building heating system and the service water heater for the central laundry and dormitory rooms. Figure 5-14 illustrates the interval natural gas data recorded for a series of weeks in April through June 2013.

Findings: As it turns out, the hourly interval data represents only the service hot water load and does not include any space heating load. Reviewing the hourly interval data (blue points), illustrates that the facility experiences relatively high variance in the rate of natural gas consumption. The minimum consumption rate (standard cubic feet per hour, scfh) in the interval data illustrated drops to almost zero. The peak rate typically rises to a high between 200 and 300 scfh. Since around May 24, the consumption rates (daily minimum and maximum) appear to be increasing. To make the consumption trend clearer, the red line is a rolling 7-day cumulative total (i.e., each red data point is a summation of the previous 168 hours of natural gas consumption). Examination of the rolling trend line clearly illustrates that natural gas consumption is on the rise.

Outcome: Further investigation with the facility manager and staff reveals that not only is the facility near maximum capacity, but the guests staying at the facility are participants in a series of active competitive games. The result is an unusually higher than normal load on the service water heating system involving both the showers and the laundry facilities. The event should continue for another week before occupancy returns to a more normal pattern.

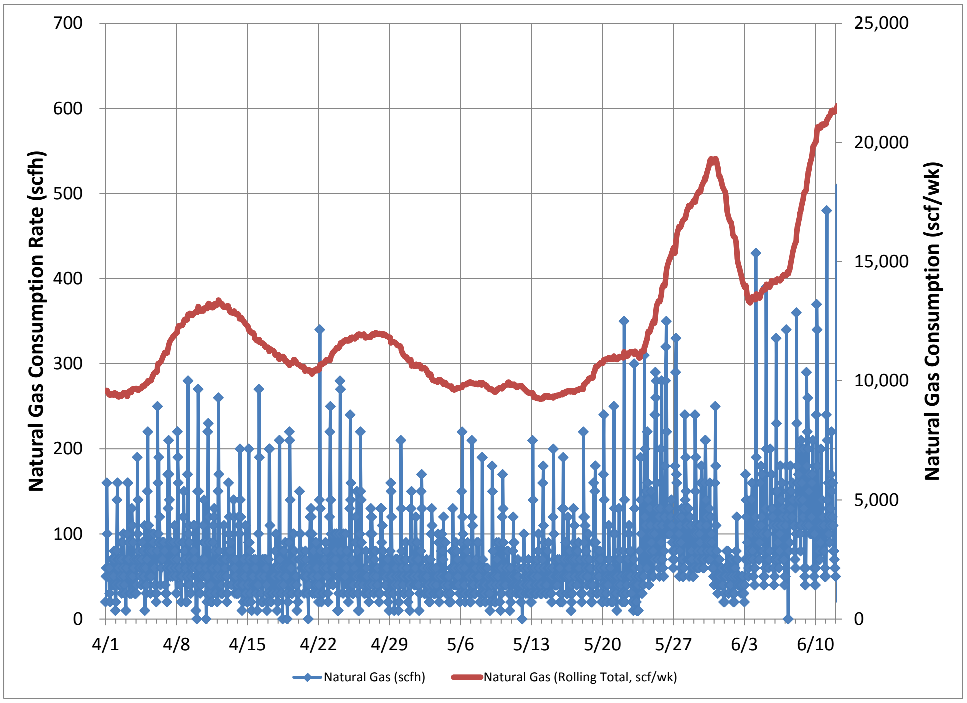

Figure 5-14. Interval Natural Gas Data Indicating Notable Increase in Energy Consumption

5.2.12 Interval Data—Assessing a Seasonal Variance in Building Performance

Objective: Assessing interval metered data to identify an equipment operating problem during a seasonal startup.

Situation: A dormitory complex is located on a military facility in the eastern United States. The complex consists of three interconnected, three-story wings around a central courtyard. The building complex houses active military personnel permanently stationed at the facility. There is a sub-meter on the chiller that provides chilled water to the complex. Additional data are monitored and recorded by the site-wide building automation system (BAS). Electric power serves lights, ventilation, miscellaneous plug loads, and the central chiller. Natural gas serves a central boiler providing hot water to the facility for space heating and a central service water heater provides hot water to the dormitory bathrooms.

Findings: Figure 5-15 illustrates 5 weeks of 15-minute interval electric data for the dormitory. Electric power rose from ~40 kW to 60 kW over the first 2 weeks on the chart. In late May, power became very erratic, bouncing between 40 kW and 120 kW. By early June, the power levels settled into a range between 100 kW and 160 kW. Over the same period, the housing manager reported that occupancy rates for the dormitory complex were stable at 90%. This raises the question, why have power levels tripled?

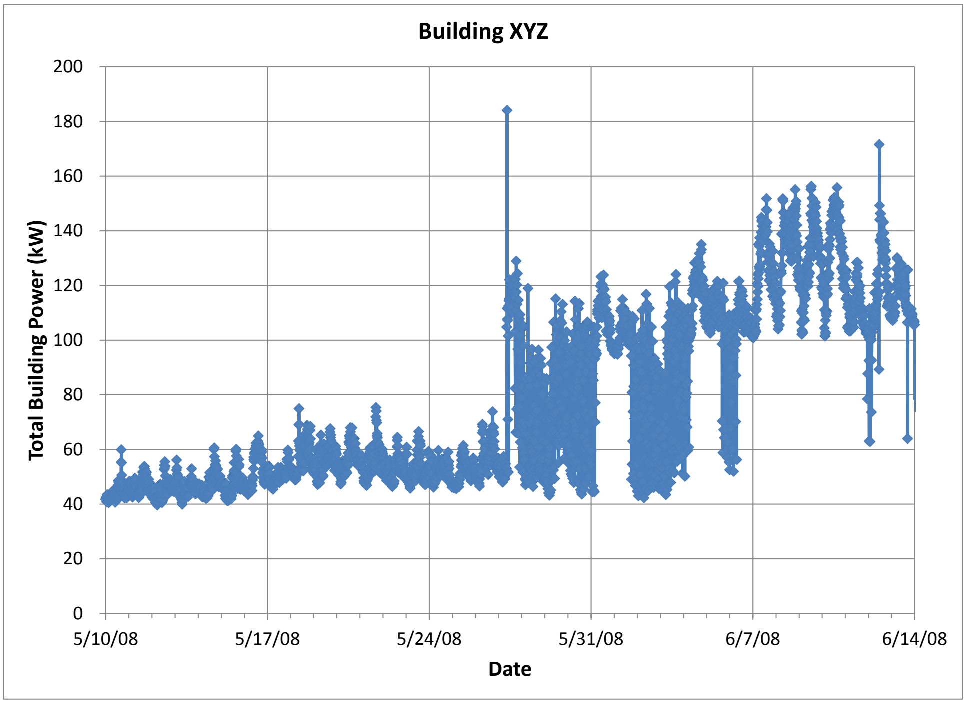

Figure 5-15. Electric 15-Minute Time-Interval Data

Outcome: Further investigation involved examining building schedules, the additional chiller sub-metered data, and the outside air temperature data available from the BAS. Figure 5-16 overlays the building-level metered data with the additional chiller sub-metered data and the outside air temperature data. The jump in power levels is clearly attributed to the chiller being brought online for the summer cooling season at the end of May. While the local temperature was already achieving daily highs near 80°F, local operating procedures did not allow the mechanical cooling system be turned on until after Memorial Day. While the amount of energy required to support the cooling system is a significant portion of the building's total electric energy, the metered data allowed the investigation to identify the cause of the jump in power. Further investigation will be required to identify if there is cost-effective energy-saving opportunity here.

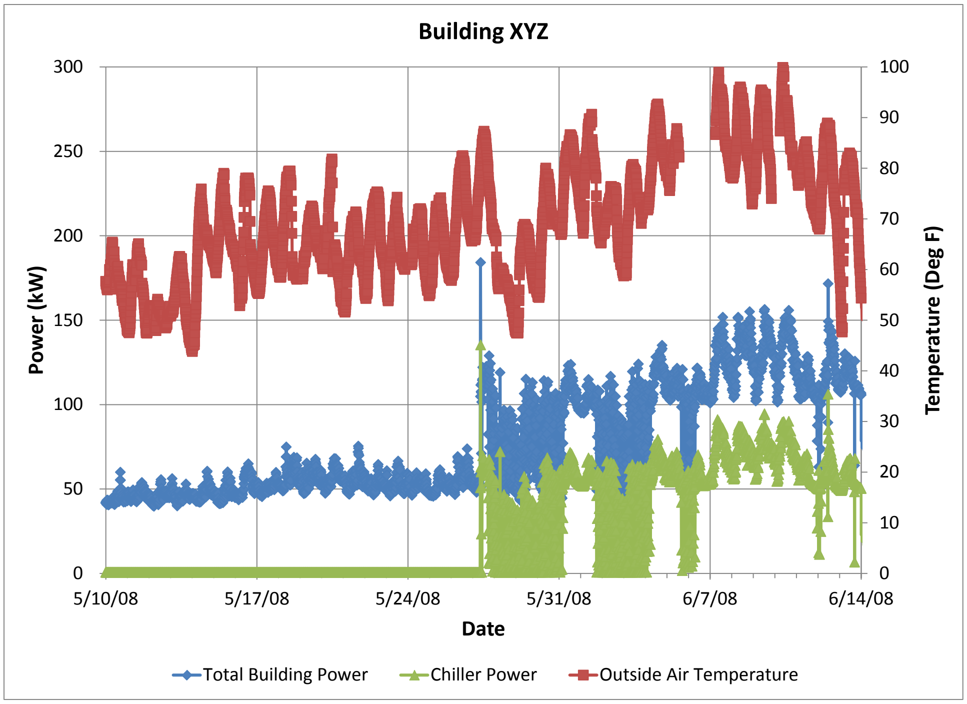

Figure 5-16. Building-Level and Chiller Time-Interval Data Plus Outside Air Temperature Data

5.2.13 Interval Data—Using Interval Energy Meters to Validate Boiler Performance

Objective: Characterize (5-minute energy) time-series metered data to validate boiler performance.

Situation: This case involves a facility with a central boiler plant with space heating and process loads. Interval meters are installed on the natural gas fuel supply to the boiler and the (high-temperature hot water) heated water circulation system. Data reported are for a full heating season for both pre- and post-installation periods surrounding a change in the boiler control system.

Findings: Charting the 5-minute natural gas fuel input versus the 5-minute heated water circulation system energy output yields the energy performance of the boiler at various loads (data collected with individual interval meters on the boiler). Figure 5-17 presents these data in a scatter chart (also known as an X-Y chart) showing both pre- and post-installation data surrounding a change in the boiler control system.

Outcome: The interval data clearly shows a reduction in natural gas consumed (increase in system efficiency) versus the thermal output (load) on the boiler across the monitored load range experienced by the boiler during the study period.

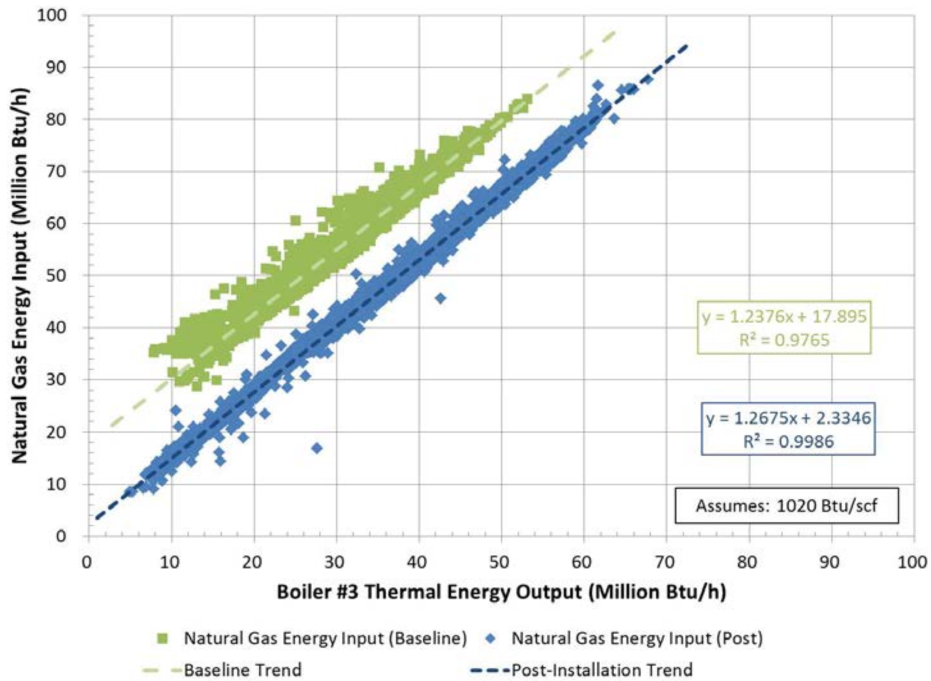

Figure 5-17. Boiler Performance Data

5.2.14 Interval Data—Assessing Building Performance

Objective: Use interval metered data to assess space heating building performance.

Situation: A high-rise office building in the southeastern United States has three natural gas sub-meters with interval pulse outputs connected to the building automation system (BAS). One meter specifically sub-meters the central space heating plant, which consists of four natural-gas-fired hot-water boilers. The other two meters cover the employee cafeteria and the service hot water system. Figure 5-18 illustrates the 5-minute interval data collected from the boiler sub-meter during January 2012.

Findings: Fine resolution data can be very difficult (sometimes impossible) to interpret. Analytical software tools can make interpretation easier and faster. Figure 5-19, a scatter chart (also known as an X-Y chart), puts the data in relative context. First, the high-frequency interval data are consolidated into hourly intervals. Next, the natural gas consumption data are plotted versus the average outside air temperature (which is also measured and recorded by the BAS but is also available from local weather stations). Consolidating the data into hourly intervals, rather than using the raw 5-minute interval data, reduces the impact of equipment cycling; thereby smoothing the data, making it easier to visually interpret. Plotting the data versus outside air temperature allows the analyst to see the metered data as it relates to outside air temperature; thereby illustrating the causal relationship.

Fine resolution data can be difficult to interpret. Put the data in a useful context to reveal performance.

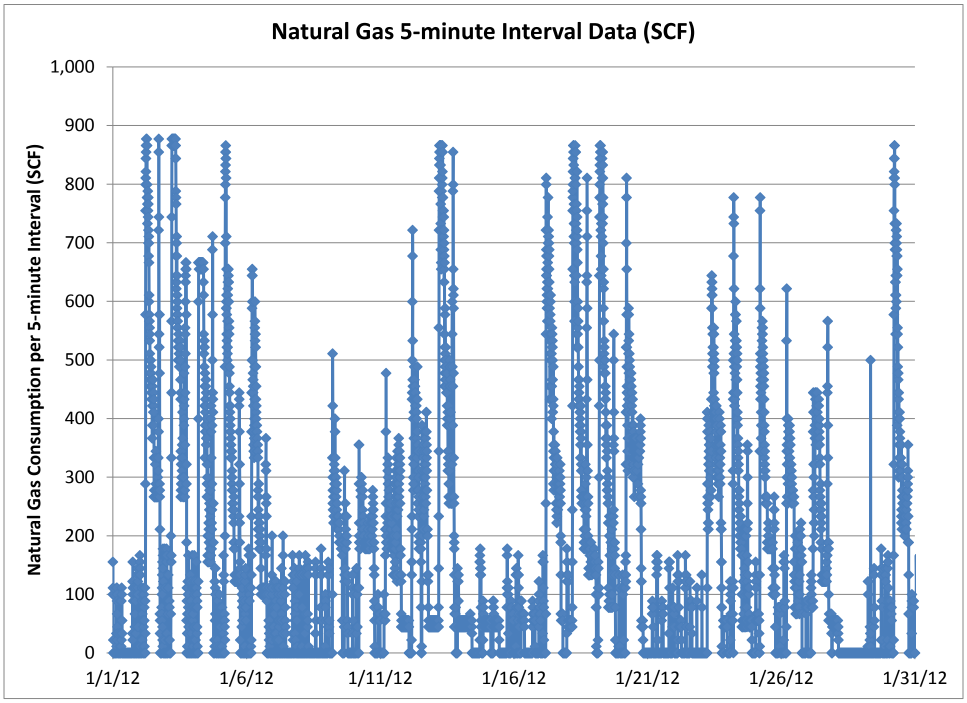

Figure 5-18. Natural Gas 5-minute Time-Interval Data, January 2012

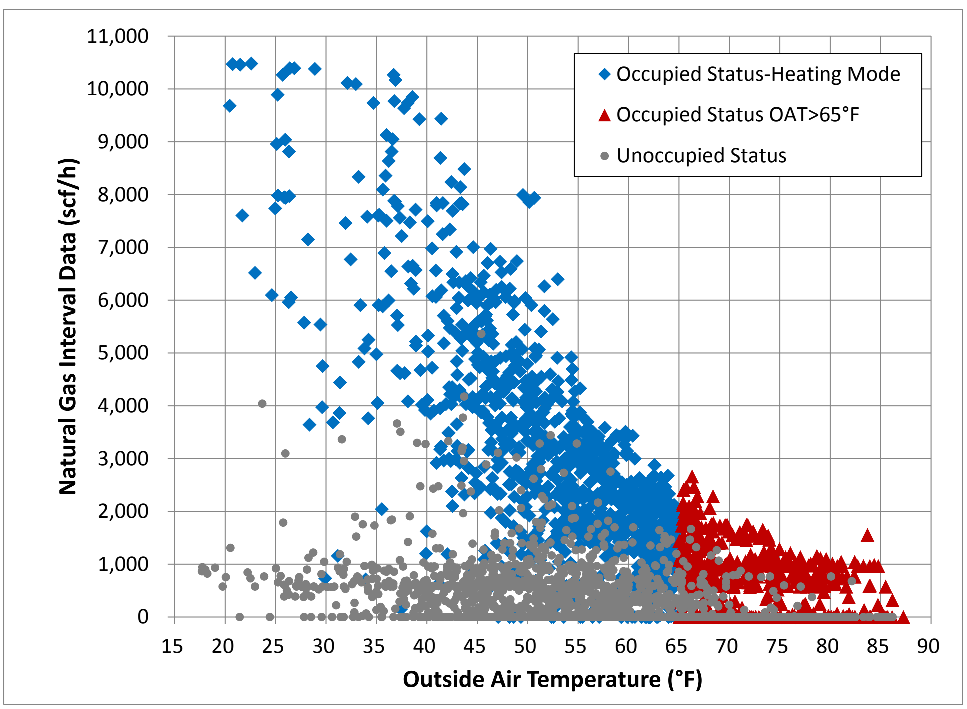

Figure 5-19. Natural Gas Interval Data Charted Versus Outside Air Temperature, FY2012

Outcome: Examination of the data illustrated in Figure 5-19 reveals some key building performance factors. First, building performance, as it relates to natural gas demand, is very different between when the building is operating in an occupied mode versus when the building is operating in an unoccupied mode. This facility clearly has an effective night setback strategy that significantly reduces the natural gas demand (and consumption) when the building is in the unoccupied mode. Second, while the metered natural gas is only for the sub-metered space heating system, there is significant natural gas consumption occurring when the outside air temperature is greater than 65°F. The boiler is typically offline during the late summer months; however, further investigation is warranted to determine why the space heating boiler system continues to operate when the outside air temperature is greater than 65°F (even when greater than 85°F) given that the facility does not use reheat in the space-cooling mode.

5.2.15 Interval Data—Using Energy Intensity Charts and Average Daily Load Profiles

Objective: Use time-interval data to observe building energy systems operation.

Situation: Figure 5-20 represents 1 year of electric interval energy data for an administration building. In the main image, the X-axis represents 24 hours in the day and in the Y-axis each row represents 1 day in the year. The color represents the interval data measurement. Green is low intensity, red is high intensity, and yellow is average for the building. White space represents missing data. To the right of the energy intensity chart, there are two additional chart images illustrating the heating degree days (red) and cooling degree days (blue). The degree day charts line up with the corresponding day on the energy intensity chart.

Following the energy intensity chart, there are two average daily demand profile charts. Figure 5-21 illustrates the average demand profile for each day type, while Figure 5-22 illustrates the average demand profile by season. These charts help illustrate that interval energy data can reveal how the building operates and if a potential problem exists, but it is still up to the energy manager to recognize the issue and take action.

Findings: The setback schedule for this building is quickly evident. The building transitions from unoccupied mode to occupied mode (starts) at 5:00 AM (0500) and transitions from occupied mode to unoccupied mode (stops, or setback begins) at 10:30 PM (2230). This can be seen as the intensity color changes at the same time throughout the year. This is a long occupied period and should be compared to the actual building usage periods of occupancy. Does the BAS schedule need to be in occupied mode from 5:00 AM (0500) through 10:30 PM (2230)?

The weekend schedule for this building is also quickly evident. The green (low intensity) stripes repeat every 7 days illustrating that this building also has an unoccupied mode during the weekends.

The building's electricity consumption is cooling dominated. The red (high intensity) occurs when there are high cooling degree days. Higher cooling degree days correspond to higher electric intensity (higher electricity consumption per interval). Heating may come from natural gas or some other fossil fuel because electricity consumption does not appear to elevate in response to increasing heating degree days. Electricity does peak July through September in response to elevated cooling degree days.

Evident by looking at unoccupied periods across days with varying cooling degree days, cooling still occurs during the unoccupied mode, although at a reduced level than the occupied mode. This is more evident looking at Figure 5-22, where the daily profile for the summer season is greater than the shoulder and winter seasons during the unoccupied period.

There was a change in late July where the intensity level increased although the level of cooling degree days appears to be less than during June and early July. This may be a season impact because the same color pattern contrast appears when comparing October 2012 to May 2013, which had similar level of cooling degree days. The unusual high intensity that occurred around May 1, 2013 likely is the result of unusual weather—note the high level of cooling degree days shifting abruptly to heating degree days, then again back to a high level of cooling degree days in the matter of a few days. An energy manager examining this chart on a regular basis would be advised to check the status of the cooling system set points for overrides or failed sensors/controls.

More evident in the daily load profile charts, the base demand is ½ the peak demand during the winter. During the summer, the base demand is still 1/3rd the peak demand. This implies that much of the equipment in the building still operates during the unoccupied period. The energy manager should investigate what equipment is operating during the unoccupied period. Likely culprits are plug loads, lighting, and ventilation fan motors not being setback.

Outcome: The first time an energy manager develops and uses these charts, the objective is to compare expectations (schedule) to observations (data). Does the data reveal opportunities for reducing energy consumption based on schedules and recurring events. Periodically revisiting these charts, as time progresses, can assist the energy manager in catching and correcting energy waste quickly—before the losses cumulate and become significant.

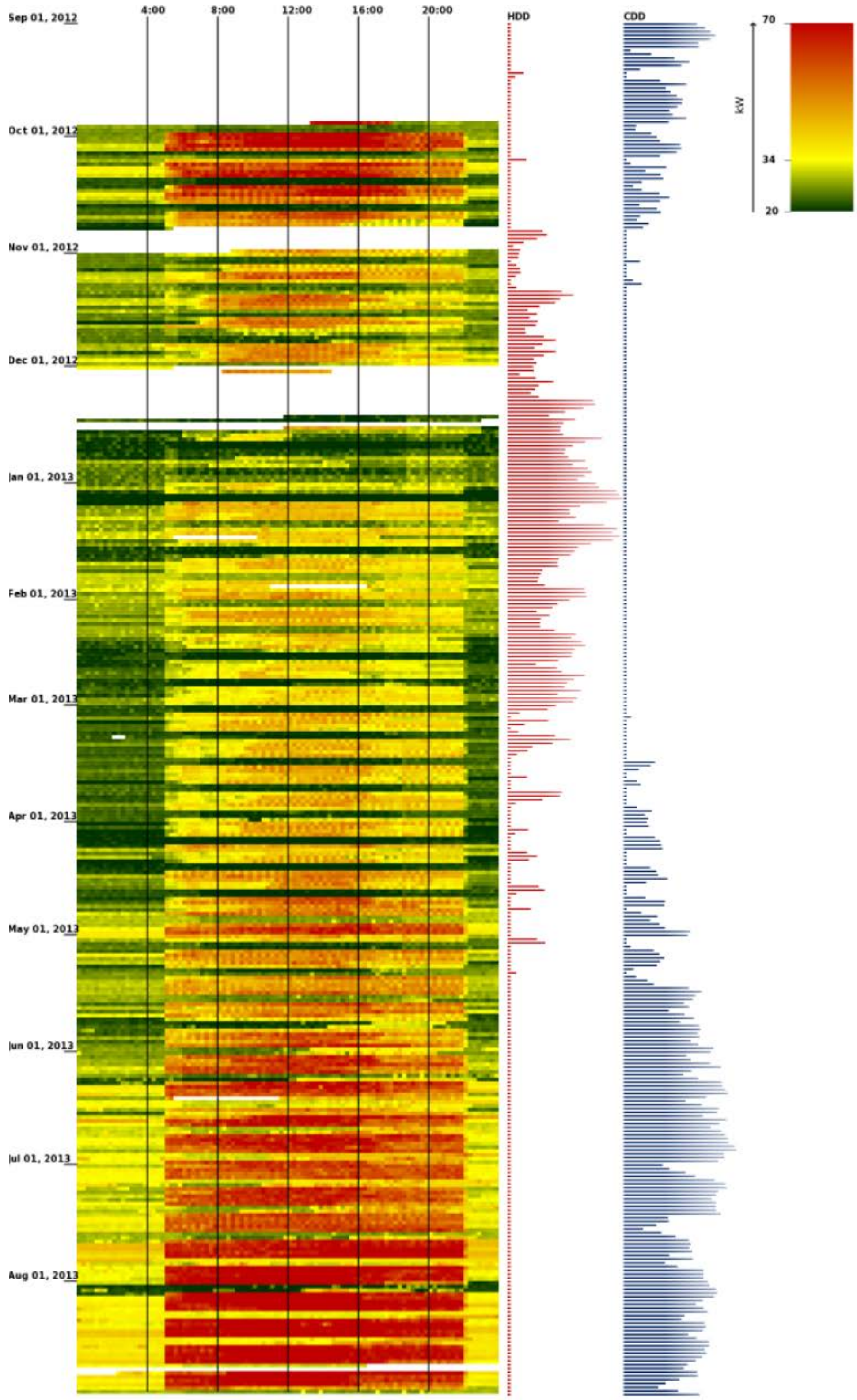

Figure 5-20. Energy Intensity Profile for an Administration Building

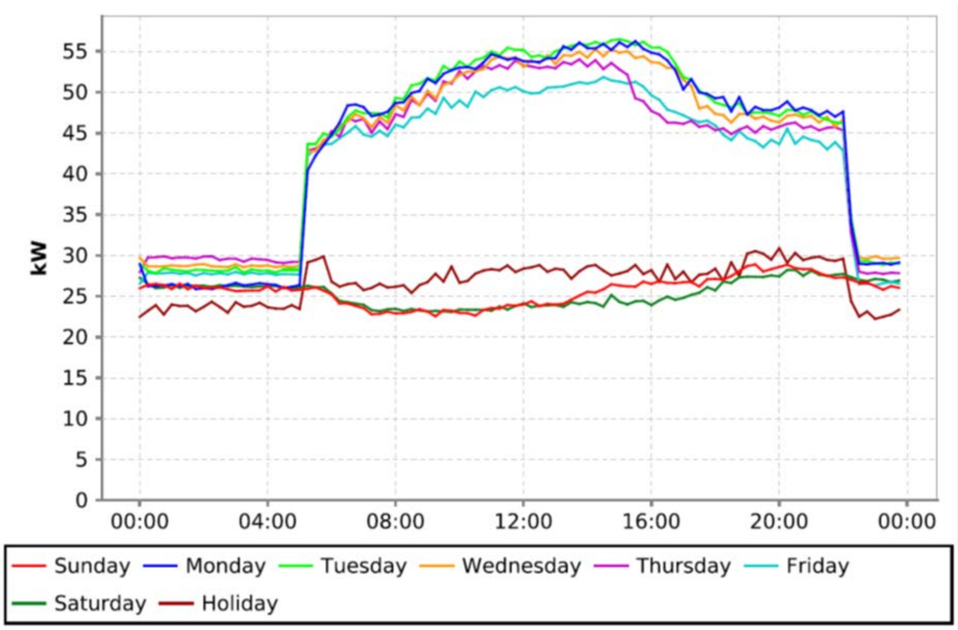

Figure 5-21. Average Daily Demand Profile by Day of Week

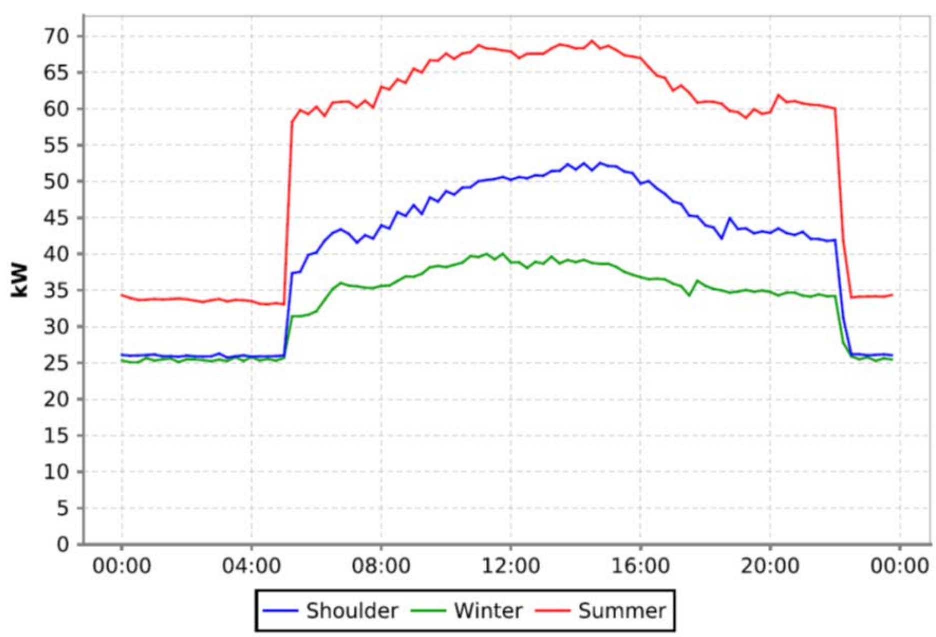

Figure 5-22. Average Daily Demand Profile by Season

5.2.16 Interval Data—Using Interval Data to Identify Equipment Operating Problem

Objective: Use time-interval metered energy data to identify frequent boiler cycling.

Situation: A facility is heated with a small central heating plant consisting of three fuel-oil-fired hot-water boilers. One fuel oil flow meter is used to measure the total fuel oil flow to the heating plant. The fuel oil supply system is gravity fed and is not a circulation system. The fuel-oil flow meter generates a calibrated pulse, which is recorded by a central data acquisition system in 5-minute time intervals. The local outside air temperature data are also collected by the data acquisition system, but stored in 15-minute interval data.

Findings: Reviewing the 5-minute fuel oil interval data, presented in Figure 5-23, reveals the fuel flow is cycling off 3 to 4 times per hour even as the outside air temperature drops to -2°F (the local heating design temperature). Assuming the boilers are firing in unison, this implies that each boiler is cycling off 3 to 4 times per hour.

Outcome: The data indicate the boilers are cycling at a high frequency, which indicates the heating plant may be oversized. Additional study is warranted to determine if there is an opportunity to reduce the cycling frequency and thereby improve operational efficiency. Installing run-time meters on the boiler combustion air fans would verify the cycling frequency of the individual boilers. The energy saved by changing the boiler control settings (cut-in/cut-out set point temperatures) or turning one boiler off could be validated with the fuel oil flow meter installed.

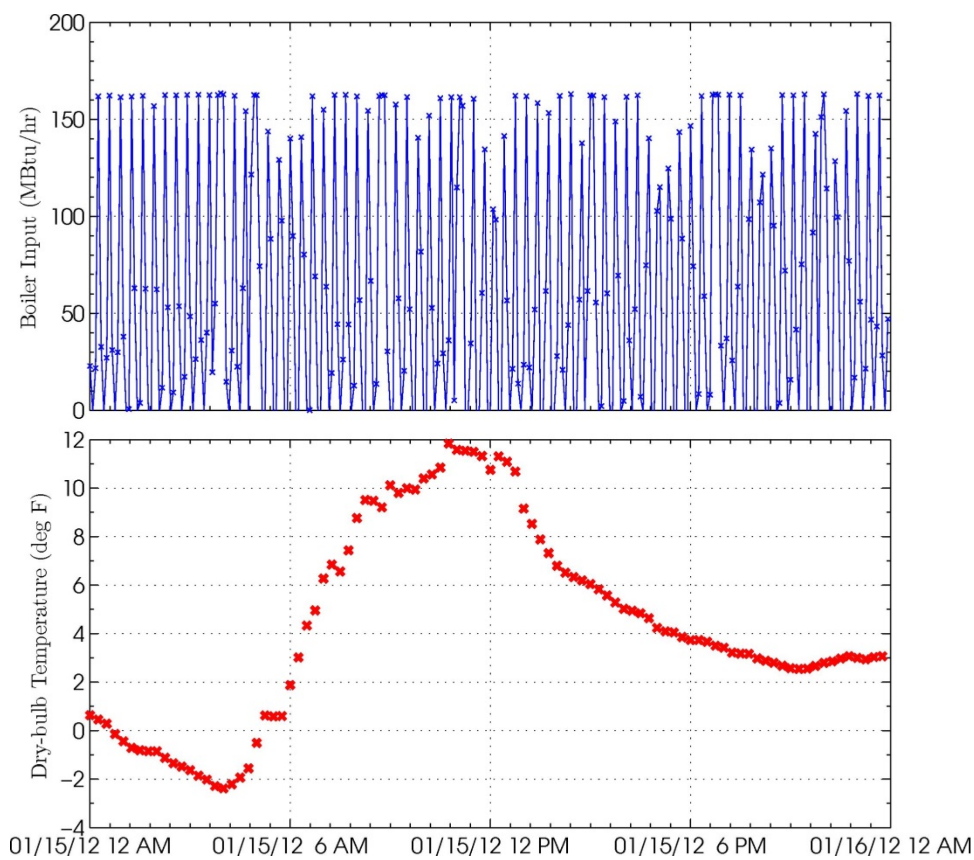

Figure 5-23. Snap-Shot of Boiler Fuel Input and Outside (Dry-Bulb) Temperature for One Day

5.2.17 Interval Data—Assessing Peak Demand Reduction Opportunity

Objective: Use interval demand data to identify, value, and ultimately reduce peak demand (LBNL 2004).

Situation: A facility has process loads and a peaking demand concern. Using interval demand data, a load-duration curve can be used to assess the potential for demand reduction.

By building a load duration curve, opportunities for valuing and reducing peak demand become evident.

Findings: By building a load duration curve – curve presenting the number of hours that a building's demand is greater than some predetermined value – opportunities for valuing and reducing peak demand become evident. In the graph and accompanying data below (Figure 5-24 and Table 5-2), only 1% of the time (or about 7.5 hours) during July was the demand above 2,102 kW.

Outcome: Given that peak demand for the month was 2,289 kW allows for calculation of the difference between the peak and the 1% value (2,289 – 2,102) = 187 kW. This difference, 187 kW, represents demand that occurred during just 7.5 hours in the month. At a peak demand charge of $17.92/kW, this demand cost over $3,350 for this month. Put differently, if this demand could have been avoided (during those 7.5 hours), the monthly savings of $3,350 could have resulted. This general concept is scalable (i.e., consider avoiding the top 2%) and, when spread over 12 months, can have a significant monetary impact. To affect these savings, a clear understanding of the site's utility rate structure (not always an easy endeavor), including any demand ratchet clause, is necessary.

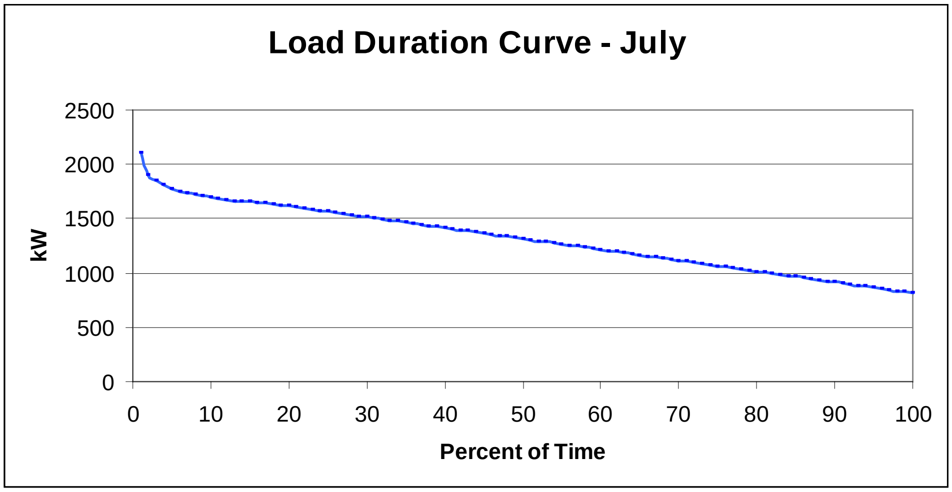

Figure 5-24. Load Duration Curve

Table 5-2. Load Duration Curve Data

Percentage of Time (Month of July)	Electric Demand from Interval Data
Peak	2,289
1%	2,102
2%	1,905
3%	1,849
4%	1,807
5%	1,768

5.2.18 Sub-meter Data—Data Center Monitoring

Data center presence and capacity is rapidly growing in both the public and private sectors. This growth, fueled by the Internet economy and an ever increasing need for information storage and processing, has transformed data centers into one of the most energy-intensive building types and end uses. As shown in Figure 5-25 (CEC 2009), annual data center energy cost is second only to that of the clean room and more than four times that of a hospital.

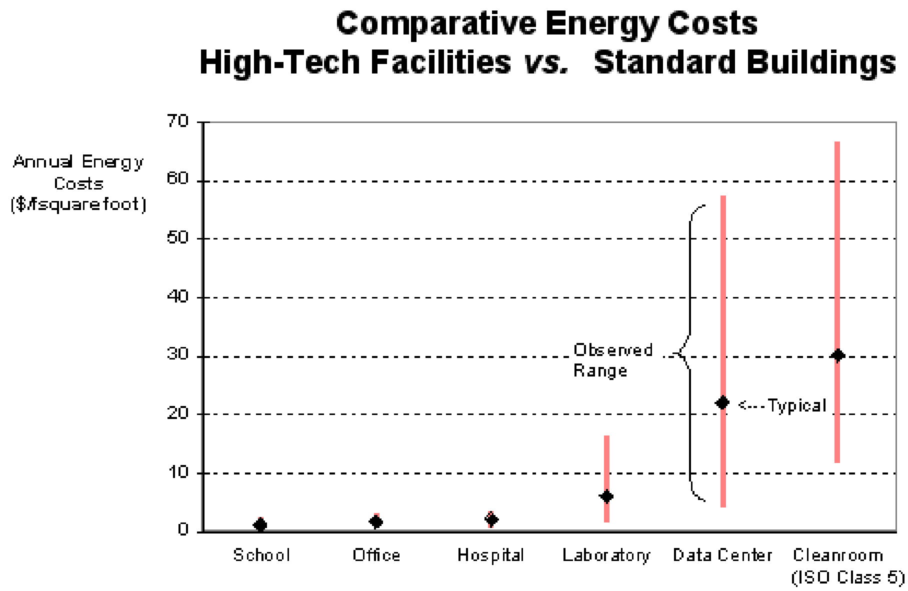

Figure 5-25. Comparative Annual Energy Costs of Different Facility Types

Data centers require the understanding of how energy is being used and how a variety of parameters may impact system reliability. Data centers frequently require a reliability of "six nines"; put as a function of downtime, "six nines" is equivalent to 31.5 seconds per year of downtime. The metering used to achieve this high reliability is typically more sophisticated, detailed, and expensive. Depending on the function and data needs, a data center can be located in a small closet/communications area, a dedicated data center room, or occupy entire floors. A typical data center room is shown in Figure 5-26**.** Typical Data Center. (CEC 2009)

Figure 5-26**.** Typical Data Center

When a data center experiences an outage, it is usually the result of power quality issues, circuit overloading, or human error. In each of these cases, proper metering will afford predictive diagnostics and thus reduce potential downtime. To achieve the highest levels of reliability, considerations for metering in data centers should include:

- Building-level electric
- Service panel mains and sub-panels

- Critical HVAC/computer room air conditioning (CRAC) systems
- Back-up generators
- Uninterruptible power supplies (UPSs)
- Critical data communications equipment
- Server rack breakers.

The actual points and parameters to collect will vary with data center operation and equipment. The key diagnostic for each of these parameters is a noted "change in value"; specific diagnostics will be a function of system type/operation and beyond the scope of this document. However, through trending of these data points, "exception reports" and "out of range" values will be apparent and warrant further investigation.

Typical metering will include the full suite of diagnostics for the above points and include:

- ***Voltage regulation and imbalance***. Voltage imbalance relates to the maximum deviation from the average of the three-phase voltages or currents. A typical source of voltage imbalance is single-phase loads on a three-phase circuit or the dropping of one phase of the circuit because of circuitry failure, fusing, or poor connections. Diagnostics include monitoring of:
  – Phase voltages, both individual and phase-to-phase
  – Root mean square (RMS) magnitudes
  – Sampling of maximum, minimum, and averages
- ***Voltage sags and swells***. These two parameters are defined as decreases (sags, also known as dips) or increases (swells) in system voltage. The predominant causes of voltage sags and swells relate to the switching on (sags) and off (swells) of large loads (e.g., process or HVAC motors) that have large start-up current draws. Diagnostics include monitoring of:
  – Phase voltages and currents
  – Equipment response
- ***Power factor***. The ratio of true power to volt-amperes in an AC circuit. Power factor (PF) is expressed in a percent of unity (lagging for inductive loads or leading for capacitive loads; resistive loads have a unity PF) and have economic implications depending on the utility rate structure. Diagnostics include the monitoring of:
  – PF measured at the service feed, breaker, or end-use level
  – Correction considered for values <0.85
- ***Harmonics/harmonic distortion***. Harmonics represent the sinusoidal voltages (or currents) with frequencies that are integer multiples of the operational system frequency. Harmonic distortion relates to the nonlinear characteristics of the loads on the system and the impacts these may have on sensitive loads. Diagnostics include monitoring of:
  – Phase voltages and currents
  – Waveform characteristics

- Neutral conductor loading
- Trend analysis to predict impending issues

Because of the critical nature of this metering, it is suggested that a detailed metering plan specific to the application be developed. Plans of this nature can be very complex and are best developed with IT staff knowledgeable of both the system and metering equipment capabilities.

5.2.18.1 Data Center Benchmarking

Beyond the reliability needs for data centers, energy efficiency is becoming a very closely monitored attribute. A key metric for data center energy use is the power usage effectiveness (PUE) and is defined as:

Power Usage Effectiveness (PUE) = Total Facility Power/Total IT Equipment Power

Where

Total Facility Power = all power delivery components (external to the IT equipment), all HVAC, lighting, and other miscellaneous loads
Total IT Equipment Power = all loads directly associated with IT equipment including storage hardware and computers used to monitor or control data systems

Benchmarks for PUE have been developed and are constantly being assessed for validity. Current benchmark PUE values are presented in Table 5-3:

Table 5-3. Benchmark Data Center Power Usage Effectiveness

Benchmark Level	Power Usage Effectiveness (PUE)
Standard	2.0
Good	1.4
Better	1.1

5.2.18.2 Available Software Tool

Data Center Profiler (DC Pro)

Description: The Data Center Energy Profiler, or DC Pro, is a free online software tool provided by the U.S. Department of Energy. Organizations can use the DC Pro software tool suite to identify and evaluate energy-efficiency opportunities in data centers. The suite features a profiling tool and a set of system assessment tools to perform energy assessments on specific areas of a data center. The DC Pro tool suite is designed for data center owners and operators who want to diagnose how energy is being used by their data centers and determine ways to save energy and money.

Availability: http://datacenters.lbl.gov/tools.

5.3 Overcoming Common Metering Challenges

In the course of any metering exercise, there will be challenges that arise – these may occur in planning, specifying, purchasing, installing, or in the maintaining of the metering system. This section focuses on some of the more common metering challenges with the hope that identifying these early in the process mitigates potential impact.

Metering Planning. The planning step of the metering process is critical to program success. Some of the challenges in the planning process include:

- ***Best Information***. Good information drives good planning and decision making. It is incumbent on the planners to make sure the best available information is accessed and used. In metering of existing buildings, access to electrical plans, one-line diagrams and panel schedules is critical. However, as is often the case, these documents (when available) are incomplete, outdated or are not considered "as-built." A recommended step in the planning process is the access and verification (possibly confirming with field inspection and spot measurement) of all technical documents.
- ***Under/Overestimating Breadth of Project***. A key to metering planning resides with an ability to estimate current and future needs. While it is difficult to accurately predict future needs, efforts to plan for future system expansion are critical to the economic success of the system. This is often done by scenario phase-planning whereby different project implementation assumptions are used to create best, most likely and worst-case scenarios. These different scenarios are then factored into the planning process.
- ***Management Buy-in and Support***. Obtaining and maintaining management support for project planning and implementation is an often overlooked activity. Providing management with regular updates on activities and successes is one way to keep the project visible and maintaining this support.
- ***Milestone Development***. While many plans focus on the "what," effective plans also focus on the "how." Developing how and when the steps of the process will be implemented are critical to assuring a successful metering program.

Equipment Specification. The identification of the correct equipment is crucial to the project's success and longevity. This requires an ability to distinguish the necessary parameters for proper function.

- ***Operating range***. When selecting metering equipment, understand the operating range of the expected measurements. Metering equipment capacity should be sized based on the expected operating range and never based on pipe size or circuit capacity.
- ***Accuracy***. As defined, the accuracy of a metering system is the difference between the measured value and the actual value. While overall system accuracy is important and often reported for standard operating ranges, accuracy should be addressed for each component of the system and, importantly, over the entire range of expected values. Current transformers (CTs) and fluid meters present good examples of this need.
  - CTs are usually accurate over a broad range. Basic CTs provide high accuracy from 10% to 110% of the rated current. Higher quality CTs, however, can provide high accuracy from 1% to 120% of the rated current. CT sizing should be done with care and full knowledge of the expected measurement range, paying particular attention to the low end of the range.

  - Fluid meters are often specified on average and maximum flow rates. In systems with a wide range, and including low flows, accuracy can suffer. In these cases, compound meters can be specified to accommodate the two different flow rate regimes to achieve desired accuracy.

- ***Operation***. Prior to the identification and procurement it is important to understand the equipment; that is, its function, operation, and maintenance needs. This step must involve input from those who will be using the equipment. Parameters to consider include:
  - Meter installation and setup, paying particular attention to spatial constraints and code requirements
  - Flow meters may require strainers or filters; straight pipe runs or flow conditioners; and isolation valves for ease of maintenance.
  - Software configuration and ease of use.
  - Process and schedules for maintenance of system, sensors, and battery needs.
  - Data synchronization for various meters and data acquisition systems.

- ***Communications***. Meters from different vendors or product lines can have different data sampling rates, sampling intervals, and communicate and transmit data using different protocols and formats (ACEEE 2010). To mitigate any potential issues with communication consider the following guidance:
  - Standardization on manufacturer and/or data protocols. There are a number of established and developing protocols (e.g., BACnet, LonWorks, Modbus, pulse); make certain that the meters specified have a common protocol or can be converted for proper communication.
  - Data collection intervals. To assure accurate data processing, meters should be set to a universal time stamp (i.e., time-series records reference the same time stamp) and be collecting and integrating over the same interval (e.g., a 15-minute interval).
  - Data interoperability. Depending on how data are collected and processed, routines may need to be employed that pre-condition or consolidate the data for final processing.

- ***Cost of Ownership***. An important metric in specification is total cost of ownership over the equipment's life. Identifying what the defined life of the system is the first step. It is important to determine the recurring cost, including any periodic calibration, needs for part/sensor replacement, or upgrades to system software or licensing. All of these parameters should be readily available from equipment vendors and should be received in writing. Most important, weigh the real benefit of additional features and options. Do not "over buy" metering equipment by adding features and options that add costs without corresponding savings.

Purchasing. The details and specifications of items procured are very important when purchasing metering equipment and accompanying sensors. Procurement specifications should be developed with engineering and facilities management input/oversight and include a thorough review before any purchase orders are signed.

- ***Manufacturer Standardization***. While it is not always possible, there are some advantages to standardizing on one equipment manufacturer; these include:
  - Single source of information and product
  - Minimization of finger pointing when "system" problems occur
  - Volume procurement/discount opportunities.

Installation. Following all manufacturers' guidelines and relevant code requirements is essential to proper and safe installation. Additional recommendations to consider include the following:

- Offer an explicit instruction set for all installations, provide relevant contacts for installation questions, and develop checklists for installation check out. Typical installation faults include:
  - CT directionality or flow direction
  - Voltage and phase consistency
  - Meter constants, inputs, and programming
  - Maximum output signal communication distances
  - Meter power supply
- Develop installation commissioning protocols. Verify each meter individually.
  - Develop "expected" values for each meter
  - Compare output against "expected" values and spot measurements
- In multi-meter installations verify that the sum of the parts equals the whole.
  - Individual end use, distribution centers, and building-level
- Develop communication commissioning protocols.
  - Verify each meter individually
  - Confirm time series output received at endpoint/data center
  - Confirm summed data received over duration (week/month) are accurate and expected

Maintenance. Once installed and operating, facility staff must focus on keeping metering systems productively functional. Meter/sensor calibration, data receipt, and accuracy are the key meter maintenance parameters most often neglected. To prevent these issues from arising, the following are suggested:

- Consider developing time-based checklists of manufacturer's maintenance recommendations and including these in regular maintenance activities.
- If the site uses a computerized maintenance management system (CMMS), all relevant metering information (manufacturer, model, date of installation, size, and procedures) should be entered into the CMMS from where automated work orders will be generated.

Chapter 6 References

42 USC 8253(f)(8). 2007. "Benchmarking of Federal Facilities." *National Energy Conservation Policy Act*, as amended.

42 USC 8253(e)(1). 2007. "Metering of Energy Use." *National Energy Conservation Policy Act*, as amended.

Alberta Utility Commission. *Rule 021, update 2.4*. Calgary, Alberta, Canada. January 2014. www.auc.ab.ca.

American Council for an Energy-Efficient Economy (ACEEE). 2010. *Toward the Holy Grail of Perfect Information: Lessons Learned Implementing an Energy Information System in Commercial Buildings*. K Kirchner, G Ghatikar, S Greenberg, D Watson, R Diamond, D Sartor, C Federspeil, A McEachern, and T Owen, ACEEE Summer Study on Energy Efficiency in Buildings, Washington, D.C.

American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE). 2002. *Guideline 14-2002: Measurement of Energy and Demand Savings*. Atlanta, Georgia.

ANSI/ASHRAE/USGBC/IES. 2011. Standard 189.1-2011. *The Standard for the Design of High-Performance Green Buildings*. American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Atlanta, GA.

ANSI/ASHRAE/IES. 2013. Standard 90.1-2013. *Energy Standard for Buildings Except Low-Rise Residential Buildings*. American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Atlanta, GA.

ANSI/NEMA. 2008. *American National Standard for Electric Meters Code for Electricity Metering.* NEMA/ANSI C12.1-2008. National Electrical Manufacturers Association.

ANSI/NEMA. 2008. *American National Standard for Electric Meters—0.2 and 0.5 Accuracy Classes.* C12.20-2010. National Electrical Manufacturers Association.

Architectural Energy Corporation (AEC). 2003. *Advanced Utility Metering*. Under contract NREL/SR-710-33539, Boulder, Colorado.

Auber, Ari. 2011. "*Drought Effects Extend Far Beyond Water Restrictions*." The Texas Tribune. August 4, 2011.

Best Manufacturing Practices Center of Excellence (BMP). 2007. *Best Manufacturing Practices 2007. Best Practice: Cooling Tower Make-Up Water Metering*. College Park, Maryland. Available at: http://www.bmpcoe.org/bestpractices/internal/polar/polar_15.html.

Better Bricks. 2014. *Interpreting Electric Metered Data Training Series*. Better Bricks, Northwest Energy Efficiency Alliance, Portland, OR. Available at: www.betterbricks.com/building-operations/interpreting-electric-meter-data-series.

Better Bricks. 2014. *Software*. Better Bricks, Northwest Energy Efficiency Alliance, Portland, OR. Available at: www.betterbricks.com/building-operations/software

Better Bricks. 2011. *The High Performance Portfolio: Energy Tracking and Accounting*. Better Bricks – Bottom Line Thinking on Energy. Available at: http://www.betterbricks.com.

Boyd, BK. 2010. *Guidelines for Estimating Unmetered Industrial Water Use*. PNNL-19730. Pacific Northwest National Laboratory, Richland, Washington. Available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-19730.pdf.

Buildings. 2014. "*Power Outages Increase in 2013,*" Industry News, Buildings Magazine. April 1, 2014. (http://www.buildings.com/news/industry-news/articleid/17206/title/power-outages-increase-in-2013.aspx).

CALIBRE. 2014. *Army Meter Data Management System (MDMS).* CALIBRE, Alexandria, VA. Available at: http://www.calibresys.com/documents/service/Army%20MDMS.pdf

California Public Utility Commission (CPUC). 1999. *Direct Access Standards for Metering and Meter Data (DASMMD); Attachment VEE—Standards for Validating, Editing, and Estimating Monthly and Interval Data; California Interval Data VEE Rules, Revision 2.0*. March 1999.

Carbon Trust. 2005. *Good Practices Guide: Reducing Energy Consumption Costs by Steam Metering*. London, United Kingdom. Available at: http://thecesh.com/wp-content/uploads/2010/05/GPG018.pdf.

CEC. 2007. *Continuous Performance Monitoring Systems, Specification Guide for Performance Monitoring Systems*. Available at: http://cbs.lbl.gov/performance-monitoring/specifications.

CEC. 2007. *Enhanced Automation Vendor/Contractor List*. California Energy Commission (CEC), Sacramento, California.

CEC. 2008. *Savings Persist with Monitoring-Based Commissioning*. CEC-500-2008-053-FS. California Energy Commission's Public Interest Energy Research Program, CA. Available at: http://www.energy.ca.gov/2008publications/CEC-500-2008-053/CEC-500-2008-053-FS.PDF

CEC. 2009. *Save Energy Now in Federal Data Centers: An LBNL Case Study*. Presentation to the Consortium for Energy Efficiency (CEE) June 2009 Meeting, Boston, Massachusetts. California Energy Commission, Sacramento, California.

CEQ. 2013. *Implementing Instructions: Federal Agency Implementation of Water Efficiency and Management Provisions of Executive Order 13514*. July 10, 2013. Council for Environmental Quality, Washington, D.C. Available at http://www.whitehouse.gov/administration/eop/ceq/sustainability/water-instructions.

Canadian Industry Program for Energy Conservation (CIPEC). 2004. *Energy Management Information Systems*. Natural Resources Canada, published by the Office of Energy Efficiency of Natural Resources Canada.

Electric Power Research Institute (EPRI). 1996. *End-Use Performance Monitoring Handbook.* EPRI TR-106960, Palo Alto, California.

Energy Independence and Security Act of 2007 (EISA 2007). 2007. Public Law 110-140, as amended, Section 434(b), Management of Federal Building Efficiency, Section 543 (42 USC 8253), (e) Metering of Energy Use.

Energy Policy Act of 2005 (EPAct 2005). 2005. Public Law 109-58, as amended, Section 103, Energy Use Measurement and Accountability, Section 543 (42 USC 8253), (e) Metering of Energy Use.

English, MC. 2011. *Methods and Applications of Monitoring Based Commissioning (MBCx).* Presented at the 19th National Conference on Building Commissioning, Cincinnati, OH. Available at: http://www.bcxa.org/ncbc/2011/documents/presentations/07_ncbc-2011-mbcx_methods_applications-english.pdf

Executive Order 13693. 2015. *Planning for Federal Sustainability in the Next Decade*. Signed March 19, 2015.

Federal Real Property Statistics (FRPS). 2010. *FY 2009 Federal Real Property Report.* The Federal Real Property Council. Available at: http://www.gsa.gov/graphics/ogp/FY2009_FRPR.pdf.

Friedman H, E Crowe, E Sibley, and M Effinger. 2011. *The Building Performance Tracking Handbook: Continuous Improvement for Every Building*. Portland Energy Conservation, Inc., Portland, OR.

Granderson J, G Lin, and MA Piette. 2013. Energy Information Systems (EIS): Technology Costs Benefit, and Best Practice Uses. LBNL-6476E. Lawrence Berkeley National Laboratory, Berkeley, California.

Granderson, J, MA Piette, B Rosenblum, L Hu, et al. 2011. Energy Information Handbook: Applications for Energy-Efficient Building Operations. LBNL-5272E. Lawrence Berkeley National Laboratory, Berkeley, California.

Granderson J, MA Piette, G Ghatikar, and P Price. 2009. *Building Information Systems: State of Technology and User Case Studies*. LBNL-2899E. Lawrence Berkeley National Laboratory, Berkeley, California.

Gregerson J. 1997. *Commissioning Existing Buildings.* TU-97-3, E Source, Boulder, Colorado.

Haasl T and T Sharp. 1999. *A Practical Guide for Commissioning Existing Buildings.* ORNL/TM-1999/34, Oak Ridge, Tennessee.

Hart, R. 2012. *Where's the Beef in Continuous Commissioning? Results from 140 Buildings in Commercial Property and Higher Education.* Presented at ACEEE Summer Study on Energy Efficiency in Buildings, Pacific Grove, CA. Available at: http://www.aceee.org/files/proceedings/2012/data/papers/0193-000090.pdf

Heller J. 2005. *Energy 2005 Effective O&M Solutions: Draft Metering Policy*. Presentation at GovEnergy 2005.

Independent Electricity System Operator (IESO). 2012. *Market Manual 5: Settlements; Part 5.2: Metering Data Processing, Issue 25*. MDP_PRO_0032. Toronto, Ontario, Canada. September 2012. www.ieso.ca.

Independent Electricity System Operator (IESO). 2013. *Mater Data Management and Repository (MDM/R)—VEE Standard for the Ontario Smart Metering System, Issue 4.3*. IESO_STD_0078. Toronto, Ontario, Canada. January 2013. www.ieso.ca.

Institute of Electrical and Electronic Engineers (IEEE). 2003. *IEEE 1547 Standard for Interconnecting Distributed Resources with Electric Power Systems*. Approved June 2003. IEEE, Washington, D.C. Available at: http://grouper.ieee.org/groups/scc21/1547/1547_index.html.

Interstate Renewable Energy Council (IREC). 2009. *Connecting to the Grid, A Guide to Distributed Generation and Interconnection Issues*. 6th Edition, Interstate Renewable Energy Council, Washington, D.C. Available at: http://www.irecusa.org/wp-content/uploads/2009/10/Connecting_to_the_Grid_Guide_6th_edition-1.pdf.

ISO. 2014. *ISO 50001 - Energy management*. International Standards Organization. Available at: http://www.iso.org/iso/home/standards/management-standards/iso50001.htm.

Kramer H., J Russell, E Crowe and J Effinger. 2013. *Inventory of Commercial Energy Management and Information Systems (EMIS) for M&V Applications: Final Report.* Report #E13-264. Portland Energy Conservation, Inc., Portland, OR.

Lawrence Berkeley National Laboratory (LBNL). 2004. *Using Energy Information Systems (EIS): A Guidebook for the U.S. Postal Service*. LBNL-54862, Berkeley, California.

Lawrence Berkeley National Laboratory (LBNL). 2006. *Enterprise Energy Management System Installation: Case Study at a Food Processing Plant*. LBNL_STAC, Berkeley, California.

Lewis J. 2010. *Advanced Metering Workshop*. Presented at the FEMP Forum on Advanced Metering Solutions for Federal Agencies. Available at: http://www1.eere.energy.gov/femp/pdfs/ns/advmet_12072011_lewis.pdf.

Mills E. 2009. *Building Commissioning: A Golden Opportunity for Reducing Energy Costs and Greenhouse Gas Emissions*. Report prepared for the California Energy Commission, Public Interest Energy Research. Lawrence Berkeley National Laboratory, Berkeley, California. Available at: http://cx.lbl.gov/documents/2009-assessment/lbnl-cx-cost-benefit.pdf.

Mills, E. and P. Mathew. 2009. Monitoring-Based Commissioning: Benchmarking Analysis of 24 UC/CSU/IOU Projects. LBNL-1972E. Lawrence Berkeley National Laboratory, Berkeley, CA.

Moore, S. 2008. Key Features of Metered Data Management Systems. Itron White Paper. Itron, Inc. Liberty Lake, WA. June 2008. https://www.itron.com/na/PublishedContent/Key%20MDM%20Features%20Whitepaper_FINAL.pdf.

Motegi, N. and MS Piette. 2002. *Web-Based Energy Information Systems for Large Commercial Buildings*. LBNL-49977. Lawrence Berkeley National Laboratory (LBNL), Berkeley, California.

National Institute of Standards and Technology (NIST). 2010. *National Institute of Standards and Technology Policy on Traceability*. Available at: http://www.nist.gov/traceability/nist_traceability_policy_external.cfm

National Institute of Standards and Technology (NIST). 2011. *Special Publications Series 800*. NIST Computer Security Division, Computer Security Resource Center. Gaithersburg, Maryland.

National Science and Technology Council (NSTC). 2011. *Submetering of Building Energy and Water Usage: Analysis and Recommendations of the Subcommittee on Buildings Technology Research and Development*. Executive Office of the President, Washington, DC.

New Buildings Institute (NBI). 2009. *Advanced Metering and Energy Information Systems*. Report prepared for the U.S. Environmental Protection Agency. Vancouver, WA. Available at http://newbuildings.org/advanced-metering-and-energy-information-systems.

NFPA. 2008. *NFPA 70-2008, National Electric Code*. National Fire Protection Association. Quincy, Massachusetts. Available at: http://www.nfpa.org/.

Portland Energy Conservation, Inc. (PECI). 1997. *What Can Commissioning Do For Your Building?* Federal Energy Management Program, U.S. Department of Energy, Washington, D.C.

Portland Energy Conservation, Incorporated (PECI). 1999. *Portable Data Loggers Diagnostic Tools for Energy-Efficient Building Operations.* Prepared for the U.S. Environmental Protection Agency and U.S. Department of Energy by Portland Energy Conservation, Incorporated, Portland, Oregon.

Sullivan, GP, R Pugh, AP Melendez, and WD Hunt. 2010. *Operations & Maintenance Best Practices: A Guide to Achieving Operational Efficiency, Release 3.0,* prepared by the Pacific Northwest National Laboratory for the Federal Energy Management Program, U.S. Department of Energy, Washington, D.C. Available at: http://www1.eere.energy.gov/femp/pdfs/omguide_complete.pdf.

Texas A&M. 2002. *Continuous Commissioning Guidebook for Federal Energy Managers.* Federal Energy Management Program, U.S. Department of Energy, Washington, D.C.

U.S. DOE. 2005. *Facility Metering for Improved Operations, Maintenance, and Efficiency*. O&M Program Fact Sheet developed for the Federal Energy Management Program, U.S. Department of Energy, Washington, D.C. Available at: http://eere.energy.gov/femp/pdfs/om_metering.pdf.

U.S. DOE. 2007. *FEMP Metering Training Course Session 2: Metering Technologies, Communications, and Data Storage*. Federal Energy Management Program, U.S. Department of Energy, Washington, D.C. Available at: http://eere.pnnl.gov/femp/metering_webcast.stm.

U.S. DOE. 2007. *FEMP Metering Training Course Session 3: Metering Planning, Financing, Uses for Data and Case Studies.* April 4, 2007. Federal Energy Management Program, U.S. Department of Energy, Washington, D.C. Available at: http://eere.pnnl.gov/femp/metering_webcast.stm.

U.S. DOE. 2007. *Wireless Temperature Sensors for Improved HVAC Control*. DOE/EE-0319, Federal Energy Management Program, U.S. Department of Energy. Washington D.C.

U.S. DOE. 2008. *M&V Guidelines: Measurement and Verification for Federal Energy Projects – Version 3.0*. Federal Energy Management Program, U.S. Department of Energy, Washington, D.C. Available at: http://www1.eere.energy.gov/femp/pdfs/mv_guidelines.pdf.

U.S. DOE. 2010. *Best Practices Guide for Energy-Efficiency Data Center Design*. Prepared by National Renewable Energy Laboratory for the Federal Energy Management Program, U.S. Department of Energy, Washington, D.C.

U.S. DOE. 2010. *Guidelines for Estimating Unmetered Landscaping Water Use*. PNNL-19498. Prepared by the Pacific Northwest National Laboratory for the Federal Energy Management Program, U.S. Department of Energy, Washington, D.C. Available at: http://www1.eere.energy.gov/femp/pdfs/est_unmetered_landscape_wtr.pdf.

U.S. DOE. 2014. *Federal Building Energy Use Benchmarking Guidance*. Federal Energy Management Program, U.S. Department of Energy, Washington, D.C. Available at: http://energy.gov/sites/prod/files/2014/09/f18/benchmarking_guidance08-2014.pdf.

U.S. DOE. 2014. *Federal Building Metering Guidance*. Federal Energy Management Program, U.S. Department of Energy, Washington, D.C. Available at: http://energy.gov/sites/prod/files/2014/11/f19/metering_guidance.pdf

U.S. DOE. 2014. *ISO 50001 Energy Management Standard*. Energy Efficiency and Renewable Energy, U.S. Department of Energy, Washington, D.C. Available at: http://www1.eere.energy.gov/energymanagement/.

U.S. EPA. 2008. *U.S. Environmental Protection Agency Wastewater Flow Measurement. Scientific and Ecosystem Support Division (SESD) Operating Procedure – Wastewater Flow Measurement*. SESD PROC-109-R2. Washington, D.C.

U.S. EPA. 2014. ENERGY STAR Portfolio Manager. U.S. Environmental Protection Agency, Washington, D.C. Available at: http://www.energystar.gov/buildings/index.cfm

Appendix A: Glossary

Advanced meters – An advanced meter records energy or water consumption data hourly or more frequently and provides for daily or more frequent transmittal of measurements over a communication network to a central collection point. Features of advanced meters vary depending on the utility they are serving.

Advanced metering device: A separate electronic device coupled to a standard meter or to a building automation system that enables it to function as an advanced meter.

Advanced metering system – A system that collects time-differentiated energy or water usage data from advanced meters via a network system on either an on-request or defined schedule basis. The system is capable of providing usage information on at least a daily basis and can support desired features and functionality related to energy-use management, procurement, and operations.

Agency: An executive agency as defined in section 105 of title 5, United States Code, including sub-agencies of the agency, and excluding the Government Accountability Office.

Air conditioning – The process of treating air to control its temperature, humidity, and cleanliness while distributing it to cool building space.

Amperes (amps, A): The measure of electric current flow in a conductor and usually measured with an ammeter or current transformer. Some electrical equipment, such as wire size or circuit breaker size, is rated by its maximum capacity to safely handle electrical current.

Appropriate: The installation of standard meters or advanced meters is "appropriate" in all Federal buildings that are not excluded from metering within the 2014 Federal Building Metering Guidance.

Automated meter reading (AMR) – A form of advanced (or enhanced) metering that uses communications devices to communicate data from the meter to the meter data-management provider. AMR may be used to transmit simple energy-use data from the meter, or to transmit more complex measures of energy recorded in the meter, or to implement advanced functionality, such as outage detection or remote programming.

Average demand – The demand on, or the power output of, an electric system or any of its parts over an interval of time, determined by dividing the number of kilowatt hours by the number of hours in the interval.

Avoided cost – The total economic costs (consisting of the capital and operating costs to provide generation capacity and fuel, transmission, storage, distribution, and customer service) to serve end-use energy requirements using a given set of resources. These costs are referred to as "avoided" when an alternative set of resources is used to serve requirements. A better term for these costs would be "avoidable cost." Avoided cost must be determined to assess the cost effectiveness of potential supply-side and demand-side resources.

Base load – The minimum average electric load over a given period of time.

Baud rate – The rate of speed at which information is transmitted over communications lines; expressed in bits per second.

Benchmarking – The practice of accounting for and comparing a metered building's current energy performance with its energy baseline or historical performance, or comparing a metered building's energy performance with the energy performance of similar types of buildings.

Benchmarking System – A tool, or system of tools, that enables the performance of a metered building to be benchmarked. ENERGY STAR Portfolio Manager is the designated building energy use benchmarking system for fulfilling Federal benchmarking requirements.

Benchmark Metrics – ENERGY STAR Portfolio Manager tracks kBtu/ft^2 for site and source energy, \$/ft^2 for energy costs, kgal/ft^2 for indoor water consumption, and kgCO2e/ft^2 for greenhouse gas emissions.

Billing demand – The demand for which a customer is billed. Because billing demand is based on the provisions of a rate schedule or contract, it does not necessarily equal the actual measured demand of the billing period.

Bits – A contraction of binary digits, the smallest unit of information in binary notation. A bit has the value of a zero (0) or a one (1). For example, the binary number 0110 consists of four bits.

British thermal unit (Btu) – A commonly used unit of energy, especially for fuels or heat. A kilowatt hour is equal to approximately 3412 Btu. Quantity of heat required to raise 1 pound of water by 1°F, close to the equivalent amount of energy generated by burning a kitchen match.

Building envelope – The exterior surfaces of a building, such as the roof, walls, windows, doors, etc., that are exposed to climatic conditions.

Capacity – The maximum quantity of electrical output for which a supply system or component is rated.

ccf – Hundred cubic feet.

Coincident demand – Two or more demands that occur during the same time interval. Often used to express the demand level of subgroups of customers that occurs at the time of the electric system's overall maximum peak demand.

Constant dollars – Monetary value based on the purchasing power within the base year—inflationary impacts are not reflected in the value of the constant dollars.

Control – Any manual or automatic device designed to regulate the operation of a system or system component.

Cooling loads – The energy required to achieve the desired (space cooling) temperature level.

Cost avoidance – In regard to energy efficiency—the implementation of energy saving measures will result in a dollar savings, which will offset any fuel price increase.

Cost-effective: Studies show reduced operation and maintenance costs when metered data is used to manage building energy consumption. These life-cycle cost savings exceed the life-cycle costs for installation and maintenance of the meters. Therefore, installation of meters is “cost effective” at all appropriate Federal buildings (including multi building installations).

Covered facility: A facility that an agency has designated as subject to the requirements of section 432 of the Energy Independence and Security Act of 2007 (Pub. L. No. 110-140, as codified at 42 U.S.C. § 8253(f)), which requires agencies to designate covered facilities comprising at least 75 percent of their total facility energy use. A covered facility may be defined as a group of facilities at a single location or multiple locations managed as an integrated operation. A covered facility may also be a single building, if so identified by the agency.

Damper – A valve or movable plate that is attached to a duct to regulate the flow of air or other gases.

Degree days (cooling) – For a single day, cooling degree days are determined by the difference between the average daily temperature and a base temperature, when the average daily temperature is higher than the base temperature. Cooling degree days for a longer period are determined by summation of (daily) cooling degree days through the period. The standard base temperature selected is 65°F.

Degree days (heating) – For a single day, heating degree days are determined by the difference between the average daily temperature and a base temperature, when the average daily temperature is less than the base temperature. Heating degree days for a longer period are determined by summation of (daily) heating degree days through the period. The standard base temperature selected is 65°F.

Dehumidification – The process of removing moisture.

Demand – A measure of the average real power over a specified time interval. The rate at which electricity is delivered by a system or part of a system, or to a load point or set of loads. It is measured in kilowatts, kilovolt amperes, or other suitable unit at a given instant or averaged over a designated period of time. Depending on the utility, the specified interval will be between 5 minutes and 1 hour. A 15-minute demand interval is the most common used in the United States, while a 30-minute demand interval is more common in Europe.

Dew-point temperature – The temperature level in which the moisture in the air begins to condense.

Diversity – The diversity among customers’ demands, which creates variations among the loads in distribution transformers, feeders, and substations at a given time. A load’s diversity is the difference between the sum of the maximum of two or more individual loads and the coincident or combined maximum load. It is usually measured in kilowatts.

Domestic hot water (DHW) system – A system designed to provide hot water for domestic needs—the energy required for a DHW system will vary according to building size, design, and human needs.

Dry-bulb temperature – The temperature level as measured on a standard thermometer.

Ductwork – A series of piping in which air is transferred from its source to the space that is to be conditioned. Ducts, which should be insulated to improve their efficiency, are generally made from fiberglass or galvanized metal.

Economizer cycle – Use of outside air without further mechanical cooling for space cooling when conditions are appropriate. Typically, this is accomplished by locking out the cooling coil.

Electric utility – A corporation, agency, authority, or other legal entity or instrumentality that owns and/or operates facilities for the generation, transmission, distribution, or sale of electric energy primarily for use by the public. Within the United States, its territories, or Puerto Rico, an entity that files forms listed in the Code of Federal Regulations, Title 18, Part 141. Facilities that qualify as cogenerators or independent power producers under the *Public Utility Regulatory Policies Act* (PURPA) are not considered electric utilities.

Emission factor – The ratio of emissions to energy produced or fuel consumed, denominated in units of tons of emissions per unit of energy.

End use – Useful work, such as light, heat, and cooling, which is produced by electricity or other forms of energy.

Energy – The capacity for doing work as measured by the capability of doing work (potential energy) or the conversion of this capability to motion (kinetic energy). Energy has several forms, some of which are easily convertible and can be changed to another form useful for work. Most of the world's convertible energy comes from fossil fuels that are burned to produce heat that is then used as a transfer medium to mechanical or other means to accomplish tasks.

Energy audit – Analysis of a facility's electricity and other energy usage, often including recommendations to alter the customer's electric demand or reduce energy usage. An audit usually is based on a visit by an energy analyst or engineer to the home, building, or manufacturing or agricultural facility.

Energy charge – The charge for electric service based upon the amount of electric energy (kWh) consumed and billed under an applicable rate schedule.

Energy cost liability – Estimated future energy expenditures without energy saving improvements.

Energy management system – A full or partially computerized system designed to monitor and control energy use to achieve optimal efficiency.

Energy or Water Baseline – A baseline is an initial 12-month period of metered energy and water consumption used as a point of reference for comparison purposes. Most benchmarking analyses make use of a 12-month baseline period to attempt to capture all seasonal aspects of energy or water use.

Energy-use intensity (EUI) – Annual Btu/square foot energy use. The standard index used in most analyses to measure all fuel and energy used in a given building or group of buildings.

Ethernet – A specification for local communication networks that employs cable as a passive communication medium to interconnect different kinds of computers, information processing products, and office equipment at a local site.

Extensible markup language (XML) – A markup language specification that defines a set of rules for encoding documents in a format that is both human-readable and machine-readable.

Facility: Any building, installation, structure, or property (including any applicable fixtures) owned or operated by, or constructed or manufactured and leased to, the Federal Government. This document uses the term "facility" when referring to multiple buildings or sites and uses the term "building" to refer to individual structures.

Federal building: Any building, structure, or part thereof, including the associated energy or water consuming support systems, which is constructed, renovated, leased, or purchased in whole or in part for use by the Federal Government and which consumes energy or water; such term also means a collection of buildings, structures or facilities and the energy or water consuming support systems for such collection. This document uses the term "facility" when referring to multiple buildings or sites and uses the term "building" to refer to individual structures.

Firewall – A system designed to prevent unauthorized access to or from a private network. Firewalls can be implemented in both hardware and software, or a combination of both.

Gateway – In local area networks (LANs), a computer system and its associated software that permit two networks using different protocols to communicate with each other. A gateway translates all protocol levels from physical layer up through applications layer and can be used to interconnect networks that differ in every detail.

Harmonics: A measure of the electrical frequencies beyond the fundamental frequency of 60 hertz and usually labeled as the first harmonic (60 hertz), second harmonic (120 hertz), and so on. Harmonics are created by non-linear loads (e.g., computer power supplies, electronic ballasts) that draw current in short pulses rather than the traditional smooth (ac) sine waveform. Among other problems, harmonics can cause excessive heating of metal wires and certain types of electrical interference.

Hourly metering – A type of interval metering where the measurement or recording of customer use is collected in 6-minute intervals. The competitive metering model is based upon the implementation of hourly metering of customers or the application of load profiles, which average customer use over hourly periods.

Hypertext transfer protocol (http) – The underlying protocol used by the World Wide Web. Hypertext transfer protocol defines how messages are formatted and transmitted and what action Web servers and browsers should take in response to various commands.

Incremental cost – The difference in costs between two alternatives, for example, between that of an efficient technology or measure and the standard technology.

Industrial, landscaping and agricultural (ILA) water use – Non-potable freshwater (surface or groundwater) produced onsite or all purchased non-potable water used in industrial, landscaping, or agricultural applications.

Instantaneous peak demand – The demand at the instant of greatest load, usually determined from the readings of indicating meters or graphic meters.

Integrated demand – The summation of continuously varying instantaneous demands during a specified demand interval.

Interconnection – The physical connection of the customer's generation source to a utility's distribution network. Implicit in this are the requirements and protocols for code compliance and safety standards.

Interface – A device that allows communication between systems or ports of systems.

Interval metering – The measurement of customer energy use by fixed time periods or intervals. Typically, the interval time period is 15 minutes, but can vary according to the customer or transmission and distribution system needs. Today, interval metering is provided to commercial and industrial customers and some residential customers. In the future, in an unbundled environment, the residential market may require more frequent interval measurements.

IP address – Internet protocol address. See also **Ethernet**.

Islanding – The condition in which onsite power is still being generated while the grid is down. This situation creates a variety of safety and equipment concerns and is usually a stipulated code issue. Many modern onsite power systems have (as are required) anti-islanding mechanisms that cease to energize upon detection of line voltage/frequency anomalies.

Kilowatt-hour (kWh) – A standard unit of energy equivalent to 1,000 watts over 1 hour.

Levelized cost – The uniform annual cost that results in the same net present value over the planning horizon as the stream of actual annual average costs. An example of a levelized cost is a monthly mortgage payment.

Life-cycle costing – The analytical process for estimating the total cost of a product or system over the life of the product or system, including the operational and maintenance costs.

Line losses – Kilowatt-hours and kilowatts lost in the transmission and distribution lines under specified conditions.

Load – The amount of electric power consumed at any specified point or points on a system. Load originates primarily in the power consuming equipment of the customers.

Load aggregation – Aggregation of energy consumption from facilities that are geographically separate from each other for purposes of acquiring and billing utility services.

Load duration curve – A graph showing a utility's hourly demand, sorted by size, as well as by the amount of time a given level of demand is exceeded during the year.

Load factor – The ratio of the average load in kilowatts supplied during a given period to the peak or maximum load in kilowatts occurring during that period. Load factor may be calculated for a customer, customer class, or the entire electric system.

Load leveling – A process in which the energy demand can be temporarily reduced during certain periods. Typical examples include the intermittent operation of certain electrical equipment and shutting off equipment when rooms or buildings are not in use.

Load management – The controlling, by rescheduling or direct curtailment, of the power demands of customers or groups of customers to reduce the total load that a utility must meet at times of peak demand. Load management strategies are designed to either reduce or shift demand from on-peak to off-peak, while conservation strategies reduce usage over larger multi-hour periods. Load management may take the form of normal or emergency procedures. Utilities often encourage load management by offering customers a choice of service options with varying price incentives.

Local area network (LAN) – Computer network that spans a relatively small area.

Megawatt (MW) – 1 million watts or 1,000 kW.

Modbus® protocol – A messaging structure developed by Modicon in 1979, used to establish master-slave/client-server communication between intelligent devices. It is a de facto standard, truly open, and the most widely used network protocol currently available.

Modem – Modulator-demodulator. A device or program that enables a computer to transmit data over telephone lines.

Multi-point communications – A method of communication in which a single device can communicate to multiple devices.

MV-90 – The utility industry de facto standard for data collection and storage systems. This system was developed so meters from different vendors could be read and the data stored in a consistent manner.

NEMA standards – Property characteristics adopted as standard by the National Electrical Manufacturers Association.

Net Metering: A utility procedure for crediting customers for electricity generated onsite and in excess of their own needs. In its simplest form, this allows for the flow of electricity both to and from a customer's location through a single bi-directional meter (IREC 2009).

Net present value – The value of future energy savings—less all project construction and operating costs, discounted to present value.

Network – A group of computing devices that are connected to each other by communications lines to share information and resources.

Nominal levelized cost – The uniform cost of electricity, in mixed current dollars, for which the present value of the cost of electricity produced over the life of the plant is equal to the present value of the costs of the plant.

Non-volatile memory – Memory that retains its contents when power is lost.

Normalization – In comparing benchmarked buildings, it is often the case that other influencing factors need to be taken into account for a fair comparison. Examples of these factors include variations in climatologic data, building area (square feet), landscape area, occupancy patterns, or some other utilization factor designed to equalize the comparison. To account for these differences, some benchmarking tools have developed routines that allow the user to enter values to account for these variances.

Off-peak energy – Electricity supplied during periods of relatively low system demand.

Peak demand – The maximum rate of electricity consumption, expressed in gigawatts or kilowatts during a specified period of time. May be expressed for groups of electricity users or the whole system, and by season (summer or winter) or annually. This value is typically used by the utility to assess peak demand billing. See **demand**. Also called peak load.

Peak load – The maximum anticipated demand for any given system.

Peaking unit, or peaker – A generating station that is normally operated to provide power during maximum load periods.

Planning period – The time period over which the utility integrated resource planning (IRP) analysis is performed.

Potential resources – Resources, either supply-side or demand-side, which are either currently commercially available, feasible, or are expected to be commercially available within the planning period.

Power factor (PF): The ratio of "real power" (watts) to "apparent power" (volt-amperes) and defined as the cosine of the phase angle between voltage and current wave forms. For resistive loads (in an alternating-current circuit), the voltage and current are "in phase" and the cosine of the angle is 1.0, resulting in a power factor of unity. For loads with reactive components (e.g., induction motors, electrical ballasts), the voltage and current are not "in phase" resulting in a power factor of less than unity. Power factors significantly less than 1.0 (e.g., 0.85) can result in surcharges from the utility because of their need to make up the balance resulting from the low power factor. The significance of power factor is that the electric utility supplies customers with volt-amps but bills the customer for watts. A power factor below 1.0 requires the utility to supply greater current resulting in greater load losses in the distribution system.

Power Line Carrier – Communication system that transmits data between devices over power lines.

Present value – The value of a cost or stream of yearly costs that have been discounted to reflect the fact that future benefits or expenditures are worth less than current benefits or expenditures. Also called present worth.

Programmable Logic Controller – A solid-state control system that has a user programmable memory for storage instruction to implement specific functions such as input/output (I/O) control logic, timing, counting, arithmetic, and data manipulation.

Protocol – A standardized procedure for establishing a communications link between devices and that is based on such elements as word structure or word length.

Radio frequency (RF) – Refers to the rate of oscillation, any of the electromagnetic wave frequencies, in the range extending from below 3 kilohertz to about 300 gigahertz, and that include the frequencies used for communications signals.

Rating – The relative indicator of performance obtained from a benchmarking tool, such as the ENERGY STAR Score from Portfolio Manager. The rating allows the energy performance of the metered building or facility to be compared over time with itself and with the energy performances of similar types of buildings and facilities.

Real-time metering – Metering that records consumer use in the same time frame as pricing changes in the market, typically hourly or more frequently.

Real-time pricing – The instantaneous pricing of electricity based on the cost of electricity available for use at the time the electricity is demanded by the customer.

Relative humidity – The percentage of moisture contained in the air compared to saturation.

Retrofit – Energy saving improvements to a building structure or any of its energized systems involving modification of that structure or system.

Return on investment – The discount rate which, when used to discount all present and future project costs and savings, brings the net present value to zero.

RS-485 serial communications bus – An Electronics Components Industry Association (ECIA) standard for multi-point communications. RS-485 is similar to RS-422 but can support more nodes per line because it uses lower-impedance drivers and receivers.

Server – A computer or device on a network that manages network resources. For example, a file server is a computer and storage device dedicated to storing files.

Shadow metering – The process to quantify and verify the system generation and assure proper "net metering" credit.

Standard meter: An electromechanical or solid state meter that cumulatively measures and records aggregated usage data that are periodically retrieved for use in customer billing or energy management. A meter that is not an advanced meter is considered to be a standard meter under this guidance.

therm – Equals 100,000 Btu.

Time of use – The pricing of electricity based on the estimated cost of electricity during a particular time block.

Tons of refrigeration – A standard for identifying cooling capacity. One ton of refrigeration is equal to 12,000 Btu/hour of cooling.

Total harmonic distortion (THD): THD is a measure of the content of all harmonic frequency current or voltages in relation to the fundamental current or voltage frequency. This content is usually expressed as a percentage of the fundamental frequency and is defined as the square root of the sum of the squares of the harmonics divided by the fundamental frequency.

Transmission control protocol/internet protocol (TCP/IP) – The suite of communications protocols used to connect hosts on the Internet. TCP/IP uses several protocols, the two main ones being TCP and

IP. TCP/IP is built into the UNIX operating system and is used by the Internet, making it the de facto standard for transmitting data over networks.

Utility discount rate – A rate that reflects the utility's weighted cost of capital. Pre-tax or, more commonly, after tax.

Valley filling – The building of off-peak loads. An example of valley filling technology is thermal storage (water heating and/or space heating or cooling) that increases nighttime loads and reduces peak period loads. Valley filling may be desired in periods when the long-run incremental cost of supply is less than the average price of electricity. (Adding off-peak load under those circumstances decreases the average price.)

Variable operating and maintenance costs – The additional cost per kWh of electricity produced that goes toward operation and maintenance of the plant. These costs vary with the output of the plant and are expressed in cents per kWh of electricity produced.

Voltage (volts, V): The measure of electric potential between two points in a circuit and typically measured with a voltmeter or potential transformer. Voltage may be expressed in terms of line-to-neutral (L-N) for a two-wire system or line-to-line (L-L) for a multi-wire system.

Volt-amperes (volt-amps, VA): The measure of "apparent" power, or rate of energy, supplied to an electric load. The volt-ampere (designated VA) can be determined by the voltage multiplied by the current. The volt-ampere is frequently the metric used to rate the capacity of electrical equipment, such as transformers or switchgear.

Volt-ampere reactive (VAR): A measure of the system's reactive power, useful for identifying the system's power factor correction needs.

Watt – A measure of power, or rate of energy flow, delivered to an electric load. The rate of energy transfer equivalent to 1 ampere flowing under a pressure of 1 volt at unity power factor. Power can be measured instantaneously (kW) or averaged over time (kWh/h). Average time interval power will also satisfy the time interval data required to be metered and recorded by EPAct 2005.

Watt-hour – The total amount of energy used in 1 hour by a device that draws 1 watt of power for continuous operation. The measure of electric energy flow or electricity consumption. Typically expressed in terms of kilowatt-hours (kWh, 1000 Watt-hours) or higher multiples, this is the time interval data required to be metered and recorded by EPAct 2005.

Appendix B: Regulatory Requirements for Federal Agencies

For Federal agencies, this guide can assist you in the implementation of Federal building metering requirements in accordance with the

- *Energy Policy Act of 2005* (EPAct 2005) [key language extracted below]
- *Energy Independence and Security Act of 2007* (EISA 2007) [key language extracted below]
- Executive Order 13693: *Planning for Federal Sustainability in the Next Decade*
- *Federal Building Metering Guidance,* updated December 2014.

Agencies need to review the Federal Building Metering Guidance to understand the current requirements for metering of Federal buildings.

Energy Policy Act of 2005

SEC. 103. ENERGY USE MEASUREMENT AND ACCOUNTABILITY.

Section 543 of the National Energy Conservation Policy Act (42 USC 8253) is further amended by adding at the end of the following.

"(e) METERING OF ENERGY USE—

"(1) DEADLINE—By October 1, 2012, in accordance with guidelines established by the Secretary under paragraph (2), all Federal buildings shall, for the purposes of efficient use of energy and reduction in the cost of electricity used in such buildings, be metered. Each agency shall use, to the maximum extent practicable, advanced meters or advanced metering devices that provide data at least daily and that measure at least hourly consumption of electricity in the Federal buildings of the agency. Such data shall be incorporated into existing Federal energy tracking systems and made available to Federal facility managers.

"(2) GUIDELINES—

"(A) IN GENERAL—Not later than 180 days after the date of enactment of this subsection, the Secretary, in consultation with the Department of Defense, the General Services Administration, representatives from the metering industry, utility industry, energy services industry, energy efficiency industry, energy efficiency advocacy organizations, national laboratories, universities, and Federal facility managers, shall establish guidelines for agencies to carry out paragraph (1).

"(B) REQUIREMENTS FOR GUIDELINES.—The guidelines shall—

"(i) take into consideration—

"(I) the cost of metering and the reduced cost of operation and maintenance expected to result from metering;

"(II) the extent to which metering is expected to result in increased potential for energy management, increased potential for energy savings and energy efficiency improvement, and cost and energy savings due to utility contract aggregation; and "(III) the measurement and verification protocols of the Department of Energy;

"(ii) include recommendations concerning the amount of funds and the number of trained personnel necessary to gather and use the metering information to track and reduce energy use;

"(iii) establish priorities for types and locations of buildings to be metered based on cost effectiveness and a schedule of one or more dates, not later than 1 year after the date of issuance of the guidelines, on which the requirements specified in paragraph (1) shall take effect; and

"(iv) establish exclusions from the requirements specified in paragraph (1) based on the de minimis quantity of energy use of a Federal building, industrial process, or structure.

"(3) PLAN—Not later than 6 months after the date guidelines are established under paragraph (2), in a report submitted by the agency under section 548(a), each agency shall submit to the Secretary a plan describing how the agency will implement the requirements of paragraph (1), including (A) how the agency will designate personnel primarily responsible for achieving the requirements and (B) demonstration by the agency, complete with documentation, of any finding that advanced meters or advanced metering devices, as defined in paragraph (1), are not practicable.

Energy Independence and Security Act of 2007

SEC. 434. MANAGEMENT OF FEDERAL BUILDING EFFICIENCY

METERING—Section 543(e)(1) of the National Energy Conservation Policy Act (42 USC 8253(e)(1)) is amended by inserting after the second sentence the following: ''Not later than October 1, 2016, each agency shall provide for equivalent metering of natural gas and steam, in accordance with guidelines established by the Secretary under paragraph (2).''

From NECPA, the information regarding paragraph 2 is provided below:

"(2) Guidelines

(A) In general

Not later than 180 days after August 8, 2005, the Secretary, in consultation with the Department of Defense, the General Services Administration, representatives from the metering industry, utility industry, energy services industry, energy efficiency industry, energy efficiency advocacy organizations, national laboratories, universities, and Federal facility managers, shall establish guidelines for agencies to carry out paragraph (1).

(B) Requirements for guidelines

The guidelines shall-

(i) take into consideration--

(a) the cost of metering and the reduced cost of operation and maintenance expected to result from metering;

(b) the extent to which metering is expected to result in increased potential for energy management, increased potential for energy savings and energy efficiency improvement, and cost and energy savings due to utility contract aggregation; and

(c) the measurement and verification protocols of the Department of Energy;

(ii) include recommendations concerning the amount of funds and the number of trained personnel necessary to gather and use the metering information to track and reduce energy use;

(iii) establish priorities for types and locations of buildings to be metered based on cost effectiveness and a schedule of one or more dates, not later than 1 year after the date of issuance of the guidelines, on which the requirements specified in paragraph (1) shall take effect; and

(iv) establish exclusions from the requirements specified in paragraph (1) based on the de minimis quantity of energy use of a Federal building, industrial process, or structure."

Appendix C: Metering Codes and Standards

Codes and standards applicable to metering equipment and installation are generally governed and promulgated by national organizations and enforced by local entities such as building code officials.

Because different parts of the country have traditionally referenced different code organizations for specific codes, the authors of this guide recommend contacting local building code officers (electric, natural gas, and plumbing inspectors) prior to initiating any meter selection or installation project.

Below are presented some of the more common standards as they apply to the major metering categories.

Electric Meters and Installation Codes and Standards

All electric meters installed must comply with the National Electric Code as found in the National Fire Protection Association (NFPA) 70. Additional standards from the American National Standards Institute (ANSI) are provided below.

American National Standards Institute (ANSI) C12 metering standards:

- ANSI C12.1 – American National Standard Code for Electricity Metering
- ANSI C12.4 – American National Standard for Mechanical Demand Registers
- ANSI C12.5 – American National Standard for Thermal Demand Meters
- ANSI C12.6 – American National Standard for Marking and Arrangement of Terminals

Self-Contained A-Base Watt-Hour Meters

- ANSI C12.9 – American National Standard for Test Switches for Transformer-Rated Meters
- ANSI C12.10 – American National Standard for Electromechanical Watt-Hour Meters
- ANSI C12.11 – American National Standard for Instrument Transformers for Revenue Metering, 10 kV BIL Through 350 kV BIL
- ANSI C12.13 – American National Standard for Electronic Time-of–Use Registers for Electricity Meters
- ANSI C12.14 – American National Standard for Magnetic Tape Pulse Recorders for Electricity Meters
- ANSI C12.15 – American National Standard for Solid-State Demand Registers

Electromechanical Watt-Hour Meters

- ANSI C12.16 – American National Standard for Solid-State Electricity Meters
- ANSI C12.17 – American National Standard for Cartridge-Type Solid-State Pulse Recorders

The Institute of Electrical and Electronics Engineers (IEEE) has standards related to electromagnetic immunity including:

- IEEE C.37-90.1-1989 – IEEE Standard Surge Withstand Capability (SSWC) Tests for Protective Relays and Relay Systems (ANSI). All inputs tested, except for the network communications port.

ANSI is a member of the IEC (International Electrotechnical Commission), which has adopted the following standards related to metering:

- IEC1000-4-2 (EN61000-4-2/IEC801-2) – Electrostatic Discharge (B)
- IEC1000-4-3 (EN61000-4-3/IEC801-3) – Radiated EM Field Immunity (A)
- IEC1000-4-4 (EN61000-4-4/IEC801-4) – Electric Fast Transient (B)
- IEC1000-4-5 (EN61000-4-5/IEC801-5) – Surge Immunity (B). Certified by American Electric Power (AEP)
- IEC1000-4-6 (EN61000-4-6/IEC801-6) – Conducted Immunity
- IEC 60687 0.2S, section 4.6.1, 4.6.2, 4.6.3.

The Federal Communications Commission (FCC) also regulates electromagnetic emission:

- FCC Part 15 Subpart B, Class A: Class A Digital Device, Radiated Emissions. d. IEC Compliance.

Other organizations might impose local requirements. For example, the California Independent System Operator (ISO) has standards and protocols for installing, reading, and maintaining meters on the system including:

- ISO MTR1-96 – Engineering Specifications for Poly-Phase Solid-State Electricity Meters for use on the ISO Grid.

Many of the standards addressed above are very specific and not always applicable. Their presentation highlights the depth to which metering and communication standards apply. As mentioned, the best resource may well be a local building code official for these and other code/standard issues and questions.

Natural Gas Meter and Installation Codes and Standards

All natural gas meters installed must comply with the National Fuel Gas Code as found in the National Fire Protection Association (NFPA) 54. Additional codes and standards may apply as issued by state and local code authorities. The best resource for complete and up-to-date code information may well be a local building code official.

Water Meter and Installation Codes and Standards

Water meters and installation are usually governed by the Uniform Plumbing Code but will often be superseded/amended by local ordinances specific to the region. The best resource for complete and up-to-date code information will be a local building code official.

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