

Measurement & Verification Resources and Training Opportunities

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INTRODUCTION & OVERVIEW

Measurement and verification (M&V) of energy savings, generated through building systems retrofits and upgrades, requires special project planning as well as unique engineering practices. Although several common practices exist for M&V of energy savings, it is not an exact science. There are many resources available that can be used to learn more about the engineering techniques and tools used for verification of energy savings. This document lists some of those resources. It is not intended to be a comprehensive listing of resources, an endorsement or recommendation for a product, but rather indicative of the types of tools that are available. Table 1 includes a summary of the items included in this guide.

Table 1: Overview of M&V Resources

Report Section	Includes	Purpose in M&V
M&V Guidelines	-IPMVP -FEMP -ASHRAE 14-2002	Provide M&V standards based on accepted, proven strategies.
Utility & State Program M&V Guidelines and Lighting Wattage Tables	-California SPC -NYSERDA -State of Texas Utility Programs	Provide M&V standards based on accepted, proven strategies, which may be simplified and specified for certain applications.
Case Studies	-California SPC Program -FEMP -NYSERDA	Example applications of M&V strategies.
Training Opportunities	-AEE M&V Courses -FEMP Courses -LEED -Texas A&M	Upcoming training classes and tools in topics related to M&V.
Software Tools	-Building energy simulation software -System performance simulation software -Utility cost management software	Available tools that can be used to: model building and systems to estimate savings; track utility costs to verify savings.
Hardware Tools	-Sources for guidance on tool selection -Hardware data collection tools	Many data logging and measurement equipment are available to measure and record operating parameters
Other Resources	-Commissioning & Retro-commissioning resources -Other resources	Other resources that could be utilized when preparing for and implementing the measurement and verification of energy savings.

M&V GUIDELINES

Several guidelines have been published on measurement and verification energy savings. Each of the guidelines listed in this section are unique, albeit similar, and are intended for use in different instances. All of these documents provide standard M&V methods that are proven and accepted strategies.

International Performance Measurement and Verification Protocol

The International Performance Measurement and Verification Protocol (IPMVP) is a document which discusses procedures that, when implemented, allow building owners, energy service companies, and financiers of buildings energy efficiency projects to quantify energy conservation measure (ECM) performance and energy savings. The IPMVP provides an overview of current best practice techniques available for verifying savings from both traditionally- and third-party-financed energy and water efficiency projects.

The IPMVP was recently revised, and is now in three volumes, available at <http://www.evo-world.org/>

- ❖ Volume I - Concepts and Options for Determining Energy and Water Savings (2001)
- ❖ Volume II - Concepts and Practices for Improved Indoor Environmental Quality
- ❖ Volume III -
 - Concepts and Options for Determining Energy Savings in New Construction (2003)
 - M&V for Renewable Energy Technologies (2003)

FEMP M&V Guidelines Version 2.2

The Federal Measurement and Verification (M&V) Guideline provides procedures and guidelines for quantifying the savings resulting from the installation of energy conservation measures. The FEMP Guidelines are fully compatible and consistent with the IPMVP. Intended for use in Energy Savings Performance Contracting (ESPC) and utility program projects, the guideline provides the methodology for establishing energy cost savings called for in the ESPC rule. These guidelines are available at http://www1.eere.energy.gov/femp/financing/superespcs_measguide.html

Detailed Guidelines for FEMP M&V Option A

FEMP has developed the M&V Option A Detailed Guidelines (May 2002) which provides recommended practices for using the Option A methods described in FEMP's M&V Guidelines for Federal Energy Projects, Version 2.2. The Option A guidelines bridge the differences between the FEMP M&V Guidelines and the latest revision of the *Measurement & Verification Protocol* (MVP 2000). <http://ateam.lbl.gov/mv/>

FEMP M&V Guidelines: Draft Renewable Energy Guide (Chapter 35)

Proposed revision to Chapter 35 Renewable Energy Technologies, of the FEMP Measurement and Verification Guidelines for Federal Energy Projects. Alternatively, this may be published as a separate guide. http://ateam.lbl.gov/mv/docs/FEMP_Renewables.pdf

ASHRAE Guideline 14 - 2002

ASHRAE Guideline 14-2002, titled *Measurement of Energy and Demand Savings*, was developed by ASHRAE to provide guidance on the minimum acceptable level of performance in the measurement of energy and demand savings for the purpose of a commercial transaction based on that measurement. ASHRAE Guideline 14 deals only with the measurement of energy and demand savings and is available for \$80 from the ASHRAE <http://www.ashrae.org>

M&V Guidelines from Current Utility & State Programs

Many electric and gas providers in the U.S. offer incentive payments for verified energy savings. Each of these incentive programs has guidelines specifying their individual requirements for the

measurement and verification of energy savings. This list of programs is not comprehensive, but includes programs that have M&V guidelines that are easily accessible.

California Utility SPC Program

San Diego Gas & Electric, Pacific Gas and Electric Company and Southern California Edison (Utility Administrators) are offering this statewide energy-efficiency program under the direction of the California Public Utilities Commission (CPUC).

The Large Non-Residential Standard Performance Contract (LNSPC) Program is a performance-based program that offers incentive payments to Project Sponsors who develop projects delivering verified energy savings at Host Customer facilities. This program offers fixed incentive prices to Project Sponsors for verified and documented energy savings achieved by the installation of specific, energy-efficiency measures. Energy savings will be measured and verified annually by the Project Sponsor over a two-year period following the approval and installation of the energy-efficiency equipment. Additional information about the programs, including M&V protocols, can be found at http://www.pge.com/docs/pdfs/biz/rebates/spc_contracts/2005_manuals_forms/1.0_SPC_Policy.pdf <http://www.sce.com/RebatesandSavings/LargeBusiness/SPC/SPCOverview/> <http://www.sdge.com/business/1.0SPCPolicy.pdf> - page=1

NYSERDA

The New York State Energy Research and Development Authority offers the Energy \$martSM Commercial/Industrial Performance program. This program offers fixed-price incentives to energy service companies (ESCOs) that install cost-effective electric energy efficiency measures. Project-specific incentives are paid based on measured data from the performance period as specified in an SPC Agreement. An M&V Template for this program can be found at <http://www.nyserda.org/Funding/1101MVplan.doc>. Additional information on the Commercial / Industrial Performance Program (CIPP) is available at <http://www.nyserda.org/funding/855PON.html>

State of Texas Programs

Texas has statewide programs sponsored by the Public Utilities Commission of Texas. The PUC supports a Commercial and Industrial Standard Offer Program through several electric utilities within the state of Texas, as detailed below.

American Electric Power (AEP)

American Electric Power (AEP) offers several energy efficiency programs with specific measurement and verification requirements. The Commercial & Industrial Standard Offer M&V requirements are specified on their web site at <http://www.aepefficiency.com/cisop/downloads/index.htm>.

Entergy

The Large Commercial and Industrial Standard Offer Program (C&I SOP) provides incentives for the retrofit installation of a wide range of measures that reduce energy costs, reduce peak demand and save energy in non-residential facilities with an electric demand of more than 100kW. http://www.entropy-texas.com/energy_efficiency/ci_mv.aspx

Oncor (formerly TXU Electric)

Oncor currently has several energy efficiency programs, including: Residential and Small Commercial Standard Offer Program and a Commercial and Industrial Standard Offer Program. The M&V guidelines for these programs can be found at <http://www.oncorgroup.com/electricity/teem/candi/default.asp>

Center Point Energy

Center Point Energy offers many energy efficiency programs. Their Commercial & Industrial Standard Offer Program has specific measurement and verification criteria, which are available in their program documents. Information is available at <http://www.centerpointefficiency.com/>

Lighting Wattage Tables

Standardized tables of typical lighting equipment wattages are included in several existing programs. The data from these tables is typically used rather than field measured data.

California Utility SPC Program

The California Standard Performance Contracting Program (SPC) is offered by Southern California Edison, SDG&E and PG&E. Lighting wattage tables are included as Appendix B of the SPC Program Manuals:

http://www.sce.com/NR/ronlyres/7A3455F0-A337-439B-9607-10A016D32D4B/0/spc_B_Std_Fixture_Watts.pdf

<http://www.sdge.com/business/archive/2004/StandardFixtureWatts.pdf>

NYSERDA

New York State Energy Research and Development Authority operates a Small Commercial Lighting Program. Although lighting power tables are not available, the web page has good information on lighting design with an emphasis on photometrics and lighting quality.

<http://www.nyserda.org/SCLP2/technicalguide/index.asp>

State of Texas Programs

Texas has statewide programs sponsored by the Public Utilities Commission of Texas. The PUC supports energy efficiency projects across all electric utilities within the state of Texas. A lighting wattage table is available, and may be maintained on a regular basis. The wattage table is listed as *CI Retrofit Wattage Table* at

<http://www.puc.state.tx.us/electric/projects/22241/22241arc/010501cirwtable.pdf>

Utility program sponsors AEP, Entergy, Oncor, and Reliant Energy also post the state maintained lighting table:

<http://www.aepressop.com/Swepco/downloads-SWEPCO.shtml>

[http://www.energy-](http://www.energy-texas.com/content/Energy_Efficiency/documents/Small_CommercialWattageTable_020504.xls)

[texas.com/content/Energy_Efficiency/documents/Small_CommercialWattageTable_020504.xls](http://www.energy-texas.com/content/Energy_Efficiency/documents/Small_CommercialWattageTable_020504.xls)

http://www.txuelectricdelivery.com/electricity/teem/services/candi/2007_E1.xls

http://www.txuelectricdelivery.com/electricity/teem/services/candi/2007_N1.xls

<http://www.centerpointcisop.com/downloads/downloadsindex.html>

CASE STUDIES

One of the best ways to understand measurement and verification of energy savings is to learn from examples. Several sources of case studies and related materials are listed below.

California SPC Program Case Studies

Several example M&V Plans are included in Appendix D of the California Utility Standard Performance Contract (SPC) Program M&V Guidelines. Included in this document is M&V Plan Template, along with example M&V plans for a VSD Installation, Constant Speed Chiller

Replacement, Variable Speed Chiller Replacement, and Calibrated Simulation. Appendix D is available at http://www.pge.com/docs/pdfs/biz/rebates/spc_contracts/2000_on_peak_incentive/append_d.pdf

FEMP Case Studies

- ❖ An example M&V plan for a federal performance contracting project (SuperESPC) was developed using the 2004 SuperESPC IDIQ requirements for M&V plans. It is available at <http://ateam.lbl.gov/mv/>.
- ❖ A review of the M&V used at seven SuperESPC project sites in the western region, *Application of FEMP M&V Guidelines on Super ESPC Projects: Observations and Recommendations*, is available at http://ateam.lbl.gov/mv/docs/MV_Assess_FINAL-f1.pdf
- ❖ Demonstration projects provide first-hand details on some of the latest federal projects at http://www.eere.energy.gov/femp/newsevents/fempfocus_filter.cfm/catid=33
- ❖ The Evaluation of a 4,000-Home Geothermal Heat Pump Retrofit at Fort Polk, Louisiana. Final Report, Report ORNL/CON 460 (1998), by P.J. Hughes and J.A. Shonder, Chapter 7 "Measurement and Verification of Energy Savings." Additional information is available at http://www.eere.energy.gov/femp/pdfs/ftpolk_methods_ocon_462.pdf
- ❖ Fictional M&V Case Study -This power point presentation takes you through the details of negotiating a measurement & verification plan at a fictional FEMP SuperESPC project site. <http://ateam.lbl.gov/mv/>

NYSERDA

The New York State Energy Research and Development Authority (NYSERDA) offers several one-page case studies of Commercial / Industrial Performance Projects (CIPP) at http://www.nyserda.org/programs/Commercial_Industrial/cippcasestudies.asp

TRAINING OPPORTUNITIES

Several organizations offer classes on measurement and verification of energy savings or other aspects of performance contracting. Some upcoming courses are listed below.

AEE M&V Courses

Association of Energy Engineers (AEE) will offer *Fundamentals Of Measurement & Verification: Applying The New IPMVP*. This seminar will examine current methods of measuring and verifying savings, specifically reviewing the International Performance Measurement & Verification Protocol (IPMVP). Attendees will learn the process of designing a proper M&V program for their projects, including cost/accuracy tradeoffs, baseline adjustments, the role of stipulations, maintaining space conditions, the role of verifiers, and the data needed for emission trading.

AEE, in conjunction with IPMVP, is now offering an M&V certification, Certified Measurement and Verification Professional (CMVP). The course is three days, with an additional fee for the 1/2-day exam. The class is not mandatory for taking the certification exam. More information is available through <http://www.aeecenter.org/seminars/> or (770) 447-5083, ext. 223.

Atlantic City, NJ / April 3-5, 2007

(held in conjunction with Globalcon 2007 <http://www.globalconevent.com/>)

Seminar held at Atlantic City Convention Center

Hotel rooms at Sheraton Atlantic City Convention Center / (609) 344-3535

Long Beach, CA / June 5-7, 2007

(held in conjunction with West Coast EMC 2007 <http://www.energyevent.com/>)

Seminar held at Long Beach Convention Center

Hotel rooms at Westin Long Beach / (562) 436-3000

Atlanta, GA / August 14-16, 2007

(held in conjunction with WEEC 2007 <http://www.energycongress.com/>)

Seminar held at Georgia World Congress Center

Hotel rooms at Atlanta Marriott Marquis / (404) 521-0000

Member/Government/Non Profit Price: \$1,050.00

Non-Member Price: \$1,150.00

FEMP Courses

The Federal Energy Management Program (FEMP) offers courses related to various aspects of performance contracting. A complete listing of courses is available at http://www.eere.energy.gov/femp/services/cfm/training_schedule.cfm. Selected upcoming courses are listed below.

FEMP Super ESPC Workshops

There are two different options for this course. **Introduction to ESPC** is a two day course intended for those who have little or no knowledge of Super ESPCs and may be considering doing a delivery order. **Advanced ESPC/Financing** is a three day course, intended for federal agency personnel who are developing a Super ESPC delivery order and want to gain an in-depth understanding of the Super ESPC process, with special emphasis on the financial aspects.

Introduction to ESPC

January 23-24, 2007 Dallas or Houston, TX

May 15-16, 2007 San Diego, CA

Advanced ESPC/Financing

March 20-22, 2007 Golden, CO

June 12-14, 2007 Philadelphia, PA or Boston, MA

USGBC LEED: Leadership in Energy and Environmental Design

The LEED Green Building Rating System is a voluntary, consensus-based national standard for developing high-performance, sustainable buildings. Members of the U.S. Green Building Council representing all segments of the building industry developed LEED and continue to contribute to its evolution. LEED standards are currently available or under development for new construction, existing buildings, commercial interiors, core and shell projects, homes, and neighborhood development. Several workshops are offered ranging from an introduction to the LEED standards to technical reviews of the process required to become LEED certified. More information and course schedules are available at

<http://www.usgbc.org/Events/EventsConferenceCalendar.aspx?CMSPageID=143>

Texas A&M University / Energy Systems Laboratory Courses

The Energy System Lab actively supports the Texas LoanStar program by providing M&V services and training, and Continuous Commissioning activities.

These seminars are sponsored by the State Energy Conservation Office (SECO), funded through the United States Department of Energy under a Special Grants program. <http://www-esl.tamu.edu/education/workshops.htm>. Courses range from \$65 to \$175.

IECC Residential Energy Code Training:

This seminar provides builders, designers, building officials, plan reviewers and inspectors with information they need to understand and achieve compliance with the energy provisions of the International Residential Code and the residential provisions of the International Energy Conservation Code, as published by the International Code Council.

IECC Energy Code Training:

The State of Texas adopted an energy code through Senate Bill 5, 77th Texas Legislature. This seminar provides building officials, inspectors and design professionals with basic information they need to enforce or comply with the commercial energy provisions of the International Energy Conservation Code.

ASHRAE Standard 90.1

ASHRAE Standard 90.1-2001 is the energy standard for commercial buildings adopted by Chapter 7 of the 2003 International Energy Conservation Code and provides a range of alternatives to the "acceptable practice" approach of IECC Chapter 8. Design professionals, code officials and building owners will benefit from this course, which presents an overview of the standard, the requirements and the methods of compliance.

SOFTWARE TOOLS FOR DATA COLLECTION AND ANALYSIS

Several types of software related to energy analysis are available. Some software is available at no cost, while other programs can be purchased. This is not intended to be a comprehensive list of all programs that are available nor a recommendation for any particular tool, but rather an indicator of the types tools available. The tools are categorized as either: Building Energy Simulation, System Performance Simulation, Utility Cost Management, or Data Acquisition and Management. Information on additional energy software tools are available at <http://tmpwebesl.tamu.edu/resources/software.htm>

Building Energy Simulation Software

DOE-2.1E

Performs hourly simulation of new and existing buildings based on the building's climate, architecture, materials, operating schedules, and heating, ventilation, and air-conditioning (HVAC) equipment. Available through LBNL, Buildings Technology Program, <http://gundog.lbl.gov/>. Software prices range from \$300 for a US Government application to \$1,200 for foreign use.

Energy-10

Energy-10 is a simple graphical building simulation program for evaluating buildings while still in the design stage. Good for residences and small offices. Can be used to evaluate different potential energy-efficiency measures including passive solar. Software is available through the Sustainable Buildings Industries Council (SBIC), Washington, DC. This software is suitable for use on smaller

buildings, approximately 10,000 square feet or less. <http://www.sbicouncil.org/store/index.php>. The software costs \$300 with discounts for SBIC members and students.

EnergyPlus

EnergyPlus is a new-generation building energy simulation program based on DOE-2 and BLAST, with numerous added capabilities. Released in April 2001, the program was developed jointly by Lawrence Berkeley National Laboratory, the University of Illinois, the U.S. Army Construction Engineering Research Laboratory, GARD Analytics, Inc., Oklahoma State University and others, with support from the U.S. Department of Energy, Office of Building Technology, State and Community Programs. More information and a free download of the software is available at <http://gundog.lbl.gov/>.

eQuest

eQuest is a DOE2 based building simulation software program that facilitates evaluation of energy costs while still in the design stage. It uses a wizard to assist the process of setting up DOE2 input files, it provides users with many options on building construction, central plant and HVAC equipment, occupancy and rate schedules, and weather files. Good for most commercial and institutional buildings. The software is free and can be downloaded from <http://www.energydesignresources.com/resource/130/>

Trace 700

Trane Air-conditioning Economics (TRACE) is a robust software package which can model buildings, HVAC systems and can perform economic analysis of operating scenarios. Trane sells the software for about \$2,000 and more information is available through <http://www.trane.com/commercial/software/trace/index.asp>

VisualDOE 4.0

VisualDOE is a graphical version of DOE2.1E. Users can model complex buildings and HVAC systems. Provides results in graphical format. Software is \$980 through Architectural Energy Corporation, Boulder, CO. <http://www.archenergy.com/products/visualdoe/>.

System Performance Simulation Software

AirMaster +

AirMaster+ provides comprehensive information on assessing compressed air systems, including modeling, existing and future system upgrades, and evaluating savings and effectiveness of energy efficiency measures. Free software through DOE at <http://www1.eere.energy.gov/industry/bestpractices/software.html>

Market Manager

Simulation software using standard ASHRAE algorithms that allow modeling of building systems, sub-systems, and components including heating and cooling equipment. Software is available through Optimum Energy Products with a free 30 day trial period, or to purchase for about \$2,500. <http://energymanager.electricitymetering.com/>

Motor Master 4.0

An energy-efficient motor selection and management tool, MotorMaster+ 4.0 software includes a catalog of over 20,000 AC motors. Version 4.0 features motor inventory management tools, maintenance log tracking, efficiency analysis, savings evaluation, energy accounting, and environmental reporting capabilities. The U.S. Department of Energy (USDOE) funded the MotorMaster+ 4.0 software program. Software is free through <http://www1.eere.energy.gov/industry/bestpractices/software.html>

ProjectKalc 3.02

ProjectKalc offers full analysis of potential lighting upgrades. It provides comprehensive energy and economic analysis of upgrades involving controls, relamping, delamping, tandem wiring, and more. It includes user-modifiable databases of costs, labor time, and performance for over 8000 common hardware applications. This free software is available through the EPA Energy Star Program at http://www.energystar.gov/index.cfm?c=business.bus_projectkalc

Pumping System Assessment Tool 2004 (PSAT)

The Pumping System Assessment Tool helps industrial users assess the efficiency of pumping system operations. PSAT uses achievable pump performance data from Hydraulic Institute standards and motor performance data from the MotorMaster+ database to calculate potential energy and associated cost savings. Software is available through <http://www1.eere.energy.gov/industry/bestpractices/software.html>

Utility Cost Management Tools

Cost Analyst & Energy Analyst

Cost Analyst and Energy Analyst are part of a combined software package sold through Itron which analyzes energy cost and verifies utility billing. Itron also offers utility bill management services. More information is available through http://www.itron.com/pages/products_detail.asp?id=itr_000404.xml

EnergyCAP

Energy Efficiency Software records monthly utility bills; automatically audits them to spot billing, metering or consumption problems; prepares a variety of management and analysis reports; and helps to ensure overall organizational energy efficiency. Advanced functions include electronic invoices (EDI), 15-minute meter interval data, budgeting, submetering and tenant re-billing, accruals, benchmarking, rate analysis, cost avoidance reports ("M&V"), weather and baseline adjustments, web based reporting and more.

<http://www.energycap.com/products/index.asp>

Energy Accounting Guide

The California Energy Commission publishes a guide *Energy Accounting: A Key Tool in Managing Energy Costs*, which discusses some of the reasons for energy accounting, background information needed to understand it, and explains how to get started with a program. With emphasis on computer software, this document will discuss some of the methods and means of energy accounting, focusing in on energy accounting software packages. The appendix reviews and provides information on some of the most popular, commercially available energy accounting software packages. It is available at http://www.energy.ca.gov/reports/efficiency_handbooks/index.html.

Energy Manager Software Solutions

Energy Manager 2000 by Lifespring Resources can collect, store, manipulate, and display data. The software is Windows based and can display data in custom graphical formats. Uses include predictive maintenance and documenting the performance of utility systems such as steam, gas, electricity, or heated water. (no known web site; telephone 888-863-3593)

Metrix

Metrix is software designed to track utility usage and costs in order to track operating cost savings or verify the impacts of utility performance measures. Metrix creates a historical baseline using a multi-variant linear regression to correct for weather and other independent variables that affect utility cost. It establishes performance targets and can track an unlimited number of sites, facilities, and meters. Appropriate for use with IPMVP/FEMP Option C. Software is available for about \$4,000 through Optimum Energy
<http://energymanager.electricitymetering.com/>

Portfolio Manager

The U.S. Environmental Protection Agency (EPA) operates a web-based utility bill tracking system that normalizes energy usage to weather conditions and operating hours. Its primary feature is that it ranks a facility to its peers nationally and assigns a score indicating its position relative to all other buildings. A score of 75 indicates that the building uses less energy than 75% of the buildings of its type and makes the building eligible to earn the Energy Star label (assuming other conditions are met). It can also track energy savings from a project relative to a baseline period and now tracks water use as well. <https://www.energystar.gov/istar/pmpam/>

Utility Manager Pro 4.0

This software is sold by SMR (Save More Resources) to access, track, view, and graph monthly billing information in itemized detail. This company also provides utility bill payment services. <http://www.smr.tv/solutions/inhouse.php>
The software is also available through Abraxas Energy at <http://www.abraxasenergy.com/products.php>.

YourEnergyBill.com

YourEnergyBill.com is an online utility accounting software sold by Optimum Energy. Features include utility bill management and reporting tools to enable precise accounting. Additional information is available through <http://www.optimumenergy.com/index.php>

HARDWARE TOOLS FOR DATA ACQUISITION AND MANAGEMENT

Many tools are available which help collect and analyze system-wide HVAC, controls and lighting performance data over time. Data may include power (kW), energy (kWh), or operating parameters such as temperature, humidity, pressure, flow rates, status, lighting levels, etc. Data can be collected through one-time measurements or can be recorded in user-defined intervals. Prices, applications, and complexity of these tools vary.

Guidance on Tool Selection

Guidance on selecting data loggers and other tools is available through several publications as well as tool-lending libraries.

Articles on Selecting Tools

- Refer to IPMVP Volume I Appendix C for an explanation what type of loggers or meters are appropriate for various applications. http://www.evo-world.org/index.php?option=com_content&task=view&id=61&Itemid=80.
- A PEGI/DOE document called *Portable Dataloggers-Diagnostic Monitoring Tools for Energy-Efficient Building Operation* describes the suppliers and uses of data loggers. It is available through http://www.peci.org/library/PECI_DxMonitoring1_0302.pdf.
- A Park Service article *Datalogger Applications In Monitoring The Museum Environment, Part I: Comparison Of Temperature And Relative Humidity Dataloggers* compares the performance of temperature and humidity loggers. It can be downloaded from <http://www.cr.nps.gov/museum/publications/conservoogram/03-03.pdf>.
- Article from Onset Computer Corp. describes the applications for data loggers – *The Use of Low-Cost Data Loggers in Monitoring Building Systems Performance*. It can be downloaded from <http://www.automatedbuildings.com/news/nov99/articles/onset/onset.htm>.

Tool Lending Services

PG&E Tool Lending Library

The PG& E Energy Center maintains a tool lending library and has information on a variety of handheld measurement tools.

http://www.pge.com/003_save_energy/003c_edu_train/pec/toolbox/tll/tll_home.shtml.

WAPA Equipment Loan Program

The Equipment Loan Program through WAPA (Western Area Power Administration) provides technical equipment and training to customers through loan agreements. Utilities use the program to "test drive" new technologies. Equipment such as infrared cameras, demand analyzers, and power quality monitors allow customers to track their own and their customers' energy use. WAPA's customer representatives work with customers to ensure needs are met.

<http://www.wapa.gov/es/loan/default.htm>.

Hardware Tools

Abacus

Abacus tools provide wireless meter information that can be used to detect abnormal energy use and assess the impact of measures immediately. <https://abacus2.ameren.com/>.

ACR Systems

ACR offers a complete line of compact Information Loggers. Small portable data loggers record temperature, relative humidity, electric current, pressure and other standard variables.

<http://www.acrsystems.com>.

Amprobe

Amprobe makes a variety of tools for testing and measuring electrical properties in various field applications. Their DM-II Data Logger/Recorder is a true RMS poly phase power meter that can

record voltage, current, power, energy and demand. The tool includes voltage and power sensors. <http://www.amprobe.com/cgi-bin/pdc/pgview.cgi?id=main&type=elec>.

Analysis North

Analysis North is a manufacturer and distributor of energy monitoring and software products for energy and HVAC professionals. <http://www.energytools.com/index.htm>.

Architectural Energy Corporation

Architectural Energy Corporation's (AEC) MicroDataLogger[®] portable data acquisition system is a battery or line-powered, four-channel data logger and hand-held meter which records time-series data from many different sensors or transducers, including temperature, relative humidity, pressure, electrical current, power, air flow, velocity or lighting levels. The accompanying Enforma[™] software allows visualization and analyses of short-term data taken from portable loggers. Tools are available through Architectural Energy Corporation, Boulder, CO and <http://www.archenergy.com>.

Boonton Test Solutions

Boonton supplies high-performance test instruments and sensors. <http://www.boonton.com/2002/index.html>.

Continental Control Systems

Continental designs and manufactures AC power and energy meters. Available products include standard pulse-output watt-hour transducers and LonWorks interoperable power, energy, and demand meters. Applications include utility sub-metering, end-use metering, equipment performance monitoring, verification, evaluation, and diagnostics. <http://www.ccontrols.com/>.

Controlotron

Controlotron makes a variety of non-Intrusive and clamp-on flowmeters. Appropriate for thermal HVAC measurements, the flowmeters attach to the outside of a pipe to monitor and trend the energy consumption of liquid thermal energy applications such as chilled or hot water HVAC installations. <http://www.controlotron.com/>.

Dent Instruments

Dent offers a variety of energy monitoring products, including tools designed to measure, record, analyze, and present data. Portable devices record the time-of-use and run-time of devices, current, temperature, pulse counts, true RMS 3-phase power characteristics, demand & power metering, environmental monitoring, power quality monitoring, and liquid flow metering. Data analysis software is also available for use with these loggers. Tools are available through Dent Instruments in Bend, OR <http://www.dentinstruments.com/>.

Dickson Monitoring Solutions

Dickson makes a variety of data loggers developed to record and monitor temperature, humidity, pressure and a variety of other variables. <http://www.dicksonweb.com/info/home.php>.

Dranetz-BMI Technology Inc.

Dranetz provides a wide range of electric power quality instruments and systems in the industry. <http://www.dranetz-bmi.com/>.

E-MON Corporation

E-MON Corporation makes solid state electric meters and meter reading systems and software. E-MON D-MON electric meters install easily to meter kWh and/or demand (kW) of electricity. E-MON CE-MON systems and software can be installed on either E-MON meters or any manufacturer's meters for automatic meter reading and profiling. E-MON Corporation is headquartered in Langhorne, PA. <http://www.emon.com/>.

Enernet Corporation

Enernet offers power measurement equipment and measurement and verification services. Their K-20 multi-channel power loggers measure true RMS power as well as any desired discrete parameters. <http://www.enernetcorp.com>.

Field Diagnostics

The ACRx service tool acquires and processes technical data (air temperatures, refrigerant temperatures and pressures, etc.) on packaged HVAC units, and identifies pending service needs. Information is available through Field Diagnostic Services, Warminster, PA, <http://www.acrx.com>.

Fluke Corporation

Fluke manufactures, distributes and services electronic test tools, including power meters, multi-meters, and other diagnostic tools. <http://www.fluke.com/>.

GE Sensing

Panametrics (owned by GE Sensing) manufactures and distributes ultrasonic testing equipment. Their non-invasive ultrasonic flow meters are useful for data collection for chiller water plants and other flow applications. <http://www.gesensing.com/panametricsproducts/>

Hanwell Instruments

Hanwell Instruments offers a wide range of miniature data logging, monitoring, and control hardware including temperature, relative humidity, light levels, shock, and tilt. <http://www.hanwellusa.com/>.

Highland Technology

Highland Technology makes some advanced energy measurement products. Information is available at <http://www.highlandtechnology.com/>.

K-TECH, Inc.

K-Tech specializes in power measurement and control instruments. <http://www.k-tech.com/>

Langan Products Inc.

Langan manufactures portable measuring instruments for recording temperature, humidity, solar radiation, carbon monoxide, carbon dioxide, barometric pressure at user defined intervals. http://www.langan.biz/main_frame.html.

MetreTek Technologies, Inc.

Metretek Technologies provides instrumentation to measure natural gas. <http://www.metretek.com/frames.html>

Ohio Semitronics

Over the last thirty-five years Ohio Semitronics has a wide array of energy measurement devices and instrumentation available. <http://www.ohiosemitronics.com/>.

Onset Computer Corporation

Onset offers over 70 models of miniature data loggers and logger/controller engines. The popular HOBO & StowAway loggers, paired with BoxCar Pro software for Windows, allow you to quickly and easily record temperature, relative humidity, light intensity, lighting run time, rainfall, AC current, DC voltage, motor on/off, light on/off, open/closed states and events. Tools are available through Onset Computer Corporation, Pocasset, MA, <http://www.onsetcomp.com>.

Pace Scientific

Pace Scientific makes the XR440 Pocket Logger, four-channel data logger with sensors for temperature, humidity, pressure, AC current, light, pulse, process signals, etc. <http://www.pace-sci.com>.

PSI Flow Instruments

PSI Flow Instruments provides process control and instrumentation, including a wide range of flow meters.

Information is available at <http://www.psi-kc.com/html/products/flow.html>.

Square D

Square D makes a full line of power monitoring equipment. More information is available through [http://www.squared.com/us/products/power_management.nsf/unid/6E2BE9FED06AB9CC85256A1D006B0EB0/\\$file/pwrmgmtprodshomeFrameset.htm](http://www.squared.com/us/products/power_management.nsf/unid/6E2BE9FED06AB9CC85256A1D006B0EB0/$file/pwrmgmtprodshomeFrameset.htm).

Summit Technology, Inc.

Summit Technology makes the PowerSight, a tool for measurement and analysis of electric power. Features include demand analysis, harmonic analysis, power quality analysis and data logging. More information is available at <http://www.summittechnology.com>.

Texas A&M

Texas A&M has developed various software programs designed to help users manipulate and analyze energy consumption data. Information and costs are available through Texas A&M at <http://esl.eslwin.tamu.edu/resources/software.html>.

Thermo Westronics

Thermo Westronics offers a full line of Ranger Power Quality Recorders including harmonic analyzers, power quality monitors and software, meter loggers and data loggers. These instruments are used in a variety of process and power applications. <http://www.thermo.com/>.

Veris Industries

Veris Industries offers a variety of sensors including power meters, humidity, pressure, and temperature sensors. Most of their equipment is for permanent installation. Information is available at <http://www.veris.com/>.

Veriteq

Veriteq offers compact precision data loggers for relative humidity, temperature, voltage & current. Advanced data acquisition instruments, Veriteq loggers combine high-accuracy performance with palm-sized, portable, and battery-operated simplicity. <http://www.veriteq.com/index.htm>

WattStopper

WattStopper makes a line of occupancy sensors, and lighting specific controls, data loggers, and sensors. The Watt Stopper's IT-200 IntelliTimer Pro Logger monitors both occupancy and lighting usage to give you and estimates savings possible with occupancy sensors. The PL 100 analyzes plug loads and estimates savings possible with occupancy sensors. <http://www.wattstopper.com>

Xymetrex (Previously Measuring and Monitoring Services)

Services include measurement and verification services, end-use metering, load research, energy monitoring and analysis, water system monitoring as well as related hardware and software products. Their TimeFrame tool is for data collection of lighting and motor projects which include sensors (current or voltage types) that are hardwired at the site and remote computer for data collection and storage and analysis. Information is available Xymetrex, Tinton Falls, NJ, <http://www.xymetrex.com/>.

OTHER RESOURCES

There are many additional resources that could be utilized when preparing for and implementing measurement and verification of energy savings. Some of these resources are included here.

Commissioning & Retro-Commissioning Resources

ASHRAE Guideline 0

Guideline 0 –2005 - The Commissioning Process describes the methods used to verify that specific elements, assemblies, or systems meet the Owner's Project Requirements. This guideline describes the procedures, methods, and documentation requirements requirements for each phase of the Commissioning Process. Document is available through <http://www.ashrae.org/> for \$59.

ASHRAE Guideline 1

Guideline 1-1996 - The HVAC Commissioning Process describes the commissioning process that will ensure HVAC systems perform in conformity with design intent. Document is available through <http://www.ashrae.org/> for \$36.

Model Commissioning Plan and Guide Specifications

A complete toolkit of materials to incorporate building commissioning into your project. Developed by Portland Energy Conservation for US Department of Energy Seattle Regional Support Office. Version 2.05 modifications sponsored by: Oregon Office of Energy. Available for download at <http://www.peci.org/library/mcpgs.htm>
Printed copy: Version 2.04 of this document is available printed and bound from the National Technical Information Service (NTIS). Call NTIS at 1-800-553-6847 and request document ID# DE97004564.

A Practical Guide for Commissioning Existing Buildings

A guide of almost 150 pages prepared by the staff of Portland Energy Conservation, Inc. and Oak Ridge National Laboratory that covers the benefits and how-to's of retro-commissioning projects. The report is available for download from:

<http://eber.ed.ornl.gov/commercialproducts/retrocx.htm>.

Portland Energy Conservation Inc. (PECI)

Portland Energy Conservation Inc.'s page for commissioning and O&M resources contains links to documents and organizations related to building commissioning and operation and maintenance.

<http://www.peci.org/library.htm>.

FEMP Continuous Commissioning Guide

This guidebook was developed by Texas A&M for the Federal Energy Management Program to present the principles and results of Continuous Commissioning to federal agencies. It is available for download at <http://eber.ed.ornl.gov/commercialproducts/contcx.htm>.

Miscellaneous Resources

PNNL M&V Instructional Tool

The FEMP Measurement and Verification (M&V) Instructional Tool (CD Rom) is designed to give the Federal employee access to information on metering and M&V for use with on-going energy projects, energy savings performance contracting (ESPC), operations and maintenance (O&M) activities, and in-house energy efficiency efforts. It is meant to provide an introduction to metering and M&V for energy projects for the beginner and provide ample links to the appropriate M&V documents for the more experienced. Software downloadable from the Web at

<http://metering.pnl.gov/MandV/FEMPMVtool.htm>.

Predicting and Verifying Energy Savings for Energy Service Companies Using Short-Term Monitoring

This study by W. Mark Arney, Stuart S. Waterbury, Matthew J. Ossi was published in 1998 ACEEE *Summer Study On Energy Efficiency In Buildings Proceedings*. It can be ordered through

<http://www.aceee.org/pubs/pan398.htm>.

Rebuild America Program Manual

Rebuild America has a series of documents sponsored by the DOE. *The Energy Efficient Project Manual* is published by the National Association of Energy Services Companies (NAESCO) and the Department of Energy for the Energy Fitness Program. It is sub-titled *The Customer's Handbook To Energy Efficient Retrofits: Upgrading Equipment while Reducing Energy Consumption And Operating And Maintenance Costs*. This overview of performance contracting has a chapter on measurement and verification. It is available from <http://www.naesco.org/bookstore/default.htm> for \$40.

Risk & Responsibility Matrix

Included in the IDIQ contract for all Super ESPC service providers, the Responsibility Matrix is a concise tool used to allocate risk in a performance contract. The responsibilities are assigned for typical financial and operational parameters. This document can be downloaded from

<http://ateam.lbl.gov/mv/>.