PNNL-24501

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Metering Plan

Enhanced Operations Through Measuring and Monitoring of Utility Resource Consumption

July 2015

JE Pope

U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
under Contract **DE-AC05-76RL01830**

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Pacific Northwest National Laboratory
Richland, Washington 99352

Summary

The Sustainability Program at Pacific Northwest National Laboratory (PNNL) has adopted a "triple-bottom-line" approach of environmental stewardship, social responsibility, and economic prosperity to its operations. Metering at PNNL works in support of all three, specifically to measure and inform building energy use and greenhouse gas emissions and minimize water use. The foundation for metering at PNNL is a core goal set, which consists of four objectives: providing accurate data without interruption; analyzing data while it is still new; providing actionable recommendations to operations management; and ensuring PNNL's compliance with contract metering requirements. These core objectives guide the decisions that we make during annual planning and as we operate throughout the year.

This 2015 edition of the Metering Plan conveys the metering practices for and vision of the Sustainability Program. It presents our progress toward the metering goals shared by all federal agencies and highlights our successful completion of metering requirements. Currently, PNNL is fully compliant with the applicable legislative and Executive Order metering requirements. PNNL's approach to the installation of new meters will be discussed. Perhaps most importantly, this Plan details the analysis techniques utilized at PNNL that rely on the endless streams of data newly available as a result of increased meter deployment over the last several years. Previous Metering Plans have documented specific meter connection schemes as PNNL focused on deploying meters in a first step toward managing energy and water use. This Plan serves not only to highlight PNNL's successful completion of agency metering goals but also can be used as a guideline for meter installation and data analysis.

Acronyms and Abbreviations

ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BOCC	Building Operations Control Center
BSF	Biological Sciences Facility
BTU	British thermal unit
CEDR	Consolidated Energy Data Report
CEM	Certified Energy Manager
CO_2	carbon dioxide
COP	coefficient of performance
CRAC	computer room air conditioner
CSF	Computational Sciences Facility
DOE	U.S. Department of Energy
DSOM	Decision Support for Operations and Maintenance
ECM	energy conservation measures
EISA	Energy Independence and Security Act of 2007
EMSL	Environmental Molecular Sciences Laboratory
EO	Executive Order
EPA	U.S. Environmental Protection Agency
EPAct	Energy Policy Act of 2005
ETB	Environmental Technology Building
FEMP	Federal Energy Management Program
FIMS	Facilities Information Management System
F&O	Facilities and Operations
FMCS	Facilities Management Control System
FUA	Facility Use Agreement
HPSB	high performance and sustainable building
HVAC	heating, ventilation, and air conditioning
ILA	industrial, landscaping, and agriculture
ISB	Informational Sciences Building (1 and 2)
LSB	Laboratory Support Building
MSL	Marine Sciences Laboratory (Sequim, WA)
NSB	National Security Building
PNNL	Pacific Northwest National Laboratory
PSF	Physical Sciences Facility
PUE	power utilization effectiveness
RCL	Radiological Calibrations Laboratory
R&D	research & development
RDHx	rear door heat exchanger
ROB	Research Operations Building
SME	subject matter expert
SPO	(PNNL's) Sustainability Performance Office
SSP	Site Sustainability Plan
VOC	volatile organic compounds
WCM	water conservation measures

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1.0 Introduction

Pacific Northwest National Laboratory (PNNL) has an established Sustainability Management and Operations Program with an annual submittal of a Metering Plan as one of its three program deliverables. The other deliverables are:

- The contractually required Site Sustainability Plan (SSP) and associated Consolidated Energy Data Report (CEDR)
- The annual report on progress toward comprehensive energy and water assessments as required in the Energy Independence and Security Act (EISA) of 2007.

Metering at PNNL is managed within the Sustainability Program. All three program deliverables rely on data collection, analysis, and professional recommendations resulting from metering efforts performed within the Sustainability Program.

This 2015 edition of PNNL's Metering Plan conveys the metering practices for and vision of the Sustainability Program. The current version of the Metering Plan presents our progress toward the metering goals shared by all federal agencies and highlights our successful completion of metering requirements. PNNL's approach to the installation of new meters will be discussed. Perhaps most importantly, this Plan details the analysis techniques utilized at PNNL that rely on the endless streams of data newly available as a result of increased meter deployment over the last several years. Previous Metering Plans (Pope, Olson, Berman, and Schielke 2011; Pope 2012; Pope 2014) have documented specific meter connection schemes as PNNL focused on deploying meters in a first step toward managing energy and water use. This Plan serves not only to highlight PNNL's successful completion of agency metering goals but also can be used as a guideline for meter installation and data analysis.

2.0 Advanced Metering Plan

2.1 Vision

The PNNL Sustainability Program has adopted the “triple-bottom-line” approach of environmental stewardship, social responsibility, and economic prosperity to its operations. Metering at PNNL works in support of all three, specifically to measure and inform building energy use and greenhouse gas emissions and minimize water use. The foundation for metering at PNNL is a core goal set consisting of four objectives:

- Provide accurate data without interruption. Data should be of sufficient quality, quantity, and timeliness to enable effective analysis and support real-time commissioning.
- Analyze data while it is still “fresh.” Data analyses and the resulting recommendations are most relevant when real-time data is used.
- Provide actionable recommendations to operations management.
- Ensure PNNL’s compliance with contractual metering requirements.

These core objectives guide the decisions that we make during annual planning and as we operate throughout the year. Additionally, metering works to enable the SMART^3 initiative, PNNL’s Facilities and Operations (F&O) Directorate’s vision to integrate the *smartest* facilities connected to the *smartest* people by the *smartest* systems (PNNL 2014). The SMART^3 initiative near-term objectives are to deploy sensors in 100% of our managed facilities; use the Building Operations Control Center (BOCC) to monitor and control building performance; leverage existing research & development (R&D) technical capabilities; and ensure optimal control, response, and efficiency across all F&O managed facilities using interconnected hardware and software tools.

Sensors deployed as part of the SMART^3 initiative are termed *smart sensors*, which reduce operational costs by quickly allowing staff to troubleshoot equipment and correct system operation, allowing for energy saving strategies, enabling condition-based preventative maintenance, and generating diagnostics to enhance reliability. Its specific values are to:

- increase occupant comfort (temperature and environmental control)
- improve operations (troubleshooting and monitoring)
- allow for energy saving strategies (advanced programming techniques)
- enable condition-based maintenance (perform maintenance as needed)
- perform diagnostics (detect system abnormal conditions).

The SMART^3 initiative begins by defining sensors through a graded approach based on added value and cost effectiveness. In working with the Plant Operations, Sustainability and Energy Group, and Engineering several smart sensors were identified as providing the most impact in the five value areas.

The top value smart sensors are space temperature sensors, demand-based ventilation sensors (carbon dioxide [CO_2] or volatile organic compounds [VOC]), air filter differential pressure sensors, discharge temperature sensors, British thermal unit [BTU] meters, occupancy sensors, and status sensor on fans/pumps (current transducer). Sensor installation is combined with programmed functions and control routines to enable the *smart sensor* capability. An example of installed *smart sensors* in action is detailed in the Case Study section of this report.

2.2 Goal Progress

Compliance with contractual metering requirements at PNNL is measured against three federal metering legislative and Executive Order (EO) drivers. Those documents and the appropriate metering requirement sections are:

- The Energy Policy Act of 2005 (EPAct), Section 103: Energy Use and Management Accountability, requiring that all federal buildings install electric metering systems by October 1, 2012.
- EISA of 2007, Section 434(b): Metering, requiring that all federal buildings be metered for natural gas and steam by October 1, 2016.
- EO 13693 (2015): “Planning for Federal Sustainability in the Next Decade,” Section 3(a)(ii)(B): Sustainability Goals for Agencies, requiring all data centers to have advanced energy meters installed and monitored by 2018.
- EO 13693 (2015): “Planning for Federal Sustainability in the Next Decade,” Section 3(f)(ii): Sustainability Goals for Agencies, requiring agencies to begin installing water meters in 2016.

Guidance for the installation of meters is provided in the *Federal Building Metering Guidance (per 42 U.S.C. §8253(e), Metering of Energy Use* (U.S. Department of Energy [DOE] 2014). Buildings are considered “appropriate” for metering unless identified for exclusion using criteria set forth in the Guidance.

Currently, PNNL is fully compliant with the legislative and EO requirements above. Considering goals listed in EO 13693, water meters at the Marine Sciences Laboratory (MSL) in Sequim, specifically at MSL1 and MSL5, will be installed. Table 2.1 through Table 2.4 detail meter installations for buildings listed in the Facilities Information Management System (FIMS). Meters are described as advanced, defined in the Guidance as a meter that “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;” or standard, defined as “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.”

Both EPAct and EISA require the installation of advanced meters where practicable, and require the Secretary of Energy to define what is practicable by issuing the Metering Guidance described above. Per this Guidance, existing standard meters used to calculate monthly utility bill invoices can substitute for the installation of new meters if the information is incorporated in agency or sub-agency tracking systems. The use of existing standard meters is only approved in lieu of new meters when the meter measures consumption for a single building, not a campus. Because PNNL tracks all utility invoices using EnergyCAP, a commercial energy management software, and uses that data to inform agency tracking devices (e.g., CEDR) and benchmarking tools (e.g., U.S. Environmental Protection Agency’s [EPA’s] ENERGY STAR® Portfolio Manager® [EPA 2012]), meters noted as both advanced and standard are consistent with the Guidance and meet the legislated requirements above. As detailed in F&O Administrative Procedure ADM-CM-057-PG-01, *Engineering Design Standards* (PNNL 2013), it is the policy of PNNL to install advanced electric, natural gas, and water meters on all new facilities constructed.

Table 2.1. Buildings Appropriate for Energy and Water Metering

Property ID	Property Name	Size (square footage)	Water Use (gal/day)	Meter-Potable Water	Meter-Electricity	Meter-Natural Gas
325RPL	325 Radiochemical Processing Lab	144,820	1,122.08	Metered-Advanced	Metered-Advanced	Metered-Advanced
331	331 Life Sciences Laboratory 1	120,751	4,331.22	Metered-Advanced	Metered-Advanced	Metered-Advanced
3020EMSL	3020 Env Molecular Science Lab	234,566	28,381.09	Metered-Advanced	Metered-Advanced	Metered-Advanced
3410	3410 Material Science and Tech Lab	79,878	9,455.38	Metered-Advanced	Metered-Advanced	Metered-Advanced
3425	3425 Ultra Low Background Count Lab	7,418	2,363.84	Metered-Advanced	Metered-Advanced	Metered-Advanced
BSF	Biological Sciences Facility	71,000	5,329.87	Metered-Advanced	Metered-Advanced	Metered-Advanced
CSF	Computational Sciences Facility	74,000	5,329.87	Metered-Advanced+Standard	Metered-Advanced	Metered-Advanced
ETB	Environmental Technology Building	100,358	1,331.53	Metered-Standard	Metered-Advanced	Not Used
GUESTHOUSE	Guest House	29,108	1,593.35	Metered-Standard	Metered-Standard	Not Used
ISB1	Information Sciences Building 1	50,200	1,309.09	Metered-Standard	Metered-Advanced	Not Used
ISB2	Information Sciences Building 2	60,080	1,847.69	Metered-Standard	Metered-Advanced	Not Used
LSB	Laboratory Support Building	83,921	3,216.62	Metered-Standard	Metered-Advanced	Not Used
LSL2	Life Sciences Laboratory 2	102,107	8,610.08	Metered-Standard	Metered-Advanced	Metered-Advanced
MATH	Mathematics Building	29,416	1,787.84	Metered - Advanced	Metered-Advanced	Metered-Advanced
MSL1	Beach Office/Laboratory	12,748	unknown	Not Metered	Metered-Advanced	Not Used
MSL5ABC	Marine Sciences Laboratory 5, 5A, 5B, 5C	24,893	unknown	Not Metered	Metered-Advanced	Not Used
POP	Port of Pasco Airport Hanger	11,120	2,872.52	Metered-Standard	Metered-Standard	Not Used
PSL	Physical Science Laboratory	89,379	7,181.30	Metered - Advanced	Metered-Advanced	Metered-Advanced
ROB	Research Operations Building	69,586	2,782.75	Metered - Advanced	Metered-Advanced	Metered-Advanced
RTL520	Research Technology Laboratory	56,158	10,510.13	Metered-Advanced	Metered-Advanced	Metered-Advanced
SIGMA1	Sigma 1 Office Building	20,000	2,932.36	Metered-Standard	Metered-Advanced	Not Used
SIGMA2	Sigma 2 Office Building	20,100	1,735.48	Metered-Standard	Metered-Advanced	Not Used
3820SEL	Systems Engineering Laboratory	24,412	1300 est.	Metered - Advanced	Metered-Advanced	Metered-Advanced

Table 2.2. Buildings Appropriate for Energy Metering but Not Appropriate for Water Metering Due to De Minimis Consumption Threshold

Property ID	Property Name	Size (square footage)	Water Use (gal/day)	Meter-Electricity	Meter-Natural Gas
318	318 Radiological Calibrations Lab	37,025	261.82	Metered-Advanced	Metered-Advanced
350	350 Plant Ops and Maint Facility	22,048	523.64	Metered-Advanced	Not Used
2400STV	2400-2410 Stevens Office-Lab	99,414	119.69	Metered-Advanced	Not Used
3420	3420 Radiation Detection Laboratory	81,369	463.79	Metered-Advanced	Metered-Advanced
3430	3430 Ultratrace Laboratory	70,299	463.79	Metered-Advanced	Metered-Advanced
3440	3440 Large Detector Laboratory	5,488	67.32	Metered-Advanced	Not Used
AML	Atmospheric Measurement Laboratory	9,311	149.61	Metered-Standard	Metered-Standard
AUD	Auditorium	12,110	97.25	Metered-Advanced	Metered-Advanced
BRSW	Battelle Receiving & Shipping Whse	9,654	157.09	Metered-Standard	Metered-Standard
EDL	Engineering Development Laboratory	16,071	695.69	Metered-Advanced	Metered-Advanced
ESB	Engineering Support Building	12,595	590.96	Metered-Standard	Not Used
MSL7	Marine Sci Lab 7 Office	9,688	224.42	Metered-Advanced	Not Used
NSB	National Security Building	100,358	987.43	Metered-Advanced	Not Used
PDLE	Process Development Laboratory East	3,882	880.21	Metered-Standard	Metered-Standard
PDLW	Process Development Laboratory West	6,826	880.21	Metered-Advanced	Metered-Standard
SALK	Salk Building	10,140	29.92	Metered-Standard	Not Used
SEF	Systems Engineering Facility	47,712	979.95	Metered-Advanced	Metered-Advanced

Table 2.3. Buildings Not Appropriate for Metering Due to Not Meeting the De Minimis Threshold for Size

Property ID	Property Name	Size (square footage)
312	312 Pump Pit 3614A Rvr Wtr Support	560
318TRL4	318TRL4 Office Trailer	3,669
350A	350A Paint Shop	1,400
350B	350B Warehouse	2,122
350C	350C Storage Building	212
350D	350D Oil Storage Facility	960
3455	3455 Trailer	1,792
3465	3465 Trailer	1,792
3475	3475 Laboratory Support Warehouse	20,092
CEL	Chemical Engineering Laboratory	600
GES	Grounds Equipment Storage	2,100
LSL2A	Chemical Storage &Transfer Facility	764
MSL1W	Waste Water Treatment Building	280
MSL2	Biotech, Conference and Shop Bldg	3,023
MSL3	Filter Building	489
MSL4	Pumphouse	100
POS	Port of Skamania Lab-Warehouse	2,620
RSW	Research Support Warehouse	8,000
RTL510	Chemical And Flammable Storage	577
RTL524	Fire Riser Facility	192
RTL530	Radioactive Storage	172
RTL540	Paper Shredder Facility	810
RTL550	Technical Services	4,365
RTL560	Utility Building	3,925
RTL570	Autoclave Center	678
RTL580	Crafts Shop	1,448
RTL590	Warehouse RTL590	4,001
TSW	Technical Support Warehouse	8,000

Table 2.4. Buildings Not Appropriate for Metering Due to Being a Partially Leased Building Where Lessor is Not Paid Based on Actual Energy Consumption

Property ID	Property Name
ALBUQUERQUE	Albuquerque NM Office
APEL	Applied Process Engineering Lab
BSRC	Battelle Seattle Research Center (ILA)
BWO	Battelle Washington Office (ILA)
CSI1	Coastal Security Institute 1
JGCRI	Joint Global Change Research Inst
MBI11	Microproducts Breakthrough Inst 11
PORTLAND	Portland Office
POS2	Port of Skamania Tietzel Office
VTARC	Virginia Tech Applied Research Corp
WSUBSEL	WSU Bioproducts Sci and Engr Lab

In 2015, the Sustainability Program performed a metering assessment with the following scope:

1) Perform a review of PNNL buildings. Buildings included in the assessment are those identified in FIMS. Determine which buildings are appropriate for energy and water metering using the criteria outlined in the *Federal Building Metering Guidance* (DOE 2014). The four criteria in the Guidance used to exclude buildings at PNNL are:

   - The building is planned to be sold or razed within the next 5 years.
   - The building is leased or owned, but the agency either does not pay the utility bill or does not pay the lessor for utilities based on actual consumption.
   - The building is less than the de minimis threshold for energy metering of 25,000 square feet for warehouses and 5,000 square feet for other buildings.
   - The building is less than the de minimis threshold for water metering of 5,000 square feet or consumption less than 1,000 gallons per day.

2) Document existence and type of metering for each building deemed appropriate per the Guidance.

During the 2015 assessment, eighty (80) buildings at PNNL were evaluated, of which 40 were found to be appropriate for energy metering and 22 were found to be appropriate for water metering. Eleven (11) buildings were not appropriate for energy or water metering because they are leased buildings in which the agency does not pay the lessor based on actual consumption. A single building, the Battelle Inhalation Laboratory, was deemed not appropriate for energy or water metering because the building is planned to be eliminated from FIMS within the next 5 years. Twenty-eight (28) buildings were deemed not appropriate for energy metering because they did not meet the de minimis use threshold of 25,000 square feet for warehouses or 5,000 square feet for other building types. Forty-five (45) buildings were deemed not appropriate for water metering because they did not meet the de minimis use threshold of 5,000 square feet or consumption of 1,000 gallons per day.

Buildings deemed *appropriate* for energy metering, water metering, or both are detailed in Table 2.1 and Table 2.2. Buildings deemed *not appropriate* for energy or water metering are detailed in Table 2.3 and Table 2.4. Of the 40 buildings deemed *appropriate* for electricity metering, all 40 are metered; of the 23 buildings deemed *appropriate* for natural gas metering, all 23 are metered. The original core campus consisting of buildings Research Operations Building (ROB), Math, PSL, EDL, LSL2, and the Auditorium are served from a central plant and electrical distribution system, which is extensively metered, with approximately 70 sub-meters installed. An engineered pro rata allocation of the main service meter measurements for these facilities has been developed over several years using sub-meter data. These buildings are considered advanced metered due to the metering installed and the appropriate energy percentage allocation.

Some existing buildings at PNNL still use steam for heating. Steam for these facilities is generated on site, and the water and energy used to generate the steam is measured using water, electric, and natural gas meters. Additional metering of steam would be redundant and is not necessary because no steam is purchased from an off-site utility nor is any steam sold off site.

Of the 23 buildings deemed *appropriate* for water metering, 21 are metered. Two buildings, MSL1 and MSL5, were identified as appropriate for water metering but do not have water meters installed. Water meters are required as per EO 13693, with installation beginning in 2016.

PNNL has advanced metering installed on data centers in the Informational Sciences Building (ISB)2, EMSL, and Computational Sciences Facility (CSF) 1811 (Table 2.5). The advanced metering is used to calculate power utilization efficiency (PUE) and is reported in our annual SSP.

Table 2.5. Data Center Metering

Data Center Name	Meter-Electricity
ISB 2	Metered - advanced
EMSL	Metered - advanced
CSF 1811	Metered - advanced

2.3 Implementation

PNNL's Metering Plan uses four generic approaches to metering across campus. From our commitment to metering as a key component of the Sustainability Program, we typically focus on long-term metering. We evaluate installations on a case-by-case basis and consider costs and returned benefits from metering. As a result, we are equipped to deploy any of the four basic approaches for metering based on specific need.

- **One time/spot measurement**: Achieved through measurement by an electrically trained and qualified craftsman. Used to meter equipment where the current draw does not typically modulate and a single measurement is needed, typically as a consideration for a design project.
- **Run-time measurement**: Achieved exclusively through our facility management and control system. Run-time measurement is used as a diagnostic tool and also to alternate between motors on equipment where lead/lag settings are used in the control sequence to facilitating even wear.
- **Short-term monitoring**: Used to quantify savings from a specific project when a permanent meter installation is not warranted. Most short-term monitoring is for the purpose of measuring electrical consumption. We typically use battery-powered HOBO meters by Onset to meet this need. Examples include installing a temporary meter to baseline air compressor power for 30 days before a project to repair leaks in the distributed compressed air system throughout a building. At the conclusion of the project, the system is again monitored for 30 days to estimate savings as a result of the repairs. Likewise, we install a temporary meter on a lighting circuit before implementing advanced lighting control. This scenario enables us to quantify savings and assists in commissioning the system because we can monitor how often the lights are off in the night when the building is unoccupied. This monitoring has alerted us to occupancy sensors installed in less than desirable locations, such as near air discharge registers, where false occupancy is detected.
- **Long-term monitoring**: Our standard approach. Long-term monitoring provides valuable information in the short run but also allows trending over time, a primary input to our data analysis approach. PNNL collects data from long-term electric meters at the service for each building. Likewise, natural gas and water meters installed at the building entry are also long-term installations.

2.4 Design and Installation

The PNNL Metering Plan employs a variety of meter types and technologies. Along with a cursory review of existing metering, new projects should begin design by working through the three questions detailed below.

► *Do I need any additional meters to manage energy use?*

Required meters are detailed in the legislative and EO drivers discussed in section 2.2, Goal Progress, above. The *Federal Building Metering Guidance* (DOE 2014) and *Metering Best Practices: A Guide to Achieving Utility Resource Efficiency, Release 3.0* (Parker et al. 2015), discuss the best way to prioritize meter installation.

Once it is determined that metering will be installed, the first tier is at the whole-building level for electricity, natural gas, and water. After ensuring that requirements for metering at the whole-building level are met, consideration should be given to installing the sub-metering necessary to divide electrical consumption into four load categories: heating, ventilation, and air conditioning (HVAC); IT; lighting; and miscellaneous plug load (discussed in section 2.5, Data Analysis). PNNL buildings should consider metering necessary to show the load for each lab, usually at the panel. Further metering necessary for process optimization should be considered based on the project scope.

► *What meters should I use?*

Existing **electric meters** installed across the campus take on different characteristics due to the time period in which they were installed, design preferences, and project design constraints. Electric meter types installed include Veris, E-Mon, PQube, Square D, Cutler Hammer, Utility provider pulse, and others. New installations must be evaluated on a case-by-case basis given the design constraints.

On new switchboard installations, metering can be included as part of the manufactured package. The Veris product line has proven robust and affordable for applications requiring retrofitting of existing equipment with metering. To date, PNNL has installed hundreds of Veris Enercept meters, which have a compact design, no local display, and communicate directly with the Facilities Management Control System (FMCS). Recently, the new Veris E50 meter has been selected for several installations and is functioning well.

The E50 communicates using the Building Automation and Control network (BACnet) protocol with a compact local display and data logging capability. Separate meter power on the E50 has made it an attractive option for installations at equipment fed from two sources of power via a three-position transfer switch. PNNL is following an industry-wide trend to move toward control equipment that communicates using the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)-developed communications protocol standard. The primary benefit of selecting equipment that uses BACnet is its open protocol, allowing freedom from proprietary systems that limit future options.

In some applications, electric usage data for a specific piece of equipment can be obtained from a variable frequency drive or other installed component. When possible, we prefer to take advantage of existing metering or specify metering integral to a system being installed.

A common **natural gas meter** at PNNL is the Dattus by Itron. This solid-state meter uses fluidic oscillation technology and has data logging capabilities. Due to meter failures and the unavailability of direct replacements, PNNL began replacing Dattus by Itron gas meters with the Onicon F-5100 series insertion thermal mass meters with a pulse output. Other meters in use include the Roots by GE (formerly Dresser), also installed as a flanged or threaded meter in the gas line; and the Sage Prime, a thermal mass flow insertion meter that can be installed in an existing line. Meters for natural gas tend to be the most costly to purchase and install.

PNNL employs several technologies for **water meters** across campus. The most accurate (and most costly) to purchase and install is the compound meter, which combines disc and turbo meters in a single body. The Badger Compound Series is installed at several buildings and has proven to work well. Because of the ease of installation and low cost, the insertion turbine meter is an attractive, effective option. An additional benefit of the insertion meters is the ability to "hot tap" an in-service line, eliminating the need for a system outage. The Onicon 1100 and 1200 series meters offer an alternative to a full bore meter like the Badger Compound. Care must be taken during the design phase to ensure that minimum flows are met. Considerations can be taken, such as reducing the pipe diameter for a short section to increase fluid velocity across the meter. The Onicon F-3500 is an electromagnetic insertion meter used most recently at PNNL that allows accurate readings at lower flow levels than the insertion turbine meters. To meter water used for irrigating outdoor landscaping, a McCrometer propeller meter is installed in the non-potable water line. This type of meter is especially suited to dirty water flows and handles solids suspended in water without clogging. It also requires no external power or batteries and is thus appropriate for installation in irrigation lines far from buildings where power is not readily available.

Guidance on meter installation is included in PNNL F&O Administrative Procedure ADM-CM-057, PG-01 (PNNL 2013).

► *How do I link these meters to the appropriate data collection systems?*

Most of the electric meters installed communicate to the Johnson Controls Metasys FMCS using either BACnet standard communication protocol, the JCI N2 communication protocol or a meter pulse output collected on an accumulator point within the Metasys system. Gateways or translators are also used to take proprietary communication protocols like Modbus and Eaton's INCOM and translate them to an option that is compatible with the JCI system. Metered data is stored, trended, and can be accessed using the Metasys interface. PNNL also employs stand-alone advanced electric meters that store data and can be accessed directly either through a phone line or network connection. Data from meters not connected to the FMCS are retrieved by the Decision Support for Operations and Maintenance (DSOM) program, which also has the ability to gather FMCS data.

Most gas meters, including all those employed at PNNL, use a pulse output from the meter collected on an accumulator point within the FMCS. This is a reliable, relatively simple way to collect data from the meter. The Dattus meters also log information that can be retrieved locally with a laptop and feature a local display.

PNNL has worked with the City of Richland, which is the main water purveyor on the campus, to retrofit some existing Badger water meter recorders with a pulse output module allowing data to be accumulated by the FMCS for real-time data without installing a separate meter in some locations. Most of the insertion turbine meters also offer a pulse output, with each pulse accounting for a stated number of gallons measured at the meter. Insertion turbine meters are also available with an analog output of 4−20 mA or 1−10 VDC and measure water velocity or flow rate.

As previously noted, the above guidelines are used to select meters on a case-by-case basis. Additional considerations for new installations include the availability of existing infrastructure, space constraints, and consistency with other meters within a building.

2.5 Data Analysis

The importance of data analysis within the PNNL Sustainability Program cannot be overstated. In performing data analysis, we seek to achieve the following four objectives (Hooke, Landry, and Hart 2009):

- **Determine energy use and cost** – Determining energy costs provides an increased awareness of where energy is being used and what utilities and areas are the highest consumers. Targeting heavy users offers an opportunity for larger savings with the same percentage reduction than a smaller user. Graphics are the best way to illustrate the division of use and cost. In addition to being a valuable analysis tool, energy use and cost graphics are used to increase understanding and awareness among laboratory employees.

  Currently, the total energy and water use at PNNL is broken down by building for electricity, gas, and water. Sub-meters are used heavily to monitor specific systems or pieces of equipment. The preferred sub-metering strategy for new installations is to create a load profile for each building that will divide electricity use into four subsystems: HVAC, IT, lighting, and plug load. Metering laboratory panel boards also allows us to identify labs with high electrical intensity that may be a candidate for focused energy reduction efforts.

- **Calculate performance levels** – To compare our buildings and processes against other buildings and processes, industry standards, or the same buildings and processes from an earlier period, we calculate performance levels. These can be simple such as kW per square foot for an entire building or more detailed such as coefficient of performance (COP) for a refrigeration system, boiler efficiency, or PUE of a data center. Examples of how performance levels are used at PNNL are detailed in section 2.6, Benchmarking, and section 2.10, Data Centers.

- **Understand the reasons for variable energy use and performance** – Energy use and performance levels can vary based on factors outside of our control, such as weather. The goal of our analysis is to understand the reasons for the variability and to identify parameters within our control that can improve performance and reduce energy use. Understanding the load profile for a building as a division of base load, weather load, and variable load can assist in this analysis. Using metered data and analysis techniques, we are working to establish optimum settings for HVAC equipment in various weather conditions. An example of high variability in performance levels is the COP in chiller plants at different loads. An example of the process that PNNL uses to understand varied energy use is discussed in the Benchmarking portion of this report.

- **Track progress toward energy use targets and identify poor performance** – As a DOE national laboratory, our energy and water use target is clearly defined. PNNL contract clause H-43 requires reducing energy intensity by at least 30% by 2015 compared to a 2003 baseline. It also requires reducing potable water use by at least 26% by 2020 compared to a 2007 baseline and reducing industrial, landscaping, and agricultural (ILA) water 20% by 2020 compared to a 2010 baseline. PNNL is working aggressively toward these energy and water reduction goals. In addition to comparing current energy and water use to our mandated reduction goal, we also compare with historical data trended and archived within our EnergyCAP utility payment software system. Most commonly, we will compare observed use with an earlier period such as the previous month or the same month from a previous year as discussed below.

2.6 Benchmarking

Monthly meetings with building management teams (known as Core Teams) are an important part of the benchmarking strategy at PNNL. Metered electricity, natural gas, and water data are consolidated in a “Campus Energy Consumption” spreadsheet. Data are maintained through a partnership with the Energy and Environmental Directorate, a research organization within PNNL. Monthly core team meetings are held to discuss benchmarking goals, perform trend analysis, and identify opportunities for energy savings. Meetings are conducted in the BOCC, a state-of-the-art asset capable of displaying multiple trends simultaneously on oversize wall monitors and accessing real-time data. Attendees at these meetings typically include the building manager, one or more building engineers, the PNNL campus utility manager, and the sustainability engineer. Graphics are frequently used to illustrate benchmarking results and track progress toward energy goals. An example of a trend used in a 2014 benchmarking meeting for the LSB Building is shown in Figure 2.1. This trend displays the BTU/day/square foot vs. the monthly average temperature over several years.

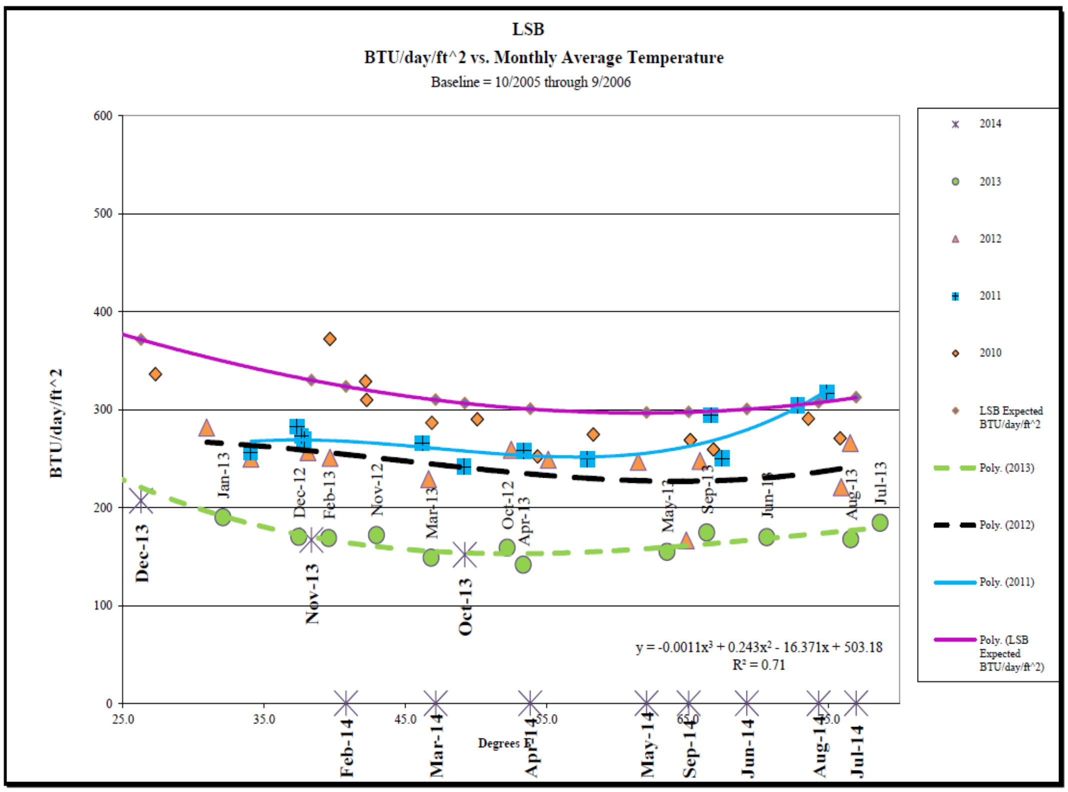

Figure 2.1. Example Trend – 2014 LSB Building Benchmarking Meeting

2.7 Portfolio Manager®

PNNL uses the EPA's Portfolio Manager® tool to track and assess energy and water consumption for our EISA "Covered Facilities" as well as evaluate progress toward High Performance and Sustainable Building (HPSB) goals. Data collected from electricity, natural gas, and water provider meters are entered into EnergyCAP and is uploaded to Portfolio Manager®'s database. DOE's Sustainability Performance Office (SPO) now uses Portfolio Manager® (Figure 2.2) to report EISA "covered facility" energy and water usage. Portfolio Manager® has benchmarking tools and the ability to compare building energy performance with similar buildings away from the campus. Additional information about Portfolio Manager® is available at
http://www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager.

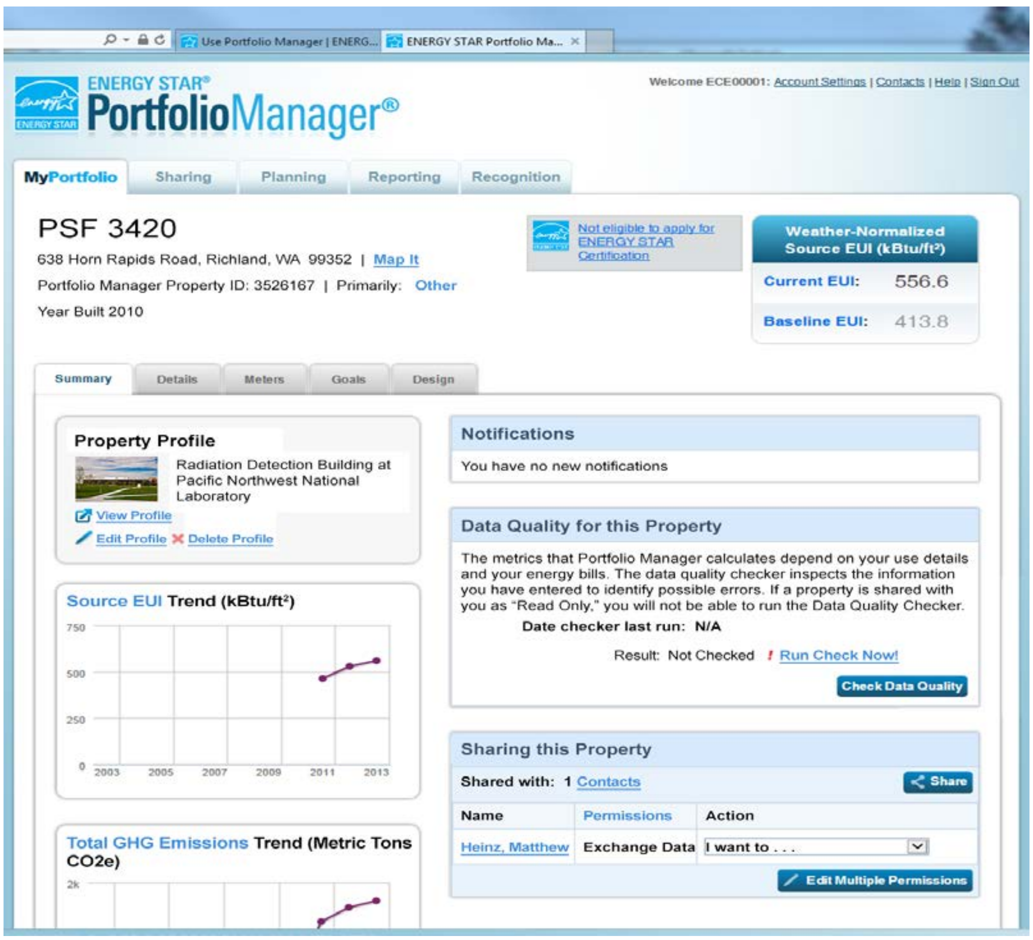

Figure 2.2. Portfolio Manager®

2.8 DSOM

To aid in data analysis, graphical presentation, and data storage, PNNL utilizes the DSOM tool. Developed by PNNL, the DSOM system is an advanced supervision and diagnostic tool to reduce plant operating and maintenance costs and extend plant life.

Linking plant operators, maintenance staff, engineers, and administrators in one enterprise-wide system, DSOM combines online condition monitoring of equipment with unique diagnostic routines. Originally created for efficient operation of nuclear power plants, the science at the core of DSOM has been adapted cost effectively to meet the needs of industrial processes, including power plants, continuous industrial processes, facility plants, HVAC systems, and today's metering.

DSOM software collects and verifies operations data, analyzes them in a customized facility database and lets operators know in real-time if a system is malfunctioning or running below expectations. Beyond early warning signs, DSOM identifies conditions that could potentially lead to a problem.

DSOM is built around the concept of condition-based management. DSOM's diagnostic capabilities prompt operators to make changes to keep systems operating at peak performance and avoid degradation and failures. It has been successfully integrated with standard sensor technology plus advanced systems like vibration monitoring, laser systems, ultrasonic monitoring, and utility meter plus sub-metering.

Field experience has validated that cost reductions of 20 to 40% can be realized through improved process efficiency, reduced operations and maintenance workload, reduced maintenance parts and labor, reduced energy consumption, and equipment life extension.

DSOM is integrated into the PNNL daily operations and tracking of energy and water goals.

2.9 BOCC

PNNL remains aggressive about reducing its water use 26% and energy intensity 30%. To meet these reduction goals, the BOCC monitors and reports using benchmarking, energy and water meetings, and energy and water conservation measures. As a hub for the FMCS, graphics, and analytics systems to connect with building managers, building engineers, design engineers, and the building occupants, the BOCC is the driving force for ensuring that energy and water goals are met through continuous monitoring and reporting. Specifically, the BOCC links historic, real-time monitoring and diagnostics with analytics to optimize energy and water, extend asset life, and enhance the reliability and efficiency of the PNNL campus. The BOCC leverages data from the FMCS and in-house developed R&D software—DSOM—to perform diagnostics, trending, and analytics. These two systems are the backbone of the BOCC.

The goal of the BOCC is to create an intelligent infrastructure that uses real-time data to make informed decisions resulting in reduced building operational cost (Belew 2014a). Costs are reduced by using information from sensored buildings to create condition-based maintenance service requests, preventing equipment failures using real-time commissioning, reducing energy cost by monitoring and reporting building operations and implementing energy and water conservation measures (ECMs and WCMs, respectively), which are used to reduce building energy consumption by identifying projects with life-cycle cost effectiveness and return on investment. ECMs can be used to substantiate upgrades on existing out-of-date equipment and systems to improve the overall operation of the building. ECMs can range from no cost/low-cost sequence modifications to complete equipment replacements. The BOCC collaborates with Projects and Engineering, building management and building engineers, and R&D to identify, prioritize, and plan ECMs and WCMs. The BOCC through real-time commissioning and energy meetings maintains the Master ECM List for each core team.

In 2015, the BOCC was relocated to the newly constructed 3820 Systems Engineering Laboratory (Figure 2.3). The new location positions the BOCC at a more central location within the Richland campus and will increase collaboration opportunities with research staff.

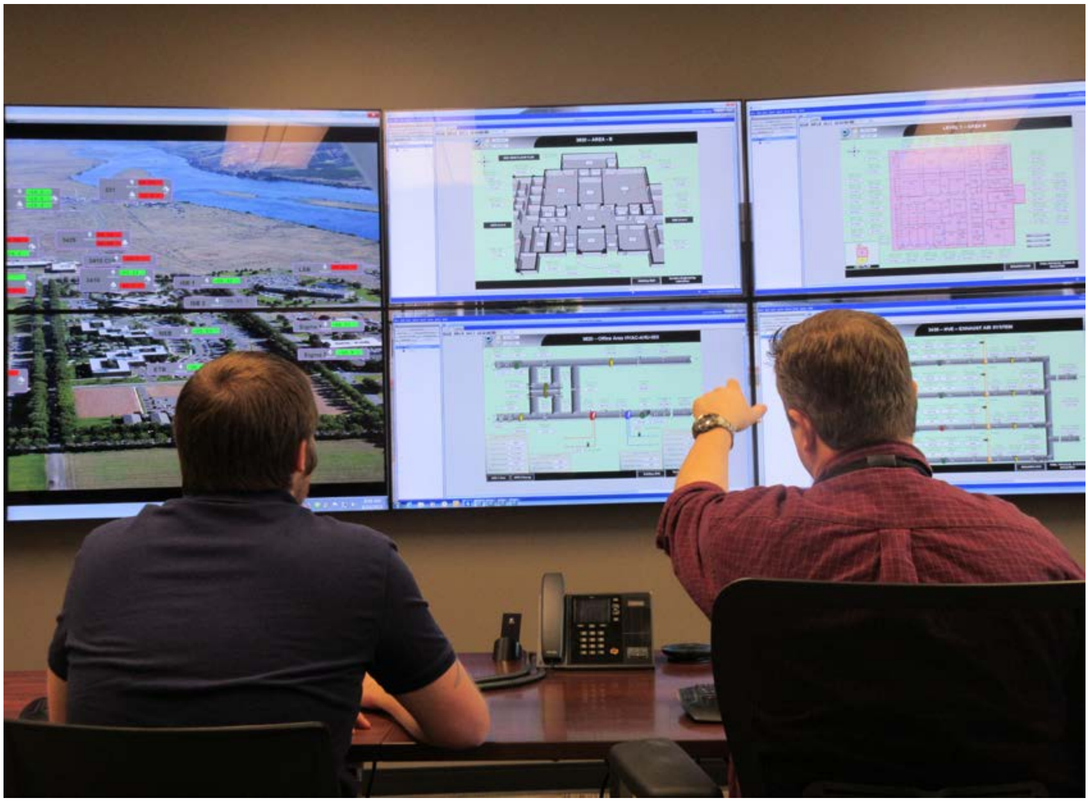

Figure 2.3. BOCC

2.10 Data Centers

PNNL has three data centers located in the CSF, ISB2, and the Environmental Molecular Sciences Laboratory (EMSL). Each center has meters installed to measure the IT equipment load and the facility support load such as lighting and cooling. Metered data are used to calculate PUE for each center. As the primary measure of efficiency, PUE is used to benchmark one data center against another and as a means of verifying energy savings inside a single data center. EO 13693, “Planning for Federal Sustainability in the Next Decade,” requires agencies to meter data centers and establishes a power usage effectiveness target of 1.5 for existing data centers. To reduce the weighted average of the three centers at PNNL to a PUE of 1.5, innovative energy conservations measures have been implemented and installed metering has verified the results. The newest data center at PNNL in the CSF space uses well water and a plate and frame heat exchanger to supply cool water to rear door heat exchangers (RDHx) on server racks (Figure 2.4). The water is also supplied to a chiller that serves a computer room air conditioner (CRAC) when needed. The diagram below shows the flow for this ground source system and shows the location of meters measuring electric power, water temperature entering and leaving the RDHx and CRAC, and water flow rate in these two systems. These meters validate the excellent efficiency of this system, which yields a PUE of 1.1 with only the RDHx in operation and 1.2 when the CRAC is running.

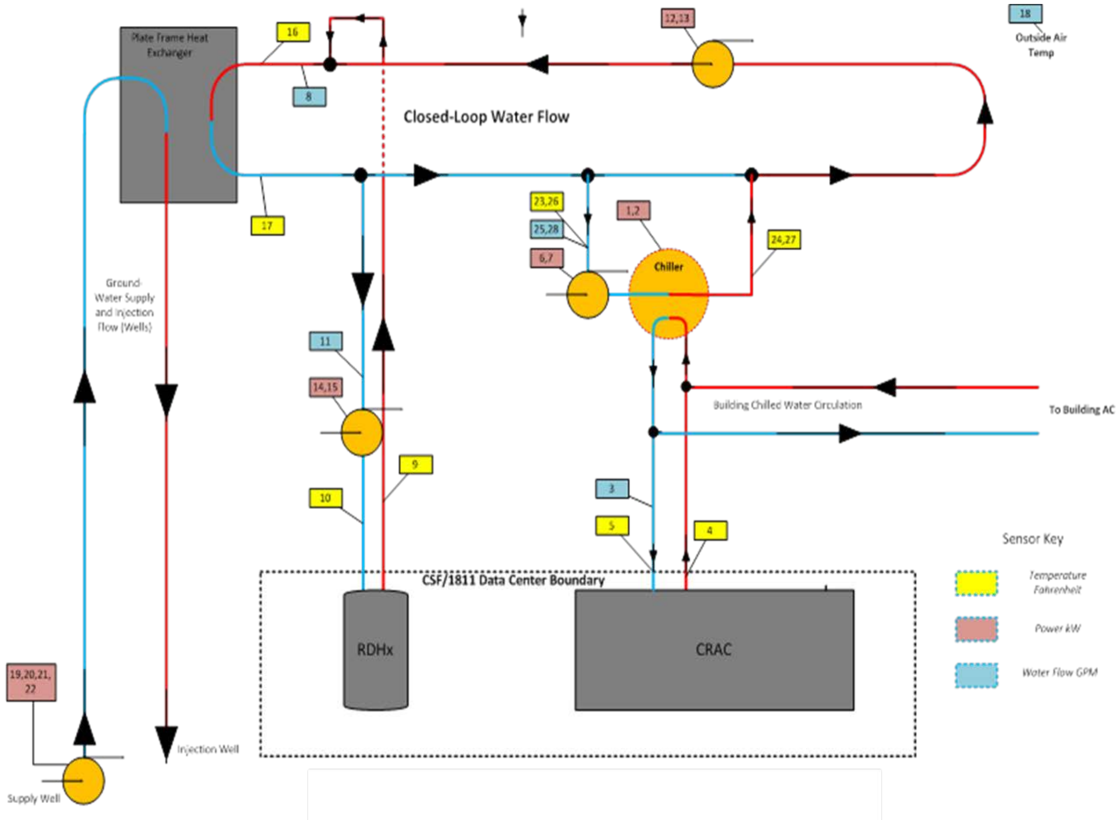

Figure 2.4. CSF/1811 Groundwater Cooling System

In ISB2, the meters measuring IT load and facilities load are connected to APC's StructureWare Central and SynapSenss software packages. The program plots the various loads and displays PUE components graphically. Temperature sensors throughout the data center are displayed on a heat map to assist in locating hot spots. The data center manager uses the metered data to analyze the system and provide customers with a graphical representation of the efforts to reduce energy and cost (Figure 2.5). Using virtual machine software, the total number of servers in the data center has been reduced. The dip in the kW (upper) trace below during the month of April 2014 was a result of taking several single-purpose servers out of service and transferring that capability to virtual machine servers serving multiple users. The reduction of power toward the end of the month was a result of shutting down a 3Par storage array and transferring the capability to existing machines yielding an annual savings of 126,144 kWh and $6,937.92.

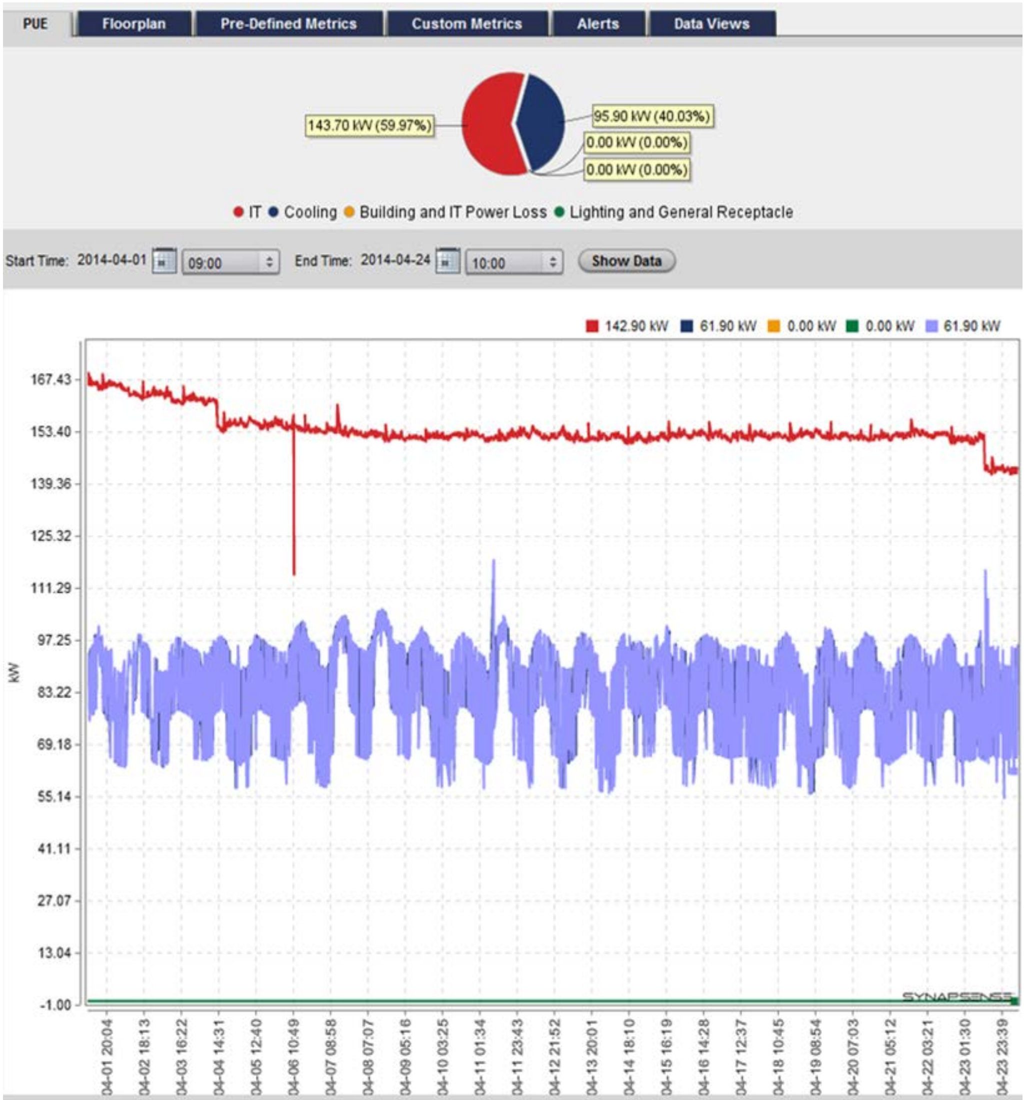

Figure 2.5. Electrical Consumption in the ISB2 Data Center

2.11 Case Study

An example of analytics developed using metered data and the FMCS system is new diagnostics summary page shown below (Belew 2014b). Using this technique, it was discovered that one of the heat pump compressors at the 350 Building had failed and was using the more costly auxiliary strip heat. Mixed air and discharge air temperature sensors, part of the "smart sensor" suite, were utilized to diagnose this failure that would have otherwise gone unnoticed. Figure 2.6 shows a screen-shot summary page developed to diagnose problems with the roof-top conditioning units at the 350 Building.

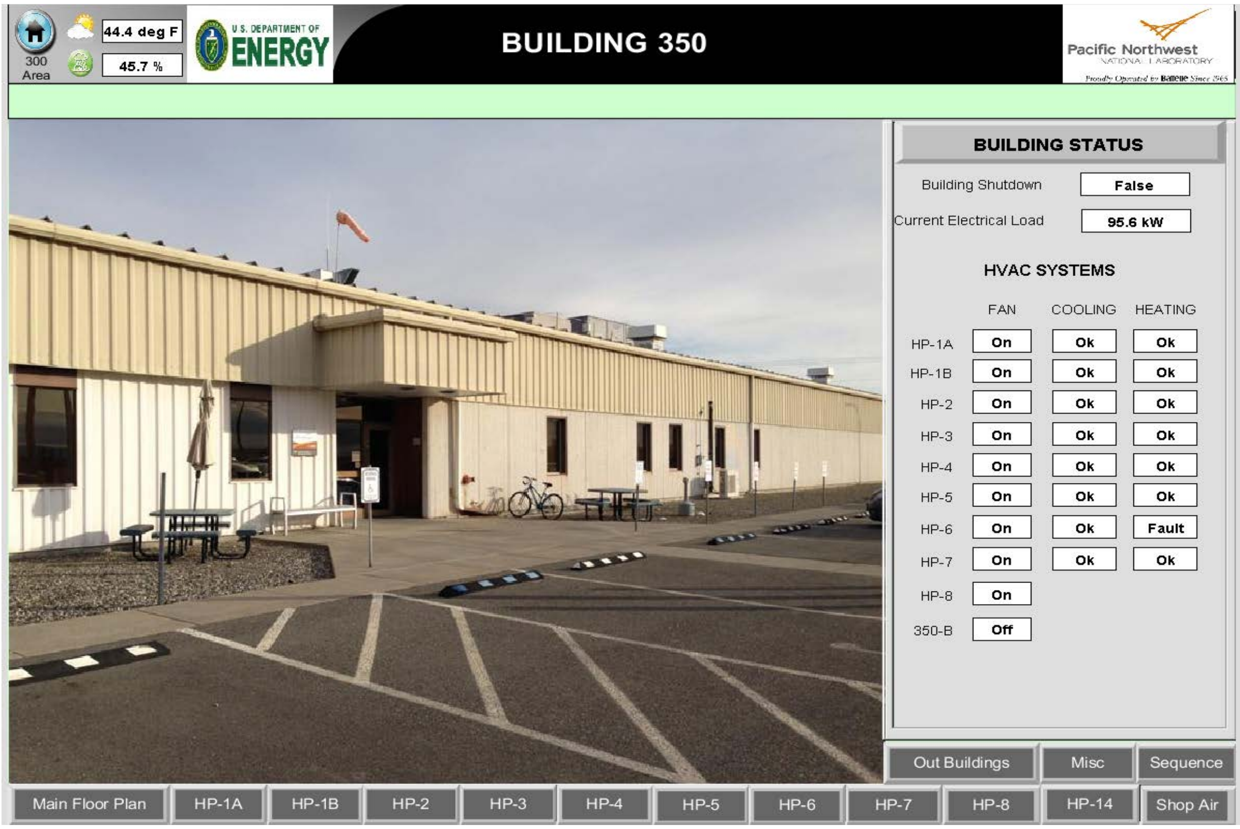

Figure 2.6. Building 350 Diagnostic

Using sensor inputs and logic programmed into the FMCS system, the temperature difference across the unit compressors is compared to the normal operating range in the heating mode, around 20 degrees Fahrenheit. For this example, we see that temperature delta on March 21, 2014 was less than 12 degrees, triggering a fault on the diagnostic screen. The trace in Figure 2.7, which compares discharge air temperature and mixed air temperature, illustrates what the fault looks like and when it occurs.

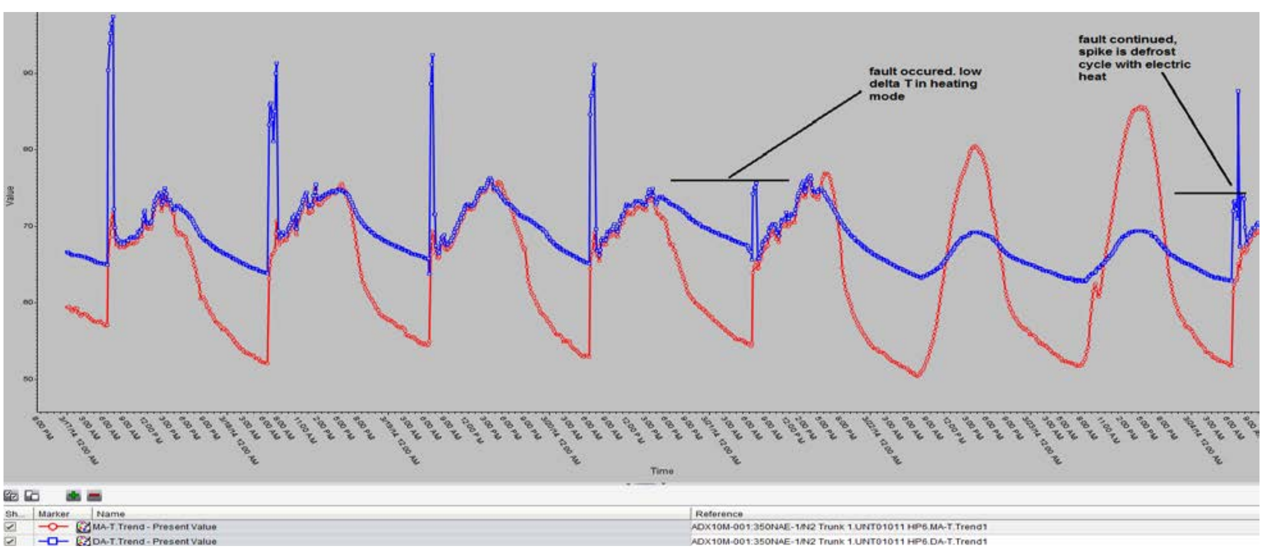

Figure 2.7. Trace Illustration for Building 350

The heating fault programming compares the two temperatures during the heating stage and generates a fault warning if the temperature difference is less than 15 degrees (Belew 2014b). This diagnostic is used to identify operational issues before impacting occupant comfort, reliability of the equipment, and before excessive energy and water costs are consumed.

2.12 Personnel Training

Metering technologies, the systems that aggregate the data, and the software that assists in data analysis are all rapidly advancing. As the nation steps up to face energy and water challenges, PNNL practitioners must stay current and relevant. To maintain that edge, the Sustainability Program promotes the following for its staff:

- taking an active role in working groups within the industry
- continuing education for FMCS technicians and engineers to maintain current working knowledge of the rapidly changing options and solutions for connecting new meter technologies to the existing and updating FMCS infrastructure
- encouraging engineers to certify with industry professional peer groups such as the Certified Energy Manager (CEM) certification through the Association of Energy Engineers
- attending trade shows and vendor trainings.

Much of the training, development, and mentoring of staff members at PNNL will utilize the resources of the BOCC. Access to real-time data and control on the multiple large display screens provides a rich learning environment. The diversity of specialization working through the BOCC such as FMCS specialists, Air Balance Operators, Commissioning Engineer, Sustainability Engineer, Controls Engineer, and research and development staff creates an incubator for cross-training and collaboration.

2.13 Funding

Funding is necessary to maintain the Metering Plan equipment and staff, data collection, analysis, and reporting activities. Funding for the Metering Plan is established in the annual Sustainability Program budget. Key implementations are outlined in the Sustainability Maintenance & Operations Program description and are divided into three categories – people, systems, and processes – from which the Metering Plan draws from two. In the *people* category, the Metering Plan uses four key implementations: sustainability subject matter experts (SMEs), sustainability engineer, facility energy manager, and utility data management specialist. Likewise, in the *systems* category, the Metering Plan feeds data into the FMCS in two ways: installation of strategic metering in support of goals and objectives; and maintenance, corrective actions, and upgrades for existing metering and data collection systems.

While priorities are established and funding is set on a fiscal year basis, PNNL’s Sustainability Program maintains a nimble, agile approach. If unexpected opportunities arise during the year, the Program remains poised to act and can adjust based on emerging needs.

2.14 Data

2.14.1 Meter Data Validation

Once meters are installed, it is important to validate the resulting data. Meter data should go through an initial validation and then be checked periodically as part of an ongoing validation effort.

- **Initial**: The initial performance validation of the meter involves comparing the meter data with billed data. Because billed data lags, the real-time metered data validation of a new whole-building meter can take several months.
  - The absence of specific billed data for sub-meters (less than the whole-building level) makes validation more difficult. Expected totals as a result of engineering calculations designed to allocate a whole-building load to a more specific level are often used to compare with values yielded by sub-meters. Our experience with meter validation is that usually meters come correctly calibrated from the factory. Errors are almost exclusively attributed to an incorrect multiplier in the totalization phase, either by assuming an incorrect electric CT size, gas delivery pressure, or assigning an incorrect pulse value.
- **Ongoing**: Ongoing validation is performed in a similar manner as the initial check. Our experience has shown installed and validated meters rarely drift from calibration, rather that meters occasionally fail and stop sending information. When one of the collection systems stops receiving data from a meter in the field, troubleshooting and repair are initiated. Our experience has also shown that gas meters require more maintenance and calibration than electric meters. Gas meter repair and calibration is performed by qualified, manufacturer approved, off-site service providers. Spot-checks of meters to validate field readings are consistent with billed data are also performed.

2.14.2 Support of HPSB

In 2006, DOE signed the "Federal Leadership in High Performance and Sustainable Buildings Memorandum of Understanding," along with 21 other agencies. Originally, the document committed DOE to follow the Guiding Principles for new construction and major renovations and was revised in 2008 to include transforming existing buildings into HPSBs. The Guiding Principles for sustainable existing buildings focuses on five topic areas:

- employ integrated assessment, operation, and management principles
- protect and conserve water
- enhance indoor environmental quality
- optimize energy performance
- reduce environmental impact of materials.

EO 13423 "Strengthening Federal Environmental, Energy, and Transportation Management" (2007) and EO 13514 "Federal Leadership in Environmental, Energy, and Economic Performance" (2009) require that 15% of an agency's existing buildings and leases meet the Guiding Principles by 2015. Additionally, EO 13514 requires agencies to make annual progress toward 100% of buildings meeting the Guiding Principles.

Metering at PNNL directly supports the effort to reach these goals. PNNL is exceeding this requirement, and at the end of FY 2014 had 36% of the FIMS buildings certified as HPSBs. Three of the five topic areas in the Guiding Principles require the use of meters and sensors. Requirements include meters to quantify the reduction of electricity, natural gas, and water; using meters to benchmark building performance; measuring and verifying building utility usage; and measuring the amount of renewable energy generated on site and fed back into the campus distribution system.

2.14.3 Support of ASHRAE Analysis

Metering at PNNL supports ASHRAE Standard 55-2004 *Thermal Environmental Conditions for Human Occupancy* analyses performed on campus buildings as part of the HPSB effort. Compliance with ASHRAE Standard 55-2004 is a requirement to meet the *Enhance Indoor Environmental Quality* Guiding Principle. To perform the analysis, permanently mounted temperature sensors located throughout the building are used. Typically 10 sensors in varying locations, on the perimeter and interior, and on each floor, are chosen for examination. One year's worth of data at each sensor measured every 15 minutes during operating hours is analyzed, about 115,000 measurements. The data points are plotted and compared to the minimum and maximum acceptable temperatures of 68 and 81 degrees. As shown in Figure 2.8, 1 year of data is plotted from a sensor in the Laboratory Support Building (LSB). Data points from all 10 sensors examined in this building were in the acceptable range 99.70% of the time, with no individual sensor being in the acceptable range less than 98.26% of the time. Using this method, we determined that all of the spaces analyzed in the LSB exhibited acceptable thermal environmental conditions.

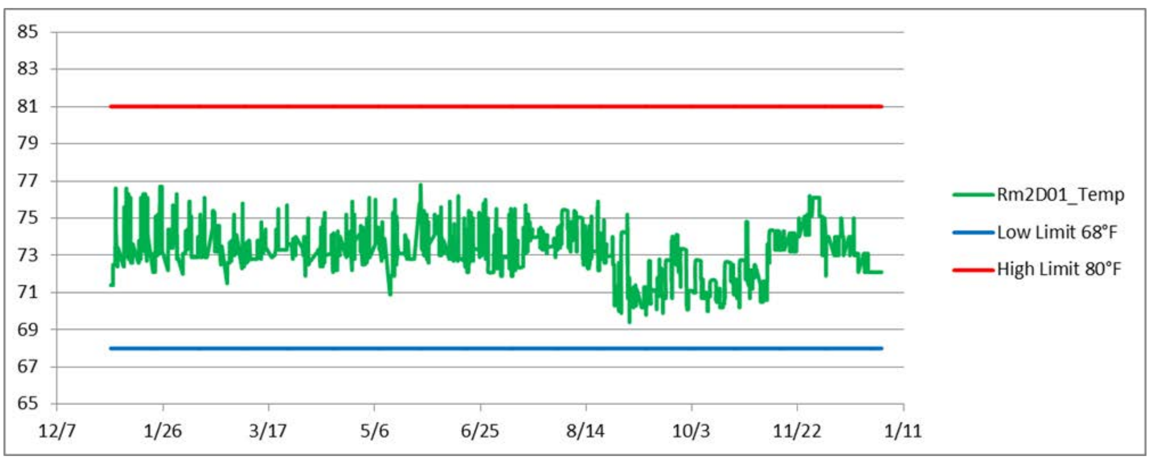

Figure 2.8. Sample Trace Showing 1 Year of Temperature Data in LSB Room 2D01

2.14.4 Support of FUA for Temperature Compliance

Metering at PNNL also supports the effort to verify temperature conditions are consistent with those outlined in the Facility Use Agreement (FUA), an agreement that formally captures the physical attributes of the facility and operational boundaries, among other things. This agreement is between the F&O Directorate and the directorates performing research in each building. Permanently mounted temperature sensors are used to create temperature maps that are monitored in the BOCC. As shown in Figure 2.9, temperatures in the Sigma II office building are displayed and spaces are color-coded to indicate temperatures in relation to the set point. Temperature maps indicate which conditioning zone each space is in to aid in troubleshooting hot or cold spots.

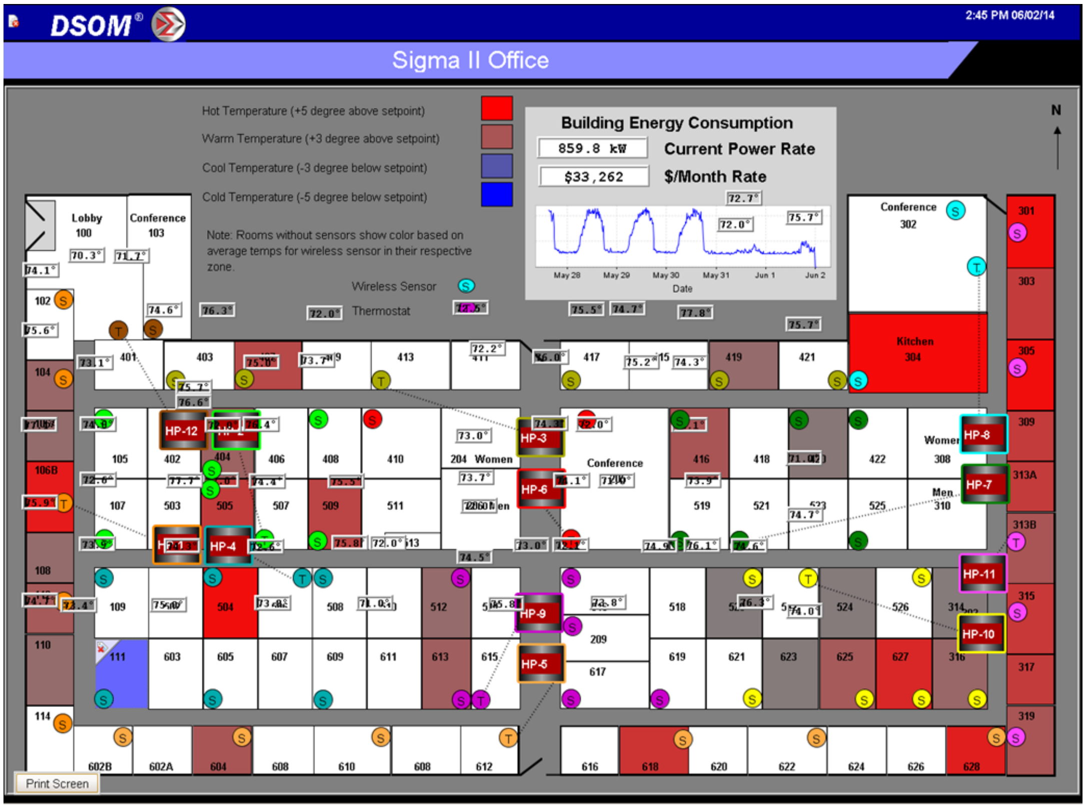

Figure 2.9. Sigma II Office Temperature Map

2.14.5 Support of ILA Management

Metering at PNNL supports the contractual goal of a 20% reduction of ILA water usage by 2020 from the 2010 baseline. Installation of water sub-meters measuring ILA water use at PNNL began in 2013. Prior to the installation of ILA meters, irrigation water use was estimated by prorating based on area for facilities fed from the only existing master meter and by using standard assumptions to estimate use for facilities with no meter installed. ILA sub-meters have been installed at the Physical Sciences Facility (PSF) complex, which includes buildings 3410, 3420, 3425, 3430, and 3440; the combined grounds for ISB1 and ISB2; the combined grounds for the National Security Building (NSB) and Environmental Technology Building (ETB); at the User Housing Facility; and at Biological Sciences Facility (BSF) and CSF, where two meters are summed to provide the total for these facilities. The meter chosen for these applications is the McCrometer propeller with local display. Two additional meters are planned for installation at EMSL that will provide accurate usage information, allowing energy managers to implement and measure the effectiveness of water reduction strategies. One strategy is to benchmark irrigation intensity at different facilities across the campus to identify areas that may be over-irrigated. Another strategy is trending irrigation use over several years to identify higher than normal consumption.

2.14.6 Support of Dashboards

Dashboards are an effective way to convey real-time and historic data graphically. Meters supply the information used to inform three separate graphics-based tools used by energy professionals to optimize operations and troubleshoot systems. Two important dashboards at PNNL are DSOM (Figure 2.10) and the Metasys Building Status (Figure 2.11). DSOM uses meter data collected at PNNL to provide an energy and water summary to occupants. Dashboards such as that shown in Figure 2.10 display the year-to-date use of energy and water for a particular building as well as the running 7-day electricity usage. Dial indicators compare the current year to previous year for a quick visual gauge on whether use is trending up or down. Dashboards are also used by Sustainability Program staff for a quick assessment. More detailed information can be attained from the dashboards by clicking on the icons.

Figure 2.10. Building 350 DSOM Energy Dashboard

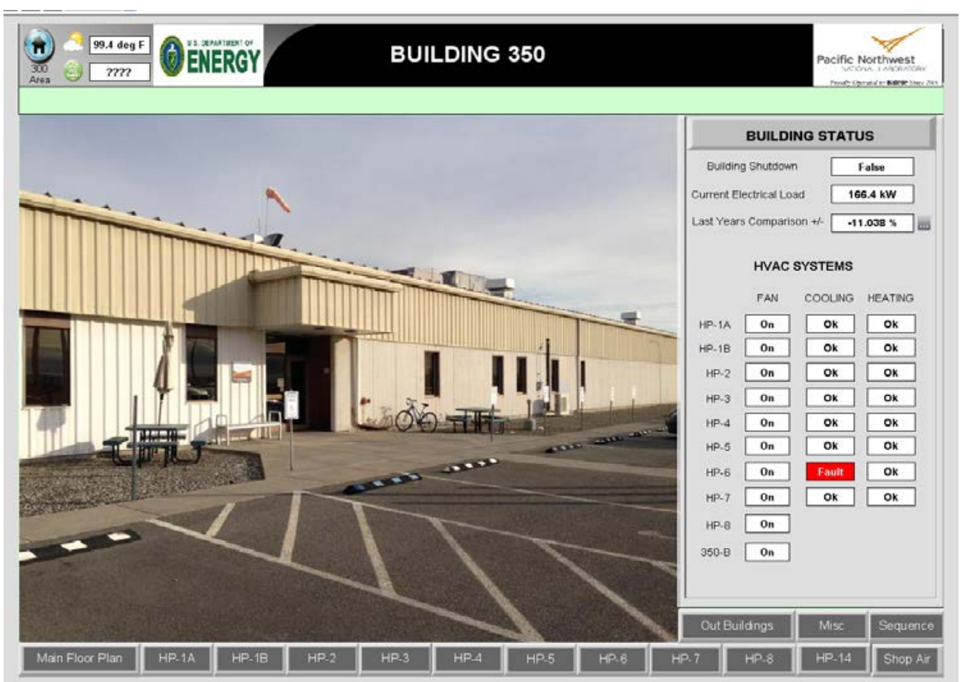

Figure 2.11. Building 350 Metasys Building Status Dashboard

Metasys dashboards (Figure 2.11) are used by a smaller group of more technical personnel such as building and sustainability engineers, operators, and technicians. The routines are custom programmed by on-site controls specialists and observe temperature, run indicators, pressure sensors, etc. These dashboards pinpoint the component level to identify failed or over-ridden equipment and allow users to get a complete look at a building system in on screen.

Currently being implemented are the newest campus and building dashboards prepared by Lucid Design Group. Lucid's Building OS and Building Dashboard products (Figure 2.12) will be utilized to create enhanced graphics of building energy and water use for access by all lab occupants. Features include the ability to embed live graphs into other webpages and compare energy use against both other buildings and energy reduction goals, among others. The Lucid product will also interface with EnergyCAP software, the location for storage of billed energy and water totals, allowing for comparison of measured vs. billed quantities. We will also use Building OS to interface with ENERGY STAR®'s Portfolio Manager®, providing monthly updates to the benchmarking service.

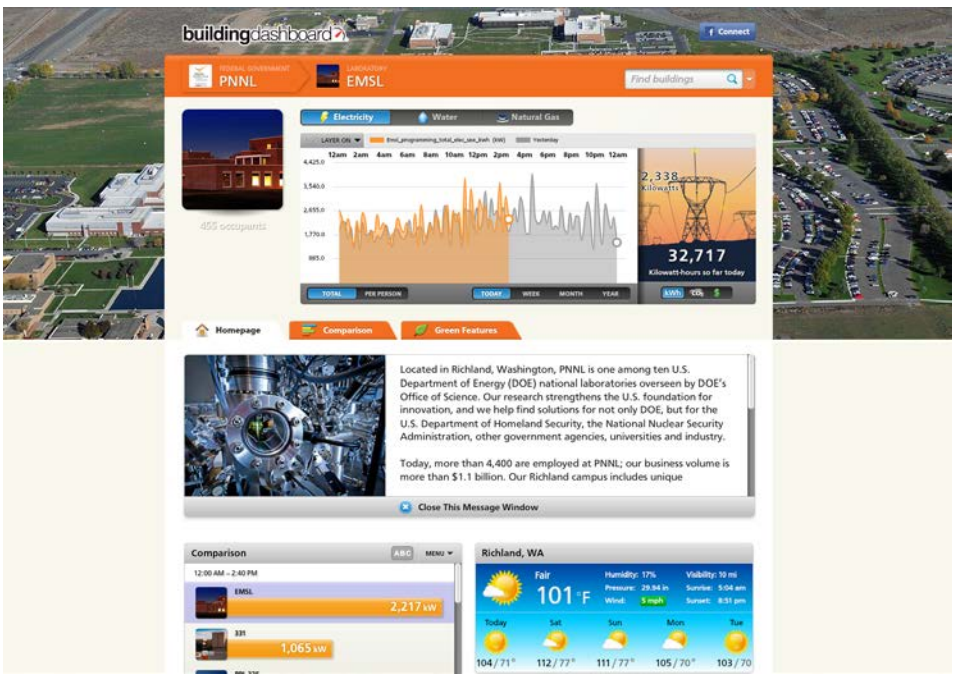

Figure 2.12. Building EMSL Lucid Building Dashboard

2.14.7 Support of EISA Audit and Commissioning

Section 432 of EISA (2007) requires comprehensive energy and water evaluations performed for all designated Covered Facilities at each federal agency. Covered Facilities are identified as all buildings comprising at least 75% of the each federal sites total energy usage. Covered Facilities at PNNL from 2014 are EMSL, 331, 325, CSF, PSF 3430, PSF 3420, PSF 3410, BSF, PSL, and LSL-II. Together, these eight facilities used 76.6% of the total PNNL site energy.

EISA evaluations consist of performing energy/water audits and commissioning assessments on a 4-year cycle for each Covered Facility. The energy/water audits and commissioning assessments can be performed separately using qualified in-house staff and/or contracted with private sector auditors and commissioning agencies. The PNNL Sustainability/Energy Program Office is responsible for the implementation, completion, and reporting for all EISA requirements.

EISA requires an energy/water audit similar to a Level 1 ASHRAE energy audit, which consists of an initial building walkthrough and identification of ECMs. Targeted systems audited include:

- Building Envelope
- Water Usage
- Electrical Usage
- Interior/Exterior Lighting

Test procedures resulting from EISA and HPSB commissioning assessments provide the foundation for an optimized commissioning strategy using portable technology coupled with the metering capabilities monitored in the BOCC along with in-house staff to maintain efficient building performance as a real-time commissioning strategy to ensure optimized building performance (Lechelt 2014). Metering at PNNL supports the EISA audit process specifically by supplying data for the electrical and water usage analyses.

2.15 Data Recovery

The backbone of our recovery plan is early detection when a data loss problem arises. Often, data loss can be attributed to a disruption in communication from meter to data collection system, usually Metasys or DSOM. Data recovery after a communication failure is made much simpler when advanced meters are installed with data logging capability. In the Federal Energy Management Program (FEMP)-sponsored *Metering Best Practices: A Guide to Achieving Utility Resource Efficiency* (Parker et al. 2015), advanced meters are defined as having the capability to measure and record interval data (at least hourly for electricity) and communicating the data to a remote location in a format that can be easily integrated into an advanced metering system, which includes data acquisition and analyses.

When a communication failure is discovered, efforts to restore the line should begin immediately. As some meters can be read locally with a laptop computer, this feature can be used to restore lost data sets manually, although it is time consuming. Meters that will cache data for a month or more and report after a failed communication line has been restored are preferred. It is also possible to use trend and historic data to fill in gaps on buildings where reporting is required, but our goal is accurate, timely information.

3.0 Conclusion

The Sustainability Program has been successful in meeting contractual energy and water metering goals as well as submitting this Plan as one of the three Program deliverables. As meter installations continue, data analysis and data organization move to the forefront in our effort to reduce energy and water consumption. PNNL will continue to strive to meet the energy and water reduction challenges. The Metering Plan will be updated as needed as the PNNL building portfolio changes.

With the program established, metering at PNNL is on solid ground, consistently delivering reliable data for benchmarking, analysis in the BOCC, and advanced analytics like DSOM. As efforts lean toward new challenges, our goal of environmental stewardship will never cease or go out of focus. The tenets of our program – to provide accurate data, analyze that data, and provide actionable recommendations – are the mileposts along the road to reductions in building energy and water use and greenhouse gas emissions.

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