SUBMETERING OF BUILDING ENERGY AND WATER USAGE

ANALYSIS AND RECOMMENDATIONS OF THE SUBCOMMITTEE ON BUILDINGS TECHNOLOGY RESEARCH AND DEVELOPMENT

National Science and Technology Council
Committee on Technology

Subcommittee on Buildings Technology
Research and Development

OCTOBER 2011

EXECUTIVE OFFICE OF THE PRESIDENT OF THE UNITED STATES

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The Buildings Technology Research and Development (BTRD) Subcommittee is the interagency body responsible for coordination of Federal program activities in support of the research, development, and demonstration of building technologies and related infrastructure. The BTRD Subcommittee coordinates interagency buildings technology R&D activities by providing guidance aimed at supporting advances in buildings technology and related infrastructure, with a particular focus on enabling the energy-efficient, automated operation of buildings and building systems and the sustainable renewal of the nation's physical infrastructure. The Subcommittee collaborates with Federal agencies that own, construct, lease, or provide financial assistance for facilities to identify their buildings technology R&D needs.

About this Document

This report presents the BTRD's guidance and recommendations on the benefits and complexities in the use of submetering technologies for new and existing buildings. Proven demonstrations of new building technologies are essential to high-performance and sustainable building designs and operational practices that positively impact the effective stewardship of our Nation's resources. A promising avenue for advancement of these goals involves the deployment of advanced building instrumentation and submetering for real-time measurement of energy and water usage. To this end, the Subcommittee has developed this report documenting the current state of submetering, relevant case studies, preliminary findings relating to submetering system costs and return on investment, and references to relevant publications for continual and accurate measurement of resource consumption, focused design and retrofit strategies, improved building management procedures, and changes in human behaviors that lead to significant reductions in energy and water usage.

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October 21, 2011

Dear Colleague:

I am pleased to forward this report entitled *Submetering of Building Energy and Water Usage*, which provides an overview of the benefits and complexities of advanced metering technologies for fine-grained and real-time measurement of energy and water systems in buildings. The use of advanced metering technologies supports resource-efficient design and retrofit strategies that can drive energy and water consumption reduction. Commercial and residential buildings consume about one-third of the world's energy and account for more than 40 % of total U.S. energy consumption. If current trends continue, by 2025 buildings worldwide will consume more energy than the transportation and industry sectors combined.

The refined measurement of energy and water use represents a key enabler for the improved performance of new and existing buildings. For building operators, a detailed record of system performance provides a critical means of not only detecting system malfunctions easily but also focusing future design and retrofit activities on the most cost-effective energy and water system improvements. For building occupants, detailed information on consumption promotes resource conservation through behavioral changes.

The Federal sector has already demonstrated leadership in conserving energy and water resources through the introduction of advanced metering. I anticipate that this report will provide the basis to initiate new Federal submetering demonstrations that can document even greater energy- and water-use effectiveness that will in turn result in increased adoption of submetering by Federal and private-sector building owners.

Sincerely,

John P. Holdren

John P. Holdren
Assistant to the President for Science and Technology
Director, Office of Science and Technology Policy

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Executive Summary

The submetering of buildings, through the refined measurement of energy and water use, enables the improved performance of new and existing buildings. Submetering provides the operations and maintenance transparency necessary to enable more efficient management of energy and water resources. In addition, submetering can drive behavioral change related to energy conservation and advance real-time building interaction with the Smart Grid. Each of these potential benefits can dramatically improve building performance and lead to reduced resource consumption. For building operators, a detailed record of system performance data is critical not only to detect system malfunctions, but also to focus future design and retrofit activities on the most cost-effective energy and water system improvements. For building occupants, submetering provides detailed information on their consumption behaviors, which in turn promotes resource conservation.

This report provides an overview of the key elements of submetering and associated energy management systems to foster an understanding of the many potential benefits and complexities associated with use of these systems. While submeters by themselves have no direct impact on resource use, the data they capture informs real-time energy and water performance, can pinpoint performance variations over time or relative to other buildings, feeds into building automation systems that drive continuous operational improvements, and provides the information needed to encourage behavioral and operational changes by building operators and occupants.

This report lays the groundwork for the economic and operational benefits achievable through the submetering of buildings. Evaluating the feasibility and impact of a submetering investment requires a life cycle cost approach to accurately assess the long-term economic costs and benefits of implementation. Costs include not only hardware and software, but also the regular maintenance of submetering systems by properly trained O&M staff and an ongoing program of behavioral and operational improvements for building operators and occupants.

The benefits of submetering vary by building type, use, and mode of operation, as well as by external factors such as climatic zones, utility regulations and policies, and energy and water rate structures. The case studies presented herein offer supporting evidence that the resource savings and economic return on investment in submetering can be substantial. They also highlight benefits that can emerge when submetering is integrated with building automation systems and with operations and maintenance (O&M) procedures. Equally important are technical details of submeters and the accompanying data networks, software, and services that gather and synthesize meaningful information for building operators and occupants. The manner and mode of this acquisition and presentation of information influence the rate of acceptance by these same stakeholders and the gains enabled by submetering.

Ongoing behavioral studies focused on energy conservation for buildings yield a good understanding of how human behaviors affect energy conservation, especially in the residential sector. For commercial buildings, Vornado Realty Trust estimated that between 60 and 80 percent of the energy used in commercial office buildings is consumed by tenants within their spaces, yet no widely available tools exist to help tenants understand their energy consumption or to compare it against their peer group.[1] Analogously, O&M staff lacking the proper tools and training may overlook opportunities to improve building operations enabled by submetering. In both cases, appropriate instruction, feedback mechanisms, and incentives are central to encouraging the changes that result in energy-efficient building operations and energy conservation using submetering capabilities.

The building community should view submetering as an essential component of future building operational improvements for energy efficiency and conservation improvements, to monitor-based continuous commissioning, and to improve indoor environmental quality. Submetering systems must be carefully designed to meet stated operational criteria and objectives, i.e., data analysis and operations management requirements must guide submetering hardware and software selections and specifications of the system configuration. In addition, submetering systems must be installed and maintained by properly trained and incentivized O&M technical professionals to achieve the design performance objectives.

The BTRD Subcommittee offers the following recommendations to building program managers, owners and operators, as well as to Federal and state policy officials in their examination of submetering as a potential tool to meet energy and water conservation goals. These recommendations cover a range of issues, both human and operational—from design to procurement, installation, and ongoing full production operations.

Recommendation 1: As part of overall building design and retrofit projects, building owners should evaluate the economic and technical feasibility of submetering using life cycle cost analysis for the economic justification and business-case development.

Recommendation 2: When evaluating submetering opportunities, design teams should collaborate with building owners, operators, and occupants, and design, engineering, and information technology professionals to identify data needs and appropriate submetering systems and configurations.

Recommendation 3: Submetering systems should, when possible, be integrated into building automation systems and used to identify building system impairments or dysfunction, to improve operational procedures, drive behavioral changes that improve building energy efficiency and conservation, and augment building-side automation systems that interface with the Smart Grid.

Recommendation 4: Submetering information and feedback mechanisms should be tailored to intended users to effect operational and behavioral change in building operators and occupants. Information and feedback should be of an appropriate form and frequency and should focus on useful breakdowns of resource use; include historical data when appropriate to facilitate comparisons with past use; and, when possible, suggest specific actions that can be taken to reduce consumption.

Recommendation 5: Submetering systems should be operated as production-quality building management systems with high levels of reliability, information assurance and security, established data acquisition/ archival procedures, and periodic system maintenance requirements.

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[1] Vornado Realty Trust. http://www.vnooffice.com/sustainability/welcome

1. Introduction

1.1 Submetering and the Smart Grid

With Federal funds from the American Recovery and Reinvestment Act (ARRA) apportioned for weatherization programs, loan guarantees, block grants, and new investments in green technology, initiatives promoting resource efficiency and the use of renewable resources have begun to make significant progress. As government and private institutions invest time and resources, proper prioritization of building projects and initiatives becomes essential to responsible fiscal management. To properly direct these efforts, planners must understand where energy or water is consumed, at what rate and cost, and how current consumption compares to historical baselines or similar buildings. Historical and comparative analysis provides context for resource consumption and can identify areas for improved efficiency. By narrowing the scope of the examination to specific buildings, rooms, areas, or systems, this knowledge helps to pinpoint potential resource savings. When used for this purpose, sensing technologies go beyond their passive measurement role to active and continuous remediation, resulting in significant resource savings and improved overall building operation and maintenance.

Meters are simply sensors that measure and record resource use, such as energy or water consumption. Metering can be employed at several different scales, and is used to support effective management of a building's systems, including management of comfort, energy and water consumption, delineated cost burdens, and investment decisions in the short and long term. Historically, utility metering has occurred on an aggregate basis, with measurements taken for whole buildings or campuses roughly once per month. While this model has supported utility cost-recovery and billing practices, in recent years the utility sector has looked to greater integration of information technologies as potential sources of resource conservation and economic savings. Associated technologies promise a variety of benefits through more accurate and timely management of system operations, as well as a greater sharing of resource consumption information with consumers.

As a prominent example, electrical-energy stakeholders have presented alternate visions of the future smart grid, with an enhanced information and communications infrastructure embedded into the electrical distribution system. Funds from the American Recovery and Reinvestment Act (ARRA) legislation have enabled significant investments in an advanced electrical metering infrastructure, which allows for more frequent data collection on electricity use and other power characteristics.

Thus far, among consumer-focused smart grid technologies, smart meters have received the bulk of public attention and funding, with less emphasis placed on submeters or the metering of resources not related to energy. Whereas advanced meters generate more temporally resolved longitudinal data, submeters provide more spatially resolved measurements for individual areas, systems, or equipment. Moreover, while utility companies have led smart meter deployments, submetering requires involvement of and investment by individual building owners as well as more detailed tailoring to specific building configurations.

1.2 Fundamentals of Submetering

Resource use can be measured from an entire campus down to an individual building, from a building system or interior space, or even at the scale of an occupant's end-use load. As metering infrastructures are deployed at greater densities, more spatially and temporally resolved data become available; advanced metering may provide data at hour- or minute-long intervals at a full building scale, while submetering is capable of providing data at near-continuous time resolution and at a sub-building scale. As an example, end-use loads from electrical devices used by building occupants (both commercial and residential) represent the area of largest demand growth in buildings.[2] Through the use of submeters, these plug loads may be quantified using an individual measuring device at each plug outlet or at multiple outlets along a single distribution line.

Higher-resolution data points are necessary for certain types of resource reduction strategies. In general, there are two ways a building manager can pursue reductions in energy or water use: through increased resource efficiency or through resource conservation. Resource efficiency is usually increased through the installation of new technologies that deliver the same service (lighting, heating and cooling, hand washing, etc.) while using less energy or water. Resource conservation, on the other hand, is achieved through improved operation and maintenance (O&M) practices and/or occupant behaviors such as reducing unnecessary lighting or heating loads and reprogramming energy control systems.

Metrics for both efficiency and conservation require knowledge of current resource use and practices, generally at the sub-building level, but the temporal scales for the data may be different. Retrofits for resource efficiency can sometimes be identified through snapshot data such as those obtained through an energy audit. While helpful, energy audits are of limited utility in that they provide data only for one specific period of time. Submetering, on the other hand, can drive long-term and deeper efficiency and conservation improvements by introducing a localized, continuous timescale. This refined timescale provides insight into daily, weekly, or seasonal O&M issues, occupant behaviors, performance of installed equipment (e.g., HVAC and lighting), and verification of installed efficiency technologies. A time-series approach to analysis also provides the necessary insight to drive conservation through changes in occupant behaviors or continual improvements to building O&M procedures as conditions change over time. Moreover, these refined data points may reveal other system problems or potential efficiency measures that were not immediately apparent with snapshot data.

These main benefits—identifying operation improvements and efficiency retrofit opportunities—and others are discussed in Section 2 along with case studies illustrating real-world examples of their implementation. Section 3 elaborates on the economic calculations needed to evaluate the costs and benefits of submetering. To be useful in decision-support, information from meters, submeters, and other sensors must flow to the relevant entities making operational, behavioral, and investment decisions—building occupants, facilities managers, metering data management companies, and in some cases, utility companies.

However, while data from submeters and other sensors can increase awareness of energy consumption and motivation to reduce it, actually changing a building's consumption profile and achieving expected

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[2] DOE/EIA Annual Energy Outlook 2010, http://www.eia.doe.gov/oiaf/aeo/demand.html.

financial payback from the submetering investment may require new building management practices, financial incentives, enabling technologies, decision-support tools, and input from operations and human factors research. These requirements can only be met through the integration of submetering data with existing building automation systems, discussed in Section 4. As submeters and other sensors are added to a building and connected to building automation systems, the data points are transmitted via communications networks and analyzed for use by O&M staff and occupants, as well as by facilities managers, possibly in remote locations. Such coordination is especially important in complex commercial and multi-unit residential buildings, in which many systems overlap, and decisions affecting operating characteristics (e.g., how air conditioning needs are supplied) may be shared among multiple parties including occupants, owners, building managers, and utilities. These sensing and control technologies separate the decision-making into smaller elements, with oversight and management offered to those most appropriate to the particular task, such as the room occupant(s), the facility manager, or the smart grid's operations manager.

In many situations, these operational decisions can be partially or wholly automated; common examples include: motion sensor-activated light switches, elevator scheduling, and temperature controls. Improvements in all of these areas—from sensing and mechanical controls to analytics and human interface design—push toward the "intelligent building" paradigm, where appropriate levels of automation are used for the task and the occupants' needs, and building systems and managers are more responsive and adaptive to consumption factors such as weather and occupants' use of space.

1.3 Regulatory Context

Until recently, despite the potential benefits of detailed resource measurement in buildings, there have been relatively few instances where either building-level metering or submetering was specifically required by Federal or local regulations. Appendix A discusses in more detail the relevant Federal, state, and local building code regulations. A summary of these requirements is provided in this section.

In the Federal sector, building-level metering of electricity is required by Section 103 of the Energy Policy Act of 2005 (EPAct 2005). The Energy Independence and Security Act of 2007 (EISA 2007) built on this precedent by requiring that agencies establish energy benchmarks for their facilities' portfolios, implement life cycle cost-effective energy management projects through both commissioning and retrofits, and monitor and verify performance of the measures they implement. The Department of Defense (DoD) Instruction 4170.11, Installation Energy Management (November 22, 2005), requires DoD to meter electricity, natural gas, and water at appropriate facilities and to meter steam at steam plants. Executive Order 13514, signed in 2009 by President Obama, expanded the previous energy and water goals to include more comprehensive sustainability goals for the Federal government, such as reductions in greenhouse gas emissions and in water consumption.

Advanced metering (including submetering systems) is a critical catalyst for compliance with these requirements because it enables identification of life cycle cost-effective measures, provides benchmark data, and supports monitoring and verification of energy performance. The Department of Energy's Federal Energy Management Program (FEMP) has issued guidance for this requirement in its Guidance for Electric Metering in Federal Buildings,[3] and in its best practices guide entitled Metering Best Practices: A Guide to Achieving Utility Resource Efficiency.[4]

In the private sector, building-energy use is regulated mainly at the state and local levels through building energy design codes. For commercial codes, the ANSI/ASHRAE/IESNA Standard 90.1—Energy Efficient Design of New Buildings Except Low-Rise Residential Buildings—provides the basic compliance standard for new construction in most jurisdictions. Although the 1989 version of this code briefly required certain types of submetering—separate metering for tenants in multi-tenant buildings and for shared electrical, heating/ventilation/air conditioning (HVAC) or service water heating (SWH) systems—these provisions were eliminated from all subsequent versions, including the most recent 2010 edition. As a design standard, submetering requirements proved difficult to justify solely on a cost basis when their benefits would not be assessed until after the building was occupied and if the metering data points were used in ways that resulted in energy conservation or energy efficiency improvements through other activities.

Recently, there has also been action at state and local levels. For instance, the New York City Council passed legislation requiring the installation, by January 1, 2025, of submeters in tenant spaces that (i) exceed 10,000 gross square feet on one or more floors of a Covered Building let or sublet to the same person, or (ii) consist of a floor of a Covered Building larger than 10,000 gross square feet consisting of tenant spaces let or sublet to two or more different persons. Once installed, the meters must be read at least on a monthly basis, and each tenant must be provided with a monthly statement showing the amount of electricity measured for each area covered by the submeter. This requirement is just one of many approved to mandate ongoing efficiency improvements in large existing commercial buildings.

In the absence of specific regulatory requirements, submetering decisions often rely upon economic savings and payback justification. The Federal government's efficiency retrofit policies require valuation methodologies such as savings-to-investment ratios, payback periods, and life cycle costs (on a 40-year basis) to ensure these retrofits provide value. The appropriate economic analysis methods commonly used are discussed further in Section 3.

Submetering systems are unusual among building retrofits in that they themselves do not reduce resource consumption; rather, they provide the sensor infrastructure and data necessary for the efficient operation of buildings and for accurate benchmarking of performance. This distinction presents the challenge of associating a direct and clear means of linking specific energy cost reductions with the submetering investment, handicapping these technologies vis-à-vis other investments. However, submetering systems may also provide indirect benefits such as ongoing and improved operational efficiencies, resulting in lower building-wide O&M costs and reduced energy-related emissions, all of which may be difficult to quantify in purely financial terms.

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[3] Federal Energy Management Program, "Guidance for Electric Metering in Federal Buildings," February 3, 2006, http://www1.eere.energy.gov/femp/pdfs/adv_metering.pdf.

[4] Federal Energy Management Program, "Metering Best Practices: A Guide to Achieving Utility Resource Efficiency," October 2007, http://www1.eere.energy.gov/femp/pdfs/mbpg.pdf.

2. Benefits and Uses of Submetering Data

Submetering can benefit building owners, O&M staff, and business operations managers in several ways. As discussed above, buildings may be submetered to measure resource use of heating, cooling, or lighting systems and reduce these loads in response to market drivers (e.g., utility costs) or regulation. Individual systems or pieces of equipment may be submetered to determine if they are "working efficiently" with regard to both economic and comfort considerations. There are also practical benefits in some cases—a building or campus currently served by one utility-owned master meter may be submetered for different tenants to promote more appropriate allocation of utility charges and to effect potential reductions in peak demand costs. Finally, submetered data can be used to provide feedback on energy consumption to tenants or building users to promote behavioral change that leads to energy conservation. These different uses of submetering may also be combined within a single building. For example, a building on campus served by a single utility meter might be submetered to facilitate more equitable billing of tenants as well as to better manage particular systems, subsystems, or end-use plug loads.

All of these forms of submetering are useful, as they provide building owners with the measurement capability to better control resource use in buildings. It is imperative that the efficient control of energy and water usage be exercised in a manner that minimizes energy and water consumption while properly maintaining a building's indoor environment and functionality. It is also the case that submetering data analysis can identify situations where energy or water operations and management can be modified to provide a higher quality environment and better meet occupant needs.

The following text box lists many commonly cited submetering benefits in four categories. The first, enabling monitoring-based commissioning, involves tracking the performance of building equipment over time and optimizing it to save energy and water and to increase user comfort. The second, identifying and monitoring building retrofits, involves the use of submeters to both locate where retrofits will save the most resource and to verify that these planned savings actually occur. The third, aligning incentives for behavioral change, involves providing either direct monetary (i.e., tenant-specific billing) or non-monetary (i.e., energy use compared to peers) feedback to induce resource conservation behavior among building users. Finally, an ancillary benefit of submetering may be a reduction in peak demand charges via utility bills, provided that the utility accepts "virtual aggregation" as an acceptable billing scheme. These benefits are discussed further in the next sections, complete with case studies describing their application.

Case Study Descriptions

1) Enabling Monitoring-Based Commissioning

- Identifying performance improvements and guiding preventive maintenance—trends in monthly and annual use of water and energy help to identify the benefits of system upgrades and the systems (e.g., boilers, cooling towers) that may need attention following unexpected increases in consumption.
- Enabling quick response to failures of system components, assuming the meters are linked to an energy management system (EMS) or a building management system (BMS).
- Supporting life cycle financial planning by developing a dataset to support trend analysis.
- Focusing accountability for building operations on the facilities department, encouraging building managers to control energy and water consumption.

2) Identifying and Monitoring Efficiency Retrofits

- Verifying savings from energy and water improvement projects.
- Helping to compile baseline energy use for setting contractual terms with an energy service company (ESCO).
- Helping to make decisions about energy and water upgrades in buildings by comparing use in similar facilities.

3) Aligning Incentives and Enabling Behavioral Conservation

- Facilitating charge-backs to departments or other campus units as a way to encourage energy and water efficiency measures.
- Providing data to building occupants about the impacts of their behavior on energy and water consumption.

4) Peak Demand Reductions

- Lowering peak demand charges on electrical utility bills through virtual aggregation of different submeters.

Taken in part from ENERGY STAR®, "Sub-Metering Energy Use in Colleges and Universities: Incentives and Challenges," http://www.energystar.gov/ia/business/higher_ed/Submeter_energy_use.pdf.

Reducing overall energy consumption through efficiencies gained by submetering can provide long and enduring financial benefits. Emerging market data indicate that commercial buildings with lower energy usage—and the means to track energy usage by tenant—are more desirable, easier to lease, and have higher market value. A 2008 study examined Class A office leasing activity in 46 markets across the United States and found that green-labeled buildings achieve significantly higher rents—estimated at 7.3 to 8.6 percent for ENERGY STAR® labeled buildings and 15.2 to 17.3 percent for LEED® Certified buildings. Estimated occupancy levels were also higher by approximately 10 to 11 percent for ENERGY STAR labeled buildings and 16 to 18 percent for LEED-certified buildings.[5] However, submeters do involve an upfront cost of installation, integration, and training. Thus, it is important that the benefits of submeters over time exceed these upfront costs. Cost and benefit considerations are discussed further in Section 3 following the examination of four types of case studies.

2.1 Enabling Monitoring-Based Commissioning

A key benefit of submetering, albeit difficult to directly quantify, is the ability to enhance the performance of buildings. The availability of submetering data provided at more discrete levels can be used by automation systems as part of fault detection, thereby identifying problems with installed equipment before occupants observe adverse effects in utility bills. Additionally, submetering data may identify abnormal energy and water consumption as a result of system faults that may not be recognizable in the entire building's utility usage data. This detailed information enables more condition-based preventive maintenance in buildings, avoiding the higher costs typically incurred with deferred or unplanned maintenance. As part of a resource management plan, submeters can also provide the necessary data to document performance levels required by various energy labeling programs.

The case study presented below is based on in-depth benchmarking of a portfolio of 24 buildings located throughout the University of California and California State University systems. One specific California university building provides a good example of how submeters can provide critical operational insight.

Case Study:[6] In this building, electric and gas meters were installed for a number of years, and they were manually read each month. After the existing electric and gas meters in the building were tied into the campus energy management system (EMS), and their energy use was trended, high nighttime electricity and natural gas use became immediately obvious. Much of the lighting was found to operate after hours and the air handlers operated continuously, even though the building was unoccupied at night. The chiller and boiler also operated at night, performing simultaneous heating and cooling; the manual usage readings had not triggered any alarms that would have revealed this problem. Having found these issues, the nighttime operation was easily corrected by reprogramming the EMS. The project also included installation of a BTU (British thermal unit) meter on the hot water output of the building's boiler. Initial readings revealed that the calibration factor used for the gas meter was not properly corrected for gas pressure, thus all of the historical gas meter readings were incorrect. The new gas readings are based on the correct multiplier and now compare properly with the metered hot water use.

2.2 Identifying and Monitoring Efficiency Retrofits

As part of the requirements outlined in EPAct 2005, EISA 2007, and EO 13514, Federal agencies must quantify their resource use and conduct comprehensive evaluations of potential energy and water retrofits. Often O&M managers rely upon energy and water audits to establish a snapshot of current resource

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[5] Wiley, J.A., J.D. Benefield, K.H. Johnson, "Green Design and the Market for Commercial Office Space," *J Real Estate Finan Econ* (2010) 41:228–243.

[6] Taken from: Mills, E., Mathew, P. "Monitoring-Based Commissioning: Benchmarking Analysis of 24 UC/CSU/IOU Projects," Report No. LBNL-1972E. Lawrence Berkeley National Laboratory, Berkeley, California, 2009.

use, peaks in resource demand, and, for electricity, the quality characteristics of the power delivered and consumed. Energy and water audits inform retrofit analysis and implementation by ranking which retrofit projects are most effective.

Energy audits are generally the first step a facility manager takes to determine the best investments to achieve greater building resource efficiency. Audit data provide a brief, short-term assessment of the performance of major systems and equipment. In order to rank the cost effectiveness of potential retrofit options, assumptions and approximations must be used to generate a rough estimate of energy or water savings over time. Often when using these retrofit estimates, they must be weighed against other operational realities, priorities, and ambiguities. These estimates can be significantly more accurate and realistic using submetering data on building and system performance over a longer time period, as it provides temporal, spatial, and seasonal usage measurements under actual operational and environmental conditions.

Similarly, water audits analyze a facility's water use, detect water losses, and identify ways to make it more water efficient. Audits often analyze domestic, sanitary, landscaping, and process water use and identify ways to increase a facility's water efficiency. Some local water utilities provide water audit services for no charge. The American Water Works Association (AWWA) provides free water audit software.[7]

Accurate measurement and verification is critical to ensuring the success of energy and water retrofit projects, particularly those undertaken using an energy service performance contract (ESPC) or utility energy service contract (UESC) with an energy services company (ESCO). The measurement capability of submetering verifies that the products and services offered in the contract are properly installed and operating as designed, prior to final acceptance. Additionally, under the ESPC, accurate measurement guarantees that the appropriate savings from the investment goes to the customer.

Energy Service Performance Contract (ESPC) / Utility Energy Service Contract (UESC)

An ESPC or UESC establishes a partnership between an energy services company (ESCO) and its customer for financing and implementing cost-saving energy-related improvements or renewable energy capacity, avoiding what can be a lengthy and time-consuming process to secure upfront capital funding. The ESCO pays the upfront cost of purchasing and installing new equipment, and the customer repays the ESCO over the life of the contract using cost savings resulting from the project. For an ESPC, the contract often specifies that customer retains savings in excess of the projected savings amount and the ESPC pays the customer the shortfall to that savings amount. Measurement and verification of system performance provided by submetering is central to both ESPCs and UESCs.

The use of ESPCs and UESCs can overcome a major barrier to submetering—financing the investment. For facility managers, securing funds for large capital improvements can be a lengthy, time-consuming, and difficult process. Due to this barrier, many Federal agencies are broadly embracing the use of ESPCs and UESCs, with over $1 billion in contracts signed in fiscal year 2010.

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[7] http://www.awwa.org/Resources/WaterLossControl.cfm?ItemNumber=48511

Case Study:[8] Adobe Systems Inc. installed real-time main electric meters (revenue graded and Ethernet ready) in three high-rise office buildings, totaling just under 1 million square feet. The facilities included a cafeteria, fitness center, and 30,000 square foot data center. The meters were purchased and installed at a cost of $19,969. Adobe spent a total of $1.1 million on energy and energy-related projects, received $350,000 in rebates for these projects, and saved $1 million per year in reduced costs. Adobe earned a 122 percent return on investment, with a 10-month average payback. Shortly thereafter, Adobe installed real-time digital water meters (pulse meters) on cooling towers to record water loss through evaporation and water leaks in order to reduce its sewage treatment bill. The installation cost was $43,000, and the savings attributed to reduced sewer treatment charges resulting from water leakage totaled $12,000 that year.

Case Study:[9] Southern Connecticut State University (SCSU) responded to a legislative mandate to accurately distribute costs associated with various university buildings in accordance with their source of funding. This initial project consisted of installing 14 submeters at various locations. The intent was to identify where older, obsolete equipment needed to be replaced. New high-performance equipment was installed along with digital controls to maximize energy savings. Rebates were applied for and granted for these projects; in some cases, the rebate paid up to 87 percent of the equipment premium. The average cost to purchase and install a submeter connected to the Direct Digital Control system was approximately $3,000.

Project	Initial Operating Performance	New Operating Performance	Reduction in Energy	Initial Upfront Costs and Rebates	Payback
Replace 300 chillers in science building	0.80 Kwh/ton	0.51 Kwh/ton	36%	Cost: $32,000 Rebate: $26,500	0.3 years
Replace 600-ton cooling tower	2–15 Hp single-speed drive fans	2–5 hp VFD drive fans	70%	Cost: $12,000 Rebate: $6,000	2 years
Install new 600-ton chiller complex	Initial design, 0.60 Kwh per ton, part load performance 0.59 Kwh per ton	0.51 Kwh per ton full load, 0.34 Kwh per ton part load performance with VFD drives on chiller	30%	Cost: $98,000 Rebate: $85,000 Calculated annual electrical savings: $22,500 (2002 Dollars)	0.6 years

Case Study:[10] In 1977, the city of Boston, Massachusetts, could not account for the use of 50 percent of the water used in its municipal water system. After installing meters, the city undertook a vigorous leak detection program. Water that was unaccounted for dropped to 36 percent after metering and leak-detection programs were started.

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[8] U.S. Environmental Protection Agency, "State of the Art Submetering," ENERGY STAR Monthly Partner Web Conference, August 16, 2006. http://www.energystar.gov/ia/business/networking/presentations/Aug06_Submetering.pdf.

[9] U.S. Environmental Protection Agency, "Best Management Practices for Colleges and Universities," 2007. http://www.epa.gov/region1/assistance/univ/pdfs/bmps/SCSUSubmetering1-8-07.pdf.

[10] Grisham, A., Fleming, W.M., Long-Term Options for Municipal Water Conservation. *Journal AWWA*, 81-3, 34-42, 1989.

2.3 Aligning Incentives and Enabling Behavioral Conservation

In addition to energy reductions from more efficient equipment operation or from replacing old equipment, it may be possible to reduce the energy use of a building by changing energy-use behavior of the building's occupants. Recent research in the residential sector, summarized in Appendix B, has shown moderate success with certain strategies aimed at changing the energy-related behaviors of residents. Literature reviews from the last ten years[11] find that energy reductions from a variety of feedback mechanisms can range from 0 to 20 percent. Reductions in energy use are achievable by providing occupants with appropriate forms of feedback on their energy use and highlighting ways to help them reduce their consumption. Research has also found that better forms of feedback are immediate and frequent, more disaggregated to different energy end uses, and comparative with both past energy use and with other similar users. However, there are challenges in applying these conclusions from the residential sector to commercial buildings due to obvious motivational differences among commercial occupants, who may lack direct financial incentives to reduce energy use. See Appendix B for more details.

Submetering can help encourage behavioral-based energy conservation in several ways. One is through aligning financial incentives directly to the occupants in multi-tenant buildings. By introducing building submetering of energy, building managers can bill each tenant based on actual energy and water use rather than on an average share of the total resource use. This provides tenants with an economic motivation to reduce their energy use, as they see an immediate financial gain from doing so. A similar strategy uses submetered data to provide rebates or prizes through competitions to various tenants or departments for decreasing resource use.

A major difference between the residential and commercial sectors is the level of system control of the average building occupant. Because commercial building occupants (including multi-tenant) generally do not control major energy subsystems, like HVAC and automated lighting, the potential reductions from a behavioral campaign are lower than in the residential sector. One exception is water systems, which may have more potential for behavioral changes, as occupants can alter or lower water consumption from improved sink and toilet flushing habits, (e.g., using less faucet water and one-flush per use). However, one important area of high impact is that of electrical plug loads, the fastest-growing source of energy consumption in all buildings. Occupant behavior such as turning off computers and other ancillary devices could potentially result from feedback mechanisms and other means using data from end-use meters.

Case Study:[12] For multi-family residential dwellings, the State of New York and its energy research arm, NYSERDA (New York State Energy Research and Development Authority), have been prolific in facilitating the implementation of submetering and accurately documenting energy-saving results. In late 2009, NYSERDA released an updated survey of their submetering case studies for multi-family residential buildings. This report[13] confirmed their estimated savings of 18–26 percent through submetering using new and prior case studies on rent-stabilized apartments.

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[11] Abrahamse, W., Steg, L., Vlek, C., & Rothengatter, T., A review of intervention studies aimed at household energy conservation. *Journal of Environmental Psychology*, 25, 273-291, 2005.

[12] NYSERDA, "Demonstration of New Submetering Technologies," Report 86-8, October 1986.

[13] NYSERDA, "Electricity Reduction in Master Metered Buildings Low Income Rate Impact Analysis," October 2009.

Case Study:[14] About half of the 52-story Bank of America Building in San Francisco was submetered after energy managers learned that tenants exceeded by as much as three-fold their energy allowance of 3 kilowatts per square foot (kW/sq ft). More than 120 submeters were installed, and the property owner saved $1 million in excess energy usage in the first year alone. The cost of the submetering hardware and software in this application resulted in a payback period of days, not years, complemented by energy usage and cost savings of 30 percent per year.

Case Study:[15] In July 2009, Vornado Realty Trust introduced submetering using hourly consumption data to a major tenant in New York City that occupies nearly 400,000 square feet of commercial office space. The tenant's average stabilized energy use was 1,080,600 kilowatt-hours (kWh) quarterly (4,322,400 kWh annually). Using the new hourly consumption profiles, the tenant identified energy-saving opportunities.

Based on a comparison of quarterly data comparing usage from April 26–July 26, 2009, to April 26–July 26, 2010, the tenant has saved on an annualized basis:

- 795,850 kWh in overall consumption, or 18 percent below the baseline
- 57 kW in reduced demand, or 8 percent
- An overall total savings of $160,000
- 266 metric tons of carbon equivalent (expressed as tenant carbon footprint)

2.4 Peak Demand Reductions

One potential ancillary benefit of submetering, at least for energy use, is the potential to decrease charges during peak electricity demand. Utility bills are calculated through both the overall use of energy and peak power demand. Thus, if utilities allow several billing meters on a campus to be aggregated and billed instead as a single "virtual" billing meter (a process known as "conjunctive metering"), thereby lowering the aggregated peak demand, energy bills can be lowered simply by having lower peak demand at any given moment.[16] This strategy of reducing peak demand through billing at larger spatial levels is known as "virtual aggregation." Other potential benefits of virtual aggregation include reduced customer service charges and lower rate structures for larger loads.

Case Study:[17] At a large research university, the most common use of submetering data was to bill separate departments for their energy usage. As the metering program matured, the departments received more accurate billing data on energy consumption and demand. The improved accuracy resulted in increased charges to certain departments, which led to their reevaluation of energy use and improved conservation so to lower their utility bills. To achieve further savings, the university leveraged the metering system by negotiating an agreement with the power utility, allowing the utility's meters to be used as submeters as part of a "virtual aggregation" program to save on peak demand charges.

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[14] Millstein, D., "Getting Green with Submeters," Electrical Contracting Products, July 2008.

[15] Vornado Realty Trust Energy Information Portal. http://www.vnooffice.com/sustainability/welcome

[16] The peak demand is lower as the probability that each individual meter registers a peak demand at identically the same instant is negligible.

[17] U.S. Environmental Protection Agency's ENERGY STAR®, "Sub-Metering Energy Use in Colleges and Universities: Incentives and Challenges," December 2002.

The virtual aggregation of submeters installed at the building level reduced the cost of demand (kW) by at least 10 percent in all 30 buildings involved. These savings were passed on to the university departments. Submeters were also used to more accurately estimate energy and water loads, thereby reducing distribution system design requirements and lowering construction costs for new buildings.

2.5 Combination of Benefits from Submetering

Many of the benefits and uses of submetering data can be combined to achieve even more savings. As reported in the previous case study, owners may introduce submetering for one purpose, such as billing, and effectively use the data for another purpose, such as design and retrofit analysis, motivating behavioral change, or optimizing system operations. This combination of benefits is well illustrated by a second example from the same report.

Case Study:[18] The research university began submetering its campus more than 15 years ago, driven by pressures to reduce overall expenses and to allocate indirect costs to the appropriate research activities. Through an energy awareness program, the university offered departments a chance to receive payments of up to 30 percent of the savings achieved, if they cut costs relative to baseline energy usage.

- After 18 months of billing the departments for their usage, the school had reduced its usage from about 44 million kWh to 40 million kWh, saving about $300,000 per year. These energy and cost reductions were accomplished through improved operations and maintenance procedures that eliminated wasteful practices in energy intensive research departments.
- The study identified several energy retrofit projects costing about $2.5 million, with a four-year simple payback, resulting in a second round of major energy cost reductions totaling about $625,000 per year.
- The study evaluated a cogeneration capability, pressuring the utility and the utility commission to agree to secure lower, long-term rates for the school.
- From all phases, submetering has saved the university about $1 million per year for the past 10 years.

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[18] Ibid.

3. Economic Considerations

3.1 Life Cycle Cost Analysis

All energy-related investments, such as submetering, should be evaluated and prioritized using life cycle cost analysis (LCCA). The purpose of LCCA is to ensure that the investor procures building improvements that represent the best value over the useful life of the asset rather than simply those with the lowest upfront costs.

Following EISA 2007, managers of Federal buildings are now required to calculate life cycle costs[19] on a 40-year basis using the sum of the present values of:

- Investment costs, less salvage values at the end of the assets' expected useful life
- Non-fuel operation and maintenance costs
- Replacement costs less salvage costs of replaced building systems
- Energy and/or water costs

An investment is "life cycle cost effective" when the net present value of the input variables produces net savings. Conventionally, LCCA is expressed using one of three standard measures:

- Savings-to-Investment ratio (SIR)[20]—An SIR estimate greater than one indicates an economically worthwhile project.
- Present Value Net Savings (PVNS)[21]—Net project savings, discounted over time, greater than zero indicates economic value.
- Adjusted Internal Rate of Return (AIRR)[22]—AIRR is the annual yield from a project over the study period that takes into account its costs and benefits, the time value of money, and reinvestment of interim receipts. If the AIRR is greater than the minimum attractive rate of return, the project is economically worthwhile.

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[19] Life-Cycle Cost Analysis is codified in 10 Code of Federal Regulations Section 436 Subpart A—Methodology and Procedures for Life Cycle Cost Analyses. Life costing computational support is provided by the National Institute for Standards and Technology via the Federal Energy Management Program. ASTM Standard Practice E 917 provides additional guidance on performing an LCCA (ASTM International. "Standard Practice for Measuring Life-Cycle Costs of Buildings and Building Systems," E 917, *Annual Book of ASTM Standards: 2009*. Vol. 04.11. West Conshohocken, PA: ASTM International).

[20] ASTM International. "Standard Practice for Measuring Benefit-to-Cost and Savings-to-Investment Ratios for Investments in Buildings and Building Systems," E 964, *Annual Book of ASTM Standards: 2009*. Vol. 04.11. West Conshohocken, PA: ASTM International.

[21] ASTM International. "Standard Practice for Measuring Net Benefits and Net Savings for Investments in Buildings and Building Systems," E 1074, *Annual Book of ASTM Standards: 2009*. Vol. 04.11. West Conshohocken, PA: ASTM International.

[22] ASTM International. "Standard Practice for Measuring Internal Rate of Return and Adjusted Internal Rate of Return for Investments in Buildings and Building Systems," E 1057, *Annual Book of ASTM Standards: 2009*. Vol. 04.11. West Conshohocken, PA: ASTM International.

All three of these measures, when computed properly, will yield similar outcomes when applied to the same project; in practice, however, these standardized systems do not always support effective whole-building management.

For a number of reasons, many benefits of building system retrofits are difficult to accurately quantify. In some cases, a single management action to reduce energy consumption in a given building system will impact other systems. For example, a submetering report that indicates excessive use of lighting during periods the building is unoccupied can lead to a reduced lighting load, which may in turn affect the heating and/or air conditioning load. In addition, actions that improve building operations can enhance the comfort of building occupants, producing indirect benefits (both monetary and human) such as improved satisfaction and productivity. Similarly, other non-monetary benefits, such as reduced power plant emissions, generally do not factor into LCCA. Such benefits, while difficult or impossible to effectively integrate into current LCCA methodologies, represent important aspects of submetering's total value proposition and merit inclusion in the decision-making process.

3.2 Distribution of Costs and Benefits

The distribution of the costs and benefits of submetering represent another barrier, often referred to as "split incentives." For example, in buildings where owners sublet space to tenants, the owners often are responsible for installation of submeters and related software and equipment, but tenant behaviors ultimately affect changes in building resource use. The costs to install the submetering systems that lead to these changes fall to the owner, while the energy cost savings primarily benefit the tenants through reduced utility bills.

Generally, the cost-benefit calculus of submetering is similar to many building retrofits, with high upfront costs offset by long-term operational and cost benefits. The costs and capabilities of meter systems can vary widely and may be subsidized by Federal, state, local, or utility incentive programs (see Appendix C). Meters should be installed and operated by trained and qualified technicians, generating both an additional first cost as well as an ongoing maintenance cost. In addition, for metering to be useful, data must be collected from each device and analyzed to provide insight into the operation of the building—associated software, devices, displays, and networks for data collection and analysis are another first cost. Finally, if the data culled from submetering are to provide any benefit, it is most often because other actions have been taken to modify the building's energy or water usage, and a wide range of options are available as described in this paper.

Despite these challenges, building owners can reap potential benefits from submetering in several ways. First, owners of submetered buildings may negotiate better rates with utility companies for the resource(s) used, benefiting both owners and tenants, and may be combined with other strategies such as demand-side peak reduction. Owners of buildings with tenant-level electrical submetering can serve as the local power distributor, buying energy at a wholesale rate and billing tenants based on actual submetered usage that includes a reasonable rate of return. In some jurisdictions, complex rules govern how building owners are to distribute the actual cost of energy use to individual tenants. Adequate incentives must exist for building owners to make the necessary capital improvements to their buildings while at the same time protecting tenants' interests.

Second, without effective conservation measures to quell tenants' uncontrolled energy use, building owners may be required to invest in expensive capacity-extending equipment, such as larger electrical riser systems, that distribute electricity throughout the building. In this scenario, the submetering investment may yield savings through reduced or avoided capital outlays. Similarly, a more refined understanding of system performance using submetering data may result in changes in building operations through the use of intelligent controls that automatically adjust to environmental requirements. These types of strategies can save building owners money and time while also improving indoor environmental quality for tenants.

Finally, the use of secondary strategies and approaches may encourage building operators and occupants to adopt more efficient O&M strategies that reduce their resource consumption and improve efficiency. This is done by the building's submetering operator providing accurate and specific information on resource use to the building's O&M technicians and occupants, identifying high consumption areas/systems, encouraging conservation on a regular basis, and incentivizing reduced resource consumption, such as lower utility bills, to both groups.

Submetering at the tenant level, though, may not benefit all tenants equally. In buildings that were previously metered by a single master meter with costs shared proportionately, tenants with higher resource use will face higher utility bills.

Case Study:[23] In the NYSERDA report on multi-family dwellings, ratios of the highest user of electricity in a typical apartment complex to the average user of electricity in the same apartment complex typically calculated to a ratio of approximately 3:1. Analysis of usage confirmed that approximately 10 percent of the building's apartments consumed typically 20 to 25 percent of total apartment usage, and that approximately 70 to 80 percent used less than half of the total apartment usage, a finding that has been referenced in prior NYSERDA-funded studies.

While the case studies presented thus far are not intended to imply that submetering guarantees positive returns, they do suggest that a careful analysis of costs and benefits show that submetering may be economically worthwhile. At the same time, they reveal the need for well-documented, economically sound, comparable studies based on standard measures of worth (see Section 5, Next Steps). Only then can the economic discussion progress from anecdotal case studies toward the rigorous analysis necessary to inform future submetering user communities.

Operationalizing LCCA in the context of institutional operations and resource limitations creates other challenges. Although Office of Management and Budget (OMB) Circular A-11 (Preparation, Submission, and Execution of the Budget) requires life cycle cost reporting for Federal agencies, practice managers tend to do so mostly for information technology investments, not buildings, for a few reasons. First, agencies often separate capital budgeting from operational budgeting, limiting the ability to effectively link first costs to future operational costs. Moreover, agencies are often undercapitalized for high-cost, high-impact projects because the project budget estimates often exceed their limited funds. In some cases, managers can more easily justify investments based on upfront cost data rather than on subjective environmental, operational, or social variables that are difficult to quantify or—in the case of future costs and savings—difficult to forecast.

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[23] NYSERDA, "Electricity Reduction in Master Metered Buildings Low Income Rate Impact Analysis," October 2009.

4. Submetering Technical Details

For electrical systems, meters can be installed to track whole-building energy use (e.g., utility-owned advanced meters), sub-panel energy use (e.g., a lighting or process circuit), or a specific end use (e.g., an occupant's space, a motor, or a chiller). For water, natural gas, and other flow-related applications, meters are typically in-line installations on distribution lines using positive displacement, insertion turbine, or pressure-related techniques. Depending on the need, any of these meters will vary in size, type, output configuration, accuracy, and price. A definitive source for additional details beyond those provided below can be found the U.S. Department of Energy (DOE) Federal Energy Management Program's *Metering Best Practices Guide*[24] and *Operations and Maintenance Best Practices*.[25]

The four predominant levels of resource metering[26] are:

- One-time/spot measurement
- Run-time measurement
- Short-term monitoring
- Long-term monitoring

One-time or spot measurement applications are useful in many "baseline" activities to understand instantaneous energy use, equipment performance, or loading. In addition, they can measure changes in consumption following energy efficiency upgrades. Run-time measurements are often used to establish hours of operation for devices or systems as part of reducing energy consumption through shortened operation times. Short-term monitoring combines both duration of operation with energy consumption to establish a time-series record of energy or resources used. Long-term monitoring also makes use of duration of operation and energy consumption, though the equipment used is often installed on a permanent basis, and measurements are taken at a prescribed frequency and resolution to meet the established energy monitoring requirements. This last approach is the focus of the "Energy Use Measurement and Accountability" portion of EPAct 2005. For more information on the fundamentals of submetering, see Section 1.2.

The process for metering and submetering consists primarily of:

- Determining what should be measured in any particular building or location.
- Measuring the physical properties of flow through the distribution system to determine how much of each resource is being consumed.
- Collecting data at predetermined intervals and storing those measurements.
- Analyzing the measurements to determine how much of each resource is being used.
- Making informed decisions based on all information provided.

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[24] Sullivan, G.P., R. Pugh, W.D. Hunt. "Metering Best Practices: A Guide to Achieving Utility Resource Efficiency," October 2007, http://www1.eere.energy.gov/femp/pdfs/mbpg.pdf.

[25] Sullivan, G.P., R. Pugh, A.P. Melendez, W.D. Hunt. "Operations and Maintenance Best Practices," Release 3.0, August 2010, http://www1.eere.energy.gov/femp/pdfs/omguide_complete.pdf.

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

4.1 Meter/Submeter Performance Metrics and Attributes

Performance measures for meters and submeters include the metrics listed below as identified in the *Metering Best Practices Guide*.

Accuracy—Accuracy is the difference between a measured value and the true value. Published accuracies often will, and should, be referenced to specific calibration procedures, including equipment traceability to National Institute of Standards and Technology[27] equipment and procedures.

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

Turndown ratio—The turndown ratio refers to the flow rates over which a meter will maintain a certain accuracy and repeatability. The larger the turndown ratio, the greater the range over which the meter can measure the parameter.

Beyond performance metrics, other criteria useful for meter selection include:

Ease of installation—Regardless of technology, meters come in many different sizes and shapes, need a variety of inputs, and offer a variety of outputs. For specific make-and-model decisions, it is important to understand any size and weight constraints, needs for specific diameters (or lengths) of straight pipe upstream and downstream of the meter, specific electrical and communications needs, and the overall environment the meter will operate in.

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

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

Energy and water meters all require periodic maintenance. See the *Metering Best Practices Guide* for a complete description of periodic maintenance requirements.

4.1.1 Electrical Submetering

Electrical meters found on many homes and businesses are one of three types: *mechanical meters,* where electricity use is measured by the movement of a mechanical dial; *electromechanical meters,*

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[27] National Institute of Standards and Technology, "National Institute of Standards and Technology Policy on Traceability," http://ts.nist.gov/Traceability/Policy/nist_traceability_policy-external.cfm.

which are similar to mechanical meters but transmit data by electronic or pulse output; or solid-state/digital meters—also called *advanced meters*—that use non-mechanical sensors to provide data in a variety of digital formats.

Advanced electrical meters represent the highest-level components of a submetering strategy and satisfy the "Energy Use Measurement and Accountability" portion of EPAct 2005 for Federal facilities. Automated meter reading (AMR) systems, both wired and wireless, are heavily used due to Federal mandates, lower life cycle cost, and greater capacity for data capture and transmission. They contain integrated circuits with current and voltage transformers, on-board memory, and communication technology. They also have the capability to measure and record interval data (at least hourly for electricity) and to communicate it to a data collection system. Advanced meters range from the familiar circular socket-based style to an array of rack- and panel-mount configurations. Their accuracy ranges from 0.05 to 3 percent at a cost of $400–$3,000.

The three main types of electrical devices for electricity submetering (see Table 1) are electromechanical/solid-state feed-through and current transformer (CT) meters, and the electronic non-socket meters. Feed-through and CT submeters are both socket-type meters.

Feed-Through Meter: In the feed-through installation, the meter is physically connected between the receptacle and the end load; the end load plugs into the meter, which in turn plugs into the receptacle. The main advantages of feed-through meters are their accuracy and precision, both increasingly critical because of the need to measure low power or standby power levels and the richness of data provided, which can include voltage, current, frequency, power, energy, and power factor. The main disadvantages are the additional utility room space requirements and the need to temporarily unplug the load to install the meter. This configuration is generally acceptable for the vast multitude of plug loads; however, it may be a problem for loads that require a planned turn-off or shut-down with proper backup (e.g., computing or telecommunications equipment, or medical equipment).

Current-Transformer Meter: CT submeters are used with loads in excess of 400 amps—too high to directly apply to measuring instruments. A current transformer produces a reduced current accurately proportional to the current in the circuit, although installation is more complicated because they must be mounted in a large cabinet for electrical code compliance. Both feed-through and CT meters occupy between four to ten square feet and must be installed in a utility room.

Electronic Non-Socket Meter: The main advantages of electronic clamp-on CT probe meters are their availability and mature technology, as well as their mature data collection infrastructure. Clamp-on CT probe meter installations are less popular for power data collection due to the need to properly "split" the power cord for clamping the CT to a conductor. Other disadvantages are that these meters are generally better suited for higher loads, like those available as an aggregate at the panel or subpanel level, and they are limited to AC loads only. New device features appearing on the market continually improve their application features.

All three devices provide a range of measurement and reporting capabilities. Hardwired sensors utilizing a dedicated wire from the measuring device(s) to the data acquisition are probably most common, but information can also be transmitted via power line carriers or radio signals.

Table 1: Types of Electrical Submeters—Example Comparison

Specifications	**Submeter Type**		
	Electromechanical/Solid State		Electronic Non-socket
	Feed-Through	Current Transformer	
INSTALLATION			
Installed Cost (estimated)			
-Stand alone, up to 320A, 3Ø	$1,000	N/A	$700
-Stand alone, over 320A, 3Ø	N/A	$2,000–$5,000	$800
8-Meter Unit, 200A, 3Ø	$16,000	N/A	$5,500
Installation Time	2–3 Hours	6–8 Hours	1 Hour
Power Interruption	2–3 Hours	6–8 Hours	None
Amperage Limitations	320 Amp, Max.	None	None
Space Requirements	2 Square Feet	11.7 Square Feet	0.25 Square Feet
Installation Location	Utility Room	Utility Room	Anywhere
FEATURES			
Multiple Meter Units (MMU)	Yes	Yes	Yes
Size of 8-Unit Cabinet	18.1 Square Feet	18.1 Square Feet	2 Square Feet
Digital Readouts	Optional/Yes	Optional/Yes	Standard
Reset Capabilities	No/Yes	No/Yes	Standard
Multiple Load Monitoring	No	No	Yes
Subtractive Load Monitoring	No	No	Yes
Monitor Specific In-Panel Circuits	No	No	Yes
Amperage Modification in Field	No	w/ CT Change	Yes
Meter UL listed	No	No	Yes
ENHANCEMENTS			
Digital-to-Analog Profiles	Yes	Yes	Yes
Pulse Outputs	Yes	Yes	Yes
Timed Metering	Yes	Yes	Yes
Software Monitoring	Yes	Yes	Yes
Upgradeable in the Field	No	No	Yes
Power Quality Functions	Available	Available	Yes
Net-Metering Capability Form C	Yes	Yes	Yes
Control Relay Output	No	No	Yes

Source: E-Mon, LLC

Determining the types of data to collect and store, and at what frequency, can be a challenge when developing a plan and budget for electrical submetering. The frequency at which the electrical data need to be collected depends mainly on the individual end load being measured, which often dictates the minimal resolution needed for properly analyzing energy and power consumption of the end use. The proper submetering configuration, data types and frequency, software, and analysis needed to achieve prescribed operational goals can be complicated and require in-depth examination of the buildings, systems, and desired outcomes.

As the number of possible submetering configurations and applications is quite large and dependent on the building design and use, it is impossible to provide adequate details for the building designer in this paper. Please see "Submetering—A Practical Approach" by Mane (2005) for simplified examples of submetering applications and hardware requirements organized by market segment, including commercial multi-tenant buildings, residential multi-tenant dwellings, commercial retail, industrial/manufacturing, and institutional buildings.[28] See also Appendix C for examples of submetering configurations and device pricing.

4.1.2 Electrical Submetering of Plug Loads

As mentioned earlier, electrical meters can be installed to track whole-building energy use (e.g., utility meters), sub-panel energy use (e.g., a lighting or process load), or a specific end use. In the latter, the end-use electric load is sometimes referred to as a plug load or miscellaneous electrical load. Plug loads are generally defined as all non-main building electric loads; that is, all electric loads except those related to the main systems for heating, ventilation, cooling, water heating, and lighting. Plug loads account for an increasingly large portion of commercial and residential electricity consumption.[29] This trend is mainly due to an increase in both the number of types of end loads and the number of loads in buildings. Typically, plug loads fall into a lower power consumption category, and therefore clamp-on CT probe meters are still prevalent for subpanel metering and not plug load metering.

Plug load metering is also used to disaggregate data obtained through subpanel metering. For example, a single, submetered breaker may serve both lighting and plug loads, when only metering for lighting is desired. Plug load meters installed on individual end uses served by the same breaker may be used in conjunction with subpanel submetering to disaggregate power measurements by subtracting the plug load from the breaker's metered data—thus yielding a more accurate lighting-only measure.

In general, however, plug loads require a relatively high frequency of data collection when compared with other submetering activities. When plug loads are pervasively submetered with multiple parameters being measured (e.g., voltage, current, power, frequency, power factor), the energy and power analysis requires a rigorous, reliable, and scalable data-collection infrastructure able to handle the significant data flow. Pervasive plug load metering is currently pushing the available technology and data collection infrastructure to its limits. In addition, because of the high installation costs associated with the pervasive metering, wireless meter configurations are often favored, adding to the complexity

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[28] Mane, L., "w – A Practical Approach," GE ESL Magazine, Summer 2005. http://www.geindustrial.com/Newsletter/fall05_submetering.pdf.

[29] Energy Information Administration, "Annual Energy Outlook 2009," page 119, table A5, http://www.eia.doe.gov/oiaf/archive/aeo09/pdf/0383(2009).pdf.

and challenges of the submetering solution. As a result, deployment of large-scale submetering of plug loads is not currently widespread.

4.1.3 Potable Water Submetering

Throughout a building or campus, water is distributed by a series of pressurized distribution pipes or lines. A vast majority of buildings today measure water once upon entering the site, and do not measure successive distribution points or end uses. There is no real equivalent of an "electrical panel" for water distribution in most buildings, making meter placement more problematic. The technology and applications supporting water metering are therefore significantly less mature or pervasive than those for energy, though metering water and recording water use can improve resource conservation and enable system diagnostic capabilities.

The physical properties associated with potable water lend themselves to a wide variety of metering technologies. The lack of high temperature and/or two-phase flow allows the use of metering technologies not suitable for other applications (e.g., steam or high-temperature hot water). Because potable water metering is typically focused on the quantification of flow volume, and not energy content, lower-cost options can be used. The option selected will depend on a number of factors including, but not limited to, current design, budget, accuracy requirements, minimum flow, range of flow, and maximum flow. In general, volumetric water metering designs can be broken down into three general operating designs: positive displacement, differential pressure, and velocity including ultrasonic meters. The Metering Best Practices Guide provides more detailed information.

At the whole-building level, where nutating disk meters are the most common, calibrated pulses are the typical data output and are relatively easy to work with, though other output options are available (4–20 milliamp, 0–5 volt, Modbus, etc.).

Potable Water Meter Type	Application	Accuracy	Cost
Nutating Disk	Up to 3" connections	0.5%–1.0%	$50–$400
Orifice	0.25"–4.0"	0.25%–2.0%	$1,000–$5,000
Venturi	0.25"–4.0"	0.25%–2.0%	$1,000–$5,000
Turbine	2.0"–20.0"	0.5%–1.0%	$500–$5,000

Measuring the properties of water flow, such as flow rate and temperature, is relatively straightforward. The methods may be invasive (cutting the piping and installing a meter) or non-invasive (no cutting required). Some installations may require stable laminar flow and mandate a straight length of pipe 15 to 25 pipe diameters upstream and 5 to 15 pipe diameters downstream of the meter. Like electrical metering, the signals from these measurement devices can transmit to an appropriate data acquisition system in many ways. Hardwired sensors using a dedicated wire from the measuring device(s) to the data acquisition system are probably most common, but information can also be transmitted via power line carriers or radio signals. Using a flow totalizer system, meter data can be combined from different locations via a data network to provide functions of flow control and measurement through remote online management. Using these systems, flow measurement, pressure, and temperature are measured and can determine the density of the measured object and accumulate the flow from multiple locations over time.

Building owners or occupants interested in measuring water consumption will need to understand the entire water distribution system, choose where they want to measure, and then install appropriate meters at that location. Like electrical metering, deciding what data to collect and store, and at what frequency, can be a challenge. The signals from water measurement sensors are real-time, meaning that instantaneous values are available. The data acquisition system must be able to process and store these data and measurements to facilitate accessibility for analysis.

4.1.4 Natural Gas and Steam Submetering

Natural gas and steam submetering share similarities to water submetering. All three involve fluid flow through pipe distribution systems, though with natural gas and steam metering the "fluid" is in the gas phase and the changes in temperature and pressure can result in metering inaccuracies. Also, like water, natural gas and steam distribution systems involve life-safety issues, and gas flow consists primarily of the same three categories of measurement: positive displacement, differential pressure, and velocity.

At the whole-building level, where positive displacement diaphragm and rotary meters are the most common for natural gas, calibrated pulses are the typical data output.

Natural Gas Meter	Application	Accuracy	Cost
Diaphragm	0.75"–2.0"	1.0%	$150–$500
Rotary	1.5"–4.0"	0.25%–0.5%	$300–$500
Orifice	0.25"–4.0"	0.25%–2.0%	$1,000–$5,000
Venturi	0.25"–4.0"	0.25%–2.0%	$1,000–$5,000
Annubar	2.0"–100.0"	2.0%	$1,000–$3,000
Turbine	2.0"–20.0"	0.5%–1.0%	$500–$5,000
Vortex Shedding	1.0"–12.0"	1.0%–2.0%	$4,000–$6,000

Steam flow metering presents challenges in accuracy and maintenance. Most steam meters measure a volumetric flow due to the two-phase physical properties of steam, which may impair accurate measurement of flow rate. Steam use is less pervasive than electricity, though metering can provide valuable diagnostic capabilities in certain applications. Meter maintenance is also an issue depending on the meter technology and installation and the quality of the steam transferred.

Steam Meter Type	Application	Accuracy	Cost
Orifice	0.25″–4.0″	0.25%–2.0%	$1,000–$5,000
Annubar	2.0″–100.0″	2.0%	$1,000–$3,000
Turbine	2.0″–20.0″	0.5%–1.0%	$500–$5,000
Vortex Shedding	1.0″–12″	1.0%–2.0%	$4,000–$6,000

Measuring the properties of natural gas and steam is relatively straightforward but almost always invasive (requiring cutting of the piping and installation of a meter). Due to the flammable nature of natural gas and the high temperature of steam, meters for natural gas and steam should always be installed by qualified professionals. Like electrical and water metering, the signals from these measurement devices can transmit to an appropriate data acquisition in many ways. Hardwired sensors using a dedicated wire from the measuring device(s) to the data acquisition system are probably most common, but information can also be transmitted via power line carriers or radio signals.

Some installations may require stable laminar flow and mandate a straight length of pipe 15 to 25 pipe diameters upstream and 5 to 15 pipe diameters downstream of the meter. As with water metering, there may not be a natural location equivalent to an electrical panel to conduct natural gas or steam measurements. A building owner or occupant interested in measuring natural gas or steam consumption will need to understand the entire natural gas or steam distribution system, choose where they want to measure, and then install appropriate meters at the appropriate locations.

4.2 Installation and Integration of Submeters

Installing submeters in a building requires careful design analysis to meet a project's energy efficiency goals and objectives. As mentioned earlier, submetering by itself has relatively little impact on overall energy or water consumption—it is a tool to help building owners and occupants understand and control their usage. Proper submetering designs must include the specification of the level of submetering required, the types of data to be collected and used to reduce consumption, and the software, analysis, and communication tools necessary to manage energy usage by systems, in order to provide information to operators or occupants and/or to control the building's energy and water use directly. Submeters can interface with the building automation system, not only making it possible to integrate the control logic with the meter but also providing access to the building automation system tools for trend analysis, report generation, and user information display.

In the Southern Connecticut State University (SCSU) case study referenced earlier, submeters were installed on the secondary side of the switchgear in the building or facility. SCSU reported that besides having a lower cost, secondary submeters were much easier to install, and electricians could install them in about three hours while performing cleaning and maintenance of load centers concurrently or separately. The installation involved connecting three current sensors on the electrical feeds. Because the submeters were connected to a digital control system, the installation did not require a separate data network or other major interior changes in the building or electrical distribution system. The average cost to purchase and install a submeter connected to the data control system was approximately $3,000.

4.2.1 Selected Issues for Special Building Configurations

Special-use buildings may present other unique opportunities and challenges. Resource intensive facilities such as hospitals, healthcare facilities, and laboratories are highly complex buildings. These special building types offer even greater opportunities to improved performance. In the case study below on building commissioning for new and existing buildings, median payback periods were considerably shorter for energy intensive facilities than for other types of buildings due to the larger economic value per percentage improvement in building efficiency. Submetering is an integral component to monitor-based continuous commissioning approaches for the next generation of high-performance buildings.

Case Study:[30] In a study of 643 buildings, commissioning data revealed over 10,000 energy-related problems, resulting in 16 percent median *whole-building* energy savings in existing buildings and 13 percent in new construction, with payback time of 1.1 years and 4.2 years, respectively. Median payback periods were considerably lower for energy intensive facilities, including 0.5 years for laboratory spaces and 0.1 to 0.6 years for healthcare facilities.

Health care institutions are both energy- and water-intensive facilities—hospitals and healthcare facilities are consistently within the top 10 water users in their communities. Typical water use per capita in hospitals ranges from 40 gallons per day to 350 gallons per day.[31] Water use at a medical facility depends upon the services provided, in-patient vs. out-patient visits, staff attendance, equipment used, age of the facility, and periodic maintenance practices followed.

Case Study:[32] Boston's Norwood Hospital engaged in a major program of implementing water efficiency measures. By eliminating seal and cooling water on medical air compressors and vacuum pumps, 8.5 million gallons of water was saved. Using re-circulated seal and cooling water for four vacuum pumps and one medical compressor as well as removing a vacuum pump resulted in a net annual savings of 8.5 million gallons. Norwood also installed a number of sanitary retrofits—aerators and flush valves saving 3 million gallons per year. Replacing the flush valves on toilets and urinals, and installing low-consumption aerators on all lavatory faucets resulted in another savings of 3 million gallons per year. A water refrigeration system for the morgue was replaced with an air-cooled unit, saving 2.1 million gallons. Water use dropped from 51.2 million gallons in 1991 to 36.6 million gallons in 1994. Project Cost: $5,500, project savings: $13,750, payback period: 0.4 years.

In hospitals and healthcare facilities, many challenges to improved resource efficiency exist. Energy- and water-intensive medical equipment are used around the clock, thus requiring they remain "powered on" 24 hours a day. Energy and water consumption are driven by hours of operation, number of patients, staffing intensity, and healthcare functions; hospitals and tertiary care facilities generally have high consumption rates than long-term care and mental health facilities.

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[30] Mills, E., "Building Commissioning: A Golden Opportunity for Reducing Energy Cost and Greenhouse Gas Emissions", Lawrence Berkeley National Laboratory, Berkeley, CA, July 2009. http://cx.lbl.gov/2009-assessment.html.

[31] Water Use Case Study: Norwood Hospital, Massachusetts Water Resources Authority. http://www.mwra.state.ma.us/04water/html/bullet1.htm

[32] Ibid

Often medical devices are not energy rated and are therefore absent of quantified energy performance requirements and data. Such devices represent *unregulated loads* to the building and currently are not covered by building efficiency codes. Further, some of these devices may be plug loads that are shifted from room to room as needed (e.g., blood pressure and intravenous flow control machines).

Installation procedures in a hospital environment are also more challenging. Concerns about infectious disease in an operating healthcare facility require complicated infection-control and scheduling procedures. Access to utility areas above the ceiling or in pipe chases is controlled to prevent potential contamination from accumulated substances and debris. Scheduling projects such as meter installation is often complicated by the necessity of continuity of operations, and the use of wireless communication devices must not affect sensitive medical equipment that can be compromised by radio frequencies.

Computer and data communications in healthcare facilities require high levels of security protection due to privacy requirements related to sensitive patient information. Mechanical and electrical systems in facilities with special-use areas can be much more complex and diverse, with strict requirements on air pressure relationships, air exchange rates, and temperature/humidity control. Facilities also have specialized emergency electrical systems, more extensive fire and safety requirements, and other specialized building requirements (e.g., dedicated air conditioning systems). These varied requirements complicate the ability to implement submeters in a manner that will provide meaningful data. In these types of facilities, the cost-benefit analysis must include life-critical requirements, functional needs, and standard operating procedures for healthcare facilities.

Other special building types include laboratories, specialized research facilities (such as particle accelerators), and energy-intensive areas such as data centers and clean rooms. In the report cited in the previous case study, energy savings in a particle accelerator facility, attributed to a more efficient operation of chillers, resulted in a 46 percent reduction in energy and an avoided capital cost of $120,000. This report presents other dramatic case studies on the building's monitor-based commissioning using submetering data. As an interesting aside, while these special-use buildings strictly control their working environments, regularly scheduled O&M procedures frequently do not address system energy efficiency and performance requirements.

Key issues in implementing submetering in existing buildings are the inconvenience and risks presented to building occupants. The extra meters required for submetering may require rewiring, installing data networks, and other intrusive measures, which could be especially problematic in historic buildings or buildings in which meter installation may present occupational hazards, such as exposure to asbestos. To partially mitigate these problems, wireless communication technology and data transmission can be used to in place of a new data network for the building. Current wireless communication networks though may, if not properly configured, introduce network security issues related to data integrity and information security when connected to standard data networks. See also Section 4.3.2.

One of the biggest challenges with submetering lies with *in situ* electrical distribution systems, where for a specific end use the electrical feeds may be dispersed throughout multiple electrical panels. For example, to know how much power hallway lights use in a building, where the lights are connected to 15 different breakers in 10 different panels on three different floors, it is difficult and costly to measure the power through a single submetering system. As a result, this issue is driving changes to building electrical codes that would require end uses to be grouped at the electrical panel. Eventually, as submetering for natural gas and water become more common, the issue is likely to arise there as well.

Older multi-tenant buildings that previously used a single meter may have electrical layouts that combine loads from multiple areas, further complicating the process of installing measurement devices dedicated to individual areas. However, eliminating "cross-wired" spaces is essential to accurately and fairly bill tenants for their energy consumption. To help building owners learn more about submetering, the Utility Management & Conservation Association (formerly known as the National Submetering and Utility Allocation Association) offers helpful resources and information.

4.2.2 Integrating Submetering with Existing Operations

Submetering is just one important component to the overall operation and maintenance of a building. A submetering solution must be carefully defined during the specification and contracting phases to include adequate integration with existing building management systems and O&M procedures, selecting appropriate equipment and software systems, ensuring adequate training, testing, and commissioning of the installation, and providing appropriate maintenance and service costs and schedules. Ideally, the submetering solution should be designed as part of an ongoing program of continuous monitor-based commissioning. A building's O&M staff and occupants are integral to the submetering solution, as human behaviors often drive building energy use and impact overall success. Submetering may also be part of a larger effort to document and report on resource use or on evaluating building design and retrofit alternatives.

Currently, there exist a number of challenges in implementing advanced metering and submetering solutions in new and existing buildings. The first challenge concerns properly defining Requests for Proposals (RFPs) that rigorously list the performance specifications of the equipment, installation requirements, testing and commissioning, data requirements and protocols, and interfaces to new and existing building/energy management systems (BMS/EMS). To facilitate correct operation, EMS systems should be integrated into the building's automation or continuous recommissioning supervisory systems to detect failure of individual devices or meters. Ownership of the building's advanced meters can also present challenges; for advanced meters owned by utilities or other entities, agreements should be established to outline the procedures for changing out meters or altering operating specifications.

Human factors play an important role in successfully installing and operating a submetering system. Once meters are installed, trained O&M technical personnel, both on staff or under contract, must maintain the devices and ensure they operate with high levels of accuracy and reliability. Dedicated staff is essential to operate the EMS system and to make any software and programming changes, so the building management system can efficiently respond to setpoints and alarms. To meet these needs, appropriate resources must be dedicated to train staff or to contract these services, and budgets must account for replacing and repairing submetering components as dictated by maintenance schedules. Incentives to O&M staff may be required to ensure that the submetering devices remain fully operational and that they are used as designed. Additional incentives may be required for occupants to change their behaviors and effect conservation and resource savings.

Submetering systems must be designed, implemented, and maintained as production-quality building management systems, as opposed to experimental tools. High-levels of reliability, information assurance and security, established data acquisition/ archival procedures, and periodic system maintenance requirements are essential to acquiring and using the submetering data over the long term. Operational responsibility for submetering systems must be clearly designated to ensure availability, accessibility, and dependability, as occupant behaviors may obscure results, transfer loads to unmonitored locations, or result in disproportionate use of other resources. Other rules and regulations may also conflict with the implementation of submetering technologies (e.g., bans on wireless communications).

4.2.3 Integration with Whole-Building Automation Systems

One relatively easy way to collect submetered data is to connect the submeters to an existing building automation system. Automation systems collect and process system information on the performance of a building and, with appropriate connections and programming, they can compile and use submetered data as well. Since most measurement technologies for electricity, water, natural gas, or steam can be set up to provide output in the form of electrical signals, those signals can be fed into a whole-building automation system for collection and processing. Likewise, it is also possible to take specific control actions or to generate event reports based on meter data and signals.

Standards for interconnecting components in building automation systems have been developed that ease the integration of submeters. For example, Open controls protocols BACnet[33] and LonTalk,[34, 35] two standardized data communication protocols for building automation and control networks, have specific features designed for interconnection with meters. The meters can directly support the communication protocol, or pulse outputs from meters can be used by the building automation system to collect data. Most submeters can be readily integrated into building automation systems through one of these methods. Standard data protocols facilitate the identification of data from different meters as well as its consolidation into analysis and monitoring software. Once a meter is integrated with the building automation system, all of the trending, analysis, and user display tools of the system become available for use.

For many organizations, when a new data network is connected to an existing, secured data network, it must possess appropriate information assurance and security characteristics. Standard security standards, such as IPsec and Kerberos, were designed to operate only on TCP/IP networks and as such do not contain the necessary features to support control networks and protocols. To achieve these network security requirements, the control protocols have been extended with a set of network layer security messages that provide data confidentiality and integrity, device authentication, data hiding, and user authentication. See also Section 4.3.2.

Whole-building automation systems are by no means ubiquitous, and existing buildings may not have systems in place that can integrate submetering data. Installing and operating new submetering systems can be complicated and should incorporate the utility's ownership and maintenance of the primary meter, as the utility's O&M activities may pose a risk to the reliability of the submetering and

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[33] See http://www.bacnet.org/

[34] See http://www.echelon.com/communities/energycontrol/developers//lonworks/

[35] DOD Unified Facilities Guide Specifications 25 10 10 and 23 09 23 use the LonTalk (CEA/ANSI 709.1b) protocol.

data collection system. Furthermore, conflicts may arise between those responsible for the submetering system and coordination with multiple entities (occupants, data network managers, building owners, utilities) that can affect optimum system operation.

4.3 Tools for Analyzing Submeter Data

The measurement capability provided by submetering provides building owners with a structured method to reduce resource consumption and to systematically identify and eliminate operational variations that cause resource waste. In order to determine the improved efficiency of a building or of a particular retrofit, the building's performance data must be compared relative to its prior performance and to other buildings of similar design and use.

4.3.1 Benchmarking and Baselining

Energy and water use benchmarking is a process that compares the energy and water use of a building or group of buildings with other similar structures or looks at how energy and water use varies from a baseline.[36] Benchmarking energy performance helps identify best practices that can be replicated, either within a building or across a portfolio of buildings, using performance data from similar buildings. Benchmarks can be reference points for measuring and rewarding good performance. In the context of this report, building owners can use benchmarking and baselining to measure the effect on overall building performance of new processes, practices, and behaviors driven by submetering data.

Because buildings are of many varied types and uses, it is essential that any benchmarking activities focused on identifying best-in-class submetering performance explicitly recognize and address these differences. More comprehensive performance metrics such as ENERGY STAR® Performance Ratings[37] will differ across building types, and include climate zone and building characteristics such as operating hours, building size, occupancy, and number of computers.

Baseline values, or average levels of performance, are also a valuable reference point, as they provide a measure of the improvement opportunity achievable through benchmarking. A key source of baseline values is the Commercial Buildings Energy Consumption Survey (CBECS).[38] CBECS tracks energy consumption and expenditures for 12 building types and five climatic zones, and employs a weighted sample of buildings that collectively represents the entire stock of commercial buildings in the United States. Public use microdata files are also available via the CBECS Web site; these files allow more detailed cross tabulations than are provided in the various CBECS reports.

For energy use, a commonly used metric is *energy use intensity* (EUI), typically defined as the overall energy consumption of a building divided by the total floor area of the building. It is important to understand that judging a building's relative performance as indicated by the EUI depends significantly on the location and type of building. A recent study on building energy use intensities found that metrics

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[36] Environmental Protection Agency, "ENERGY STAR Building Manual," Chapter 2, http://www.energystar.gov/ia/business/EPA_BUM_CH2_Benchmarking.pdf.

[37] Environmental Protection Agency, "ENERGY STAR® Performance Ratings Technical Methodology," http://www.energystar.gov/ia/business/evaluate_performance/General_Overview_tech_methodology.pdf.

[38] U.S. Energy Information Administration, 2003 Commercial Buildings Energy Consumption Survey (CBECS), http://www.eia.doe.gov/emeu/cbecs/.

could vary based on the performance criteria used and highlights the importance of choosing the right performance metric[39] for the application. Oak Ridge National Laboratory has compiled data on 24 building types at various locations throughout the United States to which a building can be compared,[40] while EPA has created a list of 26 national average EUIs for buildings, which are currently not eligible to receive an ENERGY STAR energy performance score, to use as reference energy performance targets. Through Portfolio Manager, EPA also provides energy performance scores that account for the impact of weather variations as well as changes in key physical and operating characteristics for 14 building types.[41]

For water benchmarking, the term water use refers to water used for any practical purpose, including consumption. Water use benchmarks are either absolute or relative: absolute benchmarks define a quantity of water used; relative benchmarks represent a unit-less ratio of water used divided by a target value quantity. The most common bulk metric for water use is "per capita use" measured in gallons per person per day. The common water metric specific to water devices is gallons per hour (gph), and for reporting Federal water use mandated by EO 13514, gallons per square foot is used.

Challenges exist when using metering data to measure conservation impacts due to the aggregated use of water in the building that captures "other than efficiency" effects. And, when evaluating the water efficiency of a device relative to an absolute water use benchmark, the measurement must not only include the flow rate (gph) of the device but also the effectiveness of the device to achieve the desired results—a showerhead with a 50 percent lower flow rate that requires twice as long to rinse is no more efficient that the full flow-rate device.

From the ENERGY STAR Guidelines for Energy Management[42], the process for performance assessment is outlined below:

Baselining and Benchmarking	
Gather and track data	Collect resource use information and document data over time.
Baselining and Benchmarking	
Establish baselines	Determine the starting point from which to measure progress.
Benchmark	Compare the performance of your facilities to each other, to peers and competitors, and over time to prioritize which facilities to focus on for improvements.
Analysis and Evaluation	
Analyze	Understand your resource use patterns and trends.
Technical assessments and audits	Evaluate the operating performance of facility systems and equipment to determine improvement potential.

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[39] Peterson, K., and H. Crowther. "Building EUIs." *High Performance Buildings* (Summer 2010): 40–49.

[40] Oak Ridge National Laboratory, "Benchmarking Building Energy Performance," http://eber.ed.ornl.gov/benchmark/homepage.htm.

[41] ENERGY STAR, "Portfolio Manager Overview," http://www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager_model_tech_desc.

[42] ENERGY STAR, "Guidelines for Energy Management Overview, Step 6.1: Measure Results," http://www.energystar.gov/index.cfm?c=guidelines_evaluate_performance.measure.

4.3.2 Communication Networks and Data Storage Requirements

Regardless of the meter type, once submetering data is collected it must be transmitted via a communication network to be processed, stored, and used. The type of submetering plan with its requisite data requirements will define the communication network appropriate for the application. Current options for automated metering communications include phone modem, local area network (LAN), building automation system, radio frequency (RF), and wireless network. Submetering devices connected to existing building automation system networks provide an easy and cost-effective communication alternative by taking advantage of a site's previous investment in network infrastructure.

As mentioned previously, when data communication networks are connected to existing, secured data networks, the communication protocols should include appropriate levels of information assurance and security[43]. To achieve these network security requirements, the control protocols have been extended with a set of network layer security messages that provide data confidentiality and integrity, device authentication, data hiding, and user authentication. For wireless communication systems, see also standards IEEE 802.11 (WiFi) and IEEE 802.15.4 (appropriate for low data rate applications) for more information.

For continuous-performance monitoring systems, data storage and database systems should also meet common security and integrity requirements. The California Energy Commission's Public Interest Energy Research Program (PIER) and the Building Technologies Program of the U.S. Department of Energy have developed data specifications appropriate for energy management systems.[44]

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[43] Under the Information Technology Management Reform Act (Public Law 104-106), the Secretary of Commerce approves Federal Information Processing Standards that are developed by the National Institute of Standards and Technology (NIST) for Federal computer systems. In addition, NIST in accordance with its statutory responsibilities under the Federal Information Security Management Act (FISMA), Public Law 107-347, is responsible for developing information security standards and guidelines, including minimum requirements for federal information systems. For more information, see http://csrc.nist.gov. The National Security Agency (NSA) develops guidance for DoD's national security information and information systems, in accordance with National Security Directive 42. See also DOD Unified Facilities Guide Specifications 25 10 10 and 23 09 23 focused on control protocols.

[44] Data specifications based upon work sponsored by the California Energy Commission Public Interest Energy Research Program (PIER) and the Building Technologies Program of the U.S. Department of Energy, http://cbs.lbl.gov/performance-monitoring/specifications/.

Data Storage Specification Considerations

- Data will be stored in a structured query language (SQL)-compliant database format or time-series format. The minimum requirement is an SQL server or equivalent.
- The database will allow other application programs to read and access the data with appropriate password protection while the database is running. The database will not need to be shut down in order to access or add data.
- Trend data will be archived in a database from field equipment in time intervals of no less than once per day.
- Storage on the field equipment will be reset once data are exported to allow for trending if communication is disrupted. Data will be uploaded once communication is reestablished.
- Blank or null values in the database will be replaced with actual data.
- Calculations and other metrics will be updated once controller data are uploaded. This overall system update to check for new data should be automated to run once a day.
- All data will be stored in a database file format for direct use by third-party application programs (e.g., Energy Information System [EIS]).
- Sufficient data storage capacity will comprise at least two years of data for all data points. In addition, storage capacity will allow for compression of one year of data for historic trends and archiving.
- Time stamps will be collected on all data. The time stamp, depending on system architecture, will be captured by the field controller or system controller and directed to the database archive.
- Exported data will contain no duplicate records or duplicate time stamps in output files. Each date/time stamp for a specific point will be unique. The export query will be for a specific point or multiple points in a defined group.
- Date/time fields will be in a single column in a format automatically recognized by common spreadsheet, database software tools, or EIS.
- The data will be fully contained in a single file or table for each point. Data will not span multiple files or database tables. Users can have the option to modify the start and end dates for exporting files depending on third-party program requirements to evaluate the data.

4.3.3 Submetering Information Systems

Once installed, meters, submeters, and automated building control systems can generate large volumes of data that must be stored, analyzed, and archived. Metered energy data is analyzed at regular intervals (e.g., every 15 minutes is standard in the U.S.) and may incorporate other relevant information:[45]

- Account or location
- Usage points (e.g., lighting, HVAC)

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[45] "Mining Your Meter for Savings." Platts, a Division of the McGraw Hill Companies, Inc., 2004. http://www.oldsanteecanalpark.org/portal/page/portal/santeecooper/mybusiness/energymanagementtips/miningyourmeterforsavings.pdf.

- Kilowatt-hours of consumption
- Highest kilowatt demand
- Voltage
- Real and reactive power
- Hourly weather information (temperature, humidity)
- Dollar values of consumption, peak charge, access charge, taxes, and delivery charges
- Calculated values for load factor, per square foot or per square meter use
- Heating or cooling degree days

For water distribution systems, metered data may include:

- Water flow rate
- Peak flow rate
- Pressure
- Temperature
- Hourly weather information (temperature, humidity)
- Location

This information alone provides no significant insights into building performance unless it is integrated with software analysis capabilities. For energy systems, an Energy Information System (EIS) refers to the broad class of analysis tools ranging from spreadsheets on local computers to integrated systems with analysis capabilities, trend identification, report generation, and graphical displays. A building's advanced meter, submeters, and building automation systems can all provide data to the EIS.

Formally, EIS refers to software, data acquisition hardware, and communication systems administered by a company, partnership, or collective to provide energy information to commercial building energy managers, facility managers, financial managers, and electric utilities.[46] Appendix D contains a table of current EIS products. These systems provide a range of data acquisition, analysis, diagnostic and targeting, and reporting capabilities. The complexity of each system depends on the application and the desired level of monitoring. The text box below highlights many of the features to be considered when selecting an EIS.

Moreover, installing, managing, and communicating results from EIS systems requires technical staff and equipment, which can consume additional staff resources. A number of companies offer EIS services for a fee. These services allow the building operator to select the level of analysis granularity in reporting, and they provide expertise in diagnosing problematic, failing, or inefficient building systems.

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[46] Lawrence Berkeley National Laboratory, "Building Energy Information Systems and Performance Monitoring (EIS-PM)," http://eis.lbl.gov/.

Scoping EIS Capabilities

- **Definition of facility objectives—**How will the EIS will be used? How will it improve resource efficiency and its contribution to the financial payback of the overall metering system?
- **EIS integration with other IT systems—**What existing infrastructure can be used? A survey of existing facility software, hardware, communications, meters, and capabilities is recommended before the EIS decision is made.
- **Key reporting outputs—**How will the outputs of this system be used to fulfill the objectives of the facility and its management? How will the outputs be made available (paper copy, email reporting, Web-based reporting), and what summary options are available?
- **Data-collection needs—**What are the data-collection requirements for achieving the key reporting outputs? Are they available with existing metering elements?
- **Data analytics—**What analysis, statistical, and/or regression routines are needed to transform the data into the information desired? Are the chosen analytics capable of handling the size, frequency, and complexity of the anticipated data?
- **Management support—**Has a budget been developed to address expenses, such as ongoing training, periodic testing, technical assistance, and troubleshooting?

Taken in part from: Hooke, J.H., B.J. Landry, and D. Hart. *Energy Management Information Systems: Achieving Improved Energy Efficiency*. Office of Energy Efficiency, Natural Resources Canada.

4.3.4 Submetering Analysis and Graphical Interfaces

Analysis and graphical display software provide a powerful and convenient means for building owners and operators to assimilate building performance information and to identify opportunities for improving resource use. Dashboards with features and interfaces that are tailored to the needs of building owners, operators, and occupants are currently under development. Dashboards exist for both energy and water use applications.

Distinct from conventional Energy Management and Control Systems (EMCS), these dashboards typically do not provide detailed system operation. Instead, they are designed to display trends and anomalies, and to educate a broad range of building stakeholders about the ecological implications of building performance and user behavior. Many of these products include real-time information displays and allow users to view data using a number of different metrics, such as energy units, utility costs, or carbon emission equivalents.[47]

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[47] "Visualizing Building Information: Using information feedback to educate and influence building managers and occupants." *Centerline* (Winter 2009), 3–9, http://www.cbe.berkeley.edu/centerline/winter2009.pdf.

EIS Graphical Outputs

- **Daily profile—**Displays time-series daily load profiles with time, in intervals of an hour or less, along the horizontal axis and load along the vertical axis.
- **Day overlay—**Displays multiple daily profiles on a single 24-hour time-series graph.
- **Multi-point overlay—**Allows viewing of multiple time-series data points on the same graph.
- **3-D surface chart—**Displays the time of day, date, and variable for study.
- **Calendar profile—**Presents up to an entire month of consumption profiles on a single screen as one long-time series.
- **X-Y scatter plots—**Allow visualizing of correlations between two variables.

Taken in part from: Federal Energy Management Program, "Metering Best Practices: A Guide to Achieving Utility Resource Efficiency," October 2007,

Visualization products by a number of companies provide bundled suites of analysis software and visualization tools. These applications include energy dashboards for both the end user and the facility manager and provide detailed usage metrics, trends, and outputs for management and carbon reporting requirements. They also include real-time load profiles and baseline comparison profiles that correct for weather and other external conditions, so that occupants and building managers can accurately determine the impact of energy conservation initiatives.[48] Recent software analysis offerings can be found in Appendix D.

A report from Lawrence Berkeley National Laboratory, entitled "Building Energy Information Systems: State of the Technology and User Case Studies," presents the following summary of the state of EIS technology:[49]

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[48] Ibid.

[49] Granderson, J., M.A. Piette, G. Ghatikar, P. Price. "Building Energy Information Systems: State of the Technology and User Case Studies," Report No. LBNL-2899E. Lawrence Berkeley National Laboratory, Berkeley, California, 2009.

Business models (General)

- EIS are most commonly offered through an Application Service Provider (ASP) with no hardware or optional hardware based on client needs.
- Optional or bundled services are nearly universally offered.

Display and visualization

- Features have converged to a near common set. Data can be viewed over user-defined intervals of time, trended variables can be aggregated into totals, and the user can overlay multiple datasets on a single plot.
- X-Y scatter plotting is offered in only half of today's EIS solutions.

Energy analysis

- Two-thirds of the EIS feature greenhouse gas analysis or provide custom or configurable options to do so. Most apply a simple energy/carbon dioxide (CO_2) relationship, but almost half account for regional differences in generation or other standards.
- Nearly every EIS permits the user to quantify an energy consumption baseline; however, weather normalization is rare.
- Every tool that was evaluated supports (or will soon support) multi-site benchmarking. Distinguishing aspects include:
    - o Composition of the comparative cohort: buildings within the user's enterprise; comparison to buildings from the vendor's database; or less commonly, national data sets.
    - o Display of results: static reports versus dynamically accessible functions; results depicted in tables, plots, or charts.

Advanced analysis

- About three-quarters of the EIS address data quality, and they do so via three principal means: flagging or summative reporting, cleansing and/or correction, and linking to external or third-party software packages.
- Anomaly detection is typically trend-based and accomplished by identifying departures from normal energy consumption patterns.
- More than half of the EIS forecast near-future loads, usually by coupling historic trends and weather data; very few provide model-based capabilities.
- The large majority of the EIS accommodate some form of measurement and verification (M&V) or the ability to track the impact of operational changes.

Financial analysis

- Energy costing is supported in nearly all of the EIS, and more than half have implemented model-or tariff-based calculations.

Demand response

- Demand response (DR) capabilities have advanced since early 2000 and have converged to a common set of features.
- Automated response to DR signals is supported in all but three of the DR systems that were characterized.
- Remote control and management
- Just over half of the EIS surveyed report the ability to control according to a program, and just under half report internet-capable direct remote control.

Dozens of EIS are commercially available, yet public domain information is often vague, and demonstration software may not be available. In addition, a lack of common terminology across vendors makes it difficult to discern tool functionality or hardware requirements, or to compare the effectiveness of products.[50] Between 60 and 80 percent of the energy used in office buildings is consumed by tenants within their spaces, yet no widely available tools currently exist to help tenants understand their energy consumption or compare it against their peer group.[51] EPA's Portfolio Manager tool, for instance, is widely used for establishing building-level energy performance and ranking, but there is no comparable tool that allows tenants to do the same. Along with providing tenants their own consumption profiles and data, the EIS should offer an energy utilization index—a comparative ranking of tenants against their peer group based on their energy intensity.

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[50] Ibid.

[51] Vornado Realty Trust, undated memorandum, http://www.vnooffice.com/sustainability/welcome.

5. Summary and Recommendations

Submetering energy and water usage in buildings represents an important first step toward quantifying over time the point sources that can drive resource efficiency and conservation activities. Submetering is an enabling technology with significant potential value in new building design or the retrofitting of existing buildings. Submetering alone has no direct impact on resource use, but it provides building owners with real-time system energy and water performance data, highlights performance variations over time or in comparison to other buildings, can feed building automation systems, and establishes a basis for behavioral and operational changes by building operators and occupants. While the cost effectiveness and performance of submetering will vary by building type, building use, climatic considerations, and other factors, numerous case studies provide evidence that the return on investment (ROI) can be significant. Further, submetering provides the necessary infrastructure for more advanced conservation and efficiency techniques such as monitor-based commissioning and autonomic building operation.

This report provides the building community with an understanding of the full complexity and potential benefits of using submeters to improve building performance. The role of submetering is expected to increase over time as building performance requirements become increasingly stringent. To meet these future requirements, the NSTC Subcommittee on Buildings Research and Development makes the following recommendations (Table 2).

Table 2: BTRD Recommendations for Submetering

Recommendation 1: As part of overall building design and retrofit projects, building owners should evaluate the economic and technical feasibility of submetering using life cycle cost analysis for the economic justification and business-case development.

Recommendation 2: When evaluating submetering opportunities, design teams should collaborate with building owners, operators, and occupants, and design, engineering, and information technology professionals to identify data needs and appropriate submetering systems and configurations.

Recommendation 3: Submetering systems should, when possible, be integrated into building automation systems and used to identify building system impairments or dysfunction, to improve operational procedures, drive behavioral changes that improve building energy efficiency and conservation, and augment building-side automation systems that interface with the Smart Grid.

Recommendation 4: Submetering information and feedback mechanisms should be tailored to intended users to effect operational and behavioral change in building operators and occupants. Information and feedback should be of an appropriate form and frequency and should focus on useful breakdowns of resource use; include historical data when appropriate to facilitate comparisons with past use; and, when possible, suggest specific actions that can be taken to reduce consumption.

Recommendation 5: Submetering systems should be operated as production-quality building management systems with high levels of reliability, information assurance and security, established data acquisition/ archival procedures, and periodic system maintenance requirements.

Next Steps: The Subcommittee for Buildings Technology Research and Development is considering two possible activities to follow the publication of this report. These activities will augment the information provided in this report:

a. Development of a checklist or decision flow chart for building owners/operators/managers that guides them through decisions as to when submetering is appropriate and supporting details such as number of submeters, types of meters, types of data collection systems, data analysis tools, etc. This supplemental information will allow for a more rigorous cost-benefit analysis than the case studies provided.

b. Establishment of a stakeholders process to build an open-source platform for voluntary collecting of energy consumption data and metadata associated with Federal and privately owned commercial buildings, and for enabling open access to aggregated data for building performance benchmarking and other applications.

Appendix A: Summary of Regulations for Benchmarking and Metering

While there are relatively few legal requirements or guidance specifically dealing with submetering building resource use, there are many related efforts underway at Federal, state, and local levels in both the public and private sectors. These efforts can be classified into three main types: Federal benchmarking and metering activities, state and local benchmarking and metering activities, and private sector activities, including code development. This appendix provides an overview of some of these activities relevant to building resource metering and submetering.

A.1 Federal Benchmarking and Metering Activities

Statutory Requirements

The Federal government has metering requirements for Federal-owned buildings. Section 103 of the Energy Policy Act of 2005 (EPAct 2005) requires all Federal agencies to install metering and advanced metering *to the maximum extent practicable* by October 1, 2012, to ensure efficient energy use and reduce the cost of electricity used in Federal facilities. The Energy Independence and Security Act of 2007 (EISA 2007) adds a number of additional requirements relevant to submetering. Section 432 of EISA 2007 establishes a framework for facility project management and benchmarking. Agencies must identify all "covered facilities" that constitute at least 75 percent of the agency's facility energy use. Each covered facility must designate an energy manager who will be responsible for:

- Completing comprehensive energy and water evaluations of 25 percent of covered facilities each year, so each facility is evaluated at least once every four years.
- Following up on implemented measures, including fully commissioning equipment, implementing O&M plans, and measuring and verifying energy and water savings.
- Using a DOE Web application to certify and track compliance for energy and water evaluations, project implementation and follow-up measures, and estimated cost and savings. The results will be available to Congress, other Federal agencies, and the public, with some specific data exempted from disclosure for national security purposes.
- Entering energy use data for each metered building into a benchmarking system, such as ENERGY STAR Portfolio Manager.

EISA sections 323 and 435 add energy performance requirements for new construction and leased spaces.

Advanced meters (including submetering systems) are critical catalysts for compliance with these requirements because they enable identification of life cycle cost-effective measures, provide benchmark data, and support monitoring and verification of energy performance. Advanced meters or metering devices must provide data at least daily and measure the electricity consumption at least hourly. Each Federal agency is required to submit to DOE an implementation plan identifying the personnel responsible for achieving metering requirements as well as any determination that advanced meters or metering systems are not practicable in the agency's specific situation. FEMP has issued guidance for this requirement in its *Guidance for Electric Metering in Federal Buildings,*[52] which includes an overview of electric metering technologies and approaches, information about metering cost-effectiveness, and a section on financing metering projects. FEMP has also developed a best practices guide entitled *Metering Best Practices: A Guide to Achieving Utility Resource Efficiency*.[53]

Executive Order 13514

Presidential Executive Order 13514,[54] signed by President Obama in October 2009, establishes 23 separate goals for Federal facilities to reduce greenhouse gases, increase the use of renewable resources, and pursue cost-effective, innovative strategies to minimize consumption of energy, water, and materials. This directive requires Federal agencies to accurately and consistently quantify and account for greenhouse gas emissions using accepted greenhouse gas accounting and reporting principles. Agency efforts and outcomes in implementing EO 13514 must be transparent and disclosed on publicly available Federal Web sites. The installation and use of meters and submeters will be an essential component for Federal agencies to meet the requirements of this order and the requirements for EPAct 2005 and EISA 2007. This directive also requires that Federal facilities improve water use efficiency and management by reducing potable water consumption intensity by implementing water management strategies including water-efficient and low-flow fixtures and efficient cooling towers.

U.S. Department of Defense Instruction 4170.11

The U.S. Department of Defense (DoD) accounted for approximately two-thirds of the total energy used by Federal buildings in 2005. DoD Instruction 4170.11, Installation Energy Management (November 22, 2005 and revised on December 11, 2009), requires DoD to meter electricity, natural gas, and water at appropriate facilities (those where "metering would be cost-effective and practical as a management enhancement tool") and to meter steam at steam plants.

A.2 State and Local Benchmarking and Metering Activities

A number of U.S. states and cities are also developing building-scale data collection programs in support of sustainability initiatives. California, Washington,[55] and four major metropolitan areas (New York City,[56] Austin,[57] Seattle,[58] and Washington, DC[59]) have mandated benchmarking of energy use (and in one case,

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[52] Federal Energy Management Program, "Guidance for Electric Metering in Federal Buildings," February 3, 2006, http://www1.eere.energy.gov/femp/pdfs/adv_metering.pdf.

[53] Federal Energy Management Program, "Metering Best Practices: A Guide to Achieving Utility Resource Efficiency," October 2007, http://www1.eere.energy.gov/femp/pdfs/mbpg.pdf.

[54] Office of the President, Executive Order 13514, "Federal Leadership in Environmental, Energy, and Economic Performance," *Federal Register* 74, no. 194 (8 October 2009), http://www1.eere.energy.gov/femp/pdfs/eo13514.pdf.

[55] "Comparison of Commercial Building Energy Rating and Disclosure Mandates," Institute for Market Transformation, 2010, http://imt.org/files/FileUpload/files/Benchmark/BenchmarkingComparisonMatrixLatest.pdf.

[56] New York City Council Initiative 476-A, 2009, http://www.nyc.gov/html/planyc2030/downloads/pdf/476.pdf.

[57] Austin City Council Energy Conservation Audit and Disclosure Ordinance, 2008, http://www.austinenergy.com/About%20Us/Environmental%20Initiatives/ordinance/index.htm.

[58] Seattle City Council Ordinance 123226, 2010, http://clerk.ci.seattle.wa.us/~scripts/nph-brs.exe?d=CBOR&s1=116731.cbn.&Sect6=HITOFF&l=20&p=1&u=/~public/cbor2.htm&r=1&f=G.

[59] District of Columbia Council Clean and Affordable Energy Act of 2008, http://www.agobservatory.org/library.cfm?refID=106301

water use) for large classes of buildings. In addition, major cities such as Atlanta, Boston, Baltimore, Miami, Portland, and San Francisco are considering proposals to mandate benchmarking for commercial buildings. Table A1 below provides an overview of these activities, including which types of buildings are benchmarked, whether utility data is being used, whether benchmarks are disclosed and how, and the resources being measured.

These programs will generate large amounts of data. For example, New York City's mandate calls for annual aggregate energy and water use data to be benchmarked for approximately 20,000 buildings and eventually published as part of the city's database of property assessments.

Table A1: Summary of State and Local Benchmarking Requirements[60]

Jurisdiction	Public Buildings	Private Buildings	Disclosure	Utility Data	Building Requirement	Resource Measured
California	√	√	Transactional	√		Energy
Washington	√	√	Transactional	√		Energy
Michigan	√					Energy
Ohio	√					Energy
Hawaii	√				Public > 5,000 ft^2 or > 8,000 kWh	Energy
Washington, DC	√	√	Annual		Private > 50,000 ft^2 Public > 10,000 ft^2	Energy
Austin, TX	√	√	Transactional		Commercial > 10 yr old	Energy
Denver, CO	√					Energy
West Chester, PA	√	√				Energy
Seattle, WA	√	√	Transactional	√	Commercial > 50,000 ft^2 Multi-unit res > 5 units	Energy
New York, NY	√	√	Annual		Commercial > 50,000 ft^2 Multi-unit residential Municipal > 10,000 ft^2	Energy, Water

The primary objective of building submetering is to identify systems or areas of high resource use and make changes to those systems to conserve resources. One strategy used by cities leverages this objective by requiring public disclosure of billing data, with the idea that disclosure of building consumption is useful for performance verification by potential buyers and renters, adding transparency to real estate and rental property evaluations. For potential owners or occupants, knowing a building's energy and water usage can be useful information when comparing similar buildings. If all else is equal, why not choose the more energy- or water-efficient building?

There are a number of examples of established public disclosure programs, and probably the oldest and most well-known is ENERGY STAR.[61] The ENERGY STAR label or rating is conferred to buildings

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[60] State and Local Governments Leveraging Energy Star, http://www.energystar.gov/ia/business/government/State_Local_Govts_Leveraging_ES.pdf.

[61] ENERGY STAR®, "Guidelines for Energy Management Overview," http://www.energystar.gov/index.cfm?c=guidelines.guidelines_index.

in the lowest 25th percentile of energy consumption for each building type, as reported in the most recent Commercial Buildings Energy Consumption Survey (CBECS).[62] Currently in pilot phase, the Building Energy Quotient program[63] from ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers) is another example of a labeling program that may be used to satisfy mandatory public disclosure requirements. All of these disclosure requirements and labeling programs harness the power of the marketplace and the desire of potential tenants and buyers of energy-efficient buildings.

ENERGY STAR Program

ENERGY STAR, EPA's voluntary partnership program, offers a proven energy management strategy that helps in measuring current energy performance, setting goals, tracking savings, and rewarding improvements. Building owners and operators can benchmark any commercial facility in EPA's Portfolio Manager tool to track energy, water, environmental, and financial performance over time. EPA's 1-100 energy performance score is also available for 14 building types, including offices, schools, hotels, retail stores, and many more. For most of these building types, statistically representative models are used within Portfolio Manager to compare a building against similar buildings from a national survey conducted by the Department of Energy's Energy Information Administration. This national survey, known as the Commercial Building Energy Consumption Survey (CBECS) is conducted every four years, and gathers data on building characteristics and energy use from thousands of buildings across the United States. The models for hospitals, data centers, and wastewater treatment plants are based on robust industry surveys that gather statistically representative data on specific operating parameters and characteristics. The score is based on source energy and accounts for the impact of weather variations as well as changes in key physical and operating characteristics of each building. Buildings rating 75 or greater may qualify for the ENERGY STAR label.

For more information, see
http://www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager#rate

A.3 Model Code Requirements

In addition to government-led initiatives, some building energy codes have mandated metering and submetering. Submetering of individual tenants in multiple-tenant buildings was once a requirement in the national model energy codes. ANSI/ASHRAE/IESNA Standard 90.1-1989 Section 5.4.1.2 stated, "In multiple tenant buildings, each tenant shall be individually metered. Provisions to permit check metering of the tenant load shall be provided for those tenants having a connected load of 100 kVA or more. HVAC or solar water heating (SWH) systems shared by tenants in common need not meet this tenant check metering requirement but shall be separately metered as required." The term check metering was defined as "measurement instrumentation for the supplementary monitoring of energy consumption

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[62] U.S. Energy Information Administration, 2003 Commercial Buildings Energy Consumption Survey (CBECS), http://www.eia.doe.gov/emeu/cbecs/.

[63] ASHRAE Building Energy Quotient Program, http://buildingeq.com/.

(electric, gas, oil, etc.) to isolate various categories of energy use to permit conservation and control, in addition to the revenue metering furnished by the utility."

As a method of providing information to tenants so they could make informed decisions on energy conservation, this requirement was appropriate and ahead of its time. Unfortunately, it was deleted from later versions of Standard 90.1 and was never found in the model energy codes or the International Energy Conservation Code. Some state and local codes, however, picked up this requirement or a variant of it (e.g., the Chicago Energy Code).[64]

There has been renewed interest in metering and submetering in the energy code development communities. There were proposals to reintroduce metering requirements in Standard 90.1, but the proposals did not pass in time to be included in the 2010 version. ASHRAE/USGBC/IES Standard 189.1 2009 [65] contains sections that require metering of energy and water usage (see Section 6.3.3 for water consumption management and Section 7.3.3 for energy consumption management). The draft International Green Construction Code (IGCC)[66] contains similar provisions (see Section 604 for energy metering, monitoring, and reporting; Section 604.5 for energy load-type submetering; Section 611.5 for renewable energy system performance monitoring and metering; and Section 705.2 for water metering).

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[64] The Chicago Energy Code is viewable as Chapter 18 of the Chicago Municipal Code at http://www.amlegal.com/nxt/gateway.dll/Illinois/chicago_il/municipalcodeofchicago?f=templates$fn=default.htm$3.0$vid=amlegal:chicago_il. See section 18-13-505.7 for electrical energy consumption for buildings having individual dwelling units.

[65] ANSI/ASHRAE/USGBC/IES Standard 189.1-2009, Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings.

[66] ICC International Green Construction Code. Public Version 1, available for download via links at http://www.iccsafe.org/cs/igcc/pages/default.aspx.

Appendix B: Summary of Behavioral Responses to Energy Feedback

Residential sector research of multi-tenant or multi-space buildings shows that increasing consumers' awareness of their resource consumption patterns can lead to conservation. The installation of smart meters or submeters, if coupled with appropriate data, networks, analysis tools, and strategies, can provide stronger feedback mechanisms to help end users monitor, understand, and reduce their resource use.

Residential sector research has also focused on consumers' behavioral responses to feedback on energy consumption. There are a number of proven methods to inform building occupants and operators about their energy use—some methods are specific to end users, while others are best suited to building operators. None requires the use of a smart meter or submeter, although these devices can be effectively used to provide ongoing month-to-month performance data.

Feedback Mechanisms

Direct feedback is delivered immediately from a meter or an associated display monitor. This type of feedback ties an action to its energy cost by showing the cost immediately after the action. However, this raw usage data may also lead to information overload and overwhelm a building occupant or operator.

Indirect feedback has been processed in some way before reaching the consumer, as in a monthly utility bill. Improved forms of indirect feedback, including more frequent mailings or more salient billing (e.g., illustrative graphs) have been effective in significantly reducing energy use. Indirect feedback may also incorporate historical analysis or other creative metrics; however, the chief disadvantage is the time lag between action and feedback.

Disaggregated feedback uses the unique signatures of smart appliances to identify costs by end use. (The algorithmic approach is sometimes referred to as non-intrusive appliance load monitoring.) This can help consumers identify the most significant sources of resource use. On the other hand, the technology to perform disaggregation can be expensive and may not always be cost-effective.

Historical feedback compares present usage to usage in a prior time period (e.g., the same month in the previous year). Historical feedback allows consumers to benchmark their progress, though due to climate variability, it may not always provide a reliable comparison.

Comparative feedback presents a user's consumption with that of a comparable set of users (e.g., grouped by building, organization, or zip code) in an attempt to produce conservation through social or operational norms. One criticism of comparative feedback is the possibility of triggering a boomerang effect in which lower-than-average consumers increase resource use to match the average usage rate of the peer group; another is the possibility of antagonizing users who resent comparison.

Digital feedback uses computer and electronic displays to present multiple or interactive viewing options for feedback presented to the consumer.

Behavioral approaches also can help end users understand and reduce their energy and water use. These approaches include tailored information, goal setting, rewards, and time-of-use pricing mechanisms to reduce peak load. All have been shown to be effective in some circumstances and ineffective in others; they are often used in tandem with feedback in the objective of producing synergistic effects.

Literature reviews from the last 10 years[67] show that feedback mechanisms result in energy reductions ranging from 0 to 20 percent. However, the quality of the studies is inconsistent. Many studies are too short in duration, too small in sample size, or too uncontrolled to allow for meta-analysis or extrapolation to predict long-term effectiveness. Due to this variability, more examination is required to establish which types of feedback mechanisms, at which time intervals and through which media, will most substantially contribute to energy conservation in specific settings. Nevertheless, some consensus has emerged regarding the kinds of feedback interventions that produce the most energy conservation:

Direct feedback—The reviews generally concurred that direct feedback is more effective than indirect feedback, although indirect feedback leads to substantial savings in heating loads (which tend to manifest over longer periods).

Frequency—More frequent feedback tends to be more effective. In particular, feedback on at least a daily basis improves conservation. More frequent feedback may also lead to more persistent savings, even after the feedback has been discontinued, though this result is less well established.

Disaggregation—Detailed appliance-specific breakdowns of energy use tend to improve conservation. However, it is not as clear whether disaggregation is more effective if the data are presented via the appliance itself or remotely (e.g., from a computer).

Digitization—Computerized feedback programs, especially those with multiple and/or interactive viewing options, tend to be the most effective. Systems that allow the consumer to pick the most salient view of energy use appear to increase engagement.

Historical and comparative feedback—Studies, which included interviews, found that households tend to like detailed feedback that includes historical and comparative feedback.[68] However, they also found no significant difference between the effectiveness of historical and comparative feedback used independently, and the overall effectiveness of both methods when taken together.

Advice—Energy feedback containing personalized advice about specific actions to reduce consumption tends to enhance energy conservation. Yet advice alone is rarely effective—it tends to increase knowledge of energy-efficient behaviors but does not typically affect actions.[69]

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[67] Abrahamse, W., L. Steg, C. Vlek, and T. Rothengatter, "A review of intervention studies aimed at household energy conservation," *Journal of Environmental Psychology* 25, no. 3 (2005): 273–291; Darby, S, "The effectiveness of feedback on energy consumption," A Review for DEFRA of the Literature on Metering, Billing and Direct Displays, 2006; Faruqui, A., S. Sergici, and A. Sharif, "The impact of informational feedback on energy consumption—A survey of the experimental evidence," *Energy* 35, no. 4 (2010): 1598–1608; Roberts, S. and W. Baker, "Towards effective energy information: Improving consumer feedback on energy consumption," Bristol, UK: Center for Sustainable Energy, 2003.

[68] Ibid

[69] Henryson, J., T. Hakansson, and J. Pyrko. "Efficiency in buildings through information—Swedish perspective." *Energy Policy* 28, no. 3 (2000), 169–180.

Commercial buildings—In residential settings, the desire to save money on utility bills motivates individuals to conserve. In office settings, a similar motivation may not exist. Relatively little is understood on how to encourage conservation in this context.

Feedback design—Optimal location, content, units, and timescale of feedback require additional understanding. Only a few studies have examined the difference between, for example, giving feedback in dollars versus kilowatt-hours. In addition, very little is known about the kinds of electronic media that are most effective at engaging consumers. This could be an important factor in office settings inundated with electronic devices and displays.

Granularity—Research has typically shown that more granular feedback is more effective. However, there have been few studies comparing different timescales of feedback, and their wide variability in quality makes inter-study comparison difficult.

Source of data—In the residential sector, the source of information—e.g., a utility versus a third-party group—can affect its reception.[70] More work is needed in both residential and commercial settings to better understand what sources of feedback are likely to be heeded most often.

Combination with other techniques—Many studies and operational feedback-based conservation campaigns combine feedback with non-feedback elements, such as goal setting. However, there is not yet a systematic understanding of the synergistic or antagonistic interactions between behavioral interventions.

Long-term effects—Most studies last on average a few months, although some have been as short as two weeks or as long as two years. As a result, relatively little is known about the long-term effects of feedback, or about the lasting effects of feedback once it is removed.

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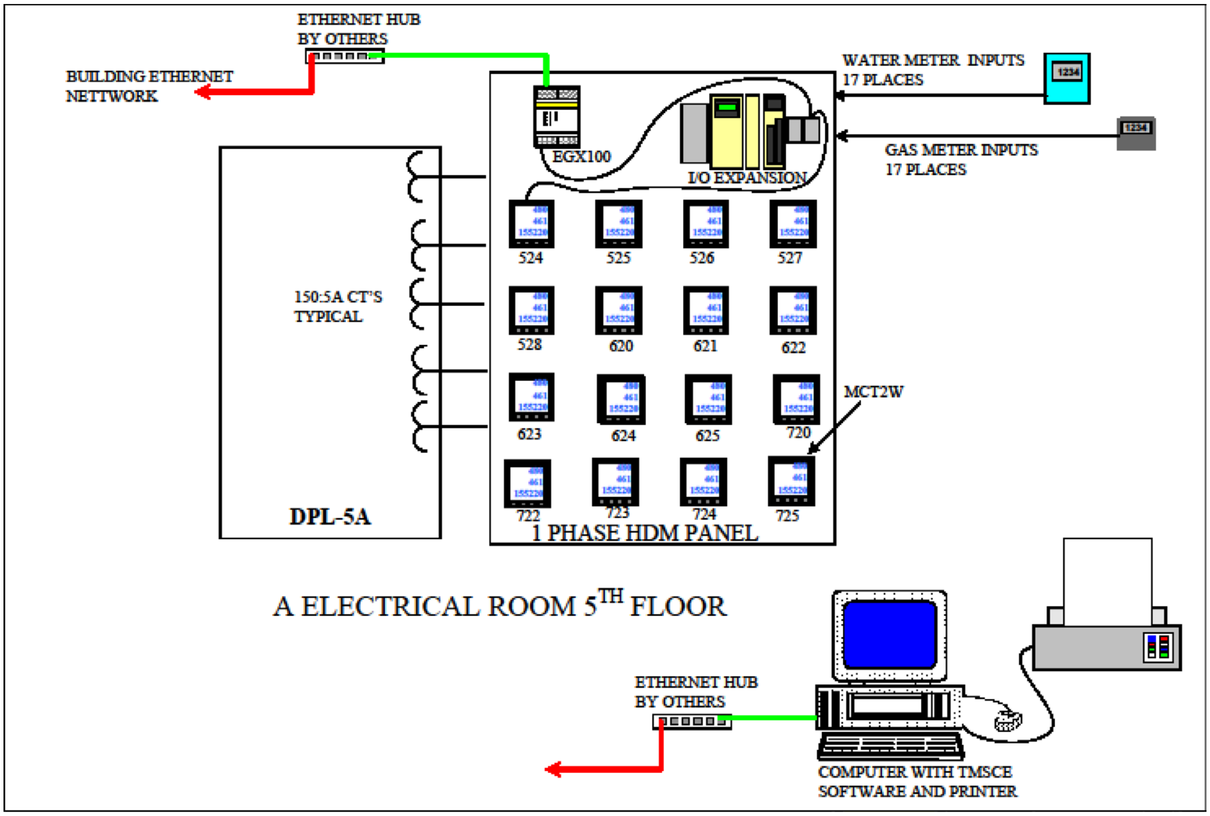
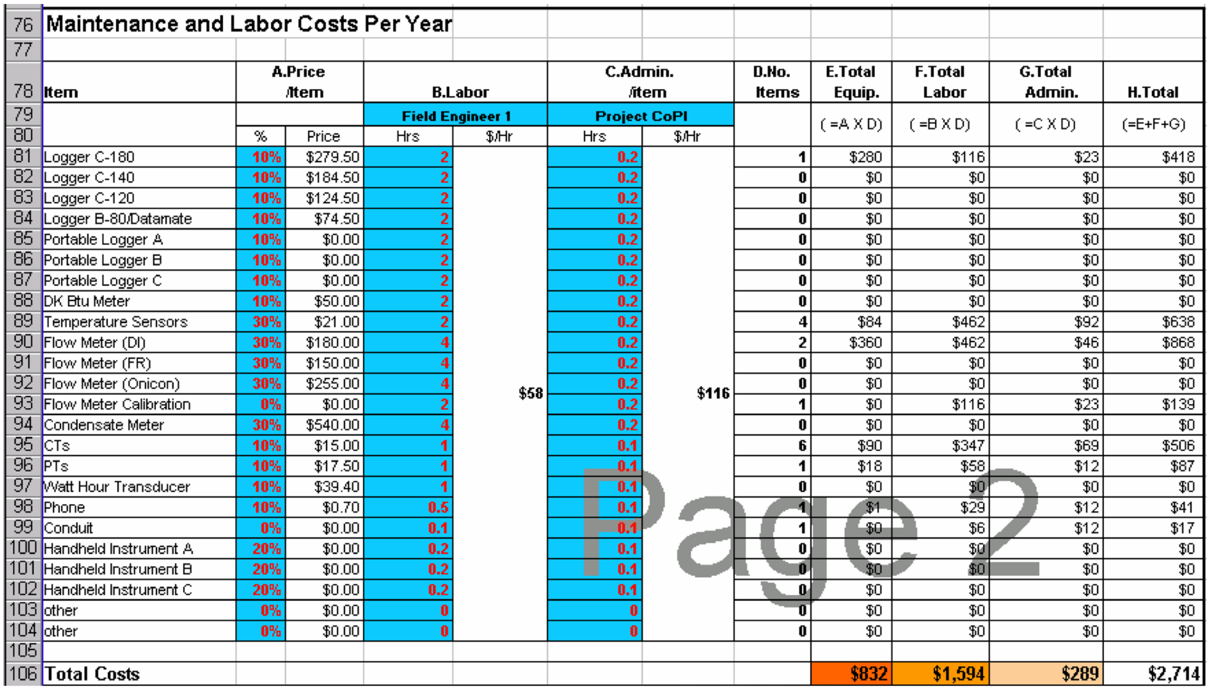
70. Craig, C. S., and J. M. McCann. "Assessing Communication Effects on Energy Conservation." *The Journal of Consumer Research* 5, no. 2 (1978): 82–88.

Appendix C: Submetering Equipment, Configurations, and Costs

The images and tables provided courtesy of Square D, a brand of North American Operating Division of Schneider Electric, Inc., for use in this report. The data represents a fictitious sample implementation and associated costs.

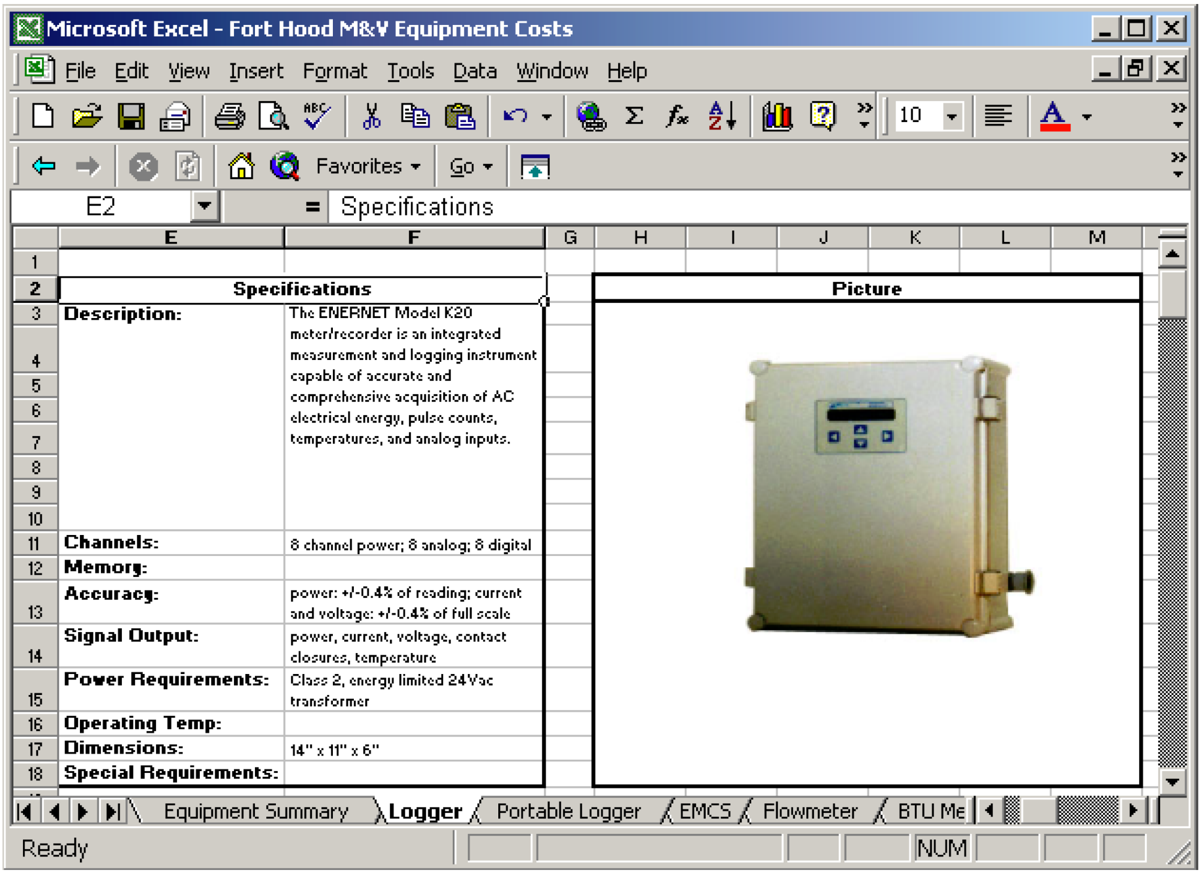


Qty	*Description*	*List Ea.*	*Total List*
	Gas & Water Metering Kits - Pulse Inputs (Field Installed in HDM Box)		
4	HDM Ethernet and I/O Expansion Kit: 1-EGX100, PS & Twido I/O 120/240V - 24VDC P/S (44 Digital Inputs)	$ 2,280	$ 9,120
	NEMA 1, Single Phase		
3	HDM, 120/208/240V, 1Ph, 1 Meter Box, 1 meter installed - PM210	$ 400.00	$ 1,200
	PM210 Tenant Submetering (240 Volt Max, 1 Phase)		
2	HDM, 240V Max, 1Ph, 16 Meter Box, 14 meter installed - PM210	$ 9,271	$ 18,542
2	HDM, 240V Max, 1Ph, 16 Meter Box, 16 meter installed - PM210	$ 10,342	$ 20,684
	Accessories		
4	2-Wire Modbus Terminator	$ 84	$ 336
	Tenant Metering Software		
1	Tenant Metering Software Commercial Edition	$ 5,880	$ 5,880
	PMO-ES Standardized PC Hardware		
1	OptiPlex 755 Minitower, Core 2 Duo E6550/2.33GHz 4M VT 1333FSB, 2GB DDR2 Non-ECC SDRAM, 800MHz (2DIMM), 160GB High Reliability SATA 3.0Gb/s and 8MB Data Burst Cache, Integrated Video (GMA3100), ONBOARD NIC, Windows XP SP2 Pro, 48X32 CDRW/DVD Combo, PS2 Serial Port Adapter, USB KB / Mouse, Energy Smart/Energy Star, vPro Secure Advanced Hardware Enabled Systems Management	$ 1,606	$ 1,606
1	Dell Ultra Sharp, Flat Panel Monitor, 19" LCD, 1280x1024 Max Pixel Resolution, Digital DVI-D and Analog Inputs, Adjustable Height Stand w/Swivel & Tilt, 4 USB 2.0 Ports	$ 662	$ 662
1	Color Laser Printer, Letter and Legal Size Paper, 600x600 DPI, USB 2.0	$ 1,531	$ 1,531
	HDM CT's		
120	150 Amp HDM Solid Core Current Transformer 1.13" Window Size	$ 35	$ 4,200
	Cold Water Meters		
65	3/4" X 7.5" LowLead C700 with Glass Digital Register	$ 213	$ 13,872
	Gas Meters		
65	G4 Gas Meter with 1 pulse per cubic foot, Sprague #1 connections, non-compensated	$ 398	$ 25,870
	Startup & Commissioning Services: PowerLogic Tier A Project		
1	Onsite Startup/Commissioning work per PMO Engineering Services Standard Scope of Work.	$ 1,778	$ 10,668
1	Documentation package that includes preliminary/as-built system drawing, as required, and project files.	$ 833	$ 833
1	Onsite Customer System Training for ES Projects Provided solutions - brief overview of products and system should be included in Startup & Commissioning quote.	$ 1,778	$ 1,778
			$ 116,782



76	Maintenance and Labor Costs Per Year											
77												
78	Item	A.Price /Item		B.Labor		C.Admin. /item		D.No. Items	E.Total Equip.	F.Total Labor	G.Total Admin.	H.Total
79				Field Engineer 1		Project CoPI			(=A X D)	(=B X D)	(=C X D)	(=E+F+G)
80		%	Price	Hrs	$/Hr	Hrs	$/Hr					
81	Logger C-180	10%	$279.50	2	$58	0.2	$116	1	$280	$116	$23	$418
82	Logger C-140	10%	$184.50	2		0.2		0	$0	$0	$0	$0
83	Logger C-120	10%	$124.50	2		0.2		0	$0	$0	$0	$0
84	Logger B-80/Datamate	10%	$74.50	2		0.2		0	$0	$0	$0	$0
85	Portable Logger A	10%	$0.00	2		0.2		0	$0	$0	$0	$0
86	Portable Logger B	10%	$0.00	2		0.2		0	$0	$0	$0	$0
87	Portable Logger C	10%	$0.00	2		0.2		0	$0	$0	$0	$0
88	DK Btu Meter	10%	$50.00	2		0.2		0	$0	$0	$0	$0
89	Temperature Sensors	30%	$21.00	2		0.2		4	$84	$462	$92	$638
90	Flow Meter (DI)	30%	$180.00	4		0.2		2	$360	$462	$46	$868
91	Flow Meter (FR)	30%	$150.00	4		0.2		0	$0	$0	$0	$0
92	Flow Meter (Onicon)	30%	$255.00	4		0.2		0	$0	$0	$0	$0
93	Flow Meter Calibration	0%	$0.00	2		0.2		1	$0	$116	$23	$139
94	Condensate Meter	30%	$540.00	4		0.2		0	$0	$0	$0	$0
95	CTs	10%	$15.00	1		0.1		6	$90	$347	$69	$506
96	PTs	10%	$17.50	1		0.1		1	$18	$58	$12	$87
97	Watt Hour Transducer	10%	$39.40	1		0.1		0	$0	$0	$0	$0
98	Phone	10%	$0.70	0.5		0.1		1	$1	$29	$12	$41
99	Conduit	0%	$0.00	0.1		0.1		1	$0	$6	$12	$17
100	Handheld Instrument A	20%	$0.00	0.2		0.1		0	$0	$0	$0	$0
101	Handheld Instrument B	20%	$0.00	0.2		0.1		0	$0	$0	$0	$0
102	Handheld Instrument C	20%	$0.00	0.2		0.1		0	$0	$0	$0	$0
103	other	0%	$0.00	0		0		0	$0	$0	$0	$0
104	other	0%	$0.00	0		0		0	$0	$0	$0	$0
105												
106	Total Costs								$832	$1,594	$289	$2,714

The image below was developed by the Energy Systems Laboratory U.S. Army Construction Engineering Research Laboratory as part of *U.S. Army Measurement and Verification (M&V) Costing Toolkit,* published in December 2003 for the U.S. Army Construction Engineering Research Laboratory.



E2 = Specifications

Specifications	
Description:	The ENERNET Model K20 meter/recorder is an integrated measurement and logging instrument capable of accurate and comprehensive acquisition of AC electrical energy, pulse counts, temperatures, and analog inputs.
Channels:	8 channel power; 8 analog; 8 digital
Memory:	
Accuracy:	power: +/-0.4% of reading; current and voltage: +/-0.4% of full scale
Signal Output:	power, current, voltage, contact closures, temperature
Power Requirements:	Class 2, energy limited 24Vac transformer
Operating Temp:	
Dimensions:	14" x 11" x 6"
Special Requirements:	

Picture

Cost estimate for a electricity submeter installation on a college campus based on six submeters in three separate locations (data provided courtesy of Kapadia Energy Services.)

Item Description	**Quantity**	**Unit Material Cost**	**Unit Labor Cost**	**Total Cost**
Electricity submeter with demand display and pulse device	6	$1,200	$450	$9,900
Current transducers	18	$300	$320	$11,160
16 point PLC reading board	3	$1,400	$600	$6,000
Terminal Interrogation Module w/modem	3	$2,400	$500	$8,700
Windows-based meter reading software	1	$3,500	$200	$3,700
Supervision of installation and setup	1		$1,500	$1,500
Total Cost:				**$40,960**

Appendix D: Recent EIS Software Products

Vendor	Product Name	URL
Abraxas Energy Consulting	EnergyCAP	https://www.abraxasenergy.com/energycap/
Abraxas Energy Consulting	Metrix4 Utility Accounting System	http://www.abraxasenergy.com/metrix4/
Activelogix	Periscope	http://www.activelogix.com/about_periscope.asp
Advantage IQ	Energy Services	http://www.advantageiq.com/WhatWeDo/EnergyServices/tabid/174/Default.aspx
Agilewaves	Building Optimization System	http://www.agilewaves.com/resource-monitor-commercial/
BITHENERGY	Utility Data Analysis Software	http://www.bithenergy.com/Utility-Data-Analysis.html
BizEE	Energy Lens	http://www.energylens.com/
Burton Energy Group	Management Reports	http://www.burtonenergygroup.com/utility-information-management.html
E Source	E Source Facility Metrics	http://www.energy-accounting.com/stark.html
EFT Energy	Energy Manager V5.2	http://www.eft-energy.com/energy/products/energy-manager-v52
Energard Technologies	Envision	http://www.energard.com/page3.htm
enerGXpert	enerGXpert	http://www.energxpert.com/
Energy Essentials	Stark RT & Stark Essentials	http://www.starkna.net/about.htm
ENERGY STAR	Portfolio Manager	http://www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager
Energy Tracking	Energy Tracking Analytics	http://www.energytracking.com/ET_Analytics.htm
Energy WorkSite	Energy Expert	http://www.energyworksite.com/corporate/
EnergyPro	EnergyPro Solutions	http://www.energyprosolutions.com/about-energypro-solutions-ltd/
EnTechUSB	Interval Data Reporting & Monitoring Service	http://www.entech.co.uk/entechusb/Services.aspx?id=7
EnVINTA	ENTERPRIZE.EM	http://www.envinta.com/?page_id=65
eSight Energy Group	eSight	www.eSightEnergy.com
FirstEnergy Solutions—The E Group	Utility Risk Management	http://egrp.org/content/egroup/what_we_do.html
Good Steward Software LLC	EnergyCAP Enterprise	http://energycap.com/
Itron	Enterprise Energy Management Suite	https://www.itron.com/na/productsAndServices/Pages/Itron%20Enterprise%20Edition%20Customer%20Care%20Suite%20%20Cl.aspx
Kilojolts	EnerCop Suite	http://www.kilojolts.com/software/
LPB Energy Management	LPB's Utility Manager	http://www.lpbenergy.com/utility-manager.htm
MACH Energy	MACH Asset Manager	http://www.machenergy.com
McKinstry	EEM Suite Financial Management Solutions	http://www.mckinstryeem.com/

Vendor	Product Name	URL
Noveda Technologies	EnergyFlow Monitor	http://www.noveda.com/solutions/core-products/energyflow-monitor/
Pace	EnControl Suite	http://www.paceglobal.com/EnergyCarbonManagement.aspx
Pulse Energy	Pulse Energy Management Software	http://www.pulseenergy.com/site/pulse-platform/
Schneider Electric	EPO Energy Profiler Online	http://www.powerlogic.com/product.cfm/c_id/2/sc_id/14/p_id/27#
Schneider Electric	EVO Energy View Online	http://www.powerlogic.com/product.cfm/c_id/2/sc_id/27/p_id/53#
Schneider Electric	PowerLogic ION EEM	http://www.powerlogic.com/product.cfm/c_id/2/sc_id/15/p_id/28
Utility Management Services	Utility Manager Pro	http://www.utilityaccounting.com/software_compare.php

Source: E Source. Last updated August 9, 2010.

Appendix E: Federal Guidance and Tools for Facility Management, Metering, and Compliance

E.1 Guidance for Federal Resource Management and Sustainability Goal Compliance

Guidance for Electric Metering in Federal Buildings (FEMP, 2006): Provides Federal building operators with interpretation and guidance related to the Energy Policy Act of 2005 (EPAct 2005) requirement for installing energy meters in all Federal buildings. An addendum to this guide addressing metering of natural gas and steam is under development.
http://www1.eere.energy.gov/femp/pdfs/adv_metering.pdf

Facility Energy Management Guidelines and Criteria for Energy and Water Evaluations in Covered Facilities (FEMP, 2008): Contains guidelines for Federal agencies related to designating covered facilities, assigning energy managers, and performing comprehensive evaluations.
http://www1.eere.energy.gov/femp/pdfs/eisa_s432_guidelines.pdf

DRAFT Guidance for the Implementation and Follow-up of Identified Energy and Water Efficiency Measures In Covered Facilities (FEMP, 2010): Establishes steps for agencies to follow when implementing comprehensive evaluations, including how to perform a commissioning assessment, how to work with energy services companies (ESCOs) to install and monitor/verify retrofits, and how to use the Compliance Tracking System (CTS), an online system for reporting benchmarking and the status of evaluations to FEMP. Currently not available online.

Building Energy Use Benchmarking Guidance (FEMP, 2010): Interprets the requirement to benchmark the energy use of all "covered facilities" under EISA 2007, including the list of criteria for covered facilities and using a benchmarking system such as ENERGY STAR Portfolio Manager.
http://www1.eere.energy.gov/femp/pdfs/eisa432_guidance.pdf

Energy Savings Assessment Training Manual (FEMP, 2010): Provides information on advancing self-sufficiency and using on-site energy audits. Currently not available online.

Federal Water Efficiency Best Management Practices (FEMP, 2010): Provides agencies with guidance to achieve water efficiency goals and assists with implementing Executive Orders 13123 and 13423.
http://www1.eere.energy.gov/femp/program/waterefficiency_bmp.html

E.2 General Guidance and Tools for Facility Management and Efficiency Projects

Building Upgrade Manual (EPA, 2008): Outlines a process for implementing strategic upgrades on commercial buildings, listing the most efficient measures and improvements in a practical order and providing case studies for specific building types.
http://www.energystar.gov/index.cfm?c=business.bus_upgrade_manual

Continuous Commissioning^{SM} Guidebook for Federal Energy Managers (FEMP, 2002): Provides a detailed discussion of commissioning measures for Federal facilities, including HVAC, air handling units, water and steam systems, chillers and heat plants, and thermal storage, as well as how to monitor these measures over time. http://www1.eere.energy.gov/femp/pdfs/ccg01_covers.pdf

Commissioning for Federal Facilities (FEMP 2008): Includes an overview of the general processes of commissioning new buildings as well as retrocommissioning, recommissioning, and continuous commissioning of existing buildings from a management perspective.
http://www1.eere.energy.gov/femp/pdfs/commissioning_fed_facilities.pdf

M&V Guidelines: Measurement and Verification for Federal Energy Projects, Version 3.0 (FEMP, 2008): Provides guidance on measurement and verification practices associated with Federal resource efficiency projects. Projects included cover areas such as energy efficiency and water conservation measures, construction, improved operations and maintenance, cogeneration, and renewable energy.
http://www1.eere.energy.gov/femp/pdfs/mv_guidelines.pdf

Operations & Maintenance Best Practices: A Guide to Achieving Operational Efficiency, Release 3.0 (FEMP, 2010): Provides facility managers with a comprehensive overview of building operations and maintenance, including Computerized Maintenance Management Systems, commissioning, metering, and predictive maintenance. http://www1.eere.energy.gov/femp/pdfs/omguide_complete.pdf

Life-Cycle Costing Manual for the Federal Energy Management Program (NIST Handbook 135) (NIST, 1996): Explains, in detail, the principles of life-cycle cost analysis and integrates them with FEMP criteria on how agencies shall use life-cycle cost analysis in making decisions about investments in products, services, construction, and other projects. http://fire.nist.gov/bfrlpubs/build96/PDF/b96121.pdf

- ***Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis—2010*** (NIST 2010): provides annual updates to the LCC Manual. http://www1.eere.energy.gov/femp/pdfs/ashb10.pdf
- ***Building Life-Cycle Cost*** software(BLCC5) provides computational support for analyzing capital investments in buildings using factors from the LCC Manual, including specific analysis capabilities for both appropriations-funded projects as well as energy savings performance contract (ESPC) or utility energy savings contract (UESC) projects financed with private capital. http://www1.eere.energy.gov/femp/information/cfm/register_blcc.cfm

Facility Energy Decisions System (FEDS) Model (PNNL 2010): Assists with optimizing life-cycle cost savings using a suite of measures that are selected based on user input about a building or group of buildings. A Windows-based software system, FEDS can be used for Federal facilities where multiple buildings use the same meter. http://www.pnl.gov/feds/

Appendix F: State of Federal Sustainability Initiatives

Federal agencies are now required to address several overlapping and partially competing goals related to sustainability. Many of these goals are quantitative and require the use of specific tools or reporting systems to calculate and report results for compliance. While a number of tools are available for budgeting energy and emissions, four are most relevant to Federal sustainability goals: EPA's ENERGYSTAR Portfolio Manager, FEMP's Sustainability Report and Compliance Tracking System (CTS), and GSA's Carbon Footprint and Green Procurement Tool. Any of these tools can be used to calculate compliance with sustainability initiatives, as summarized in Table F1. (Note: GSA's Carbon Footprint and Green Procurement Tool is a bottom-up calculator aimed to assist agencies in greenhouse gas (GHG) calculations, which can then be reported in the FEMP Sustainability Report.)

Some of these requirements, such as GHG reporting under Executive Order 13514, are too new to have status updates as their first reporting has not yet occurred (EO 13514 reporting is scheduled for January 2011). However, both GHG requirements are tracked by FEMP, and preliminary data is available up to fiscal year 2009. Current compliance with these requirements is summarized in Table F2.

Table F1: Summary of recent Executive Orders and Statutes setting quantitative goals on agency facility energy and water use and GHG emissions.

Order/Statute	Type of Sustainability Goal		
	Energy	**Water**	**Greenhouse Gas**
EO 13423	░ Decrease building energy use 3% annually or 30% by 2015, 2003 baseline	░ Decrease water use intensity 2% annually or 16% by 2015, 2007 baseline	
EO 13514		░ Decrease water use intensity 2% annually or 20% by 2020, 2007 baseline	░ Agency-wide, meet Scope 1 and 2 baseline and 2020 reduction goal by January 2010, Scope 3 by June 2010
EPACT 2005	░ Implement building-level metering in all federal facilities ░ Purchase renewable energy, 3% 2007-2009, 5% 2010-2012, 7.5% 2013 onward		
EISA 2007	▒ Implement mandatory energy benchmarking ▓ Assign energy manager for covered facilities and institute energy and water audits every 4 years		

░ Represents requirements reported to FEMP Sustainability Report; ▒ Represents requirements reported to EPA ENERGYSTAR Portfolio Manager; ▓ Represents requirements reported to FEMP Compliance Tracking System.

Table F2: Current state of implementation of quantitative Federal sustainability goals.

Order/Statute	Requirement	Quantitative Goal FY 2009	Current Status FY 2009 (All)	Current Status FY 2009 (Non-Defense)	Agency Range
EPAct 2005	Metering	N/A, 100% by 2012	80%	89%	30% – >100%[71]
EPAct 2005	Renewable Energy Purchase	3%	4.2%	4.8%	0.1% – 116%[72]
EISA	Facility Energy	12% reduction	13% reduction	18% reduction	0% – 36%
EISA	Facility Evaluations	50% (CY 2009)	38% - 45%	47% - 64%	0% – 100%
EO 13423	Facility Water	4% reduction	4.6% reduction	4.1% reduction	-15% – 22%

Perhaps most relevant to submetering, the Energy Policy Act of 2005 (EPAct 2005) requires Federal facilities to be metered for electricity whenever practical at the building scale by 2012. Already, 80 percent of Federal facilities and 89 percent of non-defense agencies are metered at the building scale as of fiscal year 2009. Agency compliance ranges from 30 percent to over 100 percent (representing agencies with buildings containing both standard and advanced meters).

In terms of facility energy use and facility water use, government-wide implementation met its goals for fiscal year 2009, with a 13 percent reduction in facility energy use over 2003 (compared to a goal of 12 percent), and a 4.6 percent reduction in facility water use over 2007 (compared to a goal of 4 percent). Because the DoD represents such a large share of overall facility resource use, the current status of Federal agencies other than DoD is shown separately. Overall, DoD has performed better than the average for water usage reductions partially due to prior metering requirements.[73] At the Federal agency level, results vary substantially, from a 0 to 36 percent reduction in energy use and a -15 to 22 percent reduction in water use, compared with the baseline year. It should be noted that the Federal Government is only meeting its goals for energy use reductions when taking source reduction credits for renewable energy purchases; without taking credit for the use, overall energy use reductions are only 9 percent compared to the goal of 12 percent.

Similarly, renewable energy purchase goals are on target, with a current proportion of renewable electricity of 4.2 percent compared to the goal of 3 percent for 2009. Agencies other than DoD are slightly higher at 4.8 percent. However, the goal will jump to 5 percent in fiscal years 2010 to 2012, and to 7.5 percent after that, so substantial investment in renewable energy generation or purchases will likely be needed in coming years.

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[71] FEMP statistics track total number of meters: buildings may have both a smart meter and a standard meter, hence values may exceed 100%.

[72] EPA generates and purchases more renewable energy than the total amount it consumes.

[73] DoD Instruction 4170.11, Installation Energy Management first released on November 22, 2005 and revised on December 11, 2009 requires metering electricity, natural gas, steam, and water at appropriate facilities for all new military construction, major renovations, and ESPC projects.

In terms of comprehensive energy and water evaluations for the Energy Independence and Security Act (EISA) Section 432, the first round of evaluations is nearly halfway done, with most agencies evaluating around 50 percent of facilities as of November 2010. These evaluations are complicated by two factors, however—first, EISA evaluations are tallied on a calendar rather than fiscal year basis, and second, FEMP released three different metrics for evaluating buildings: total facility energy use, total number of facilities, and total facility square footage. As of FY 2009, preliminary data from FEMP's CTS shows that the evaluated share of facility energy use is 35 percent, though nearly 45 percent of facilities by number have been evaluated. From a square footage basis, 38 percent have been examined. By all three measures, agencies are making steady progress, approaching the calendar year target of 50 percent.

Similar to those objectives previously described, the results for evaluations by agency are extremely mixed, with some agencies (e.g., VA and USPS) evaluating a large fraction of their facilities (97 percent and 82 percent, respectively) and other agencies lagging significantly. An interesting trend relevant to metering is that there seems to be a negative correlation between average facility size and how quickly evaluations take place in different agencies. Audits at small facilities are less time-intensive and costly than those at large multi-building facilities such as military bases and laboratory campuses. Thus, facilities with the smallest average size, such as the USPS, have audited a large proportion of buildings, and facilities with the largest average size, such as the DoD, NASA, and DOE are affiliated with the lowest percentages of evaluated energy.

National Science and Technology Council
Committee on Technology

Subcommittee on Buildings Technology Research and Development