April 2002

Sub-Metering Energy Use in Colleges and Universities: Incentives and Challenges

A Resource Document for Energy, Facility, and Financial Managers

from the U.S. Environmental Protection Agency's ENERGY STAR®

1. INTRODUCTION

The supply and costs of energy have become increasingly volatile over the last several years, and the electricity shortages and rising costs of natural gas in the summer of 2001 increased national attention on those two energy sources in particular. While many possible actions to address energy supply and cost issues exist, one option for end-users is to improve building energy efficiency to reduce demand. Decisions about improving energy systems in buildings rest, in part, on detailed knowledge of current energy use. That, in turn, depends upon the metering of all energy sources such as electricity, natural gas, steam, and chilled water.

Government agencies, K-12 schools, and privately owned facilities generally receive utility bills showing individual building energy use and costs as gathered from utility meters. However, colleges and universities with multiple buildings on campus generally do not receive utility bills for each building and have traditionally not found it cost effective to sub-meter the campus to collect such data. The volatility of energy supplies and costs, as well as the restructuring of the electricity industry, have affected this traditional view; as a result, many schools find themselves evaluating the costs/benefits of sub-metering.

This paper examines the technical and economic aspects of sub-metering individual campus buildings. The paper also presents the results of a member survey conducted by the Association of Higher Education Facilities Officers (APPA) on the number of individually metered buildings on campuses and the trend with regard to sub-metering. For copies of this paper or further information, contact Melissa Payne, ENERGY STAR National Manager for Education, at payne.melissa@epa.gov.

2. BENEFITS OF SUB-METERING: CAMPUS ENERGY MANAGEMENT STRATEGY

Sub-metering can benefit colleges from a business perspective, an engineering perspective, and a management perspective—all of them important. To a certain degree, the importance varies with the size of the school. Small, liberal arts colleges without significant research programs (and the accounting systems that must accompany them) benefit from sub-metering if it forms part of an energy/cost improvement program. Mid-size to large schools stand to benefit in a number of additional ways. The advantages of sub-metering for colleges and universities are broken out below by business, engineering, and management perspective.

From a **business** perspective, the benefits of sub-metering include:

- Assesses energy use in facilities that receive funds from different sources, e.g., state-supported vs. auxiliary, instruction vs. research, academic vs. hospital.
- Facilitates charge-backs[1] to departments or other campus units as a way to encourage energy efficiency measures.[2]
- Assists in developing cost recovery and overhead analyses as they apply to sponsored research: if a facility housing research work uses energy at a rate higher than the campus average, the agency sponsoring the research may allow cost recovery for utilities for that particular building if its energy use can be documented. Research universities must establish overhead rates with funding agencies. In most cases, schools negotiate a rate on a campus-wide basis with each funding agency. At some institutions, details on energy usage are used to determine overhead rates so that research done in one facility does not effectively subsidize work done in another.
- Verifies savings from energy improvement projects.

From an **engineering** perspective, the benefits of sub-metering include:

- Helps to compile baseline energy use for setting contractual terms with an energy service company (ESCO).
- Identifies performance improvements and guides preventive maintenance: trends in monthly and annual use of each form of energy help to identify the benefits received from system upgrades and also the energy systems (e.g., boilers or chillers) that may need attention if they show unexpected increases in use.
- Enables quick response to failures of system components, assuming the meters are linked to an energy management system (EMS).

From a **management** perspective, the benefits of sub-metering include:

- Assists in making decisions about energy upgrades in buildings by comparing energy use in similar facilities.
- Focuses accountability for building operations on the facilities department**,** encouraging building managers to control energy consumption. Facilities department staff review metered data, know which buildings consume a disproportionate amount, and can be held accountable. The data also facilitate a dialog between the energy manager and deans, leading to collaboration on ways to reduce energy consumption in buildings with high energy use.

As the list above shows, campuses can derive many benefits from sub-metering. Moreover, the results of the APPA survey indicate that many colleges and universities are already enjoying these benefits because they chose to invest in sub-metering equipment and staff training.

---

1 A charge back is a charge to, or reduction in, a department's budget for the amount of money actually used.

2 State and local governments can also employ this charge-back mechanism.. A Department of General Services or Department of Administration often pays the government's energy bills, providing individual agencies no incentive to reduce energy costs. The charge-back changes that picture.

3. CAMPUS CONSIDERATIONS

Just as office buildings differ distinctly from K-12 school buildings, facilities on college campuses have quite distinct characteristics. Campus buildings include (1) dormitories, (2) buildings with classrooms and office space, (3) gymnasiums, (4) dining halls, and (5) facilities with classrooms, office space, and energy-intensive laboratories. Sub-metering permits comparisons of energy use among buildings within these various categories. Dormitories and buildings within categories (1) and (2) encompass the largest amount of square footage on most campuses, suggesting that schools might give priority to sub-metering facilities in these two categories.

Electricity consumption and demand can account for up to 80 percent of the total energy costs on campuses. Because electricity sub-metering is less expensive than steam, chilled water, and natural gas sub-metering, many schools begin by metering electricity and subsequently meter other energy sources.

4. SUB-METERING BARRIERS AND POTENTIAL SOLUTIONS TO SUB-METERING

4.1 Utility Company Disincentives

For most large users, the local electric utility offers rate structures that can result in a lower average cost of electricity under their "General Large Service" or "General Large Time of Use" tariffs. Typically, mid-size to large college campuses have large service meters at specific points of service to the campus— for example, groups of administrative buildings, science buildings, the gymnasium, and clusters of dormitories.

Unless the utility assumes the cost of buying and installing several smaller meters, a college will not benefit from asking the utility to replace each of the large meters on a campus with smaller, more numerous sub-metering units. Utilities do not usually provide this service at no cost (unless customers are permitted to request such a change as stipulated in their utility tariff). From a billing perspective, the main disadvantage to the college of smaller metering units is that, if peak demand is billed separately, the combined peak demand charges of the smaller meters will be greater than the peak demand charge of a single large meter. Additional disadvantages include individual customer service charges for each meter and higher rate structures for smaller loads.

In a restructured market with competition among energy providers, however, some utilities may be open to the idea of "virtual aggregation" of smaller sub-meters to reduce the total demand that occurs by summing demands from individual sub-meters. The utility then reads the demand from a "single meter" after it adds the contributions from all the sub-meters. This results in lower total demand because a peak at one sub-meter may occur during a trough at another. (See Section 5.1 for more information on aggregation.)

4.2 How to Mitigate Utility Company Barriers

A campus can evaluate the cost/benefits of utility company sub-metering through the following analysis: (1) Perform a rate analysis to determine whether partitioning the utility service into several smaller meters will result in a higher overall cost for electricity. In many instances, the utility account representative will provide this analysis service free of charge. If the overall cost of electricity will not be adversely affected, then (2) determine whether the utility will provide the smaller meters at no charge, or will spread that charge over a long time period through the utility bills. If the utility agrees to provide meters, then (3) evaluate the utility proposal, including meter maintenance, if the utility continues to own the meter.

4.3 Cost of Meters

About 100 companies provide electricity metering products and services. A representative example is listed in Appendix B, along with the type of products and services offered. The cost of electricity sub-metering is largely a function of the type of product and service required and the quantity of sub-meters to be installed at a given site. In contrast, natural gas, steam and chilled water sub-metering costs depend strongly on the size of pipe whose flow will be metered.[3] The table below provides estimated costs of an installed electricity sub-metering system.

[3] Appendix C provides comments on natural gas, steam, and chilled water metering.

Cost Estimate for Electricity Sub-Meter Installation on a College Campus
Costs Based on Six Sub-Meters in Three Separate Locations on Campus

Item Description	Quantity	Unit Mat'l Cost	Unit Labor Cost	Total Cost
Electricity sub-meter 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 set-up	1		$ 1,500	$ 1,500
Total Cost:				**$ 40,960**

(Data provided by Kapadia Energy Services)

The table assumes two meters per building. Under this common practice, one meter measures the power into the building, and the second in the mechanical room measures the demands from the equipment. This arrangement permits an analysis of the HVAC equipment loads versus the lighting and plug loads.

Based on the table's figures, the average installed cost of an electricity sub-meter with data acquisition software is about $6,300 per location. Depending on meter quantity and on which accessories are needed, the price could range between $5,000 and $7,500 for each sub-metered point. This does not include any incidental or contingent costs, such as coordinating the electrical shut-down to install the current transducers or making changes to correct possible existing code violations. The estimate also assumes that the software is installed on an existing personal computer or in a building automation system central computer.

4.4 How to Mitigate the Cost Barrier

Several metering companies provide sub-metering services by owning, operating, and maintaining the meters. In some cases, these companies provide a long-term contract and incorporate the high capital cost of the sub-meters into a flat monthly fee, which includes software assistance and periodic calibration and maintenance. Monthly fees are based on the type of service needed and the quantity of sub-meters served. Monthly costs per sub-meter range from $150 to $400.

The number of sub-meters installed in a given utility service area can be reduced by one if the subtractive method for calculating electricity demand and consumption can be used. Instead of using three sub-meters, for example, two can be used and the third value can be calculated by subtracting the sum of the two sub-meters from the main utility meter. The disadvantage of this method is that the sub-meters cannot be used to corroborate the accuracy of utility meter numbers; if one meter fails or provides false data, the data for the calculated point will be erroneous.

4.5 Calibration and Maintenance

Electricity sub-meters are typically calibrated once every three to four years. The calibration cost for electricity meters is not high, because the current and voltage can be verified with an instantaneous demand meter. In some cases, colleges face the added inconvenience of shutting down service in order to open the electricity panel and place the current transducers around the conduits. While electricity meters have no moving parts, components such as current transducers can fail or provide erroneous data. An annual maintenance/calibration/certification contract with a sub-metering company will typically cost about $400 per sub-metered point.

Calibration of steam and chilled water sub-meters should be performed annually, or more frequently if meter data stray beyond expected ranges. While meter calibration is relatively inexpensive, replacing a broken meter turbine can be expensive when the costs of shutting down or isolating entire systems and opening large diameter pipes are included. If condensate flow is metered instead of steam, costs can be reduced substantially. This cost reduction occurs because small volumetric flow (condensate) meters are less expensive than high-volume gas flow (steam) meters. For example, one can monitor an 8" steam pipe with a 1½" condensate line.

4.6 Integration/Installation of an Energy Management System

Integrating a sub-meter with a data acquisition system (DAS), either stand-alone or via an existing building automation system, is the least expensive component of a sub-metering program. As long as the vendor-supplied sub-meter software program uses ANSI standard "open protocol" methods, the data generated by the sub-meter can be used in conjunction with any major brand building automation system program. (Making these data available on the Web can add to the cost, however). Because the software costs essentially the same whether one sub-meter or several hundred sub-meters are integrated into the building automation system, the cost per point can vary greatly. In many cases, the cost of integration software is included in the price of the sub-metering system, as illustrated by the estimated costs presented in the table above. (One copy of the software supports all meters.)

5. Case Studies

The two universities selected for case studies have used sub-metering for over a decade to improve energy efficiency and reduce costs. The Large Research University (Section 5.1) meters all energy sources for many buildings and has benefitted from the data collected in a variety of ways. Section 5.1.2 summarizes this as "Lessons Learned." With the cooperation of the local electric utility company, the university developed a novel method of aggregating electricity demand that has resulted in at least a 10-percent reduction in electricity demand costs.

The Technical Research University (Section 5.2) used sub-metered data as part of a successful three-phase energy reduction effort which, to a large degree, other colleges and universities across the county can replicate. Phase 1 of the plan, an Energy Awareness Program that relied heavily on sub-metered data, was so well received by the administration and faculty that it resulted in a 10-percent reduction in electricity use. Additional savings were realized through subsequent energy retrofit capital projects (Phase 2) and through negotiations for lower electricity rates (Phase 3).

5.1 A Large Research University

This university has been sub-metering its electricity and steam use for more than 15 years and its chilled water use since the mid-1990s. The driving factors behind the University's sub-metering program included verifying the utility's billing data, allocating energy use by department, and gauging consumption and demand for baseline usage and budgeting purposes. This university uses the FASER software for utility accounting, and some sub-meter data are manually fed into this program to allocate consumption and costs to various departments.

One of the more important characteristics of the University's electricity sub-metering program is the "virtual aggregation" of 30 accounts through meters installed by the utility to save on peak demand costs. Known as "conjunctive metering," the process works as follows: If each building is metered separately, the University pays a peak demand charge for each building. If a single meter (actually a virtual meter) records electricity demand for a cluster of buildings, the chances that they all peak at the same point in time is negligible. The "conjunctive metering" process results in at least a 10-percent reduction in peak demand and costs. The University's innovative, sub-metering program was established before deregulation. Because the meters are still owned and operated by the utility, the University incurred no significant cost for this project.

The University has generated a Request for Proposals to companies interested in converting all data generated by the sub-meters and collected by a data acquisition system into a central database accessible through the Internet. This conversion may take place as a monthly service or as a one-time capital project.

Chilled water meters, installed in the mid-1990s, are used to record the chilled water rate (gpm) and consumption (e.g., gal/month). These data are read and transferred manually into the FASER energy accounting program. This step remains manual rather than automatic because it allows the data entry person to check for anomalies in the data resulting from meter failures and other sources of error. Doing so avoids contaminating the energy data with erroneous values.

The University continues to replace existing turbine steam meters with vortex shedding meters on an ongoing basis. These newer meters have proven to be more reliable and to require much less maintenance. As with chilled water meters, the data generated electronically by the steam meters are manually transferred into the FASER accounting system.

The most common use of the information generated by the sub-meters at this university, and many others, is to bill separate departments for their energy usage. As the metering program matured, the various departments received more accurate data on energy consumption and demand. In some cases, this accuracy has resulted in a marked increase in billings to certain departments, which has led to a re-evaluation of energy use. For example, the older turbine steam meters could not measure steam flow below a certain flow rate, resulting in zero readings during early fall and non-heating months, despite continued use of steam for domestic hot water and other uses. The new vortex shedding meters show consumption, however slight, in non-heating months. It is believed that once the sub-meter data are available via the Internet, closer control of energy usage will become possible, especially the spikes in peak demand. Upon notification by the energy manager of such spikes, departments can check on their consumption and demand and can react quickly to sudden changes in consumption rather than be surprised at the end of the billing cycle.

5.1.1 Lessons Learned from Sub-metering at a Large Research University

- If a utility will allow its meters to be used as sub-meters and as part of a "virtual aggregation" program, that is a recommended course of action in order to save on peak demand charges.

- Sub-meter data should not be used to perform automatic billing functions. Instead, a manual review of monthly consumption data to check for failing or un-calibrated meters or other discrepancies is recommended. If a billing is false due to a failed meter, it tends to discredit the entire program.

- If project capital is tight, identify an outside company to provide the software functions of gathering sub-meter data electronically and posting them on a Web site. This spreads the capital cost into monthly service charges, which may be recoverable. For example, if a department must pay a specific amount per month for sub-metering, that addition to its utility costs may be allowable in an analysis of overhead expenses for a research funding agency.

- Size the steam meter recording range to an optimal setting. Instead of a meter that reads rates from 100 to 10,000 pounds of steam for an application where 95 percent of the recorded flows lie between 500 and 3,000 pounds, select a meter with a tighter range. This will result in more accuracy within the normal operating range.

- Where possible, install condensate meters instead of steam meters. They cost 50 percent to 75 percent less than steam meters and, unless a large amount of steam is used for process loads or humidification (thereby not being returned as condensate), the consumption numbers are equally accurate. Condensate meters, however, should not be used if measuring instantaneous steam loads.

- Where possible, install steam meters in high pressure steam lines because they are of a smaller diameter than low pressure steam lines. Meter cost rises sharply with the increase in pipe diameter.

- Require all electricity meters to meet the new ANSI standards regarding "open protocol." This will enable any future sub-metering or DAS company to interface with any product or software, giving the university the flexibility to change vendors and sub-contractors as needed.

- Use a professionally designed energy accounting system to handle all meter output data. Simple spreadsheet software is not sufficient, even in the hands of a knowledgeable energy manager; programs such as FASER or Metrix have many years of energy data-handling experience designed into them. For example, some of these programs can accept weather data and utility rate structures and analyze energy use and costs as normalized by these factors.

5.1.2 Benefits of Sub-Metering at a Large Research University

- Conjunctive metering reduced the cost of demand (kW) by at least 10 percent in all 30 buildings involved.
- Sub-meters were used to size loads for new buildings: sizes for new steam and chilled water piping and fittings were optimized to lower construction costs.
- Sub-metering for electrical usage allowed the University to determine which utility company account to add load to because the cost of electricity could be calculated on an account-by-account basis. For example, when school officials decided to install a new chiller plant, they compared the impact of electricity costs on various sub-metered points, deciding in the end to install the chiller plant in a building that had some remaining tax-abatements on the electricity tariffs. This is a complex topic, but in brief, sub-metering allows for optimizing future electrical loads.
- Combined with the FASER program, the sub-meters helped to verify the accuracy of utility meters for whole buildings.
- Sub-meters helped to determine whether expanded electrical service was necessary based on demand measured in similar facilities on campus.

5.2 A Technical Research University

This school began sub-metering its campus more than 15 years ago, driven by pressures both to reduce overall expenses and to allocate indirect costs to the appropriate research activities. That is, certain buildings used for research consumed considerably more energy per square foot than the campus average, and the school wished to recover its actual costs. This required documenting actual usage in all relevant research facilities. The school instituted a three-phase energy management plan that extended over several years, as described below.

5.2.1 Phase 1 - Establish Procedures That Result in Near-term Savings

School officials began by metering electricity at the research buildings with known energy-intensive equipment. They printed the energy usage and cost information onto a form similar to a bill and sent it monthly to the building coordinator—often the head of the largest department. Their goal was to sensitize the departments to the costs of their operations and to secure buy-in for an Energy Awareness Program. The Program sought to reduce energy costs through operational and behavioral changes—measures that could be instituted quickly.

The Program's central feature 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. At 6-month intervals, the University compared a department's most recent energy usage against that of the comparable 6-month period one year earlier. If energy use dropped by 10 percent or more, the department received a payment equal to 30 percent of the cost savings. If the energy reductions were between 5 and 10 percent, the department received a proportionately smaller part of the savings; e.g., a 5-percent reduction meant a payment of 15 percent of the savings; an 8-percent decrease resulted in a 24-percent payment. Weather adjustments were not included in this calculation.

One major research department used 10 million kWh per year. With electricity priced at about $ 0.075/kWh, the department could potentially receive $25,000 if it met the reduction target. The departments liked this plan as did the administration, and participation rates were high. After 18 months, the departments had accomplished the energy savings possible, and 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 modifications to operational procedures to eliminate wasteful practices in energy intensive research departments. These Phase 1 modifications involved existing equipment only; equipment retrofit and replacement projects were considered in Phase 2.

5.2.2 Phase 2 - Energy Savings Through Capital Investments

Throughout Phase 1 and continuing into Phase 2, the school began to meter steam and water usage at various buildings—water constituting another high usage item because of research activities. The facilities staff identified several energy retrofit projects costing about $2.5 million, with a 4-year simple payback. School management agreed to the proposal and the work proceeded, resulting in a second round of major reductions in energy costs.

5.2.3 Phase 3 - Utility Rates

Having accomplished significant savings through their own efforts, the school considered a cogeneration facility to supply some of its power. Coincidentally, the state was evaluating changes in electricity pricing that involved Independent Power Producers (IPP). The school knew its electric utility company would not welcome a cogeneration capability, so the school worked with the utility and the utility commission to secure lower, long-term rates.

The school estimates that, from the three phases, it has saved about $1 million per year for the past 10 years.

6. Results of Survey of Higher Education Institutions

EPA's discussions with campus facility managers indicated that dormitories and combination office and classroom buildings (otherwise known as non-lab buildings) constitute the largest percentage of square footage on college campuses. This applies to both large research universities and small liberal arts colleges. The Association of Higher Education Facilities Officers (APPA) offered its assistance in surveying members on the extent of sub-metering in these two types of facilities; APPA's brief survey form appears in Appendix D.

One hundred schools responded to the APPA survey, and an analysis of their data reveals the following:

- Sixty-nine percent of the schools meter all dormitory buildings, and 48 percent of the schools meter all non-lab classroom facilities (buildings that include only classroom and office space).
- Forty-five percent of the schools meter all dormitory energy sources, while 39 percent meter only some energy sources.
- Thirty percent of the schools meter all energy sources in non-lab classroom facilities, while 53 percent meter only some energy sources.
- Of those schools that meter just some energy sources, 80 percent indicate that they plan to increase sub-metering for both dormitories and non-lab classroom facilities. This 80 percent figure applies only to schools that currently meter at least 40 percent of their dormitory and non-lab classroom buildings.[4]

These results suggest that a significant number of dormitory and non-lab classroom buildings on college campuses are metered and the trend is to increase sub-metering.

[4] The 40 percent figure, while arbitrary, was used as a way to include schools involved in a significant amount of sub-metering.

7. CONCLUSIONS

The case studies from the two schools, the information obtained during communications with higher education facility managers, and the survey results lead to the following conclusions about energy use and costs and sub-metering on college and university campuses:

- Costs for electricity comprise most of the campus energy budget, exceeding those for steam, chilled water, natural gas, and other fuels. Electricity costs can equal up to 80 percent of the total energy budget.

- Colleges and universities generally sub-meter electricity before any other energy source because electricity costs dominate the energy budget.

- Facility managers do see a trend toward sub-metering for electricity usage, driven by a variety of factors, including campus cost reduction efforts, charge-back practices, accountability, and electricity industry restructuring.

- A significant amount of sub-metering currently exists on college campuses and the trend is to increase this practice. By knowing in detail where energy use is high, campuses can focus efforts to improve energy efficiency and lower costs.

APPENDIX A
SOURCES OF INFORMATION ON CAMPUS SUB-METERING

EPA gathered data on this topic through the APPA listserv, conversations with APPA staff, and conversations with campus facility managers. The following table lists the primary sources.

Name	Institution
Dr. Theodore Weidner	University of Massachusetts
Peter Sandberg	St. Olaf College
Oliver Holmes	Rensselaer Polytechnic Institute
Tony Trocchia	Columbia University
W. J. Irwin	California Institute of Technology
Becky Griffith	Embry-Riddle Aeronautical University
L. Joe Spoonemore	Washington State University
Carol Dollard	Colorado State University
Rick Catasus	University of Central Florida
Kevin Kuretich	University of Missouri – Columbia
Art Chonko	Denison University
Bob Friedman	Duke University
Lander Medlin	APPA
Steve Glazner	APPA

APPENDIX B
MANUFACTURERS OF ELECTRICITY METERS

About 100 companies provide electricity metering products and services. The table below, provided by Kapadia Energy Services, is a representative list of the major manufacturers and the types of products and services offered.

Company	City	State	Attributes/Options
ABB Automation Inc.	Raleigh	NC	AMR, cellular/PCS, FCC approved, interval data, load control systems, load profiling, power line carrier (PLC), radio modem (RF), satellite communication, solid-state meter, sub-meter, TOU metering, UL listed
Aeris.net	San Jose	CA	cellular/PCS
AES-Intellinet	Peabody	MA	AMR, energy monitoring hardware, energy monitoring software, FCC approved, interval data, load control systems, load profiling, pulse retrofit, radio modem (RF),solid-state meter, sub-meter,TOU metering, UL listed
AMCO Automated Systems	Horsham	PA	AMR, cellular/PCS, load profiling, multi-site energy data analysis software, pulse retrofit, radio modem (RF), sub-meter
Ameren DMS	St. Louis	MO	AMR, energy monitoring hardware, energy monitoring software, interval data, load profiling, multi-site energy data analysis software, pulse retrofit, solid-state meter, sub-meter,TOU metering
Antenna Products Corp.	Mineral Wells	TX	AMR, cellular/PCS, energy monitoring hardware, energy monitoring software, load profiling, multi-site energy data analysis software.
Applied Metering Technologies, Inc.	Whittier	CA	AMR, energy monitoring hardware, energy monitoring software, interval data,load control systems, load monitoring/dispatching ,meter, sub-meter, TOU metering

Company	City	State	Attributes/Options
Applied Power Technologies	Cupertino	CA	AMR, energy monitoring hardware, energy monitoring software, interval data, load control systems, load monitoring/dispatching, load profiling, multi-site energy data analysis. software, radio modem (RF), real-time pricing (RTP), solid-state meter, sub-meter, TOU metering
A-TEC Energy Corporation	Des Moines	IA	cellular/PCS, load control systems, radio modem (RF)
Badger Meter Inc.	Milwaukee	WI	AMR, radio modem (RF)
BLP Components	Manasquan	NJ	UL listed
Cannon Technologies Inc.	Wayzata	MN	AMR, energy monitoring hardware, energy monitoring software, interval data, load control systems, load monitoring/dispatching, load profiling, multi-site energy data analysis software, power line carrier (PLC), real-time pricing (RTP), sub-meter, TOU metering, UL listed
Cognyst Consulting, LLC	Pequanock	NJ	AMR, cellular/PCS, energy monitoring hardware, energy monitoring software, load control systems, load monitoring/dispatching, load profiling, multi-site energy data analysis software, power line carrier (PLC), radio modem (RF),satellite communication, sub-meter, UL listed
Comverge Technologies	Florham Park	NJ	AMR, cellular/PCS, energy monitoring hardware, energy monitoring software, FCC approved, load control systems, load monitoring/dispatching, load profiling, multi-site energy data analysis software, power line carrier (PLC), pulse retrofit, radio modem (RF),UL listed
Datamatic.Com Ltd.	Richardson	TX	AMR, FCC approved, interval data, load profiling, radio modem (RF), TOU metering
DCSI	Hazelwood	MO	AMR, FCC approved, interval data, load control systems ,load profiling, real-time pricing (RTP), TOU metering, UL listed

Company	City	State	Attributes/Options
eBidenergy.com	West Henrietta	NY	AMR, cellular/PCS, energy monitoring hardware, energy monitoring software, interval data, load profiling, multi-site energy data analysis software, pulse retrofit, sub-meter, TOU metering
Electro Industries/Guage Tech	Westbury	NY	Energy monitoring hardware, energy monitoring software, interval data, load control systems, load profiling, multi-site energy data analysis software, solid-state meter, sub-meter, TOU metering
E-MON Corp.	Langhorne	PA	AMR, cellular/PCS, energy monitoring hardware, energy monitoring software, interval data, load profiling, radio modem (RF), solid-state meter, sub-meter, TOU metering, UL listed
Energy Management Systems	Elkhart	IN	Energy monitoring hardware, energy monitoring software, interval data, load control systems, load profiling, multi-site energy data analysis software, pulse retrofit, solid-state meter, sub-meter, UL listed
Enetics, Inc.	Victor	NY	cellular/PCS, energy monitoring hardware, energy monitoring software, FCC approved, load control systems, load profiling, real-time pricing (RTP), solid-state meter, sub-meter, TOU metering, UL listed
Flex-Core Inc.	Columbus	OH	Energy monitoring software, load control systems, sub-meter
Gateway Communications Inc.	Tucson	AZ	AMR, FCC approved, interval data, load control systems, load profiling, radio modem (RF), solid-state meter, TOU metering
Hexagram, Inc.	Cleveland	OH	AMR, radio modem (RF)
Hunt Technologies Inc.	Pequot Lakes	MN	AMR, FCC approved, power line carrier (PLC), UL listed
Innovatec Communications, LLC	Milwaukee	WI	AMR, cellular/PCS, energy monitoring hardware, energy monitoring software, FCC approved, interval data, load profiling, power line carrier (PLC), radio modem (RF), real-time pricing (RTP), satellite communication, solid-state meter, sub-meter, TOU metering, UL listed

Company	City	State	Attributes/Options
Internet Telemetry Corp.	Tulsa	OK	AMR, FCC approved, interval data, load profiling, optical reader retrofit, pulse retrofit, radio modem (RF), solid-state meter, sub-meter, UL listed
Itron Inc.	Spokane	WA	AMR, cellular/PCS, FCC approved, load profiling, radio modem (RF), UL listed
KP Electronics Inc.	North Wales	PA	AMR, cellular/PCS, FCC approved, interval data, load profiling, optical reader retrofit, pulse retrofit, radio modem (RF), real-time pricing (RTP), satellite communication, solid-state meter, TOU metering
KW Aware LLC	Cota de Caza	CA	AMR, energy monitoring hardware, interval data, load control systems, load monitoring/dispatching, load profiling, multi-site energy data analysis software, real-time pricing (RTP), TOU metering
Logicon Inc.	San Diego	CA	AMR, radio modem (RF)
Main Street Networks	San Jose	CA	AMR, FCC approved, interval data, load profiling, multi-site energy data analysis software, optical reader retrofit, pulse retrofit, solid-state meter, TOU metering
Marwell Corp.	San Bernardino	CA	load control systems
Mass Installation	Norwood	MA	AMR, sub-meter
Measuring & Monitoring Services Inc.	Tinton Falls	NJ	AMR, cellular/PCS, energy monitoring hardware, energy monitoring software, interval data, load monitoring/dispatching, load profiling, multi-site energy data analysis software, pulse retrofit, solid-state meter, sub-meter, TOU metering, UL listed
Motorola Utility Solutions	Scottsdale	AZ	energy monitoring hardware, energy monitoring software, interval data, load profiling, multi-site energy data analysis software, power line carrier (PLC), solid-state meter, TOU metering, UL listed
MTC-Metering Technology Corp.	Scotts Valley	CA	AMR, cellular/PCS, energy monitoring hardware, energy monitoring software, FCC approved, interval data, load control systems, load profiling,power line carrier (PLC), radio modem (RF), solid-state meter, sub-meter, TOU metering

Company	City	State	Attributes/Options
muNet.com	Lexington	MA	AMR, interval data, load profiling, real-time pricing (RTP), solid-state meter, sub-meter, TOU metering
National Meter Industries	Bedford	NH	AMR, energy monitoring hardware, energy monitoring software, FCC approved, interval data, load control systems, load monitoring/dispatching, load profiling, multi-site energy data analysis software, radio modem (RF), real-time pricing (RTP), sub-meter, TOU metering, UL listed
National Rural Telecommunications Cooperative (NRTC)	Herndon	VA	AMR, FCC approved, interval data, load profiling, radio modem (RF), TOU metering
NexusData	Grapevine	TX	AMR, energy monitoring software, FCC approved, load profiling, radio modem (RF), UL listed
Plexus Research Inc.	Boxborough	MA	AMR, energy monitoring hardware, energy monitoring software, interval data, load control systems, load monitoring/dispatching, load profiling, multi-site energy data analysis software, radio modem (RF), real-time pricing (RTP), solid-state meter, sub-meter, TOU metering
Powel B2B Services, Inc.	West Jordan	UT	Energy monitoring software, load control systems, load monitoring/dispatching, load profiling, multi-site energy data analysis software, real-time pricing (RTP), satellite communication, solid-state meter, sub-meter, TOU metering
QuadLogic Controls Corp.	New York	NY	AMR, energy monitoring hardware, energy monitoring software, interval data, load control systems, load profiling, multi-site energy data analysis software, power line carrier (PLC), real-time pricing (RTP), solid-state meter, sub-meter, TOU metering, UL listed
Radiopath	Redmond	WA	AMR, real-time pricing (RTP), sub-meter, TOU metering

Company	City	State	Attributes/Options
Radix Corp	Salt Lake City	UT	AMR, energy monitoring hardware, energy monitoring software, FCC approved, load monitoring/dispatching, load profiling, multi-site energy data analysis software, pulse retrofit, radio modem (RF), UL listed
RAMAR Technology	Research Triangle Park	NC	AMR, pulse retrofit
SATEC Inc.	Summit	NJ	Energy monitoring hardware, energy monitoring software, interval data, load profiling, multi-site energy data analysis software, real-time pricing (RTP), sub-meter, TOU metering, UL listed
Schlumberger	Norcross	GA	AMR, energy monitoring hardware, energy monitoring software, interval data, load control systems, load monitoring/dispatching, load profiling, multi-site energy data analysis software, radio modem (RF), real-time pricing (RTP), solid-state meter, sub-meter, TOU metering
Scientific Telemetry Corp.	Raynham	MA	AMR, cellular/PCS, interval data, load profiling, radio modem (RF), sub-meter, TOU metering
Sensus Technologies Inc.	Uniontown	PA	AMR, optical reader retrofit
Siemens Power Transmission & Distribution	Lafayette	IN	AMR, cellular/PCS, energy monitoring hardware, energy monitoring software, FCC approved, load control systems, load profiling, multi-site energy data analysis software, optical, power line carrier (PLC), satellite communication, solid-state meter, sub-meter, TOU metering
Silicon Energy Corp.	Alameda	CA	Energy monitoring software, multi-site energy data analysis software
Specialized Technical Services	Richmond	KY	AMR, optical reader retrofit, pulse retrofit, solid-state meter
SpeedRead Technologies	Indianapolis	IN	AMR, FCC approved, radio modem (RF), sub-meter
StarComm Products	Huntington Beach	CA	AMR, cellular/PCS, radio modem (RF)

Company	City	State	Attributes/Options
Stark North America Inc.	Charlotte	NC	AMR, cellular/PCS, energy monitoring software, interval data, load monitoring/dispatching, load profiling, multi-site energy data analysis software, radio modem (RF), real-time pricing (RTP), sub-meter, TOU metering
Teldata Solutions	Portland	OR	AMR, cellular/PCS, energy monitoring hardware, energy monitoring software, FCC approved, interval data, multi-site energy data analysis software, radio modem (RF), solid-state meter, TOU metering, UL listed
Telenetics Corp	Lake Forest	CA	AMR, cellular/PCS, FCC approved, load control systems, radio modem (RF), satellite communication, UL listed
TransData Inc.	Richardson	TX	Cellular/PCS, FCC approved, interval data, load control systems, load profiling, radio modem (RF), real-time pricing (RTP), solid-state meter, sub-meter, TOU metering
Tru-Check Inc.	Buffalo	NY	AMR, radio modem (RF)
ViaSat Satellite Networks - LEO Data Systems	Atlanta	GA	AMR, FCC approved, satellite communication, UL listed
VSI Group Inc.	Columbia	MD	AMR

APPENDIX C
DATA FOR CHILLED WATER AND STEAM METERS

Chilled Water and Condensate Meters

The most common meters used for sub-metering chilled water or steam condensate water for general purposes are the ultrasonic, non-intrusive types, installed on a pipe surface. To function accurately, they typically require a straight pipe run of 10 diameters before the meter and 5 diameters after the meter. With no moving parts, these meters provide benefits by avoiding the need to replace parts and to perform regular calibration. Meters measuring chilled water flow require annual maintenance because condensation on the pipe surface will erode the connection on the coupling between the transducer and the pipe surface. Ultrasonic water flow meters, when combined with temperature sensors on the supply and return piping, provide the data needed to calculate Btu consumption of chilled water. The temperature sensors, typically RTD type, can be mounted either in a well or on the surface of the pipe. Well-mounted sensors require less maintenance, but are more expensive to install because the well, to be inserted into the pipe, will require draining, cutting, and welding of pipe. Surface mounted RTD sensors are less expensive but require maintenance every 6 months because the combination of scaling on the pipe surface and degradation of pipe insulation will result in a general loss of accuracy of sensed temperature over time.

APPENDIX D
QUESTIONS SENT TO MEMBERS OF
THE ASSOCIATION OF HIGHER EDUCATION FACILITIES OFFICERS (APPA)

APPA Sub-Metering Survey

The questions in (1) below apply to only two types of facilities: dormitories and buildings that are a mix of classroom and office spaces but do not house energy-intensive laboratory equipment (called here non-lab classroom buildings).

---

(1) Indicate the percent of your dormitories that are sub-metered: _________%

Are you sub-metering all dormitory energy sources? ______All _____Some ______None
("All" might include electricity, chilled water, gas, steam—all sources that would allow you to specify the heating, cooling, and lighting energy usage.)

Indicate the percent of non-lab classroom buildings that are sub-metered: _________%

Are you sub-metering all energy sources? ______All _____Some ______None

(2) Is your institution (please place an X on the line most appropriate):
increasing sub-metering activity _________,
or staying with its current level _________,
or reducing sub-metering ___________?

=====