Driving the Market for New Metering Equipment

Richard P. Mazzucchi, SBW Consulting, Inc.

Metering technology suitable for demand-side management (DSM) program evaluation has come of age over the past decade. Metering devices have moved from the domain of expensive general purpose laboratory apparatus to specific low-cost specialty loggers. Some DSM technologies, such as energy management control systems, can now be configured to provide empirical data that is useful for DSM program evaluation. In other cases it may be cost-effective to incorporate measurements into the design of equipment or implementation of a program that are useful for program evaluation.

This paper presents opportunities to motivate DSM equipment suppliers, program designers, and evaluators, to incorporate, or at least consider, the benefits of empirical measurements in their design processes. By placing value on verifiable data, utilities can help drive the market for specialized metering devices. This may stimulate manufacturers of DSM technologies, such as electronic controls, to incorporate monitoring capabilities useful for program evaluation.

Introduction

The emergence of DSM programs in the past decade has created many challenges for optimal program design, implementation, and evaluation. The variety of DSM technologies, implementation methods, and evaluation techniques is large, making generalized solutions elusive, and complicating the pursuit of cost-effective energy efficiency improvements. Furthermore, the state-of-the-art continues to evolve creating a daunting number of options and uncertainties. Nonetheless the utility and energy services industry is continually gaining experience and developing a better understanding of the costs and benefits of particular approaches.

While some projects may not require a robust evaluation of the savings estimates, it is still desirable to provide feedback to those generating estimates of energy savings pertaining to the savings actually achieved. This feedback helps identify problems and sources of error that facilitates subsequent refinements of project methods to reduce future errors. Furthermore, metered data can be of great value to ensure that DSM equipment is operating properly and to provide a basis for further efficiency improvements as warranted. The intuitive nature of savings estimates based upon changes in measured energy consumption is effective to market DSM to non-technical audiences.

This paper provides a holistic perspective of opportunities for program optimization based upon examination of the technical challenges and economic trade-offs faced by those responsible for the design, implementation, and evaluation of DSM programs. By studying each of these disciplines, the relative strengths and weaknesses of different technical options is achieved and the implications of decisions in one area on the others are understood. Unfortunately the level of specialization and contractual realities associated with the DSM industry retards the examination of these broader optimization opportunities.

The paper begins with a brief discussion of the need for DSM savings verification and some of the most common problems and issues confronted. Then we review the monitoring protocols in present use and the equipment used to estimate energy savings. The paper concludes with ideas for optimal program design and implementation by presenting specific opportunities for more accurate and affordable DSM program evaluation. This holistic perspective of the DSM marketplace encourages the design of metering hardware and monitoring approaches to better ensure cost-effective savings.

Metering Requirements

Utilities investing in DSM as part of their portfolio of energy resources must evaluate DSM programs to ensure their prudency. Metering is used to provide an empirical basis for evaluations of actual energy savings. The simplest evaluations utilize utility billing records to estimate energy savings, but often cannot accurately determine the impact of DSM that constitute a small fraction of the total load measurement. Since savings of particular measures seldom exceed 20% of the total load it is difficult to decouple measure savings from changes in building use, added equipment, and weather when only billing data is used as the empirical basis.

To more rigorously assess DSM program performance some utilities have developed verification requirements for their DSM investments. (Jersey Central Power and Light Company 1992, Northeast Utilities 1992, Harding et al. 1992, Pacific Gas & Electric Company 1993). Table 1 provides a comparison of these monitoring standards indicating the relative costs, years of use, and site specific physical measurement requirements.

Sometimes the monitoring requirements are a function of the magnitude of the project. For example one utility has developed specific metering requirements for both baseline and post-installation metering based upon the size of investment and measure type. For projects costing more than $20,000, two years of post-verification metering is called for, while those under this amount require only six months of metering. Incentives are paid to the customers based upon the results of this metering up to a total incentive cap determined when the project was proposed.

The specific metering requirements are particular to the technology to be assessed and the level of detail desired. The utility program described above provides unique requirements for lighting measures, motor measures, and temperature dependent measures. These requirements specify the number of devices that need to be metered and the type and duration of measurement necessary. These requirements are then followed by a provider of energy management services to develop a site specific verification plan for approval by the utility.

A statewide DSM advisory committee comprised of representatives of investor owned utilities in the California is developing DSM metering protocols under mandate of their public utility commission. This work is being done to provide the basis for the utilities to recover the costs of their DSM programs through their rate cases. These utilities face the difficult task of balancing the value of accurate savings estimates with the costs of accurate measurements. Other utilities are struggling with this issue as well.

In an attempt to standardize these requirements, The National Association of Energy Services Companies has produced a set of recommended measurement protocols for four generic types of DSM technologies (National Association of Energy Service Companies 1992). Each of these types has particular metering requirements for verification of savings. These types are described below.

Measures Affecting Constant Load, Non-Weather Sensitive End Uses

This method applies to measures that improve the efficiency of electric end-use systems that have a constant load, independent of time of day or season. The measures do not impact operating hours. An example would be a replacement of standard efficiency lamps with high efficiency lamps and ballasts. The protocol requires that the electrical demand (kW) be determined for the existing and retrofitted equipment. The change in demand is multiplied by a measurement (or assumption in the case of continuously operated equipment) of the run-time of the retrofitted equipment over a specified monitoring period appropriate to the system being evaluated.

Measures Affecting Operating Hours of Constant Load, Non-Weather Sensitive End Uses

This method applies to measures that reduce the operating hours of electric end-use loads that have a constant demand when operating. An example would be an automatic control system modifying the start and stop times of constant volume fans or pumps. The protocol requires the same measurements as above but the run-time metering must be conducted before and after retrofit long enough to capture use over a range of expected operating conditions. Baseline and post-retrofit consumption can then be calculated and the savings determined by difference.

Measures Affecting Variable End Use Requirements

This method applies to measures that improve the efficiency of electric end-use loads that have a variable demand. An example would be the replacement high efficiency variable load motors. The protocol requires that the power consumption and loading of the motor be measured before and after retrofit over a representative number of operation cycles. A regression equation or load curve is developed relating power input to work output for the pre and post-retrofit periods. Savings are then calculated using information on the actual motor loading and the difference between the power requirements derived using the pre and post-retrofit load curves or regression models.

Table 1. Comparison of DSM Monitoring Standards

Standard/Protocol Name	Relative Cost	Years in Use	Site Specific Physical Measurements: Energy	Temperature	Flow	Other
1. National Association of Energy Service Companies						
Constant load and operation, non-weather sensitive	Low	1	S,L			
Constant load, non-weather sensitive, operation change	Low	1	R,S			
Variable end-use requirements	Moderate	1	S	S	S	S
Other/thermal storage	High	1	L	L	L	
Other/heat recovery	?	0				
Other/energy management systems	?	0				
2. Jersey Central Power and Light						
Lighting	Low	2	R			
Motors	Low	2	R			
Chillers	High	2	S	S	S	S
Packaged and Split AC	Moderate	2	S			
Heat Pumps	Moderate	2	S			
Other/Thermal Storage	High	2	L	L	L	
3. Northeast Utilities						
After retrofit on-site engineering assessment	Low	2	SP			
Before and after retrofit on-site engineering assessment	Low	2	SP			
Short duration end-use monitoring	Moderate	2	S			
Comprehensive end-use monitoring	High	2	L			
4. Bonneville Power Administration						
Constant loads with fixed duty cycle	Low	1	SP			
Constant loads with variable duty cycle	Low	1	R,SP			
Conversion of constant load to varying load	Moderate	1	S			
Variable load changed to high efficiency load	Moderate	1	S	S	S	
5. ORNL Commercial and Related Retrofit PROTOCOL	Low	3	L			
6. ORNL Single Family Retrofit Protocol	High	5	L	L		
9. Pacific Gas & Electric Company CIA PROTOCOLS						
Lighting	Low	2	SP			
Agricultural irrigation	Moderate	2	S		S	S
Space conditioning	High	2	S	S	S	S
HVAC motors	High	2	S	S	S	S
11. PG&E Advanced Customer Technology TEST	High	1	L	L	L	L

Measurement Codes

SP = spot (one-time) metering
L = long term
S = short term metering
R = run-time

Other Technology Specific Measurement Methodologies

Specialized methods apply to thermal storage, heat recovery, and energy management control systems. For thermal storage systems the tons and ton-hours in and out of storage are measured and converted to kW and kWh impacts using system performance curves. The measurement point requirements include chilled water temperatures in and out of the chiller, flow rate through the chiller, entering condenser water temperature and ambient air temperature. Savings calculations must be normalized using typical load distributions or operating conditions. Specific protocols for heat recovery and EMCS systems are presently being developed by NAESCO.

Metering Equipment

Metering equipment for quantifying energy conservation opportunities and savings achieved has evolved over the past decade. Until recently most investigations involved the installation of expensive power measurement and logging devices. The costs and suitability of laboratory research equipment capable of measuring and recording DSM technology performance were prohibitive for routine application, and was consequently limited to research and demonstration efforts.

Advances and cost-reductions in micro-electronic devices have brought several new metering options to the marketplace. These include: (1) run-time loggers, (2) single channel time-series loggers, (3) multiple channel time-series loggers, and (4) logic controlled data acquisition systems. The cost of this metering equipment varies from about $100 to $5,000 commensurate with its capabilities and the number of devices ordered. A recent compilation of equipment types, capabilities, and costs by a federal power marketing authority describes the results of a survey of metering equipment manufacturers (Dent et al. 1991).

Another metering option has resulted from the development of electronic control systems. Most energy management control systems (EMCS's) and some variable speed drive (VSD) technologies include the capability to log specific measurements or control signals useful for performance evaluation. This is an area of particular promise for future capability enhancement, since the incremental cost of datalogging capabilities is very low where microprocessors and sensors are already employed. Each of the generic metering options is briefly described below.

Run-Time Loggers

These miniature, battery powered dataloggers record the cumulative number of hours that devices are in operation. These are among the least expensive meters to purchase and install. The loggers are read (or reset) when they are installed and when test periods are completed. The run-time can then be calculated as a percentage of the time they were in place since the last reading to provide an accurate indication of the equipment utilization.

Some of these loggers can bin the periods of use into different registers corresponding to different time periods. This would permit a determination of the number of hours that the equipment was used during various time-of-use periods of significance to the utility or customer.

The most common application of these loggers is to determine the lighting system utilization. These so called "Lighting Loggers" have integral photocells and logging circuitry for ease of installation. Some use optical fibers to pinpoint the lighting detection. Other run-time loggers known as "Motor Loggers" or "CT Loggers" detect the magnetic fields surrounding motors and electric circuits to determine run-time. These loggers have been used to measure water heater use, single speed motors, and other devices with constant loads in excess of 250 watts.

Use of these loggers in the selection and design of lighting system modifications can significantly reduce errors in system utilization estimates and support evaluations of energy saving impacts.

Single Channel Time-Series Loggers

These loggers have the capabilities of the run-time loggers with the added capability to record and store the actual times of on and off events. These loggers have integral clocks (typically powered with Lithium batteries to ensure 5+ years of data collection) and an optical or wired port to download data to a personal computer. Computer software provided with the loggers allows the user to summarize run-hours over periods of interest, print-out reports of equipment use, and produce graphics indicating periods of equipment use.

These loggers cost approximately 2 to 3 times as much as run time loggers but provide insight into the time of day and day of week schedules of the device monitored.

Multi-Channel Loggers

These loggers are capable of measuring, storing, and in most cases integrating, numerous concurrent measurements. Some systems have unlimited expansion capabilities where multiple loggers can be chained together to provide information on hundreds or thousands of concurrent measurements. Most of these loggers can be equipped with modems for remote interrogation and are sold with computer software for logger configuration and data collection and analysis.

The costs of these loggers generally are comprised of a base amount for the basic logger, and then supplemental costs for each type of sensor or channel added. Historically application of these loggers has been limited to research and development projects owing to their complexity and expense, however the recent development battery powered four-channel loggers costing less than $1000 is stimulating application for utility DSM evaluations.

Logic Controlled Data Acquisition Systems

This is a type of multi-channel time series recorder with the added capability to logically control the binning and real-time analysis of data (Lambert 1988). These loggers permit conditional logging of data (such as heat-pump consumption when it is in cooling mode) that can directly calculate performance indicators of interest. These loggers are among the most costly to purchase, but can significantly reduce the overall costs of data verification, reduction, and analysis for complex evaluations.

DSM Control Systems

The current generation of sophisticated energy management control systems and variable speed drive controllers can provide information useful for DSM technology specification and evaluation (Parker et al. 1993). Since sophisticated control hardware and software can support all the functions of a logic controlled data acquisition system, the principal challenge to application is the definition and programming of monitoring capabilities into the devices without adversely affecting control performance.

Verification plans for some utilities rely upon printed outputs of trend logs from EMCS and VSD controllers. Typically these print-outs are manually reviewed and summarized to calculate energy use impacts indirectly. A new generation of equipment is possible wherein the measurement requirements and analytic logic can directly produce reports of energy savings achieved. Incorporation of this capability can enhance the value of the technologies for DSM investments because it can significantly reduce the costs of verification and investment risks. Furthermore, ongoing examination of these reports can help ensure optimal DSM performance and assess savings persistence.

Opportunities for Ideal Program Design and Implementation

The strategic use of metering equipment during various phases of DSM program evolution and implementation can significantly improve the assurance and cost-effectiveness of program savings. In most cases the data needed for program evaluation would be valuable for program design, and on an individual site basis the evaluation metering would certainly have improved measure specification had it been available at the time.

The historically high cost of metering equipment and its installation has precluded most metering activities prior to measure installation. There are some exceptions to this, where building owners and utilities have funded instrumented audits of energy conservation potential (U.S. Congress Office of Technology Assessment 1991). Energy audits have only occasionally anticipated the evaluation and verification of savings requirements of the servicing utility. A more routine anticipation of these needs should be included in the audit, as the total project costs do carry real costs associated with verification and evaluation.

Several utility program savings verification procedures require the one-time measurement of electrical demands of baseline and retrofitted devices and measurement of post-installation run-time to calculate savings. It would be preferable to require pre-installation run time measurements rather than post-installation. The costs would be the same or lower, but the run-time data could be used to screen out devices that are seldom used and are relatively poor candidates for efficiency improvement.

In many cases the complexity of DSM savings verification is not considered when energy conservation measures are prioritized. This is a mistake for utilities that are subject to prudency hearings, since the more complex verifications can significantly increase the program costs associated with these measures. In light of the rapid evolution of micro-electronic devices the verification costs might be significantly reduced as these needs are better appreciated and incorporated into the design of new products.

Another way to reduce monitoring expenses is to amortize the cost of the metering hardware over a number of projects. Most monitoring equipment can be removed and reused at a fraction of the cost of purchasing new equipment. The monitoring protocols developed for the California DSM Advisory Committee (CADMAC) include tables of site specific measurement methods that quantify the range of sensor costs, data acquisition system costs, and the total amortized costs per measurement point for approximately 200 measurement types (SBW Consulting, Inc. 1994). These protocols cover the following measurement types: 1) electric consumption, 2) natural gas consumption, 3) temperature, 4) relative humidity, 5) flow rate, 6) BTU metering, 7) infiltration, 8) pressure, 9) solar radiation, 10) door/damper position, 11) RPM, 12) run-time, 13) wind speed, and 14) production rate.

Figure 1 displays the structure of proposed CADMAC protocols. A matrix of energy efficiency measures offered by the utilities is first consulted to determine applicable measurement groups. These measurement groups describe the specific measurement types required. For each measurement type the range of measurement costs and relative errors is quantified to facilitate tailoring the measurements to the accuracy requirements and budget thresholds.

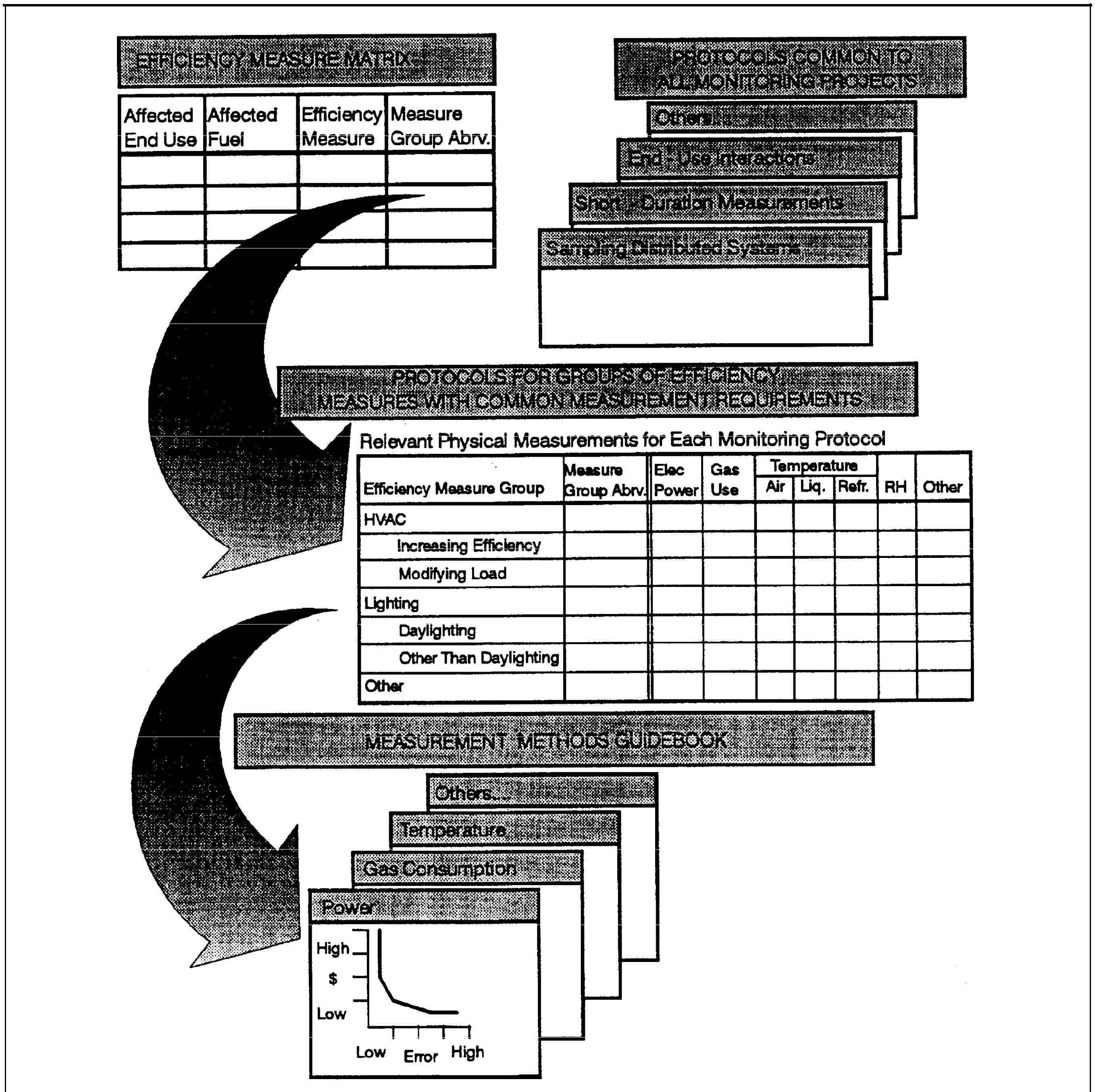

Figure 1. Structure of the Statewide DSM Monitoring Standard

Figure 2 displays the overall application of the monitoring protocols, and the decision making processes to optimize the monitoring efforts. The process begins with a series of decisions regarding the nature of the monitoring project such as: the evaluation methodology, sample size, savings estimation model, and setting a budget. Once the budget is established, the process focuses on which measurements to included in the evaluation. The first step here is to identify the monitoring protocol necessary for the particular measures to be evaluated. Next the required physical measurements are determined. Available low-cost methods can be used in instances where it can be shown that the absence of these measurements will cause substantial estimation errors and site specific measurements are too costly. The next step is to allocate the total budget to the remaining required measurements. This allocation process results in a monitoring budget for each of the required measurements. The next step is to convert the overall monitoring budget to a per site measurement budget. Finally site monitoring plans are developed that minimize measurement error and do not exceed the site measurement budgets.

More awareness of the strategic application of metering is likely to emerge as utilities and energy service providers gain experience with DSM technologies and DSM program evaluation. Using a disciplined process as described above can help ensure that measurement resources are

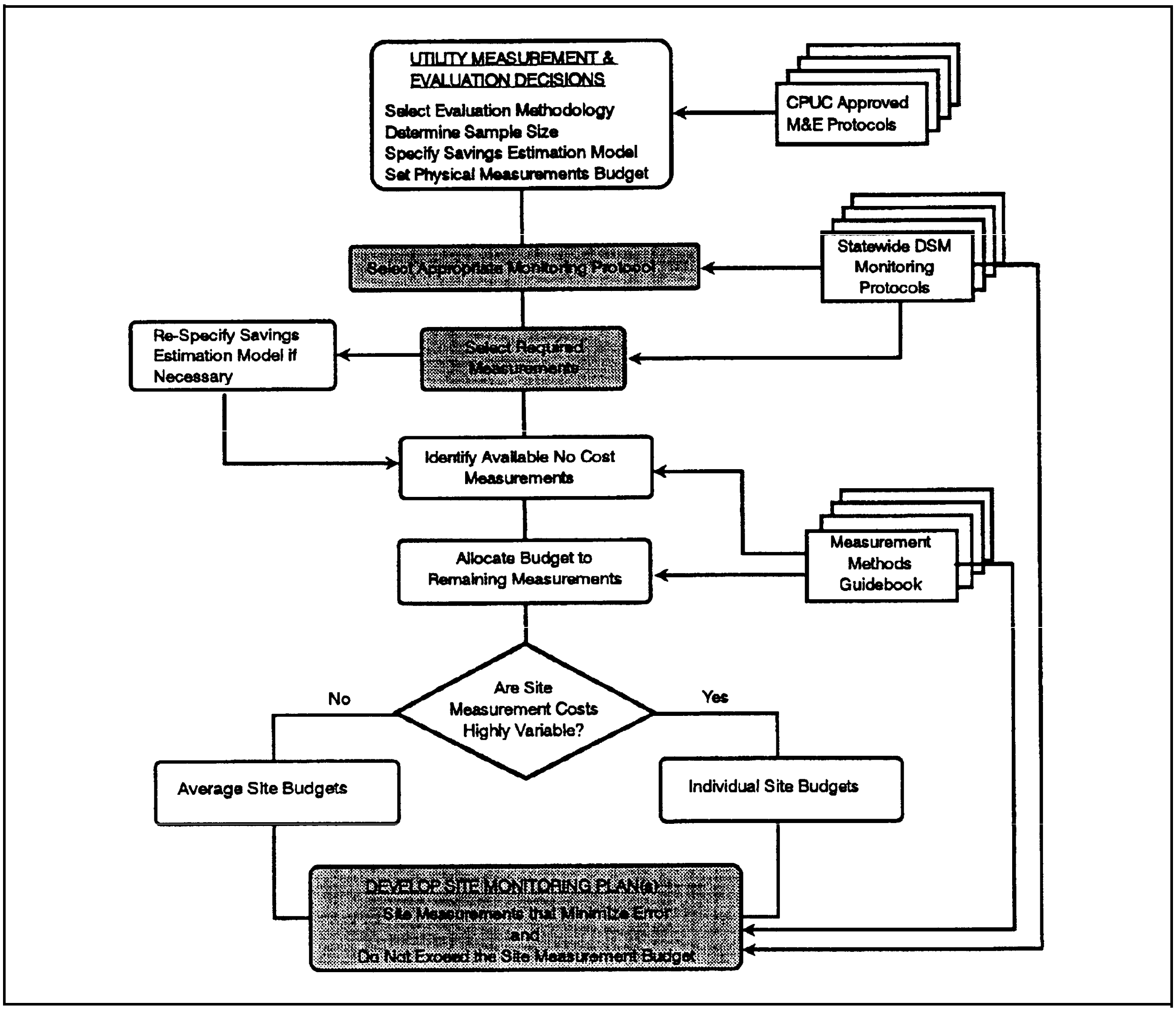

Figure 2. Application of the Monitoring Protocol to the evaluation of a DSM Program

applied to minimize estimation errors. Use of this approach can help stimulate consideration of measurement issues at the time of program design and DSM technology selection. The full value of empirical data can be most appreciated and applied at the time of measure specification rather than limited to a hindsight identification of failures that might have been avoided.

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