Measurement and Verification in the Air Force's Energy Savings Performance Contracts Program

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ABSTRACT

The United States Air Force has an active Energy Savings Performance Contracts (ESPC) program, in which energy services contractors carry out and finance energy retrofit work. The USAF base pays for these retrofits out of verified savings over a number of years. Since Measurement and Verification (M&V) of savings is an important part of the financial agreement, the contractor is required to include its plans for measuring and verifying savings in its Phase II proposal. These large, multi-million dollar projects can be technically complex. Since it would require a significant amount of technical expertise on the part of a contracting officer to evaluate the bids and implement the contracts, the USAF has retained the services of an independent third-party to participate in the review of M&V plans, assist in their development, witness verification tests and evaluate the annual revalidation of the savings. The USAF is currently developing standardized M&V plans to help define the requirements for cost effective M&V.

This paper describes the USAF program for M&V, and the process that is used for reviewing M&V plans. By examining projects at individual bases, the paper will identify some of the on-going challenges that are faced by the industry as a whole. Recommendations are made based on USAF experiences. These recommendations have wide applicability to other federal agencies and industry sectors.

The Air Force Energy Savings Performance Contracts Program

The focus of the U. S. Air Force (USAF) Facility Energy Program, conducted by the Air Force Civil Engineer Support Agency (AFCESA) is to minimize energy consumption and costs while meeting all operational mission requirements and providing quality working and living conditions for USAF personnel and family housing occupants. AFCESA is responsible for coordinating the activities of the different commands within the USAF to ensure compliance with Executive Order 13123, Greening the Government Through Efficient Energy Management. EO13123 mandates each federal agency to reduce energy consumption in facilities by 30 percent by 2005, and by 35 percent by 2010, relative to 1985 consumption. To date, the USAF has reduced energy consumption by over 20% since 1985. To meet the 35% goal by 2010 will require a substantial investment in replacing aging, inefficient infrastructure. Systems such as central heat and chilled water plants, lighting, energy management and control systems (EMCSs) and heating, ventilating and air conditioning systems (HVAC) are all potential candidates for energy improvements. The current estimate is that over $700 million will need to be invested to meet this goal. The USAF will utilize the private sector to make this investment through such programs as ESPC.

Energy Savings Performance Contracts

An energy savings performance contract (ESPC) involves contracting with a private sector company for the identification and installation of energy and water conservation measures. An ESPC contract typically includes design, acquisition, financing, installation, testing, maintenance and operations.. The Energy Service Company (ESCO) performs energy audits, installs energy conservation projects, and performs long term Measurement and Verification (M&V). Payments are based on guaranteed savings. The ESPC program provides USAF installations a method to improve energy-consuming infrastructure projects using private sector financing and utility incentives. Payments are based on guaranteed savings. Infrastructure improvements are accomplished using the savings, thus no additional government funding is required.

The original legislation that authorized this innovative type of contract was passed in October of 1986 as the Shared Energy Savings (SES) contracting. In October of 1992 the Energy Policy Act (EPAct) changed the name of this type of contract to ESPC. Federal legislation authorizes the use of ESPCs, which are performance contracts requiring the ESCO to guarantee sufficient savings to cover all costs associated with an energy conservation measure (ECM). ESPC projects must be funded solely from the savings they generate. The availability of funds for payment to the ESCO is contingent upon verification that the government realizes the guarantee of savings from the ESCO. The USAF's first contract was awarded for Randolph AFB in February of 1994.

In August of 1997, the USAF developed and issued requests for proposals for six *regional* ESCOs. Through this program, each Regional Contracting Officer (RCO) can easily work with an ESCO without having to go through an additional open-bid process. The Air Force Civil Engineer Support Agency (AFCESA) supports each of the RCOs in managing these contracts. The program has been steadily climbing, and the program surpassed $225M in investments in March of 2002.

Energy Savings Performance Contracts Process

Contracting with the Federal Government is sometimes an overwhelming prospect. The USAF ESPC program is intended to facilitate that process, although there are many steps in the process designed to ensure that government money is being wisely spent.

As the first step in the process, the USAF installation arranges with the ESCO to perform a Phase I audit, in which potential energy conservation projects are identified. This is essentially a walk-through audit. The ESCO then presents the findings and early recommendations to the installation commander. The result of this preliminary audit is documented in a Phase I proposal for the ESPC project. This Phase I proposal includes a summary of the projects recommended, costs and savings. In addition, the Phase I report should describe the overall intent of how the M&V will be performed and define the standards that will be used. The USAF installation personnel review the Phase I report to determine which projects to pursue. AFCESA has the responsibility to assist the installation with review and feedback on the Phase I proposal.

Upon acceptance of the Phase I proposal, the ESCO then proceeds to perform a Phase II audit, which is a detailed investment grade audit. At this phase a much more detailed engineering analysis of the proposed measures is completed. Measurements of energy

consumption establish a baseline for energy use and efficiency. These may be short-term or permanently installed long term measurements. The ESCO is generally encouraged to begin taking measurements as early as possible so that a solid baseline can be established. The Phase II audit may take from 3 to 12 months to complete—the wide range is due to the fact that projects can vary from simple retrofits in one building to comprehensive programs across the base.

Once the Phase II submittal is approved, a task order is signed and the ESCO proceeds to the construction and installation phase. After completion, equipment performance is confirmed and savings verified at least annually thereafter.

M&V in the USAF ESPC Program

The cost of ESPC contracts cannot exceed the savings. The savings are guaranteed by the ESCO and are used to repay the investment. The M&V is performed to verify that the guaranteed savings have been realized. The ESCO presents the M&V concept in the Phase I Report, and submits the completed M&V plan with the Phase II Report. In the Phase II proposal, the ESCO describes the entire project and itemizes the savings that are guaranteed. The Phase II proposal also includes a schedule of payments to the ESCO over the term of the contract. Implementation of the M&V occurs in Phase III, the construction and performance verification phase. Validation of the performance and savings occurs at the completion of Phase III and annually thereafter over the life of the contract. If a shortfall in savings occurs, the payment to the ESCO is proportionately reduced. M&V verifies the baseline conditions are accurately defined, verifies the actual savings and certifies payment to the ESCO.

The International Performance Measurement and Verification Protocol (IPMVP) defines numerous approaches to performing the M&V. The IPMVP was developed by the Department of Energy as a collaborative effort with industry, financial interests and government agencies. Four options (A, B, C, and D) are available and have all been used in various situations. Option A is a partially measured protocol and is primarily used for lighting and constant load ECMs. Option B is the retrofit isolation protocol and is used for large equipment M&V where the project can be isolated from other retrofits. Option C focuses on whole building energy measurements and is particularly useful when multiple interacting retrofits are put in a structure. Option D involves calibrated simulations of a facility and is useful when a baseline cannot be measured. Option D is generally the most expensive to implement since highly skilled simulation experts are needed and whole building (Option C) data are usually needed to provide data for calibration.

Regardless of which option is selected, there is a clear process for defining, agreeing to, and implementing M&V. This consists of defining an M&V Plan, defining a baseline, verifying the performance of the installed equipment after construction, testing the M&V equipment, and verifying savings annually.

M&V Plan Definition

Good M&V depends upon having a good M&V plan. The ESPC process is designed to ensure that the ESCO creates a good plan, that the USAF has ample opportunity to review and approve that plan, and that the ESCO conducts the M&V process according to the plan.

As with any planning process, the earlier problems are identified, the easier it will be to avoid them. The Air Force ESPC M&V starts with a discussion during the phase I review conference of the approach the ESCO is considering. Discussions cover the overall intent and protocols to be used in the M&V. This avoids situations where the ESCO devotes a significant amount of resources to detailing a plan that will not be acceptable to the USAF.

Once the ESCO is given approval to continue the project, they develop a Phase II proposal for the energy project. This proposal includes a detailed M&V plan, including the following elements:

- general information (such as a list of each building with full specifications for the planned equipment upgrades),
- the energy savings to be guaranteed by the ESCO,
- a baseline energy consumption model, generated using an approved analysis method,
- a clearly written procedure for verifying the performance of the installed equipment immediately after installation, before acceptance by the USAF (this includes both energy and non-energy performance),
- a clearly written procedure for verifying the performance of the M&V equipment, and
- a clearly written procedure for annual verification of the savings.

This plan must describe in as much detail as possible how the M&V will be conducted. It is important for this plan to be very clearly specified. It will be the basis for review of achieved savings for up to 20 years, and the people who wrote it or evaluated it will not necessarily be available when it is used for savings verification many years down the line.

The USAF reviews the M&V plan carefully to ensure that it will provide adequate oversight and manage their risk appropriately. Review of the energy projects are conducted by base personnel with technical assistance provided by AFCESA. AFCESA provides technical assistance either directly, or with the services of a third party. Once the AF is comfortable with the level of M&V and the adequacy of the approach taken, the contract can be signed.

Baseline Definition

An energy baseline is a measurement or calculation of the amount of energy used before the energy conservation equipment was installed. The baseline results from measurement over some period of time. If total energy consumed is the measure, the IPMVP and ASHRAE Guideline 14 require that the baseline be constructed from a year or integral years worth of data, which prevents bias in the data. If the efficiency of a particular item of equipment is the measure, Option B can be used to perform yearly measures of efficiency at specific loading. Depending on the ECM and thus the M&V method chosen, the baseline can be in the form of a single measured number, a weather-adjusted model, a calibrated simulation, or a first-principles model with some measured and some stipulated inputs. The M&V plan should very clearly identify where measurements are used, and where values are assumed or stipulated.

If the operation of the building changes significantly, an adjustment needs to be made to the baseline. This is contractually and technically difficult to do and must be very carefully specified in the contract.

Another factor in obtaining an adequate baseline is obtaining good data. The measurement equipment must be calibrated and installed correctly. The ESCO can often install equipment during the Phase I or II time frame to obtain the data needed for a total consumption baseline.

Post-Construction Performance Verification of the Installed Equipment

Performance verification is an important part of M&V. Performance verification validates that the operational requirements of the system are met. M&V consists of verification of both equipment performance and energy savings. For example, if a chiller is installed, the ESCO must verify both that it has the cooling capacity that it was required to have, and that it is achieving the savings that were guaranteed.

The plan for conducting this verification is included in the Phase II proposal, and approved by the USAF prior to contract signing. This plan will include a diagram of the system showing measurements to be made, measurement equipment to be used, and data to be taken.

Immediately after installation, performance verification tests are conducted and witnessed by USAF designated personnel. The ESCO must install and test the equipment, and certify that the installation meets manufacturers requirements. A USAF representative witnesses these tests and accepts the results if performance is achieved. Performance verification must often be conducted when the equipment can be operated over a specified range of loads. All measurement equipment must be calibrated within the previous year and have a certification of calibration.

M&V Equipment Testing

If permanent monitoring equipment is installed to provide the M&V data or if an existing Energy Management and Control System (EMCS) will provide the M&V data, testing and commissioning of the monitoring system is needed. A testing plan must be included in the Phase II Report, and approved by the USAF prior to contract signing. The plan will include the initial calibration of sensors and measurement equipment, verification of correct placement of sensors and operation of the data acquisition system, and tests to validate that the measurements are performed on the required periodic basis. All of this testing must be done according to manufacturer's specifications, must be witnessed by a USAF representative, and must be accompanied by certification of calibration. Since M&V involve yearly or other approved interval measurements, the equipment and sensors must be calibrated on a scheduled basis. The plan for this ongoing maintenance must be included in the Phase II Report.

Annual Verification of Savings

The M&V plan includes the expected annual savings, which the ESCO uses to base the guarantee. This relates to the energy and dollar amount that the ESCO guarantees will be

saved every year, as a result of the retrofit. The actual savings may differ from the guaranteed amount and needs to be based on measurements.

The M&V plan must very clearly identify how performance and savings will be verified after the retrofit. For example, in a small chiller replacement, the ESCO would clearly state the test procedures for determining whether the chiller meets performance requirements and operate at the prescribed efficiency. Test procedures would include the measurements to be made, at what loads and operating conditions and parameters and would include the methods for verifying the annual savings. If the post-installation efficiency measurement is smaller than the guaranteed amount, an adjustment will be applied to compensate the USAF for the unachieved savings. The ESCO can either restore the system to the prescribed efficiency level or reimburse the lost savings. The method of determining the course of action must be very clearly specified in the contract. Because of the lengthy term of some of these contracts, it is essential that the method of annual verification be completely and clearly defined in the contract. It is highly likely that the personnel involved in the project will change several times during the contract term. There must be sufficient documentation for a new contracting officer and new USAF energy manager to understand what measurements will be taken and how savings will be calculated from the measurements made.

Example of an M&V Application

Fairchild Air Force Base (FAFB), located in Washington state, utilized ESPC to replace an old, centralized steam plant with high efficiency, low maintenance boilers with lower operating expenses and energy loss. The project guarantees to save the USAF over thirty four million dollars over the next twenty years. The development and implementation of a cost effective M&V plan is critical to ensuring that these savings will occur. The contract for this project was recently awarded, and the detailed design for the project is currently underway.

The project disconnects seventy-nine (79) buildings from the aging central steam plant and installs one hundred and ten (110) high efficiency natural gas hot water and low-pressure steam boilers. The boilers to be installed are ranked by size and include five large size boilers, ninety-three medium size boilers and twelve small size boilers. The project captures energy and operational savings associated with the old, high-pressure steam plant, supply lines and condensate return lines. The term of the contract is twenty years. The new boilers are guaranteed to maintain a total average thermal efficiency of 85% or better throughout the life of this contract.

The plan to measure and validate the savings over the 20-year term is critical to the success of this project. The M&V plan needs to be reliable in demonstrating the true savings and be cost effective since the cost of M&V is paid for out of the savings generated. If the cost of the M&V were higher than really needed, the funds available for upgrades would be reduced. AFCESA enlisted the assistance of third party to provide M&V expertise. Agreement on a workable solution for this project came quickly. The template that was used has helped establish the standard for central plant decentralization ESPC projects.

The M&V plan involved two separate procedures. The first procedure used Option C from the IPMVP-2001 for the baseline and the first year of post retrofit operation. The steam plant had 4 years of daily gas consumption and steam production data that were used for the

baseline. After the individual boilers are installed in each building, gas meters are installed and will be read monthly. This will provide the total gas used on a monthly basis. The second procedure applied Option B from the IPMVP-2001 to measure the efficiency of each of the boilers after installation. Then after the first year, a sampling of the boiler efficiency is taken to determine that years savings. The sampled boiler efficiency allows for a cost effective method to be implemented and still assure that the savings being guaranteed would be achieved.

The activities in the Fairchild M&V plan are discussed in the following sections. First, the M&V plan was defined. Second, a consumption baseline and first year savings will be obtained from consumption measurements. Third, the efficiency baseline and efficiency measurements will be used to measure the performance of the boiler replacements from year 2 through the 20-year life of the contract.

Definition

FAFB collected gas use and steam use on a daily basis since 1997. The baseline involves a simple weather normalized energy-in before compared to energy-in after method. This is equivalent to the International Performance Measurement and Verification Protocol (IPMVP), Option C – Whole Building Approach, applied to multiple facilities at an USAF Base. Figure 1 shows the central heating plant with the associated measurements and losses. The advantage of using Option C is the relative simplicity and low cost. By knowing the heat input (natural gas) to the CHP and the local weather, a weather-normalized baseline for energy-in can be built. After reviewing all of the data, the data from the year 2000 were selected.

Baseline and Year One Savings (Option C)

Once the boilers are installed with the gas meters at each building, a post retrofit measurement can be made very economically. Since only one year is needed for consumption measurements, the cost is quite low. The USAF could not assure that the use of the installation, and thus the use of energy, would be constant over the 20 years of the contract. This is the reason that the consumption (Option C) is used for the energy consumption baseline and post retrofit first full year. Everyone agreed to the assumption that the use function will not change during this one-year time period. The four years of data taken from 1997 through 2000 validate this assumption, since the weather normalized error was under 4% over these four years.

The following procedure will be followed to verify the consumption guarantee for the first year of operation:

1. Establish a weather normalized consumption baseline using data from the year 2000.
2. Determine an average daily consumption for each month after the construction and installation is completed.
3. Obtain the average monthly temperature for each corresponding month.
4. Determine the average gas consumption per day with respect to the average monthly temperature and determine a best-fit weather normalized model using the data.

5. Use the weather data from year 2000 and the year 20XX model to calculate the modeled consumption in the base year with the post-ECM improvements.
6. Determine the energy savings obtained.
7. Compare to the guaranteed savings.

At the end of post retrofit year 1, the energy consumption savings will be verified from measurements.

Efficiency Baseline and Yearly Savings

After installation and at the end of the first year, individual boiler efficiencies will be measured and an average BTU weighted efficiency determined. Thereafter, a sampling of boilers will be taken annually to determine the BTU weighted efficiency for that year. This will be compared against the base BTU weighted efficiency to determine whether or not the guarantee is achieved. Following is the procedure to establish the BTU weighted efficiency during the first year of operation:

1. Measure the efficiency of each boiler when installed.
2. Use the American Society of Mechanical Engineers (ASME) Power Test Code 4.1 (PTC 4.1) to perform the efficiency determination.
3. At the end of the first year of operation, measure the average weighted efficiency using the approved sampling.
4. These two BTU weighted efficiency measurements will then be averaged together to obtain the BTU weighted efficiency baseline.

For each year after the first full year of operation, efficiency will be used to track performance. The following Year N procedure will be followed to verify the efficiency baseline:

1. Measure the average weighted efficiency using the approved sampling method.
2. Measure 5 large boilers, 10 medium boilers and 1 small boiler. The USAF will select the boilers to be measured from the installed boilers.
3. Use the American Society of Mechanical Engineers (ASME) Power Test Code 4.1 (PTC 4.1) to perform the efficiency determination.
4. These efficiency measurements will then be used to calculate a BTU weighted averaged efficiency boiler efficiency for Year N.

To keep the costs affordable for these measurements, all parties agreed to measure all five large boilers yearly and sample ten medium boilers and one small boiler yearly. Of the 110 boilers, 5 are large, 93 are medium and 12 are small.

Power Test Code (PTC) 4.1 “Steam Boiler Efficiency Measurement” from the American Society of Mechanical Engineers (ASME) will be used to measure the boiler efficiency. This can be used for steam and hot water boilers and has a simplified calculation and summary sheet for data collection. It provides two methods for measuring boiler efficiency. The first method requires energy in and energy out measurements. This method requires the measurement of the water or steam flow and temperature difference between the

supply and return. The second method measures the energy in and calculates the energy out from the flue temperature and other loss measurements.

Conclusion

The plan implemented at Fairchild AFB achieves a simplified but effective approach to M&V. The plan ensures the continued performance of the conservation project by measuring those parameters that have the greatest effect on the savings. Measuring the efficiency over the life of the contract puts responsibility on the ESCO to keep the efficiency of the boilers at the specified or higher level. This reduces overall costs by focusing the ESCO on maintaining equipment efficiencies and not on monitoring for changes in building use or functions. If the equipment is operating at top efficiency, then the USAF achieves the maximum benefit regardless of whether they're operating 12 or 24 hours a day. When M&V is evaluated from a cost benefit perspective, the dollars saved by reducing M&V costs can be invested in additional energy improvements.

M&V continues to be a developing area. Instrumentation costs are dropping, thus enabling measurements where cost had previously restricted the use of some measurements. Installation cost is also being reduced with new methods and sensor technologies.

The USAF has a very proactive ESPC program and is committed to continued improvements in its successful implementation. Working in partnership with their ESCOs, improvements in M&V have resulted in reduced costs, reduced development time and greater confidence in the savings guarantee.

The USAF continues to strive to meet EPAct and EO 13123 mandates through an aggressive facility energy management program using all available resources. The USAF has made excellent progress in meeting these mandates. The continued use of ESPC contracts are a primary means the USAF will use to achieve EPAct and EO 13123 mandates.

References

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