Example Measurement & Verification Plan
for a
Super ESPC Project

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Federal Energy Management Program (FEMP)
Office of Energy Efficiency and Renewable Energy
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Contents

Background

This document is a comprehensive M&V Plan for a fictitious energy performance contract project. This document is intended to serve the following purposes:

- Provide examples of M&V Plans for common ECMs that comply with the requirements set forth in the FEMP M&V guidelines, Version 2.2[1], and
- Provide and promote use of a consistent format for M&V Plans for Federal ESPC projects, as detailed by the M&V Plan Outline[2].

This document contains M&V Plans for three measures, using Options A and B, at a fictitious federal office building. The ECMs include lighting, energy management and control system (EMCS) installation, and a chiller retrofit:

- Lighting Efficiency Measure – Option A, FEMP Method LE-A-02
- Energy Management Control System Installation – Option B, FEMP Method GVL-B-01
- Chiller Replacement Measure – Option B, FEMP Method CH-B-02

[1] FEMP M&V Guideline V 2.2 available at http://www.eere.energy.gov/femp/financing/superespcs_mvresources.cfm

[2] M&V Plan Outline for FEMP Super ESPC projects is available at http://www.eere.energy.gov/femp/financing/superespcs_mvresources.cfm

Measurement and Verification Plan
for the
Piscataway Federal Center

Provided in fulfillment of Super ESPC requirements,
Delivery Order Number FAKE34621

By

ABC Engineering, Inc.

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1. EXECUTIVE SUMMARY / M&V OVERVIEW AND PROPOSED SAVINGS CALCULATIONS

1.1 Proposed Annual Savings Overview

The goal of this project is to achieve energy savings through upgrades to the building's lighting, improvements to the central plant chiller, and the addition of an energy management control system (EMCS). This project will also result in improved lighting levels and more reliable HVAC and central plant operation, thereby reducing maintenance costs. Chiller operations and maintenance savings of $12,000 is due to the replacement of a service contract with an ABC service contract as part of this Delivery Order. The $12,000 represents a net reduction in annual service expenses. Savings from the energy conservation measures (ECMs) included in the project are summarized in Table 1-1.

Table 1-1: Proposed Annual Savings Summary

ECM	Electric energy savings (kWh/yr)	Electric demand savings (kW-yr)*	Natural gas savings (therms)	Water savings (gallons/yr)	Total energy savings (MBtu/yr)	Total energy & water cost savings, Year 1 ($/yr)	O&M cost savings, Year 1 ($/yr)	Total cost savings, Year 1 ($/yr)
Lighting	186,406	690	0	0	636	$15,339	$0	$15,339
EMCS	899,252	0	0	0	3,069	$23,841	$0	$23,841
Chiller	194,119	502	0	0	663	$14,230	$12,000	$26,230
Total	**1,321,032**	**1,191**	**0**	**0**	**4,368**	**$53,410**	**$12,000**	**$65,410**

Utility usage for site during the period from January to December 2002 iscompared to project savings in Table 1.2.

Table 1-2: Site Use and Savings Overview

	Electric energy (kWh/yr)	Electric demand (kW-yr)*	Natural gas (MBtu/yr)	Other energy (MBtu/yr)	Water (kGal/yr)	Total energy (MBtu/yr)
Total proposed project savings	1,321,032	1,191	0	NA	NA	4,509
Usage for entire site	9,195,271	31,890	0	NA	NA	31,383
% Total site usage saved	14.4%	3.7%				14.4%
Project square footage (KSF)	664					
Total site square footage (KSF)	664					
% Total site area affected	100%					
Notes	-	-	-	-	-	-

MBtu = 10^6 Btu = 293 kWh
*Annual electric demand savings (kW/yr) is the sum of the monthly demand savings.
KSF = 10^3 square feet.
If energy is reported in units other than MBtu, provide a conversion factor to MBtu for link to delivery order schedules (e.g. 0.004313 MBtu / kWh).

1.2 M&V Plan Summary

ABC Engineering will perform measurement and verification (M&V) activities for each of the three ECMs in order to estimate the actual cost savings achieved in the project. The M&V plans for the three ECMs are described in Sections 3 through 5 of this document, and are summarized in Table 1-3.

Table 1-3: M&V Plan Summary

ECM	ECM description	M&V option used*	Summary of M&V plan
Lighting	Retrofit existing lighting fixtures w/ T-8 lamps, elec. ballasts	LE-A-02	Measured fixture wattages; short-term monitoring of operating hours.
EMCS	Install EMCS for automated control of HVAC systems	GVL-B-01	Instantaneous power measurements; stipulated baseline operating hours, monitored post-installation operating hours.
Chiller	Replace chiller	CH-B-02	Baseline and post-installation kW metering.

* M&V options cited are from FEMP M&V Guidelines: Measurement & Verification for Federal Energy Projects, Version 2.

2. WHOLE PROJECT DATA / GLOBAL ASSUMPTIONS

2.1 Risk and Responsibility

The Risk and Responsibility Matrix is located in the Appendix of this document.

2.2 Energy, Water, and Operations and Maintenance (O&M) Rate Data

Energy costs used to determine the value of the energy savings are based on the rates that the facility is paying as of January 2004. The energy rates will be escalated to account both for inflation and for changes to the real price of energy as anticipated by NIST[3]. In order to remain conservative without unnecessarily lengthening the term of the contract, it was decided to use the Census Region 1 fuel price indices with an assumed 3% inflation rate. The overall inflation rate over 15 years is 2.9%. If energy prices increase at a greater rate, then the agency will realize more savings than will be claimed. The agency also needs to realize that in the unlikely event that energy prices do not increase as predicted, the energy saved will still be valued at these rates.

The Federal Building purchases both electricity and gas from Public Service Electric & Gas (PSE&G). Electricity is provided under rate schedule GS-1. The following rates apply for the duration of the contract:

Table 2-1: Electric Rate Schedule GS-1

Year	Year	Index	kWh	kW
0	2003	1.00	$0.0525	$8.052
1	2004	1.02	$0.0536	$8.215
2	2005	1.03	$0.0541	$8.296
3	2006	1.03	$0.0541	$8.296
4	2007	1.04	$0.0546	$8.377
5	2008	1.06	$0.0557	$8.540
6	2009	1.09	$0.0573	$8.784
7	2010	1.13	$0.0594	$9.109
8	2011	1.18	$0.0620	$9.516
9	2012	1.23	$0.0647	$9.923
10	2013	1.27	$0.0668	$10.248
11	2014	1.31	$0.0689	$10.573
12	2015	1.36	$0.0716	$10.980
13	2016	1.42	$0.0748	$11.468
14	2017	1.47	$0.0774	$11.875
15	2018	1.54	$0.0806	$12.363

[3] NISTIR 85-3273-17 (Rev. 4/01) Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis – April 2002, Annual Supplement to NIST Handbook 135 and NBS Publication 709

2.3 Schedule and Reporting for Verification Activities

The schedule of M&V submissions is summarized in Table 2.2.

Table 2-2: Schedule of Verification Reporting Activities

Item	Time of submission	Owner's review and acceptance period
Post-Installation Report	30 days after acceptance	30 days
Annual Report	30 days after annual performance period	30 days

The Post-Installation Report will be submitted within 30 days of project completion. The Federal Building's representative will then have 30 days to review and approve the Post-Installation Report. Commissioning will be reported separately. After receipt of the Post-Installation Report, GSA will issue ABC Engineering a written notification of acceptance.

The Post-Installation Report will document any deviations from the specified equipment and, if necessary, make recommendations for approval of any adjustments to M&V plans specified herein. The Post-Installation Report will follow the format and content defined for Super ESPC projects. The specific items that will be reported are described in the M&V plan for each ECM.

The Annual Report will be due within 30 days of the end of the annual performance period. The Federal Building's representative will have 30 days to review and approve the Annual Report. The Annual Report will follow the format and content defined for Super ESPC projects. The specific items that will be reported are described in the M&V plan for each ECM.

2.4 Operations, Preventive Maintenance, Repair, and Replacement Reporting Requirements

ABC Engineering will report on all maintenance work completed in the Annual Report. GSA will continue to maintain maintenance records per existing procedures, and will make these records available to ABC Engineering upon request.

2.5 Construction Period Savings

No construction period savings have been claimed.

2.6 Status of Rebates

Prescriptive rebates are available from New Jersey's Clean Energy Program[4] for lighting efficiency upgrades. The table below lists lighting incentives available for this project. ABC Engineering has submitted an application on behalf of the GSA to PSE&G to

[4] http://www.njsmartstartbuildings.com/main/equip_inc.html

receive rebates for the lighting efficiency measure. Incentives will be provided directly from PSE&G to the GSA.

Table 2-3: Lighting Rebates from Public Service Electric & Gas

Fixture type	# Fixtures	Rebate $ / fixture	Total rebate
T-8, 4-lamp	1,347	$10	$13,470
T-8, 2-lamp	94	$10	$940
Screw-in CFLs	307	$0	$0
Exit Sign LEDs	39	$20	$780
TOTAL	1,745		$15,190

2.7 Dispute Resolution

The procedures defined in this M&V plan should prevent any disputes. In the unlikely event that a dispute does arise regarding issues such as baseline adjustments or use of measured data, the issues will be jointly reviewed and an agreeable resolution reached. Otherwise, the arbitration clause in the Management Plan of the Delivery Order will apply.

3. ECM 1 — LIGHTING M&V PLAN AND SAVINGS CALCULATION METHODS

3.1 Overview of ECM, M&V Plan, and Savings Calculation

A complete retrofit of the lighting equipment in the Federal Center is planned as a part of the ESPC agreement. The existing T-12 fluorescent fixtures (1,745 total) will be retrofitted with more efficient equipment, primarily T-8 lamps and electronic ballasts. Energy savings and demand savings will result from this retrofit. An additional benefit will be enhanced quality of lighting, as the new fixtures will provide improved color rendering and reduced flicker.

The M&V Plan for the lighting efficiency retrofit at the Federal Center will follow FEMP M&V Option A, Method LE-A-02. The variables affecting savings from this lighting project are fixture powers, hours of operation, and level of coincident operation (% operation when the building peak demand is set). Fixture powers will be measured on a sample of the most common fixture types. For less common fixture types, fixture power will be based on a table of standard fixture powers or manufacturer's data.

Operating hours will be measured on a sample of space types during the Detailed Energy Survey. The measured hours will then be used to estimate the energy and demand savings during performance period and will not be adjusted even if the actual operating schedules change.

Option A has been selected for this retrofit due to the measure's relatively small cost savings contribution of all the retrofits installed at the Federal Center, and due to the high confidence with which the fixture demand and operating hours may be determined. Equipment numbers and locations will not vary, and operating hours are not projected to change after the project is implemented.

The M&V Plan for this retrofit assumes:

- Operating hours will be measured before the retrofit. The hours for the lighting fixtures will be the same before and after the equipment retrofit for the purpose of energy savings calculations.
- Fixture powers before and after the retrofit will be measured.
- Interactive effects on heating and cooling equipment from the lighting retrofit will not be considered.
- Lighting levels will not decrease as a result of the lighting equipment retrofit. Existing lighting levels have been measured and recorded for each area. Results are included in the equipment inventory.

3.2 Energy and Water Baseline Development

During the Detailed Energy Survey, which took place during April 2003, a comprehensive lighting audit was completed. A room-by-room inventory of fixture counts, types, and circuits was made. This inventory of all existing lighting equipment, including lighting levels, is provided in the Appendices.

3.2.1 Fixture Power

During the lighting survey, fixture types (lamp/ballast combinations) present in this facility were identified. Samples of the most common fixture types were measured to determine the fixture power under actual operating conditions. The measured fixture types represent more than 75% of the baseline connected load. For the remaining fixture types that were not measured, fixture powers were taken from a table[5] of standard fixture powers.

When the fixtures are replaced, power measurements will again be taken on a sample of fixtures that represent more than 75% of the new connected load. For the remaining fixture types that are not measured, fixture powers will be taken from a table of standard fixture powers or from manufacturer specifications. The table of fixture powers to be used is from PSG&E as part of their rebate program.

In all cases, the number of power measurements taken is sufficient to achieve a 10% precision at 90% confidence as discussed in Section 3.2.3 Sample Size. Because fixture powers tend to be in close agreement with each other, usually only three measurements were required to meet this precision and confidence criteria. In some cases, three lighting circuits (rather than three fixtures) were measured where all fixtures were the same and no other loads were present. The total power measured was then divided by the number of fixtures on each circuit to determine the average fixture power. The results of the measurements are presented in Table 3-3 in section 3.2.4.

A Fluke 39 single phase power meter was used for all measurements. Measured lighting fixtures had been operating at least one hour prior to measurement in order to achieve typical operating temperature. The Fluke was used to measure actual wattage, which considers volts, amperes, and power factor.

3.2.2 Usage Group Operating Hours

Lighting usage groups were identified based on space functionality and estimated annual operation hours. For usage groups that represented more than 5% of the savings, fixture operating hours were monitored to determine the typical operating hours. Groups that represent 5% or less of the expected energy savings were not metered; operating hours were based on typical hours of occupancy. However, sufficient usage groups were monitored to account for at least 75% of the total energy savings.

During the audit, the operating hours for a sample of lighting fixtures in each usage group was measured over a three-week period. The monitored operating hours were used to

[5] PSG&E table…www…

estimate the annual operating hours for each of the seven usage groups with a precision of 20% at 80% confidence. Initial sample size for each usage group was eleven loggers before correcting for finite populations. In one case, additional loggers were deployed for a second three-week period in order to meet the desired precision and confidence criteria. The measured operating hours will be stipulated as annual operating hours during the performance period.

Hobo lighting loggers were installed inside the lighting fixtures. These loggers record the time of the change-of-state between on and off. In addition to the total operating hours recorded, logger data was evaluated to determine the number of hours that a fixture was operating between 1:00 and 4:00 p.m. This information was used to estimate the probability that fixtures in each usage group would be operating coincident with the building peak load. This data was used to determine an overall peak coincidence factor for the lighting. The results of the measurements are presented in Table 3-2 in Section 3.2.4.

The specification of the loggers is: light threshold range is 10 to 300 lumens/ft2 (fluorescent light); the sensitivity to incandescent light is about ten times greater. The lighting loggers record on-off times with an accuracy of ±1 minute per week). The results of the metered data are summarized in the following section and all metered data are included in the Appendix.

3.2.3 Sample Sizes

Appendix D.3.2 in the FEMP M&V Guidelines (V 2.2, 2000) describes the method used to determine the sample size for each usage group measurement. Precision and confidence criteria were selected based on experience with previous projects and represent a reasonable compromise between desired precision and cost-effectiveness.

A sample of monitoring points for each usage groups was determined by the following procedure:

1. Define the desired precision and confidence for each measured parameter. For measuring fixture powers, 10% precision at 90% confidence is desired. For measuring usage group operating hours, 20% precision at 80% confidence was selected.

2. Since sample size required to meet stated precision and confidence criteria is dependent on the actual measurement results, assume an initial coefficient of variation for each measured parameter. For fixture power, use $C_v = 0.1$; for operating hours, use $C_v = 0.5$. The actual precision achieved will be calculated and additional measurements made if the stated precision criteria is not initially met.

3. Using the stated assumptions and Equations D.3 and D.4 from the FEMP M&V Guidelines, estimate the sample size *n* for the total population of lighting circuits using the following standard statistical equations for estimating sample populations:

$$n = \frac{Z^2 C_v^2}{p^2} \quad (D.3); \quad n^* = \frac{Nn}{N+n} \quad (D.4)$$

where:

Z	=	Z statistic for desired confidence interval
p	=	desired precision
C_v	=	coefficient of variation
N	=	population of usage groups or fixtures
n	=	sample size assuming infinite population size
n^*	=	sample size corrected for population size

Because the sample sizes n and n* must be integers, the results from Equations D.3 and D.4 need to be rounded up to the nearest integer value. The coefficient of variation (C_v) is simply the standard deviation of the measurement divided by the average measurement value.

$$C_v = \frac{\sigma}{\bar{x}}$$

where:

σ	=	standard deviation
$\bar{x}$	=	average measured value

When the measurements have been taken, the C_v can be quickly calculated. If the actual C_v is less than the assumed value, then the precision and confidence criteria have been met. If the actual C_v is greater than the assumed value, then additional measurements must be taken. Alternatively, an investigation may reveal that one sample was misidentified and belongs in another usage group or fixture category. When taking power measurements, the standard deviation will be calculated in the field. If the C_v is greater than 0.1, three additional fixtures or circuits will be measured and the fixtures will be inspected to reveal whether any were misidentified. For operating hour measurements, a C_v significantly greater than 0.5 will require additional measurement samples such that the total number of samples satisfies Equations D.3 and D.4 using the measured C_v.

4. Using the actual C_v, the precision can be calculated from the previous equations after some simple algebraic manipulation. In practice, the finite population correction only needs to be used where the actual population (N) is less than 100.

$$p = \frac{ZC_v}{\sqrt{n}} \quad ; \quad n = \frac{Nn^*}{N - n^*} \quad ; \quad p = \frac{ZC_v}{\sqrt{\dfrac{Nn^*}{N - n^*}}}$$

5. Fixture powers will be based on the average of the measured values. Usage group operating hours will be based on the average of the measured values. The coincidence factor (CF, probability that operation coincides with building peak) for each usage group will be based on the operating hours between 1:00 and 4:00 p.m. as follows:

$$CF = \frac{Average\ Operating\ Hours\ between\ 1:00\ and\ 4:00}{3\ hours}$$

6. Using the demand savings and measured operating hours, estimate the annual energy savings from each usage group.

3.2.4 Results

Based on Equations D.3 and D.4 and the assumed initial coefficient of variation, the following table lists the initial sample size for each of the measured parameters for lighting.

Table 3-1: Initial Sample Sizes For each Usage Group

Measured Value	Precision	Confidence	Z	Assumed Cv	Initial Sample Size, n
Power, W	10%	90%	1.645	0.10	3
Hours	20%	80%	1.282	0.50	11

Table 3-2: Fixture Wattage Measurements – Types, Monitoring Points, Results

Fixture Type	Number of fixtures	% of Energy Savings	Table Power, W	Number of Measurements	Average Measured Power, W	Std Dev, W	Actual Cv	Precision at 90% confidence
F44EE	1,000	70%	144	3	140	11.2	0.08	7.6%
F42EE	60	9%	72	3	74	3.7	0.05	4.6%
F82ES	339	7%	128	6	120	18.0	0.15	10.1%
75 Watt Inc.	307	10%	75	3	75	4.5	0.06	5.7%
Inc. Exit Signs	39	2%	22					
Totals		98%						

The fixture groups and metering results are shown in Table 3-2 above. The number of samples in the Exit signs was set to zero because of their small contribution to the overall savings. The initial three measurements of the 8-ft. fluorescent fixtures revealed a C_v greater than 0.1, a result likely caused by all of the fixtures having old and flickering lamps. An additional three measurements were taken to compensate. The resulting precision of 10.1% with six measurements is considered as meeting the established statistical criteria.

The operating hours for three usage groups were monitored for a three-week period in April – May 2003. The average annual operating hours for each usage group are shown in Table 3-3, along with the actual C_v of each group. The table shows that the estimated C_v for two of the groups was less than the assumed value of 0.5 and so the precision criteria for those two groups was met. For the closed office areas, the large variability in usage resulted in a C_v greater than 0.5 and an initial precision of 24% with eleven samples. As a result, an additional eleven loggers were deployed in different closed office spaces for another three-week period in May 2003. With a total of 22 measurements, the achieved precision is less than 20% at 80% confidence as desired.

Table 3-3: Usage Group Descriptions, monitoring Points and Results

Usage Group	Number of fixtures	# Circuits (N)	# Points (n)	Demand savings, (kW)	Annual op. hours	Energy savings, kWh	% of total	C_v	Precision at 80% confidence	Coincidence 1 – 4 p.m.
24 Hour - Exit	69	21	0	0.82	Est. 8,760	7,169	4%			
24 Hour - Misc	30	9	5	1.78	8,760	15,598	8%	0.2	7.6%	72%
Closed Office Areas	673	204	22	22.96	1,900	43,377	23%	0.65	16.8%	68%
Common Office Areas	581	176	11	37.39	2,800	104,343	56%	0.43	16.1%	86%
Conference Rooms	43	13	0	2.75	Est. 1,600	4,436	2%			
Halls and Common areas	131	37	0	1.56	Est. 3,000	4,633	2%			
Storage, comp. closets	218	66	0	5.57	Est. 1,200	6,850	4%			
Totals	1745	526	38	72.83		186,406	100%			79%

The weighted peak coincidence factor is used to calculate the demand cost savings from the demand savings. The demand reduction listed in Table 3-3 is based on a reduction in the connected load. However, not all of this reduction will appear in the form of reduced demand charges on the utility bill. The coincidence factor for each usage group represents the fraction of fixtures operating when the building peak demand is set and therefore represents that usage group's contribution to the demand reduction seen at the utility meter.

3.3 Proposed Energy and Water Savings Calculations and Methodology

The baseline and post demand for each usage group will be determined using Equation 3-1.

Equation 3-1:

$$\text{kW UsageGroup}_{U,\text{baseline}} = \Sigma u\ (\text{kW}_{\text{baseline fixture}})$$

$$\text{kW UsageGroup}_{\text{Upost}} = \Sigma u\ (\text{kW}_{\text{post fixture}})$$

Energy (kWh) and demand (kW) savings will be calculated using Equation 3-2 and Equation 3-3, respectively.

Equation 3-2:

$$\text{kWh Savings} = \sum u\ \left[(\text{kW UsageGroup}_{\text{U,baseline}} - \text{kW UsageGroup}_{\text{U,post}}) \text{ x Annual Hours of Operation} \right]$$

Equation 3-3:

$$\text{kW Savings} = \sum u\ \left[(\text{kW UsageGroup}_{\text{U,baseline}} - \text{kW UsageGroup}_{\text{U,post}}) \text{ x Coincidence Factor} \right]$$

where:

kWh Savings	=	kilowatt-hour savings realized during one year post-installation
kW Savings	=	Coincident kilowatt demand saving realized
kW UsageGroup $_{\text{U,baseline}}$	=	Lighting baseline demand for usage group u
kW UsageGroup $_{\text{U,post}}$	=	Lighting demand during post-installation period for usage group u
Annual Hours of Operation	=	Annual number of operating hours for the usage group u
Coincidence Factor	=	Maximum percent of lighting operating during at time building peak electrical demand, as determined from metered data from time-of-use loggers

The annual cost savings will be determined using Equation 3-4.

Equation 3-4:

$$\text{Annual Cost Savings} = [\text{Rate}_{\text{kWh}} \times \text{kWh}_{\text{Savings}}] + [12 \times \text{Rate}_{\text{kW}} \times \text{kW}_{\text{Savings}}]$$

where energy rates are outlined in Table 2-1 in Section 2.2.

As described in the Responsibility Matrix, no alterations or renovations to the office spaces are anticipated for the duration of this delivery order. Should the GSA make any improvements, it assumes the risk that the savings calculated by this plan may not materialize.

3.4 Operations and Maintenance and Other Cost Savings

O&M savings are not being claimed or documented for this ECM.

3.5 Proposed Annual Savings for ECM

See detailed lighting inventory and retrofit specifications, along with savings calculations in the Appendices.

Table 3-4: Proposed Annual Savings for ECM 1- Lighting

	Electric energy use (kWh/yr)	**Electric demand* (kW-yr)**	**Total energy use (MBtu/yr)**	**Electric energy cost, Year 1 ($/yr)**	**Electric demand cost, Year 1 ($/yr)**	**O&M costs, Year 1 ($/yr)**	**Total costs, Year 1 ($/yr)**
Baseline use	557,365	2,090	1,902	$29,262	$16,832	NA	$46,094
Post-installation use	370,959	1,400	1,266	$19,475	$11,276	NA	$30,752
Savings	**186,406**	**690**	**636**	**$9,786**	**$5,556**	**$0**	**$15,342**

3.6 Post-Installation M&V Activities

Upon completion, an as-built inventory of post-installation lighting fixtures will be supplied, including the lighting ballasts and lamps actually installed, and lighting illumination levels (foot-candles) in each area. Savings predictions will be corrected based on as-built data and will be reported in the Post-Installation Report.

Immediately following installation, fixture power will be measured in a manner identical to that for the baseline fixtures. Sample sizes for measurements and procedures are described in Sections 3.2.1 and 3.2.3. Measurement standard deviations will be calculated in the field. Any fixture types exceeding a Cv of 0.10 will have three additional measurements taken and the fixtures will be inspected to verify that the correct fixtures have been installed. These measurements will be used to calculate actual expected energy savings, and will be detailed in the Post-Installation Report.

3.7 Performance-Period Verification Activities

Once per year, for each year of the contract, ABC Engineering will conduct a site visit, during which the lighting system will be inspected to verify proper operation, ensure that it has been maintained, and ensure that it continues to have the potential to generate the expected savings. A minimum of ten fixtures of each type measured (four types) will be opened to verify lamp counts and lamp and ballast types. Lighting replacement stock will be inspected during the annual site visit to ensure that the proper replacement equipment is available.

The Annual Report will detail the results of annual inspections, noting significant problems such as burned-out lamps and ballasts and deviations with the expected number of operating fixtures, etc. An estimate of energy and cost savings for the year will be provided. As stated in the Responsibility Matrix, the GSA is responsible for the consistency of operating hours and equipment replacement with identical or comparable equipment. Changes in equipment type or operating hours will not result in adjustments to the reported (guaranteed) savings.

4. ECM 2 — EMCS M&V PLAN AND SAVINGS CALCULATION METHODS

4.1 Overview of ECM, M&V Plan, and Savings Calculation

A new energy management and control system (EMCS) will be installed in the Federal Center to provide enhanced control of the facility's HVAC systems. This system will provide energy and cost savings by providing time of day control for the chiller, water circulation pumps, and air-handler fans.

Currently, the HVAC fans and pumps operate at constant speed under manual on/off control. The fan motors operate continuously and the chiller and pump motors run longer than necessary. The control system will use an "optimum start" sequence to determine the start-up time for this system, which will likely range between 4:00 a.m. and 6:00 a.m. This sequence will evaluate indoor and outdoor conditions by taking temperature (indoor and outdoor) and humidity (outdoor) measurements and start the equipment accordingly, so that proper set-points are reached prior to occupancy. Shut-off time will be set to 9:00 p.m. in order to give cleaning crews time to work.

Current heating and cooling set-points are determined by pneumatic thermostats which are no longer calibrated and can be changed by the occupants. The current heating and cooling set-points are not easily quantifiable, but range from 68ºF to 76ºF winter and summer. The new winter set-point (October – April) will be 68°F and the summer set-point (May – September) will be 72°F, as agreed to between ABC and GSA.

The new control system will start and stop the equipment as needed, thereby reducing operating hours, and provide savings in the form of reduced kilowatt-hour consumption. Demand savings will not be realized for this measure, because the reduced operation hours will take place at night and not during daytime peak periods.

Chiller savings due to reduced chiller runtimes will not be claimed. While the existing chiller is enabled during the evenings in the cooling season, the actual hours of evening operation are uncertain. Rather than stipulate an uncertain number of operating hours as the baseline case, savings due to reduced runtimes will not be claimed. GSA will still benefit from this reduced runtime. Operating conditions for the chiller will be monitored, but this information will be used for chiller savings verification.

Natural gas savings from reduced heating are not included due to the difficulty in quantifying these savings.

The measurement and verification plan for the EMCS installation will follow FEMP Option B, Method GVL-B-01: generic variable load project with continuous metering. The EMCS system will be used to record the actual run time of the equipment during the performance period.

Option B was chosen for this measure because of the concern that post-installation motor operation hours may not turn out as estimated. In addition, Option B was selected because the installation of the new control system readily lends itself to ongoing measurement. The control system can track the actual run times of equipment with great accuracy and very little added cost.

The following assumptions are employed for this M&V plan:

- In the absence of this project, the pump and fan performance would remain constant (and not degrade) at the levels measured during the detailed energy survey. This is a conservative estimate in that should motor demand levels increase, the overall effect on baseline energy consumption would be to increase, thus increasing the savings estimated for this project.
- Chiller savings due to reduced evening runtimes will not be claimed.
- In the absence of this project, the operation schedule of the chiller, pump, and fan motors would remain the same, and baseline operation hours would remain constant. This assumption was based on the feedback received from the facility staff who indicated that the operation schedule had not changed for the previous five years.
- The occupied hours of the facility are assumed to remain unchanged for the duration of the project, and are Monday – Friday from 7:00 a.m. to 7:00 p.m.

4.2 Energy and Water Baseline Development

The current annual operating hours that were reported by the facility staff are shown in Table 4-1. Cooling equipment (chiller and water pumps) are enabled continuously from May through September and operate as needed. The hot water pump operates continuously from October through April. The air handler fans operate continuously year-round.

Table 4-1: Equipment Baseline Operating Hours

Equipment	Operating period	Annual hours
Chiller	Enabled May – September 24/7	3,672
AHU-1 supply fan	Always on	8,760
EX-1 exhaust fan	Always on	8,760
HWP-1 hot water supply pump	On October – April	5,088

Motor kW demand is assumed to remain constant for the duration of the contract. The nameplate data of each motor was recorded, and the power draw from each was measured on May 1, 2003 by ABC staff in the presence of Mr. Handy, the Federal Center Facility Manager. These values are shown in Table 4-2.

Table 4-2: Equipment Nameplate Data and Measured Power Draw

Equipment	Nameplate data (HP)	Nominal RPM	Nominal voltage	Measured power draw (kW)
AHU-1 supply fan	75	1800	480	68.3
EX-1 exhaust fan	50	1800	480	48.7
HWP-1 hot water supply pump	25	1800	480	26.7

4.3 Proposed Energy and Water Savings Calculations and Methodology

The run-time data recorded by the EMCS equipment will be analyzed and summarized upon receipt on a bi-monthly basis. For each motor, during its operation period (Table 4.1), the total number of operating hours will be determined by summing the status data collected for each motor and multiplying by the data interval (15 minutes).

Annually, Equation 4-1 and Equation 4-2 will be used to calculate the energy savings resulting from the EMCS installation for each piece of equipment listed in Table 4-1.

Equation 4-1:

$$\text{Annual kWh}_{saved}\ \text{motor}_i = \text{kW}_{baseline}\ \text{motor}_i \times (\text{Op. Hours}_{baseline}\ \text{motor}_i - \text{Op. Hours}_{measured}\ \text{motor}_i)$$

Equation 4-2:

$$\text{Total Annual kWh}_{saved} = \text{Annual kWh}_{saved}\ \text{AHU-1} + \text{Annual kWh}_{saved}\ \text{EX-1} + \text{Annual kWh}_{saved}\ \text{HWP-1}$$

The maximum operating hours expected for the equipment with the EMCS installed are listed in Table 4-3 below. These values will be used if actual facility occupancy hours increase.

Table 4-3: Annual Post-Installation Operating Hours, Expected and Maximums

Equipment	Maximum Annual post-installation operating hours	Expected Annual post-installation operating hours
AHU-1 supply fan	5,616	4,380
EX-1 exhaust fan	2,070	4,380
HWP-1 hot water supply pump	5,616	2,544

Cost savings will be determined using energy rates detailed in Table 2-1 of Section 2.2.

4.4 Operations and Maintenance and Other Cost Savings

O&M savings are not being claimed or documented for this ECM.

4.5 Proposed Annual Savings for ECM

Table 4-4: Proposed Annual Savings for ECM 2 – EMCS

	Electric energy use (kWh/yr)	**Electric demand* (kW-yr)**	**Total energy use (MBtu/yr)**	**Electric energy cost, Year 1 ($/yr)**	**Electric demand cost, Year 1 ($/yr)**	**Other energy-related O&M costs, Year 1 ($/yr)**	**Total costs, Year 1 ($/yr)**
Baseline use	1,266,002	158	4,321	$66,465	$15,291	0	$66,465
Post-installation use	811,894	158	2,771	$42,624	$15,291	0	$42,624
Savings	**454,108**	**0**	**1,550**	**$23,841**	**$0**	**$0**	**$23,841**

4.6 Post-Installation M&V Activities

The points in the new EMCS system to be monitored for use in savings calculations are listed in Table 4-5. All of these points will be “trended” — meaning that there will be a time stamp associated with each recorded point value. From this information, the total operating hours of the affected equipment for the year will be calculated. Temperature data will be collected and analyzed to ensure that the operation of the control system is as intended. Additional points will be collected for ECM 3 (Chiller) so that this information can be used to verify the performance of that measure. A complete listing of the EMCS system parameters will be provided in the Post-Installation Report, including:

- documentation of the actual EMCS installed, detailed sequences of operations, as-built points list, and a summary of the EMCS operation features in regard to control of the chiller pump and fan motors, and
- operation manuals for the EMCS and chillers.

Table 4-5: EMCS Control Points for Savings Calculations

Equipment	Type of Point
Chiller compressor motor	kW
AHU-1 supply fan	Status
EX-1 exhaust fan	Status
CHWP-1 chilled water supply pump	Status
CWP-1 condenser water pump	Status
HWP-1 hot water supply pump	Status
Indoor air temperature	Analog temperature sensor
Outside air temperature	Analog temperature sensor
Outside humidity sensor	Analog humidity sensor
Chilled water supply temperature	Analog temperature sensor
Chilled water return temperature	Analog temperature sensor
Chilled water flowrate	Analog flow meter
Condenser water return temperature	Analog temperature sensor

The EMCS system will be set up to automatically write the run-time data to the dedicated control computer's hard-drive each day at midnight. Every other month, ABC Engineering staff will remotely download that data for analysis and back-up purposes. The data will be reviewed at that time to ensure that the control system is operating properly.

4.7 Performance-Period Verification Activities

During the first quarter of each year (January to March) a site visit to the Federal Center will be conducted by ABC Engineering personnel. Activities to be conducted during this site visit include verification of proper equipment and control sequence operation and measurement of power draw of the equipment listed in Table 4.1 to ensure that the equipment demand has not changed.

The equipment that was used for taking the baseline power measurements will be used during the annual site visit to verify that equipment performance has not changed. The meter to be used is a digital multi-meter, ACME model 40, which is calibrated by the manufacturer on a semi-annual basis. The meter has an accuracy of +0.5%. The meter specifications are included in the Appendices. Elite Industries thermistor sensors shall be used for taking temperature measurements. These sensors are rated at ±1ºF accuracy. Cut sheets are included in an Attachment to this document. Calibration will be provided each performance year.

Elite Industries humidity sensors shall be used for taking humidity measurements. These sensors are rated at ±5% accuracy. Cut sheets are included in an Attachment to this document. Calibration will be provided each performance year.

Ongoing quality assurance procedures for the metered run times of equipment include a bi-monthly review of the data to see if it is reasonable and corresponds to anticipated values. Raw data files will be stored separately and made available to the Agency upon request. In the case that some data are missing, a check for a valid reason for missing data will be made. If the data is truly missing, then operating hours for the period with missing data will be derived from data from a similar period. Sources of data used to make up for missing data will be clearly identified and will be described in the Annual Report.

The Annual Report will summarize the results of calculations that determine the savings. Monitored data and details of all calculations will be provided electronically in MS Excel™ spreadsheets. An example spreadsheet format is provided in Table 4-6.

Table 4-6: Example Monthly Calculation Format – AHU1

Day	Measured Operating Hours – AHU1	kWh_{post}	$kWh_{baseline}$	kWh Savings
1				
2				
3				
…				
…				
Totals	$Op.Hrs_{total}$	$kWh_{post\ total}$	$kWh_{baseline\ total}$	$kWh_{saved\ total}$

5. ECM 3 — CHILLER REPLACEMENT M&V PLAN AND SAVINGS CALCULATION METHODS

5.1 Overview of ECM, M&V Plan, and Savings Calculations

As detailed elsewhere in this proposal, the Piscataway Federal Center is cooled by a central chilled water plant with a 400-ton constant-speed centrifugal chiller that is 20 years old and has experienced significant degradation in performance. The existing chiller has a nominal rated full-load efficiency of 0.85 kW/ton at ARI conditions, which is significantly poorer than the efficiencies of currently available centrifugal chillers.

As part of this ESPC project, the existing chiller will be replaced with a new, high efficiency unit with the same capacity. The proposed chiller will have a nominal full-load rating of 0.52 kW/ton at ARI conditions. Part-load performance is significantly improved due to the VFD option, which allows better part-load performance than the existing chiller with inlet guide vanes. The cooling tower was replaced five years ago, and will not be modified; however, condenser water temperature will be allowed to drop below 85ºF when the wet-bulb conditions allow. This will further improve the part-load chiller performance. The chilled water and condenser water pumps will be serviced, but not replaced. No other changes to the cooling plant will be made. Energy savings for this measure will result from the reduction of chiller demand to provide the same cooling as in the baseline case.

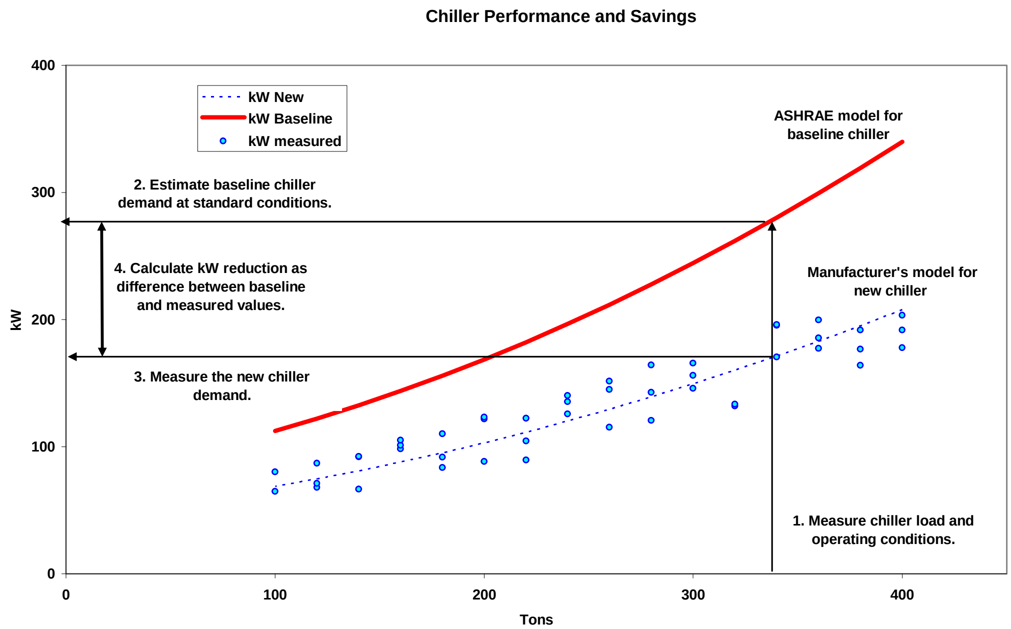
FEMP Option B, Method CH-B-02 will be used to measure and verify the energy savings from this retrofit. This method requires metering of chiller electric and load variables in both the baseline and post-installation period. Baseline metering was performed over a short-term period, and continuous metering via the EMCS will be done in the post-installation period. It is appropriate to use Option B for this project for several reasons. There is a significant uncertainty in what the actual operating hours and loads of the new chiller will be, data collection is available with the use of the new EMCS (ECM 2), and analysis of the collected data will provide a continuous performance check on the new chiller.

The purpose of collecting baseline chiller data was to develop a model of the existing chiller's performance. This model will enable the prediction of the baseline chiller demand from load and system operating parameter data. Approximately one month (August 13 to September 17, 2003) of baseline metering was conducted, with enough data points collected to successfully build the performance model.

In the post-installation period, chiller demand (kW), load data (tons, as calculated from water temperature and flow measurements), and system operating parameters (chilled and condenser water temperatures) will be collected continuously in 15-minute intervals. The load data will be used to determine the equivalent baseline chiller demand for the same interval. Savings will be determined from the difference in the calculated baseline chiller demand and the actual post-installation chiller demand.

The following figure will help illustrate the savings verification process:

Figure 5-1



1. Measure the chiller load (tons) from the chilled water supply and return temperatures and flow rates.

2. Estimate the baseline kW demand from the model of the old chiller at current operating conditions (actual chilled water temperature, tons). The baseline condenser water temperature will be held 85ºF since that was the steady-state case in the baseline due to the old chiller's operating limitations).

3. Measure the new chiller demand under actual operating conditions.

4. Calculate the demand savings for each 15-minute interval as the difference between the baseline model and the measured value.

5. If the chiller is off, demand reduction is treated as 0 kW.

6. Annual energy savings will be calculated as the sum of the 15-minute savings. This savings calculation assumes a minimum number of ton-hours of cooling per year. In the event that the measured ton-hours are less than a specified minimum, savings based on measured chiller performance may be adjusted upwards to reflect what would have occurred had the minimum number of ton-hours been provided.

This M&V plan is based on the following assumptions:

- No other physical changes are planned to the condenser pumps, chilled water pumps or the cooling tower.
- Condenser water in the baseline model will be held constant at 85ºF. The actual condenser water temperature will be allowed to fall below 85ºF to improve part-load performance.
- Baseline chiller performance will be adjusted based on actual chilled water supply temperature.
- One month of monitoring of chiller demand and load variables was adequate to develop an accurate model of the existing chiller performance.
- The building plans no major projects, such as building additions or changes which would significantly alter the current building occupancy rate, schedule, or other internal cooling loads.

5.2 Energy and Water Baseline Development

Data collection of the existing chiller's demand, entering and leaving chilled water temperatures, and entering condenser water temperature occurred during August and September 2003. The data was collected in 15-minute intervals using an Elite 6-channel data recorder[6]. In order to collect data over a full range of operating conditions (chilled and condenser water temperatures, chiller demand) expected in the post-installation period, the condenser and chilled water temperatures were reset manually. Chilled water flow was measured with a portable ultrasonic flow meter installed in the chilled water supply loop. The data was analyzed, and an appropriate model of chiller performance was developed, as described below.

The monitored data collected during the baseline period were used to develop the following model of the existing chiller performance. Because the performance depends on so many variables, the chiller model was based on ASHRAE energy efficiency Standard 90.1. The model is based on a set of bi-quadratic and quadratic equations, detailed in Equations 5-1, 5-2, and 5-3.

The following notations are applicable to the equations used in this section:

CHWF	Chilled water flow in gallons per minute (GPM)
ECHWT	Entering chilled water temperature (return temperature,°F)
LCHWT	Leaving chilled water temperature (supply temperature, °F)
CWT	Condenser water temperature (°F) to chiller
PLR	Part Load Ratio
500	Conversion from GPM to pounds per hour Btu per pound-degree Fahrenheit
12,000	Conversion from Btuh to tons

[6] See Attachment 4.

CAP_{nom}	Nominal full-load capacity of chiller (400 tons)
kW_{nom}	Nominal full load chiller demand. The nominal kW is the full-load rating multiplied by the nominal capacity (0.85 kW/ton × 400 = 340 kW)

The maximum capacity (tons) of the chiller varies with operating parameters, and can be determined from Equation 5-1:

Equation 5-1:

$$CAP_t = CAP_{nom}[a + b(CHWT) + c(CHWT)2 + d(CWT) + e(CWT)2 + f(CHWT)(CWT)]$$

In addition, the instantaneous chiller load and current part-load ratio are calculated by the following equations:

Equation 5-2:

$$TONS_t = (CHWF)(500)(ECHWT – LCHWT)(1) / (12{,}000)$$

Equation 5-3:

$$PLR_t = TONS_t / CAP_t$$

The baseline chiller electric demand is calculated with the following equations:

Equation 5-4:

$$EIR_{adj} = g + h(CHWT) + i(CHWT)^2 + j(CWT) + k(CWT)^2 + l(CHWT)(CWT)$$

Equation 5-5:

$$PLR_{adj} = m + n(PLR_t) + o(PLR_t)^2$$

Equation 5-6:

$$kW_t = (kW_{nom})(PLR_{adj})(EIR_{adj})$$

The ASHRAE model coefficients *a* through *o* for a water-cooled chiller are listed in the table below:

Table 5-1: Chiller performance coefficients (water-cooled)

	a	b	c	d	e	f
CAP_t	-1.74204	-0.029292	-0.000067	0.048054	-0.000291	-0.000106
	g	h	i	j	k	l
EIR_{adj}	3.1175	-0.109236	0.001389	0.00375	0.00015	-0.000375
	m	n	o			
PLR_{adj}	0.222903	0.313387	0.46371			

These calculations will be executed using a spreadsheet model. When estimating the baseline chiller performance, the actual chilled water temperature and tons will be used, along with a fixed condenser water temperature of 85°F. The baseline chiller currently operates at a fixed condenser water temperature and it is not appropriate to adjust the baseline to account for the new condenser water temperature strategy, as the existing chiller could not take advantage of reduced condenser water temperatures because of physical operating limitations.

5.3 Proposed Energy and Water Savings Calculations and Methodology

The energy and demand savings will be calculated using Equations 5-7 and 5-8, respectively.

Equation 5-7

$$\text{Energy Savings (kWh)} = \Sigma t\,(\text{kWh}_{t,\text{ baseline, est}} - \text{kWh}_{t,\text{ measured, post}})$$
$$= 0.25 \times \Sigma t\,(\text{kW}_{t,\text{ baseline}} - \text{kW}_{t,\text{measured post}})$$

Where:

$\text{kW}_{t,\text{baseline}}$	=	demand that the baseline chiller would have used under the load conditions encountered for 15minute interval t in the post-installation period
$\text{kW}_{t,\text{ measured, post}}$	=	measured demand of the new chiller during 15-minute interval t.

Equation 5-8

$$\text{Monthly Demand Savings (kW)} = \text{MAX}(\text{kW}_{t,\text{baseline}}) - \text{COINCIDENT}(_{\text{kWt,post}})$$

Where:

$\text{MAX}(\text{kW}_{t,\text{baseline}})$	=	maximum monthly demand of baseline chiller predicted for each 15-minute interval in the peak period (between noon and 6 p.m. weekdays, May through October) during the current month using the model developed for the baseline chiller.
$\text{COINCIDENT}(\text{kW}_{t,\text{post}})$	=	measured demand of the new chiller during the period when the predicted baseline chiller demand was at its maximum value.

Annual cost savings will be calculated using Equation 5-9.

Equation 5-9:

$$\text{Annual Cost Savings} = \text{Energy Savings (kWh)} * \text{Rate}_{\text{kWh}} + \Sigma\text{month}(\text{Monthly Demand Savings} * \text{Rate}_{\text{kW}})$$

where the rates are detailed in Table 2-1 in Section 2.2.

5.4 Operations and Maintenance and Other Cost Savings

O&M savings of $12,000 per year apply to this ECM. These cost savings are the result of ABC Engineering assuming the chiller maintenance contract for the new chiller. The cost of these annual services will be $14,000, compared to the existing contract for $26,000.

5.5 Proposed Annual Savings for ECM

Proposed annual savings are summarized in the table below. Hourly bin calculations based on TMY weather data are included in the Appendix.

Table 5-2: Proposed Annual Savings for ECM 3 – Chiller

	Electric energy use (kWh/yr)	Electric demand* (kW/yr)	Total energy use (Mbtu/yr)	Electric energy cost, Year 1 ($/yr)	Electric demand cost, Year 1 ($/yr)	Other energy-related O&M costs, Year 1 ($/yr)	Total costs, Year 1 ($/yr)
Baseline use	500,004	1,292	1,707	$26,250	$10,403	$26,000	$62,653
Post-installation use	305,885	790	1,044	$16,059	$6,364	$14,000	$36,423
Savings	**194,119**	**502**	**663**	**$10,191**	**$4,039**	**$12,000**	**$26,230**

5.6 Post-Installation M&V Activities

After the new chiller has been installed and commissioned, ABC Engineering and Federal Center representatives will conduct a post-installation inspection to verify that the chiller installed is consistent with what was proposed and has the potential to generate the cost savings predicted. ABC Engineering will provide a Chiller Inspection Report detailing actual equipment installed, and include manufacturer’s specifications and operating procedures, chilled water and condenser water flows, and documentation of the chiller model number, and its rated and factory-tested efficiencies (in kW/ton).

5.7 Performance-Period Verification Activities

Post-installation monitoring of chiller demand and load variables (entering and leaving chilled water temperatures, chilled water flow rate, condenser water temperature) will be conducted for the entire contract period. This monitoring will be accomplished using the new EMCS. The EMCS will log and time-stamp the data at 15-minute intervals, saving the data weekly to disk. ABC Engineering will remotely download this data on a bi-monthly basis for backup and quality control. In the event that there is a significant gap in the data due to a sensor or other failure, the process of replacing the missing data with interpolated or averaged data will be clearly documented.

Using the monitored post-installation data, the baseline energy use will be computed using the ASHRAE model and assuming standard (ARI) conditions as previously described.

The new chiller's performance will be compared to the manufacturers' rated performance annually to ensure that the chiller is operating as expected. This will be accomplished by using the manufacturer's performance curves, which are analogous to the ASHRAE performance curves used for the baseline chiller. The actual chilled and condenser water temperatures will be used with the manufacturer's model.

Some degradation in chiller performance is expected over the course of the delivery order contract (5 years), which has been considered in determining the expected energy savings and the annual contract payments. If substantial equipment performance degradation occurs (>15% increase in annual energy use relative to the manufacturer's model), the Agency will be responsible for taking the necessary maintenance actions to restore the chiller performance.

In the event of an unseasonably mild summer or change to the facility that decreases cooling load, the savings claimed will be based on a minimum cooling load of six hundred thousand ton-hours as defined by the typical monthly load curves included in the Appendix.

Chiller demand: The chiller demand will be monitored using solid core current transducers and voltage leads connected to each leg of the chiller's 3-phase circuit. All leads will be installed at the time of EMCS installation. These transducers will be installed on Breakers 1, 3 and 5 (the A, B and C phases) of Switch-Gear SW-1. Calibration of these sensors will be accomplished using an ACME True-RMS kW meter. Calibration of this parameter will be carried out once per year.

Chilled water flow: Chilled water flow will also be monitored through the EMCS. At the time of chiller installation, an ACME inline flow meter will be installed in the chilled water loop. The flow meter is specified by the manufacturer to have an accuracy of ±10%. The chilled water flow will be verified bi-monthly by downloading and checking data to identify sensors that have fallen out of calibration or to determine whether pump or chiller performance has degraded.

Condenser and chilled water temperatures: Water temperature sensors will be the insertion type, installed in new thermo-wells for both the condenser and chilled water temperatures. The sensors used will be ACME 2-wire, 1,000 OHM platinum RTDs paired with a 4-20 mA transmitter. The combined units will have an operating range of 20–120°F with an accuracy of ±0.50°F. An annual field check of calibration will be conducted using the analog thermometers installed in the supply and condenser water lines.

In addition to the calibration and testing procedures outlined above, all components will be tested and evaluated once each contract year. Also, the EMCS will continuously monitor the calculated kW/ton of the new chiller and issue an alarm when this value moves outside the expected range (0.40 - 1.10 kW/ton).

The data will be collected using quality control procedures for checking the measurements for reasonableness. Any and all missing intervals will be replaced either by interpolation or use of average values. Such data will be described in the Annual Report.

The Annual Report will summarize the calculated savings for the past year. Savings calculations will also be provided electronically, in MS Excel spreadsheets. All calculations will follow the procedure described in this M&V plan. In addition to the reports, all monitored data will be submitted in electronic format.

The spreadsheet will show all intermediate steps in calculating baseline chiller kW, and show how energy savings will be determined. A sample spreadsheet format is provided in Table 5-3, with variable names as described in the Chiller M&V Plan.

Table 5-3: Sample Format of Baseline Calculations

Measured Data							Calculated Data					
Time	ECHWT, °F	LCHWT, °F	CHW flow (GPM)	CWT, °F	kW_{post}	$Tons_t$	CAP_t	PLR_t	PLR_{adj}	EIR_{adj}	kW_{base}	kW_{Saved}

Summary of Risk & Responsibility Matrix

RESPONSIBILITY/ DESCRIPTION	PROPOSED APPROACH
Financial:	
Interest rates:	ABC Engineering will work with the GSA to ensure that the best possible financial terms are secured for this project.
Energy prices:	Energy prices for this DO have been set in the M&V plan. These rates are based on the current electric and natural gas costs for the Piscataway Federal Center, and are escalated at XX% based on NIST guidance.
Construction costs:	Construction costs are fixed and are the responsibility of ABC Engineering. If the DO is not awarded within 90 days of this proposal, these prices may be modified.
M & V costs:	The M&V costs are fixed for the duration of the contract. ABC Engineering accepts all risks associated with performing the M&V activities as stated herein.
Non-energy cost savings:	Non-energy cost savings in this project are the result of the transfer of the chiller maintenance contract to ABC Engineering. Since the maintenance contract is the same length as the ESPC, no verification activities are scheduled.
Delays:	ABC Engineering will work with the GSA to ensure delays are avoided and mitigated as much as possible. If delays are the result of GSA actions, ABC Engineering may submit a change order.
Major changes in facility:	No facility additions are planned for this time, however: Lighting. Major renovations or additions to the facility could affect both the number of fixtures and their operating hours, with the possibility of causing the lighting energy costs to rise. The savings for this ECM are based on measured fixture powers and operating hours, values that will be held constant throughout th contract term. EMCS. In the event that changes are made to the building, the maximum operating hours for equipment has been defined in the M&V plan. Chiller. In the event that the cooling load increases, the measured energy savings will also increase. If the annual cooling load decreases, , the minimum annual chiller use (in ton-hours) to calculate savings is specified in the M&V plan.

RESPONSIBILITY/ DESCRIPTION	PROPOSED APPROACH
Operational:	
Operating hours:	Lighting. Operating hours are based on monitored baseline data described in this plan. The post-retrofit period operating hours will be stipulated to be the same as the baseline period. Should the Agency change operating hours, the estimated savings will not change.

RESPONSIBILITY/ DESCRIPTION	PROPOSED APPROACH
	EMCS. ABC Engineering verified fan and pump motor operating hours for the baseline period, and will be responsible for monitoring operating hours in the performance period. Maximum operating hours for equipment has been defined in the M&V plan in case of substantial change in schedule. Heating setpoint will be set no higher than 68 ºF and cooling setpoint no lower than 72 ºF as agreed to by ABC and GSA. Chiller. ABC Engineering has estimated the load on the facility based on short-term monitoring and historical log data. The GSA is responsible for maintaining similar operating hours and load conditions in the post-installation period, and agrees that the chiller will be used annually for the minimum number of ton-hours defined in the M&V plan. If operating ton-hours increase, measured savings will also increase.
Load:	EMCS. Increase in loads may result in use of maximum operating hours specified in the M&V plan. Savings from reduced chiller operation between 9:00 p.m. and startup will accrue to the EMCS measure. Savings are based on measured chiller operation. Chiller. In the event that the cooling load increases, the measured energy savings will also increase. If the annual ton-hours of the new chiller falls below the amount specified in the baseline, the chiller savings will be calculated using the minimum defined in the M&V plan.
Weather:	Chiller. Although the operation of the new chiller may be affected by weather conditions, no weather corrections are to be performed. If mild conditions result in reduced chiller loads, the loads may be adjusted upwards.
User participation:	Lighting and Chiller: The savings for the lighting and chiller ECMs are based on the continuation of the current operating strategies. This responsibility is accepted by the Agency. EMCS: The savings from the operation of the EMCS is based on the control sequences outlined herein. Since these control sequences could be overridden by the facility operating staff, the Agency accepts responsibility that the EMCS will continue to operate as specified.

RESPONSIBILITY/ DESCRIPTION	PROPOSED APPROACH
Performance:	
Equipment performance:	Lighting. ABC Engineering is responsible for ensuring that the new lamps and ballasts are as specified for the first performance year and meet the Energy Policy Act of 2005 requirement in terms of minimum performance specifications. After this point, the Agency assumes this responsibility.

RESPONSIBILITY/ DESCRIPTION	PROPOSED APPROACH
	EMCS. The Agency is responsible for maintaining the fan and pump motors so that the power draws remain at the baseline level. Chiller. The chiller is expected to perform as rated by the manufacturer for the term of the contract and meets the Energy Policy Act of 2005 requirement in terms of minimum performance specifications. The GSA is responsible for maintaining all central plant equipment, with the exception of the new chiller, for the duration of the contract. Chiller performance will be verified by ABC Engineering during commissioning and checked annually for the duration of the contract.
Operations:	The Agency accepts responsibility for the ongoing operation of the equipment and systems affected by this DO, as described herein.
Preventive maintenance:	The Agency accepts responsibility for the ongoing maintenance of all equipment affected by this DO, with the exception of the new chiller. ABC Engineering will conduct annual inspections of the affected equipment, and will report any discrepancies and suggested remedies to the Agency immediately. ABC Engineering will perform preventive chiller maintenance under a separate contract with GSA. Annual calibration of chilled-related sensors will be performed as part of this maintenance contract.
Equipment repair and replacement:	Lighting. ABC Engineering is responsible for replacement of failed, defective, or burned-out lamps and ballasts for the first contract year. The Agency is responsible for replacement of failed or burned-out lamps and ballasts after the first year. Normal lifetimes of lamps are 15,000 to 20,000 hours when connected to electronic ballasts. Electronic ballast lifetimes are expected to be from 5 to 8 years. EMCS. The fan and pump motors will not be changed as part of this project, only control of the motors will be added. The motors are expected to last throughout the term of this contract, but if they should fail, the Agency is responsible for their replacement and commissioning. Savings will be calculated based on the baseline power measurements. Chiller. Expected life of the chiller substantially exceeds the contract length. The manufacturer’s warranty will determine what coverage will apply in the event of premature failure.