# Measure Information Template –

# Building Performance Monitoring

*2008 California Building Energy Efficiency Standards*

**PIER Program - EnergySoft, LLC** February 9, 2006

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# Overview

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| Description | In collaboration with building owners, property managers and system vendors, LBNL has developed a specification for energy-oriented performance monitoring capabilities for commercial buildings that can be implemented either as part of an Energy Management Control System or as a standalone system. This specification is intended to be adopted by both private and public building owners and managers and can be bid competitively by vendors.<br><br>This performance monitoring specification is designed to provide building owners and operators with necessary information needed to maintain optimum energy performance of the building systems.<br><br>The Performance Monitoring Specification contains several levels of specification for monitoring. The Class 1 specification would be something we might expect to see on a simple building with rooftop air conditioning units, while the Class 2 specification would be more likely in buildings with chilled water systems.<br><br>Note that this performance monitoring specification not only specifies measurement protocols, but it also specifies both data visualization and data archiving so that the EMCS vendors will provide these capabilities. |
| Type of Change | It is proposed that the Performance Monitoring Specification be incorporated into the Standards as both a Compliance Option in the Nonresidential Performance Method, and also as a feature related to the Acceptance Requirements.<br><br>Two documents will require changes to incorporate this feature. Section 3 of the Nonresidential ACM Manual will require an additional section describing this feature, and Chapter 8 of the Nonresidential Manual where the Acceptance Requirements are described.<br><br>In addition, software vendors will need to modify their ACM products to incorporate this feature, and to incorporate the appropriate messages on the PERF-1 form identifying both the feature, as well as the requirement for field verification via the Acceptance Requirements . |

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| Energy Benefits | By providing monitoring data on the building systems performance, information needed to ensure long term energy savings will be provided to building operators. While the Title 24 standards mandate that energy efficiency be installed in a building, there is no mechanism to ensure that energy efficiency is maintained over the life of the building. The performance monitoring specification is a step towards that goal. The current Title 24 will ensure that a building is energy efficient once operation commences, thanks to the new Acceptance Requirements . However, once the building is operating, there is no mechanism in place to ensure that the initial energy efficiency will be maintained. The Performance Monitoring Specification includes specific measurement requirements that will function in that capacity.<br><br>One additional long term benefit associated with this type of technology would be future energy standards where building performance becomes a dynamic compliance issue. The model used in automobiles would be a good example where annual testing of emissions is a requirement. The monitoring technology would provide possible future interfacing with a similar approach for buildings. |
| Non-Energy Benefits | The Performance Monitoring Specification will provide the building owner the information needed to lower operational and maintenance costs. By providing information related to equipment performance, operators will be able to identify system that might be in need of maintenance and provide that in a timely fashion. This will, in effect, extend the equipment life. In addition, equipment that might normally be on a maintenance schedule purely based upon time, could easily be configured to a maintenance schedule based upon full load hours of operation. This would alleviate the need for unnecessary equipment maintenance, particularly during seasons of low operation. |
| Environmental Impact | No perceived negative environmental impacts will result from this technology. |

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| Technology Measures | Measure Availability and Cost<br><br>While the monitoring technology (sensors, meters, etc.) have been available for years, the data visualization technology that is very useful in performance monitoring is not usually provided in the basic EMCS software suite. Also the data archiving that is useful in Performance Monitoring is much more extensive than what is typically provided in EMCS.<br><br>The basic monitoring points are something that is actually needed in many cases for the completion of the Certificate of Acceptance testing requirements. In the case of this recommendation, the monitoring points would be installed as a permanent part of the building, instead of just being added as part of the final commissioning. Once the cost of functional testing is taken into account, the performance monitoring equipment would have an incremental cost which is very low.<br><br>Useful Life, Persistence and Maintenance<br><br>The monitoring equipment has a useful life which is equivalent to the equipment that it is monitoring. The only persistence issue that is difficult to determine will be operator intervention based upon the monitor data. While it is entirely possible that no action will be taken based upon the information provided by the system pertaining to efficient operation, it is unlikely that a building owner would implement this technology without any plans to utilize the information. |
| Performance Verification | Currently, verification procedures are in place to commission the operation of the building systems via the Acceptance Requirements . The performance monitoring specifications are basically the same concept, only on a permanent basis. It is anticipated that the Acceptance Requirements could be slightly modified to ensure not only the initial commissioning of the systems, but also the verification of the monitoring equipment. |
| Cost Effectiveness | Based upon the assumption that the Acceptance Requirements already require a certain amount of temporary monitoring, the incremental cost of the permanently installed performance monitoring equipment will be relatively low. What is difficult to quantify is the cost savings associated with this equipment. However, it is safe to say that if the temporary installation of monitoring equipment has already been shown to be cost effective, and hence included in the Standards, having equipment that monitors on a regular basis should have equal or better cost effectiveness.<br><br>Numerous studies have demonstrated the gradual degradation of building performance after the initial commissioning, and recommend re-commissioning of the building after as little as three years. With permanently installed equipment providing this same type of information, as a minimum, the re-commissioning cost could be reduced considerable, if not avoided altogether. |

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| Analysis Tools | In the performance analysis approach in Title 24, the building is assumed to operate with no faults. The simulation tools assume ideal operation of the systems in the building, including daylighting controls, occupancy sensors and mechanical system performance.<br><br>To properly account for the benefits of the performance monitoring, we need to assume a building that does not operate perfectly. It is proposed to apply a similar methodology as proposed in the Fault Detection and Diagnostic measure templates and assume a less than perfectly performing mechanical system. |
| Relationship to Other Measures | No other measures are impacted by this feature in the modeling. |

# Methodology

The methodology applied here is similar in nature to the FDD measure templates that have been prepared; however, since the measure described here does not relate to fault diagnosis, the proposed modeling is slightly different. As outlined in the FDD measure templates, field data has shown that a high percentage of Rooftoop units, AHUs and VAV boxes have one or more faults, the baseline building assumption will include HVAC systems that have imperfect operation. When the Standard building includes economizers, the economizer will be assumed to have a performance degradation of 10%. Thus, the maximum outside air capability of the economizer will be 90%. For DX cooling systems, the Standard building under the performance method will have a 6% degradation factor applied to the cooling EIR. In addition, if the Standard building includes VAV boxes, a 10% degradation factor will be assumed. The minimum airflow ratio of the VAV box, which is typically 30%, will be increased to 33%. Thus, these components are assumed to be "broken" in the same fashion as we do with DX systems that do not include TXVs in the current Standards.

If the proposed building includes the performance monitoring, the economizer performance, if present, would be improved to 95% functional. For DX cooling systems, the EIR degradation would be reduced from 6% to 3%, and any VAV boxes would only have a 5% degradation factor.

# Recommendations

The following is recommended language for the Nonresidential ACM Manual. Note that this language includes both the FDD language developed in the previous measure templates with the performance monitoring language being proposed in this measure template.

Equation N2-20 should be modified to include the term $F_{fdd}$

$F_{fdd}$ Cooling system performance adjustment factor, default = 0.90.
For packaged systems with FDD controls, $F_{fdd}$ shall be 0.96.
For systems with performance monitoring equipment, $F_{fdd}$ shall be 0.93.

$$EERnf_{EWB,ODB} = 1.0452 \times EER_{EWB,ODB} + 0.0115 \times EER_{EWB,ODB}^{2} + 0.000251 \times EER_{EWB,ODB}^{3} \times F_{TXV} \times F_{AIR} \times F_{FDD}$$

Equation N2-1

In section 2.5.2.6, the entire equation for calculating the COOLING-EIR has been omitted, so it would be suggested that the following language be added, which is based upon the previous ACM Manual:

Description: ACMs shall require the user to input the EER for all packaged cooling equipment that are not covered by DOE appliance standards.

ACMs shall also require the user to input the net cooling capacity, CAPa, at ARI conditions for all cooling equipment.

ACMs shall calculate the electrical input ratio, EIR, according to Equation N2-19

DOE Keyword: COOLING-EIR

Input Type: Default

Tradeoffs: Yes

Modeling Rules for Proposed Design: The ACM shall require the user to input efficiency descriptors at ARI conditions for all equipment documented in the plans and specifications for the building.

Default: Minimum EER as specified in the Appliance Efficiency Regulations.

Modeling Rules for Standard Design (New): For the reference method, the standard design shall assign the EER and EIR of each unit according to the applicable requirements of the Appliance Efficiency Standards or the Standards. The EIR of the equipment will be based on the proposed system with an EER that meets the applicable requirements of the Standards but has the same cooling capacity and ARI fan power as the unit selected for the proposed design.

Modeling Rules for Standard Design the (Existing Unchanged & Altered Existing): ACMs shall use the EER, EIR, and the ARI fan power of the existing system. The EIR of the existing equipment must be based on the EER and the ARI fan power of existing system. ACMs shall model the existing system as it occurs in the existing building. If the permit involves alterations, ACMs shall model the system before alterations.

### *2.5.3.12 Zone Terminal Controls*

Description: ACMs shall be capable of modeling zone terminal controls with the following features:

- *Variable air volume (VAV).* Zone loads are met by varying amount of

supply air to the zone.

- *Minimum box position.* The minimum supply air quantity of a VAV zone terminal control shall be set as a fixed amount per conditioned square foot or as a percent of peak supply air.
- *(Re)heating Coil*. ACMs shall be capable of modeling heating coils (hot water or electric) in zone terminal units. ACMs may allow users to choose whether or not to model heating coils.
- *Hydronic heating*. The ACM shall be able to model hydronic (hot water) zone heating.
- *Electric Heating*. The ACM shall be able to model electric resistance zone heating.

ACMs shall require the user to specify the above criteria for any zone terminal controls of the proposed system.

The keyword MIN-CFM-RATIO shall be the minimum box position times 1.1 (not to exceed 1.0) to reflect imperfect operation of the VAV box, unless FDD controls or performance monitoring equipment is installed.

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| DOE-2 Keyword(s) | MIN-CFM-RATIO<br>ZONE-HEAT-SOURCE |
| Input Type | Required |
| Tradeoffs | Yes |
| Modeling Rules for Proposed Design: | The reference method models any zone terminal controls for the proposed design as input by the user according to the plans and specifications for the building. All ACMs that explicitly model variable air volume systems shall not allow any minimum box position to be smaller than the air flow per square foot needed to meet the minimum occupancy ventilation rate. |
| Modeling Rules for Standard Design (New & Altered Existing): | For systems 3 and 4, the ACM shall model zone terminal controls for the standard design with the following features:<br>Variable volume cooling and fixed volume heating<br>Minimum box position set equal to the larger of:<br>a) 30% of the peak supply volume for the zone; or<br>b) The air flow needed to meet the minimum zone ventilation rate; or<br>c) 0.4 cfm per square foot of conditioned floor area of the zone.<br>Hydronic heating. |

#### *2.5.3.7 Air Economizers*

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| Description: | The reference method is capable of simulating an economizer that: (1) modulates outside air and return rates to supply up to 100% of design supply air quantity as outside air; and, (2) modulates to a fixed position at which the minimum ventilation air is supplied when the economizer is not in operation. The reference method will simulate at least two types of economizers and all ACMs shall receive input for these two types of economizers: |

1. Integrated. The economizer is capable of providing partial cooling, even when additional mechanical cooling is required to meet the remainder of the cooling load. The economizer is shut off when outside air temperature or enthalpy is greater than a fixed setpoint.

2. Nonintegrated/fixed set point. This strategy allows only the economizer to operate below a fixed outside air temperature set point. Above that set point, only the compressor can provide cooling.

The default for MAX-OA-FRACTION shall be 0.9 to represent imperfect operation of the economizer.

DOE Keyword: ECONO-LIMIT
ECONO-LOCKOUT
ECONO-LOW-LIMIT
MAX-OA-FRACTION

Chapter 3 should be modified with the following language:

**3.3.20 Systems with Performance Monitoring Equipment**

Description: A nonresidential ACM may be approved with the optional capability of controls that monitor system and building performance as follows:

Class 1- Basic: Applied to a single building with a DX cooling systems.

Class 2- Intermediate: Applied to conventional buildings with built up systems which include air handlers, boilers and a chilled water plant.

**Table 1 – Performance Monitoring Requirements**

| Requirement | Class 1 - Basic | Class 2 - Intermediate |
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| Measurements | OA Temp;<br>OA WB-Temp;<br>Duct static pressure;<br>Main power;<br>RTU power;<br>Zone temperatures<br>Supply Air Temperature<br>Supply Air Fan Motor Amps.<br>Compressor motor Amps.<br>OA damper position | Add:<br>MA Temp<br>RA Temp<br>Air handler # SF & RF power;<br>Air handler # flow (cfm);<br>Air handler # Return Damper %;<br>Air Handler # OA Damper %;<br>Air handler # SF VFD freq (Hz)<br>Supply Air Temperature<br>Supply Air Fan Motor Amps.<br>Compressor motor Amps.<br>OA damper position |
| Visualization | Graphics for metrics results table and floor plan with zones temperatures | Expand metrics results table to include additional metrics.<br>Add graphics for system tables, time series plots of system block trends and system performance. |
| Data Archiving Recommended | Access Database | Sequel Server/My SQL |

DOE Keyword: COOLING-EIR
MAX-OA-FRACTION
MIN-CFM-RATIO

Input Type: Required

Tradeoffs: Yes

Modeling Rules for Proposed Design: ACMs shall model the optional feature of proposed design performance monitoring equipment as input by the user according to plans and specifications for the building. For systems with performance monitoring equipment the cooling system performance adjustment factor $F_{fdd}$ in equation N2-20 shall be 0.93. The economizer MAX-OA-FRACTION keyword shall be 0.95, and for systems that use VAV boxes,

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| | the MIN-CFM-RATIO keyword shall be 1.05 times the minimum flow ratio for the terminal box as shown in the plans and specifications. |
| Modeling Rules for Standard Design (New): | ACMs shall determine the standard design according to Table N2-10. |
| Modeling Rules for Standard Design (Existing Unchanged & Altered Existing): | ACMs shall model the existing system as it occurs in the existing building. If the permit involves alterations, ACMs shall model the system before alterations. |

# Material for Compliance Manuals

It is recommended that Chapter 8 of the Nonresidential Compliance Manual be changed to accommodate this measure since it will require verification as an Acceptance Requirement on the Acceptance Requirements . The Certificate of Acceptance forms MECH-4-A and MECH-7-A should include the additional information for verification of the performance monitoring equipment.

# Bibliography and Other Research

Information for this measure template has been taken from the PIER research contract 500-03-022, Project 4: Performance Monitoring in Large Commercial Buildings, *Performance Monitoring System Specification, Developmental Release 1.0, August, 2005*. This PIER report is available from the California Energy Commission's PIER group as an Adobe Acrobat file, and includes the detailed background and research related to this measure template proposal.

The Performance Monitoring Specification is also posted at:
http://cbs.lbl.gov/performance-monitoring/specifications .