PERFORMANCE MONITORING AND VERIFICATION SYSTEMS FOR PUBLIC HOUSING

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Summary

This paper presents a set of performance monitoring reporting formats intended to facilitate Public Housing Authorities' (PHAs) efforts to control their energy costs and enhance the operation and maintenance of their facilities. Recent changes in the U.S. Department of Housing and Urban Development regulations are providing PHAs with more incentives and resources to reduce their utility costs. An essential part of this process is a successful monitoring and evaluation process.

The recommended formats are intended for immediate application. They are presently being developed for the management and engineering staff of a northeast housing authority under the U.S. Deparment of Energy's Rebuild America program and will shortly be disseminated to several other PHAs for review and comment. They are intended to provide the necessary information to: document realized savings from present utility management efforts; address operation and maintenance requirements in a timely fashion; assist in identifying the best possible future utility saving opportunities; and document the available savings from future actions.

The focus of this present effort is on tracking and analysis of the existing utility and facility meter readings of sites in the very early stages of developing and implementing an energy management program. It is intended to be a low cost procedure that primarily utilizes the data that has been routinely collected by the engineering staff at the sites.

Implementing these procedures and using their results to guide operation and maintenance is expected to result in significant and cost-effective utility cost reductions. They also are intended to help motivate the implementation of effective capital-intensive investments in energy management. The procedures are offered as suggested extensions of the North American Energy Measurement and Verification Protocol (NEMVP)[1] for multifamily housing.

Introduction

This paper offers a format for presenting performance monitoring and verification results to the management and staff at Public Housing Authorities (PHAs). The presented formats are under development based upon working with the staff and available data from a northeast PHA under a project within the U.S. Department of Energy's Rebuild America program. They will be reviewed by the management and engineering staff at least three PHAs at various stages in their energy management programs.

These performance monitoring formats are not meant to duplicate the analysis and output of commercial monitoring software packages such as METRIX or PHASER. They are intended to supplement them with information on available savings and on the itemized performance of various sub-systems such as domestic hot water production and on key intermediate variables such as make-up water and heating system efficiency.

Background

Recent changes in the U.S. Department of Housing and Urban Development regulations are providing PHAs with more incentives and resources to manage their utility costs. An essential part of controlling energy costs is a successful monitoring and evaluation process that will:

a. **Document the actual savings from present utility management efforts**. This will enable the PHA to measure the actual financial benefits that have resulted from the implemented energy management actions;
b. **Document the savings available from future measures.** This will provide the PHA with a clear understanding of the available additional utility savings that would occur if the planned additional building improvements are made;
c. **Address operation and maintenance requirements in a timely fashion.** When the performance monitoring identifies utility costs that are outside the range of expected values, the engineering staff can

[1] U.S. Department of Energy, North American Energy Measurement and Verification Protocol, DOE/EE-0081, March 1996.

be notified to diagnose and correct the problem. Therefore, engineering and technical staff resources can be selectively sent to solve problems at their onset;

d. **Assist in identifying the best possible future utility saving opportunities.** This will assist the PHA to identify the best future measures for achieving future utility savings. It involves monitoring sub-systems such as domestic water systems, space heating systems, and various parameter such as boiler efficiency, percent make-up water, etc. to determine the potential savings contributions from specific system modifications and upgrades.

The presentation formats are targeted to two audiences:

a. **The building management** staff who are primarily interested in tracking how much money has been saved by the existing energy management efforts and what are the potential future savings from additional actions and investments; and
b. **The engineering staff** who need to make the case to management for obtaining the additional operation and maintenance resources and capital improvements necessary to effectively operate the building, and to be able to quickly identify and diagnose any trouble spots manifested by unusually high energy costs.

Description of Sites

The performance monitoring is presently being applied at four sites consisting of multiple building campuses with central power plants. The sites include low-pressure and high pressure steam systems. Space heating is accomplished by either distributing the steam directly to the apartment radiators or by producing hot water at heat exchangers and pumping it through radiator or perimeter baseboard systems. Domestic hot water is generated by using some of the steam at separate heat exchangers dedicated to domestic water heating. The heat exchangers can be either shell-and-tube units or coils submerged in the domestic hot water storage tanks.

Measurement Variables and Analysis

At present the focus is on monitoring oil use by the central heating plant, make-up water use and domestic hot water use. These utilities account for over half of the energy costs borne by public housing authorities and are highly sensitive to the level of operation and maintenance of the building systems. The input variables include basic parameters provided by the PHA on a weekly basis such as oil consumption, metered make-up-water and domestic hot water usage.

Since this performance monitoring is being done on heating systems that will be largely upgraded and/or replaced within the next 12 to 24 months, we have avoided investing in expensive on-site instrumentation and monitoring systems. Instead we have resorted to making engineering estimates of intermediate variables such as heating plant efficiency and domestic hot water system efficiency. We are also exploring simple ways to measure the heating plant efficiency based on a few easy measurements of boiler feedwater pump operating times to derive boiler feedwater input. Where possible, we will rely on data from flow accumulators that can be recorded by the engineering staff on a weekly basis rather than continuous measurement of temperature variables which requires more involved monitoring and recording instrumentation.

Setting Performance Targets

Targets can be set for operation and maintenance goals, capital improvement goals or both. They are used to assess the available utility savings that can be captured by the PHA. How targets are established is a critical step that requires input from the various participants who will be involved in the energy management program. It is critical that the target be based on a clearly defined set of potential actions and investments. For example, the targets used in developing the available savings in oil use for space heating and domestic hot water shown in Table 3 are based on the performance of low pressure steam systems at buildings with a dedicated power plant at each building and a mature energy management program at elderly housing with a minimum space temperature of 75°F at the Rochester Housing Authority (RHA)[2]. The actual data in the attached tables are for public housing sites with a district heating system with significant deferred maintenance, a wide range of resident types (including families with children), and an energy management program that is just beginning. Therefore, it is not surprising that Figure 1 indicates actual oil cost rates that are 150 to 250% above the target values. Additional information is necessary about the building and resident characteristics at RHA (for example, window and wall characteristics, resident occupancy levels, etc.) in order to determine the feasibility of other housing authorities achieving space heating oil use targets based on this housing. Ultimately, the targets will be set based on what capital improvements are economically feasible for each particular housing site.

[2]David Thurston (1996): "Public Housing Partners", Rochester Housing Authority technical report, May.

An example of another type of target is shown in Table 4. This table shows the available savings from reducing the percentage of make-up water at Site 3. The actual percentage of make-up water varies from 12 to over 40%. The available savings is based on a target value of 3%. Similar steam systems at the RHA are operating at a percent make-up water of 1 to 3%.

Description of Reporting Formats

Table 1: Building Oil Cost and Savings Comparison is a sample reporting format intended for the PHA financial and engineering management of the central administration. The upper half of the table compares the weekly rate of total oil use at various housing sites and highlights in bold print the weekly highest user for special attention. It also may be worth highlighting the best performing building each week.

The lower half of Table 1 presents the whole building actual savings that have occurred to date and the projected annual rate of actual savings. It also presents the available savings based on achieving the target performance in oil use. The actual savings are shown in two ways: cumulative to-date and in terms of annual rates of savings. This enables management to obtain a quick snap-shot of actual savings Ain the bank@ that are available for reinvestment as well as to anticipate the annual performance based on past performance.

The available savings is shown in the same two ways. The cumulative to-date indicates the Alost savings@--the savings that would have been achieved if the targets had already been achieved. The corresponding annual rate shows the available additional annual savings that can be obtained by achieving the performance target.

Note that the Table 1 format could be used to present the total utility costs--oil, gas, electricity, water--on a weekly basis.

Figure 1: Weekly Building Oil Comparison--% Variance from Target Cost graphically shows the progress of each site toward achieving the performance target. It is useful for both building management and the engineering staff to quickly identify buildings that are behaving unusually.

Tables 2 through 5 are sample formats specific to Site 3 that are intended to provide information that is useful to the management and engineering staff of a particular housing site. These tables present the available savings for various utilities, specific end uses and for specific utility management efforts. Note that the format used in Tables 2 through 4 can also be used to present the actual savings achieved to date.

Table 2: Total Available Utility Savings for Oil, Water and Chemicals presents the available costs associated with producing the steam and domestic hot water for Site 3. The water usage data is based on available information for make-up water and domestic hot water. It could include cold water used by the residents once the metered information is available

Table 3: Oil for DHW and Space Heating--Available Savings presents more detail on the savings available in the processes of producing and delivering domestic hot water and in heating the buildings.

Table 4: Available Water Utility Savings from Water Conservation presents the savings in water utility costs resulting just from eliminating leaks in the distribution systems, and conserving water in the apartments. This table can be useful for tracking the performance of a specific activity such as water conservation. The next step in developing this monitoring tool is to add the available savings in oil resulting from the lower water use.

Table 5: Key Assumptions lists the assumptions and target values used in the analysis for Tables 1 - 5 and Figure 1.

Future Steps

The above work is preliminary and under review by various PHAs. Recommended future work includes:

1. Continue working closely with one PHA to develop useful reporting formats for performance monitoring and the corresponding protocol. Develop formats appropriate for each participant/decision-maker in energy management, capital development or operation and maintenance. Coordinate this work with the performance monitoring activity of any energy service vendor retained by the PHA.
2. Identify the appropriate staff position at the PHA that will be responsible for performing this monitoring and reporting activity after this project is completed.
3. Work with other PHAs to develop a common, clear and useful format and protocol for public housing that complements existing commercially available performance monitoring systems.
4. Assess accuracy of measurements and assumptions. Estimate the meter accuracy and resulting error range in the performance monitoring reported data. Review this with the PHA and determine if any meter checks and/or replacements are necessary. Determine the effect of the key assumptions and identify any additional necessary field measurements.
5. Establish the baseline use and cost for each utility. Work on obtaining data on domestic hot water, cold water, make-up water, chemical treatment and electricity use at each site.

6. Work with the PHA to establish the performance targets for the various utility resources, end uses and any particularly significant conservation efforts. Identify what variable limits will trigger action by the management and engineering staff.
7. Document recommended actions and investments identified as a result of reviewing the performance monitoring reports.
8. Document changes in site conditions that explain any unusual variations in the performance monitoring results.
9. Document the efficiency of the significant heating system components including the distribution and temperature control systems.

TABLE 1: WEEKLY PERFORMANCE MONITORING
BUILDING OIL COST & SAVINGS COMPARISON
Public Housing Authority

Period		**Site 1** Fuel Oil Cost	**Site 2** Fuel Oil Cost	**Site 3** Fuel Oil Cost	**Site 4** Fuel Oil Cost	**Totals**	Fuel Oil Price	Notes &
From	To	($/Apt/Wk)	($/Apt/Wk)	($/Apt/Wk)	($/Apt/Wk)	**($)**	($/Gal-lon)	Comments
ANNUAL COST								
1/1/95	12/31/95	10.54		12.64	15.10		0.55	
4/1/95	3/31/96		**17.21**				0.55	Using Price of CY 1995
WEEKLY COST								
3/17/97	3/24/97	25.30	**33.48**	27.25	29.87		0.75	
3/24/97	3/31/97	22.99	**31.04**	21.72	19.20		0.75	
3/31/97	4/7/97	18.28	**28.83**	25.10	25.91		0.75	
4/7/97	4/14/97	19.62	25.87	26.71	**29.10**		0.75	
4/14/97	4/21/97	22.20	23.91	20.95	**26.05**		0.75	
4/21/97	4/28/97	21.80	**23.58**	18.35	22.74		0.75	
WHOLE BUILDING SAVINGS								
Actual Savings								
Cumulative To-Date ($) [1]		5,377	18,438	8,287	3,057	**35,160**		
Annual Rate ($/Yr)		11,358	49,678	18,646	7,883	**87,564**		
Available Savings								
Cumulative To-Date ($) [1]		16,132	55,314	24,861	9,172	**105,479**		
Annual Rate ($/Yr)		98,407	685,896	253,582	76,126	**1,114,011**		

[1] From start date of 3/18/97

FIGURE 1: WEEKLY BUILDING OIL COMPARISON
% VARIANCE FROM TARGET COST
PUBLIC HOUSING AUTHORITY

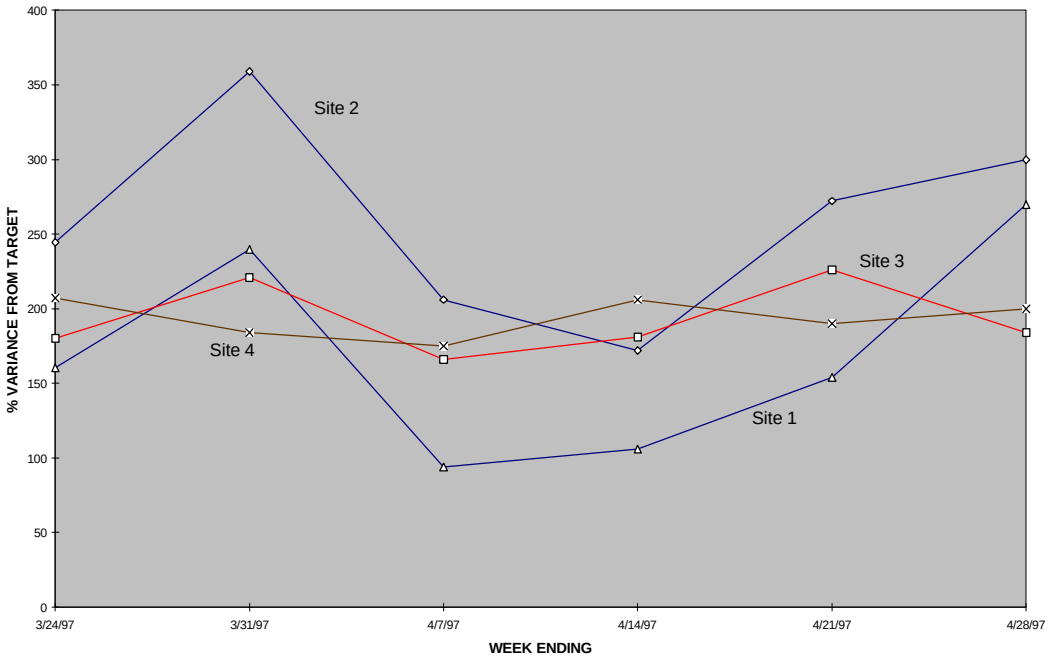

TABLE 2: WEEKLY PERFORMANCE MONITORING -- TOTAL AVAILABLE UTILITY SAVINGS
FUEL OIL[1], WATER [2], and CHEMICALS
Site 3 -- Public Housing Authority

	FUEL OIL USAGE				WATER USAGE				CHEMICAL USAGE				
Weekly Period Ending	Total Cost Target ($)	Total Cost Actual ($)	% Variance From Target (%)	**Cumulative Available Savings ($)**	Total Cost Target ($)	Total Cost Actual ($)	% Variance From Target (%)	**Cumulative Available Savings ($)**	Total Cost Target ($)	Total Cost Actual ($)	% Variance From Target (%)	**Cumulative Available Savings ($)**	**Total Cumulative Available Savings ($)**
3/24/97	2,664	7,466	180	**4,802**	1,082	2,475	129	**1,393**	39	147	275	**108**	**6,303**
3/31/97	1,854	5,952	221	**8,900**	1,077	2,360	119	**2,676**	31	118	275	**194**	**11,770**
4/7/97	2,584	6,877	166	**13,192**	1,080	2,437	126	**4,033**	36	136	275	**294**	**17,519**
4/14/97	2,606	7,319	181	**17,905**	1,081	2,442	126	**5,393**	39	145	275	**400**	**23,699**
4/21/97	1,760	5,739	226	**21,884**	1,076	2,349	118	**6,665**	30	114	275	**484**	**29,033**
4/28/97	1,615	4,592	184	**24,861**	1,072	2,277	112	**7,871**	24	92	275	**551**	**33,282**
5/5/97	1,782	3,983	124	**27,062**	1,070	2,250	110	**9,050**	21	79	275	**609**	**36,722**
5/12/97	1,955	4,321	121	**29,428**	1,071	2,277	113	**10,256**	23	86	275	**672**	**40,356**
5/19/97	1,528	2,406	57	**30,306**	1,075	2,145	99	**11,326**	13	48	275	**707**	**42,338**
5/19/97	18,349	48,655	165	**30,306**	9,684	21,010	117	**11,326**	257	964	275	**707**	**42,338**

Notes: Total[1] fuel oil is for DHW and space heating purposes.
[2] Total water is for DHW and make-up water, does not include potable cold water.
Fuel oil available savings are based upon an average price of $0.75 per Gallon of No. 4 Fuel Oil.
Water available savings are based upon a price of $5.50 / CCF.

TABLE 3: WEEKLY PERFORMANCE MONITORING
FUEL OIL FOR DHW and SPACE HEATING: AVAILABLE SAVINGS
Site 3 -- Public Housing Authority

Average		DOMESTIC HOT WATER				SPACE HEATING					
		Oil Usage		% Variance From	**Cumulative Available**	Oil Usage		% Variance From	**Cumulative Available**	**Fuel Oil Cumulative Available**	
Weekly Period Ending	Weekly Temp (°F)	Target (Gals)	Actual (Gals)	Target (%)	**Savings ($)**	Target (Gals)	Actual (Gals)	Target (%)	**Savings ($)**	**Savings ($)**	Notes & Comments (---)
3/24/97	34.9	650	1,820	180	**878**	2,902	8,134	180	**3,924**	**4,802**	
3/31/97	46.1	650	1,820	180	**1,755**	1,822	6,116	236	**7,145**	**8,900**	
4/7/97	36.0	650	1,820	180	**2,633**	2,796	7,349	163	**10,560**	**13,192**	
4/14/97	35.7	650	1,820	180	**3,510**	2,825	7,939	181	**14,395**	**17,906**	
4/21/97	47.4	650	1,820	180	**4,388**	1,697	5,832	244	**17,497**	**21,885**	
4/28/97	49.4	650	1,820	180	**5,266**	1,504	4,303	186	**19,596**	**24,862**	
5/5/97	47.1	650	1,820	180	**6,143**	1,726	3,491	102	**20,920**	**27,063**	
5/12/97	44.7	650	1,820	180	**7,021**	1,957	3,941	101	**22,408**	**29,429**	
5/19/97	50.6	650	1,820	180	**7,899**	1,388	1,388	0	**22,408**	**30,307**	
5/19/97		5,849	16,380	180	**7,899**	18,616	48,493	160	**22,408**	**30,307**	

Notes: Fuel oil available savings are based upon an average price of $0.75 per Gallon of No. 4 Fuel Oil.

TABLE 4: WEEKLY PERFORMANCE MONITORING
AVAILABLE WATER UTILITY SAVINGS FROM WATER CONSERVATION
Site 3 -- Public Housing Authority

	MAKE - UP WATER				DOMESTIC HOT WATER					
	Water Usage		% Variance	**Cumulative**	Water Usage		% Variance	**Cumulative**	**Water Cumulative**	
Weekly Period Ending	Target (CCF)	Actual (CCF)	From Target (%)	**Available Savings ($)**	Target (CCF)	Actual (CCF)	From Target (%)	**Available Savings ($)**	**Available Savings ($)**	Notes & Comments (---)
3/24/97	4.7	69	1,370	**355**	192	381	98	**1,037**	**1,392**	
3/31/97	3.8	48	1,177	**600**	192	381	98	**2,073**	**2,674**	
4/7/97	4.3	62	1,332	**919**	192	381	98	**3,110**	**4,029**	
4/14/97	4.6	63	1,266	**1,242**	192	381	98	**4,147**	**5,389**	
4/21/97	3.7	46	1,164	**1,476**	192	381	98	**5,183**	**6,659**	
4/28/97	2.9	33	1,035	**1,643**	192	381	98	**6,220**	**7,863**	
5/5/97	2.5	28	1,014	**1,785**	192	381	98	**7,257**	**9,042**	
5/12/97	2.8	33	1,084	**1,949**	192	381	98	**8,293**	**10,243**	
5/19/97	1.5	9	455	**1,988**	192	381	98	**9,330**	**11,318**	
5/19/97	30.9	392	1,169	**1,988**	1,731	3,427	98	**9,330**	**11,318**	

Notes: Water usage available savings are based upon a price of $5.50 / CCF (does not include savings in fuel oil).

TABLE 5: KEY ASSUMPTIONS :
WEEKLY PERFORMANCE MONITORING CALCULATIONS
Public Housing Authority

HEATING SYSTEM OPERATION:

BOILER EFFICIENCY:	70 %
FUEL TYPE:	No.4 Fuel Oil
FUEL HEAT CONTENT (HHV):	150,000 BTU/Gal

OPERATING PRESSURE of BOILER:

SITE 1	8 to 9 PSIG
SITE 2	120 PSIG
SITE 3	7 PSIG
SITE 4	8 to 9 PSIG

RAW MATERIAL PRICES:

1997 FUEL OIL PRICE:	$ 0.75 / Gal
1997 WATER PRICE:	$ 5.50 / 100 CF

	CURRENT CONDITIONS	**TARGET CONDITIONS**
	CHEMICALS:	
COST / MM LBS. OF STEAM PRODUCTION:	$150	$40
	DOMESTIC HOT WATER:	
DAILY DHW CONSUMPTION: (Gallons/person/apt):	Measured	25
OCCUPANCY RATE (Person/Apt):	3	
SYSTEM EFFICIENCY (%):	65	80
OUTLET TEMP (ºF):	130	120
INLET TEMP (ºF):	55	55
	SPACE HEATING:	
AVERAGE SIZE OF APARTMENT (sf/apt):	800	
ANNUAL FUEL OIL USE PER UNIT AREA (btu/sf/yr):	Measured	56,000