# COMPUTER SIMULATION/END-USE METERING

# OR

# "CAN WE COUNT ON ENERGY SAVINGS ESTIMATES

# IN DESIGNING DEMAND-SIDE PROGRAMS?"

by

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## BACKGROUND

In 1937, Congress created the Bonneville Power Administration (Bonneville) to serve as transmission and distribution agent for electricity generated by the Bonneville Dam. Today, Bonneville, as a part of the United States Department of Energy, also distributes hydroelectricity from twenty-nine other federal dams in the Pacific Northwest to its "wholesale customers", the majority publicly-owned utilities. Bonneville's full service area covers approximately 300,000 square miles in the states of Oregon, Washington, Idaho, and Montana west of the Continental Divide. Small adjacent sections of California, Montana, Nevada, Utah, and Wyoming also receive power from the Bonneville system. This service territory has a population of almost nine million.

Sweeping federal legislation in 1980 expanded Bonneville's role in supplying electricity to the region. Under terms of the Pacific Northwest Electric Power Planning and Conservation Act (the Act), Bonneville is charged with long-term planning and development of the region's energy resources.

The Act defines conservation as a power resource comparable to conventional capacity, and in fact ranks it the "resource of preference" when it is reliable and no more costly than thermal generation.

It is estimated that commercial-sector conservation cannot be left to independent consumer action. Consequently, creating mechanisms which can deliver reliable, large-scale conservation has become the focus of the Commercial Section within the Office of Energy Resources.

## COMMERCIAL RETROFIT END-USE STUDY (CREUS)

Utility, government, and private sector programs aimed at obtaining energy efficiency in commercial, industrial, and institutional buildings, typically rely on estimates of energy savings to be attained through the installation of energy conservation measures (ECMs). Savings estimates are derived by computerized simulation of building energy performance.

Although many commercial sector retrofit projects have been completed nationwide, relatively little information is available concerning the reliability of energy savings estimates prepared using computer simulations. This is particularly true for specific ECMs and end-uses.

Recent studies conducted by the Bonneville Power Administration raise questions about the reliability and cost effectiveness of computerized simulation as a tool to predict energy savings. Because Bonneville includes energy efficiency (conservation) in strategic resource planning, BPA is particularly interested in determining the accuracy and the predictive power of simulation models.

The Commercial Retrofit End Use Study (CREUS) was designed to:

* Determine the extent which actual end-use metering data have on the accuracy of energy savings predictions.

* Demonstrate reductions in commercial building energy use after installation of ECMs.

Track changes in energy use resulting from modifications in building operation, equipment, occupancy, structure, and maintenance procedures.

CREUS provided the opportunity to investigate, by metered end-use, the true electric load reductions in 18 buildings after ECM(s) installation.

## Methodology

The End-Use Load and Consumer Assessment Program (ELCAP) is a multi-year research effort designed to better understand the energy requirements and conservation potential of electrical loads in the Pacific Northwest. The Pacific Northwest Laboratory (PNL) manages this hourly end-use metering experiment.

Puget Energy Services, Inc. (Puget), a corporation in the State of Washington, is responsible for the management of the entire range of CREUS activities, from initial review of audits through re-audit methodologies, retrofit, and post-retrofit monitoring.

Eighteen buildings were selected for retrofit and analysis. There is a detailed collection of metered end-use data supported by detailed time-series characteristics data for all the buildings. The choice of energy conservation measures was determined after three audit simulations had been completed. Each of the three procedures was performed by the same auditor with varying amounts of information provided from end-use metering. We will present later the extent the amount of end-use information available to an auditor influences the accuracy of simulation estimates and/or creates changes in the recommendation of measures.

## The Audit Process

*** Conduct a "blind" audit.

Puget visited the buildings to determine occupancy/use data in order to establish current base line information to be used in the various computer simulations. An initial audit was conducted without benefit of end-use metering information.

*** Conduct a "semi-informed" audit.

The contractor then modeled each building after being provided a limited amount (one or two weeks) data for a single end-use, e.g., HVAC.

*** Conduct a "fully-informed" audit.

Finally, the performance of each building was again modeled after the auditor was provided the previous 12 months of metered data. This activity was designed to maximize the test of commercial computer modeling technology when modeling is based upon accurate time specific end-use profiles.

## Audit Methods

Audits were performed in accordance with Bonneville's "Technical Requirements for the Purchase of Energy Savings Pilot Program", dated May 15, 1986. This standard includes a list of approved energy modeling programs for different levels of building size and complexity. Buildings with consumption less than 1,000,000 kWh/year and packaged unitary HVAC systems were modelled using the ASEAM bin method program. Buildings with consumption greater than 1,000,000 kWh/year and more complex (multi-zone) HVAC systems were modelled using the PC-DOE implementation of DOE 2.1c.

Bonneville's standard requires establishing a baseline energy use model which estimates building energy use within plus or minus 15% of utility billing data. Under other Bonneville audit programs, this was generally interpreted as meaning within 15% of annual utility billing data. For CREUS, Puget staff attempted to develop models which estimated energy use within 15% on a monthly basis.

A comparison of data from the three audits performed for a typical CREUS building is shown here. The building is a 15,000 square foot, two story multi-tenant office building. Indoor lighting is primarily

fluorescent, with lighting densities of 2.1 watts per square foot. Heating and air conditioning are provided by 9 packaged unitary heat pump systems. Temperature control is provided by low voltage thermostats located in tenant spaces without locking covers. At the time of the audits, there were no automatic time controls in the building and both lighting and temperature controls were operated manually by tenants and janitorial crews.

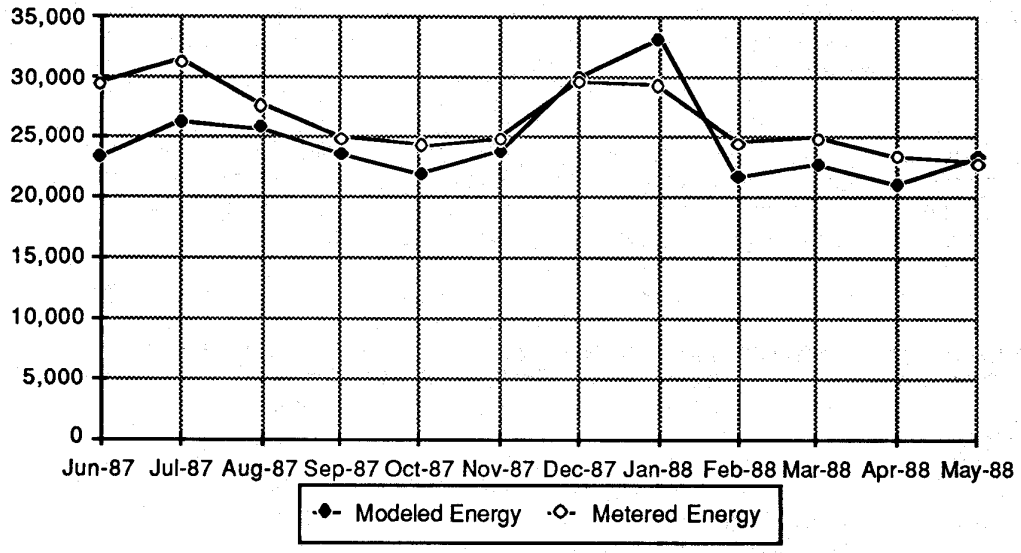


Figure 1.
Comparison of Blind Baseline with Historical Use
Audit No. J602

The "Blind" Audit resulted in an energy use baseline which estimated annual energy use within 6% of historical use, as shown in Figure 1 and Table 1.

| Period | Modeled Energy kWh | Metered Energy kWh | Difference % |
|---|---|---|---|
| Jun-87 | 23,374 | 29,560 | -21% |
| Jul-87 | 26,363 | 31,473 | -16% |
| Aug-87 | 25,731 | 27,707 | -7% |
| Sep-87 | 23,597 | 24,950 | -5% |
| Oct-87 | 21,907 | 24,237 | -10% |
| Nov-87 | 23,780 | 24,959 | -5% |
| Dec-87 | 30,071 | 29,639 | 1% |
| Jan-88 | 33,317 | 29,280 | 14% |
| Feb-88 | 21,726 | 24,552 | -12% |
| Mar-88 | 22,821 | 24,968 | -9% |
| Apr-88 | 21,138 | 23,414 | -10% |
| May-88 | 23,309 | 22,815 | 2% |
| Total | 297,134 | 317,555 | -6% |

Table 1.
Comparison of Blind Baseline with Historical Use
Audit No. J602

As shown in Table 1., the baseline model agrees with historical data within 15% for ten of the twelve months considered. The disagreement in the two earliest months of the period used was believed to result from tenancy changes in the building.

For the "Semi-Informed" Audit, each auditor was allowed to request two weeks of data for a single end use (total consumption for the same period was always provided). In the case of Audit J602, the auditor selected indoor lighting because indoor lighting was believed to offer the most savings potential, building occupants had given conflicting information about hours of use, and an unknown percentage of fixtures had already been relamped with energy efficient lamps. As a result, both the connected lighting load and its hours of operation were in doubt.

Hourly lighting end use data (for the two week period from January 1 to January 14, 1988) was used to determine actual hours of lighting use in the building and estimate actual lighting load. As a result of the two weeks of data, the auditor concluded that he had overestimated both the connected load and the amount of lighting used by janitorial crews during non-business hours. In addition, the auditor concluded that he had overestimated the degree of (manual) night setback being practiced.

The information available for the "Fully-Informed" Audit was twelve months of end use metered data. Based on this data, the auditor concluded that fan systems had been incorrectly modelled in the Blind and Semi-Informed cases. Fan systems which had been assumed to cycle with loads were modelled as continuously on based on the Fully-Informed data. The Fully-Informed data also indicated that lighting adjustments made in the Semi-Informed Audit were slightly overstated so small adjustments in lighting hours of use were also made.

The Fully-Informed baseline model predicted annual energy use to within less than one percent and predicted monthly energy use within 15% for all months. Figure 2 shows a comparison of the Fully-Informed model and the historical utility data.

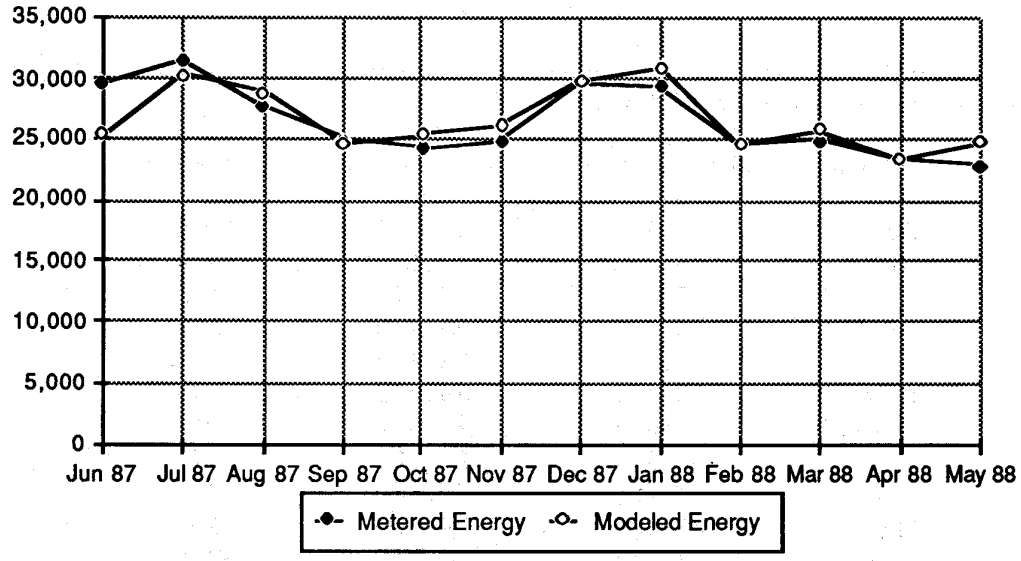


Figure 2.
Comparison of Fully-Informed Baseline with Historical Use
Audit No. J602

The Semi-Informed and Fully-Informed baselines agreed with metered end-use data much more closely than the Blind baseline. A comparison of the end-use consumption predicted in each model with the metered end uses is shown below in Table 2. Although the Blind baseline met Bonneville's technical requirements, it did not accurately model actual end use in the building.

| End Use | Blind | Semi-Informed | Fully-Informed | Metered |
|---|---|---|---|---|
| Mixed HVAC | 40,265 | 68,328 | 78,927 | 81,795 |
| HVAC Auxiliaries | 3,457 | 4,071 | 15,853 | 24,046 |
| Equipment & Plug Loads | 99,852 | 154,553 | 107,169 | 103,181 |
| Interior Lighting | 153,017 | 111,425 | 118,000 | 116,778 |
| Total | 296,591 | 338,377 | 319,949 | 325,800 |

Table 2.
Comparison of Modeled and Metered End Uses
Audit No. J602

The differences between the Blind and Fully-Informed Audits were significant and led to omission of a cost-effective measure in the Blind Audit. Based on interviews of tenants and the property manager, the auditor believed night setback was being practiced (manually) in the building and did not include programmable setback thermostats as a measure. This measure would not have shown any savings against the Blind baseline, because setback was included in the model. Fully-Informed data made it evident that night setback was not being practiced to the extent reported and the measure was added as a recommendation in the Fully-Informed Audit. A comparison of the recommended energy conservation measures (ECMs) and their estimated savings in the Blind and Fully-Informed Audits is shown below in Table 3.

| Conservation Measure | Blind | Fully-Informed |
|---|---|---|
| Programmable Tstat | #N/A | 28,084 |
| Delamp & Reflectors | 50,077 | 43,146 |
| PL Fluorescents | 2,947 | 2,794 |
| HPS Exterior Lighting | #N/A | 9,560 |
| DHW Tank Wrap | 862 | 862 |
| All ECMs | 53,886 | 84,446 |

Notes: The Thermostat and Exterior Lighting Measures were not considered in the Blind Audit. All figures are in kilowatt-hours.

Table 3.
Comparison of Annual Savings for Blind and Fully-Informed ECMs
Audit No. J602

Installation of the cost-effective ECMs identified in the Fully-Informed Audit was completed in March, 1989. End-use metering will continue until March 1990 and Puget is conducting quarterly site visits to document operation and maintenance changes in the CREUS buildings over the same period.

## Conclusions Based on Experience to Date

Following are a few of the conclusions reached based on experience gained in the CREUS project through the audit and ECM construction phases. The most important information to be developed by the project will not be available until March of 1990, when a year of post-installation end-use metering will be available.

End use data improves ability to predict end use loads (and therefore, measure energy savings). Close correlation with historical utility billing data does not ensure correlation with end uses or an accurate thermal model of a building.

Limited amounts of end-use metering data do not significantly improve auditors' ability to develop accurate building thermal models. Field measurements of space temperatures and HVAC system operating

characteristics provide more useful data but opportunities are limited (e.g. it is difficult to measure cooling system performance in mid-winter).

Building operations change so dramatically and so often, that audit findings are often valid only for a short time. For one third of CREUS buildings, operating conditions have changed in ways that will materially affect the validity of audit findings. These changes result from changes in ownership and tenancy, business failures, and fuel switching and do not readily correlate with building size or type.

In the absence of strong incentive program, owner investments in energy efficiency tend to be piecemeal and not part of a comprehensive, planned program. This leads to lost opportunities because measures installed are not optimum, but remaining opportunities are not cost-effective.

The business of business is business... not conservation or energy efficiency. Even when nearly all of the cost of measures is paid through incentives not all building owners are willing to invest their time or attention to participate in energy saving programs.