PNL-7237
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LETTER REPORT

IMPACT EVALUATION OF AN ENERGY $AVINGS PLAN PROJECT AT BELLINGHAM COLD STORAGE

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June 1990

Prepared for
Bonneville Power Administration
under a Related Services Agreement
with the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

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under Contract DE-AC06-76RLO 1830

EXECUTIVE SUMMARY

This impact evaluation of an energy conservation measure (ECM) that was recently installed at Bellingham Cold Storage (BCS) was conducted for the Bonneville Power Administration (Bonneville) as part of an evaluation of its Energy $avings Plan (E$P) Program. The Program awards cash incentives to firms that install energy conservation measures in their industrial processes. The objective of this impact evaluation was to assess how much electrical energy is being saved at BCS as a result of the E$P and to determine how much the savings cost Bonneville and the region.

The impact of the ECM was evaluated with a combination of engineering analysis, financial analysis, interviews, submittal reviews (BCS's Completion Report, Proposal, and Abstract), and process evaluation reviews. The ECM itself consists of an energy management and control system that is used to manage energy consumption by a large refrigeration system at BCS's Orchard Drive facility in Bellingham, Washington. At this facility, BCS freezes and stores fruits, berries, and fish products, while two tenants process frozen fish products.

Energy savings resulting from this ECM are expected to be at least 1,094,402 kWh during the first year (a savings of 23%) with greater savings in subsequent years. The ECM cost BCS $169,300 to install, Bonneville paid an incentive to BCS of $65,100, and the local utility paid an additional incentive of $21,700. The levelized cost of these savings to Bonneville will be no greater than 5.0 mills/kWh over the ECM's expected 15-year life, and the cost to the region will be no greater than 12.5 mills/kWh. It is expected that this ECM would have been installed within 3 years even without the incentive from Bonneville, and the levelized cost to Bonneville for just the first three years' savings is 21.03 mills/kWh or less.

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IMPACT EVALUATION OF AN ENERGY CONSERVATION PROJECT AT BELLINGHAM COLD STORAGE

1.0 INTRODUCTION

This letter report describes Pacific Northwest Laboratory's (PNL's) evaluation of the impact of an energy conservation measure (ECM) installed at Bellingham Cold Storage (BCS) in Bellingham, Washington. The ECM at BCS is one of a group of nine energy conservation projects to have its impact evaluated by PNL. All nine of the projects have or will receive incentives from the Bonneville Power Administration (Bonneville) under its Energy $avings Plan (E$P) Program for energy conservation in the industrial sector. The impact evaluation at BCS is particularly significant because a number of projects receiving incentives under the E$P are nearly identical to this one, and similar energy savings should be expected from those projects.

The E$P program is being offered so that when the need arises, Bonneville will already have developed and tested an industrial energy conservation program that can then be expanded into a full-scale acquisition effort. For the Bellingham Cold Storage project, the incentive offered under the program was equal to the lesser of 5 cents per first-year's kilowatt-hours saved or 80% of eligible project costs, up to a limit of $250,000.

The general objective of the impact evaluation was to determine how much electrical energy is saved by the ECM, and at what cost to Bonneville and the region. In support of this general objective, answers were sought to the following questions:

1. How much electrical energy is saved annually by the energy conservation measure in terms of kWh and KWh per unit of plant output? Also, did any fuel switching result from implementing this ECM?

2. If the ECM resulted in improved productivity of the process, did the firm then increase output of the process to take advantage of the productivity improvement? Did the change in output result in a net increase or decrease in energy used by the process? Did the change in output cause changes in output at the firm's other plants in the region?

3. What was the net impact to the servicing utility in terms of electrical energy consumption (in kWh) from implementing the ECM?

4. What are the levelized costs of the ECM from the perspectives of Bonneville and the region?

5. How much of the ECM's impact can be attributed to the E$P?

1.1 APPROACH FOR IMPACT EVALUATION

Before selecting individual energy conservation projects for impact evaluation, PNL developed a general impact evaluation methodology. The major finding of the methodology development was that in the industrial sector, energy conservation projects must be considered on a case-by-case basis. Accordingly, the general methodology consists of a variety of impact evaluation techniques that can be applied to individual projects according to the specific circumstances.

To evaluate the impact of the refrigeration energy management control system (EMCS) at BCS, five techniques were selected from the general methodology: engineering analysis, financial analysis, site visit and interview, review of sponsor's (BCS) submittals, and review of process evaluation results. On-site submetering by PNL was not necessary because the utility billing data used by BCS to verify energy savings in accordance with E$P program requirements is adequate to determine the project's impact; although PNL considered billing data for a longer time period than that covered by BCS's Completion Report.

As part of the process evaluation of the E$P Program, ERC Environmental and Energy Services Company conducted an interview with BCS on July 20, 1989. The results of this interview were reviewed as part of the impact evaluation because some of the information obtained in the interview applies to both the process and impact evaluations. Representatives from PNL visited Bellingham Cold Storage on September 26, 1989, to view the ECM firsthand and to conduct technical interviews with the plant's chief engineer and the company president.

1.2 PROJECT DESCRIPTION

Bellingham Cold Storage operates two plants in the Bellingham area. This energy conservation project was installed at its Orchard Drive facility, which consists of four cold storage warehouses that operate from a common ammonia refrigeration system. The storage rooms are kept at 0°F or -20°F, depending upon what is being stored in them. BCS is a contract freezing and storage firm; they freeze and store for others, but they do not own the goods in storage. In addition to the cold storage rooms at BCS, there are two tenants that operate fish processing and freezing operations at the facility. The tenants buy electricity from the primary service (BCS) and are submetered. Currently, the tenants' refrigeration equipment is operated separately from the equipment that cools the cold storage rooms. Within the next six months, all of the refrigeration systems at the site will be controlled by this newly-installed energy management control system.

The energy conservation project at BCS is a computer-based EMCS that was installed between October 1988 and January 1989 for controlling the plant's refrigeration equipment. The system consists of a mini-computer and software; computer peripherals; and sensors to measure pressure, temperature, humidity, electrical current, and power at various points throughout the plant. The EMCS reduces energy consumption by:

- increasing suction pressure and/or reducing discharge pressure when permissible to minimize pressure rise in the compressors and thereby reduce power consumption
- controlling the defrost cycle according to need instead of at fixed intervals
- limiting coil fan operation as permissible
- sequencing compressor operation so that minimum compressor power is used to meet cooling needs at all times
- recording the equipment operating parameters so that malfunctioning equipment can be readily detected and repaired or adjusted.

This ECM cost BCS $169,278 and they received incentives of $65,100 and $21,700 from Bonneville and Puget Sound Power and Light (Puget Power), respectively. As required by the ESP Program, BCS submitted three documents to Bonneville: an Abstract, a Proposal, and a Completion report. The Abstract described the ECM in general terms and laid out BCS's expectations with regards to costs and benefits. The Proposal described the ECM in greater detail and included a calculation of the ECM's expected simple payback based upon a revision of the ECM's expected energy savings. A Completion Report was submitted to Bonneville after the ECM was installed and BCS had verified the resulting energy savings. This document listed the actual costs of the ECM along with a calculation of the savings that had been achieved.

1.3 SUMMARY OF PROJECT IMPACTS

According to PNL's analysis, this E$P project is expected to save 1,094,402 kWh during its first year after installation. Savings from this ECM are likely to increase in subsequent years as the refrigeration equipment at the tenant firms is also brought under the control of the energy management control system and as the tenants implement their current plans to increase production levels. The savings will be even greater if BCS continues to expand the facility as planned.

Over the expected 15-year life of this project, levelized cost to Bonneville will be no greater than 5.0 mills/kWh (1 mill = 1/1000 of a dollar), and levelized cost to the region will be no greater than 12.5 mills/kWh with constant energy savings of about 1.1 million kWh/year. These costs are in real dollars and do not include additional savings that accrue if transmission and distribution losses are considered.

Because BCS considers energy savings to be an important part of its competitive position, this ECM would almost certainly have been installed eventually. A similar system was installed in another BCS facility in 1987 (with an incentive from the local utility), and BCS has been very satisfied with the results of that system. We estimate that the ECM would have been installed at the Orchard Drive facility within about 3 years if an incentive from Bonneville had not become available through the E$P. Bonneville's levelized cost is 21.0 mills/kWh for a project life of 3 years with annual energy savings of about 1.1 million kWh.

2.0 IMPACT EVALUATION

The following section addresses the five major objectives of the impact evaluation as described in the introduction.

2.1 ENERGY SAVINGS AND FUEL SWITCHING

1. How much electrical energy is saved annually by the ECM in terms of kWh and kWh per unit of output? Also, did any fuel switching result from implementing this ECM?

In the Completion Report, BCS and utility staff used utility billing data to compare energy consumption for a four-month period before ECM installation (January through April 1988) with a four-month period after installation one year later (January through April 1989). The energy consumption figures for both periods were normalized by dividing monthly energy consumption by the change in stored product for that month. After calculating a percentage energy savings figure from the two four-month periods, the savings percentage was multiplied by the annual consumption prior to ECM installation to arrive at an annual energy savings figure. In calculating the percent energy savings, energy consumption by the tenants was subtracted from the billing data so that only the refrigeration systems affected by the EMCS were considered. When the annual energy savings in kWh were calculated, however, the percent savings were multiplied by the total energy consumption at the facility, including the tenants. Using this method, the savings were calculated to be 1,434,419 kWh/year in the Completion Report. No separate savings calculation was made with regard to energy used for product freezing, even though savings were expected for freezing as well as storage. Instead, the savings percentage calculated from storage was applied to product freezing as well.

PNL's analysis of the energy savings at BCS was slightly more extensive than the one done for the Completion Report. Energy consumption data for the period July 1987 to November 1989, were considered, as opposed to the two four-month periods that were compared in the Completion Report. (Data covering this much time were not available at the time the Completion Report was written.) In addition to correcting for changes in the tenants' energy consumption and normalizing the energy consumption data for the amount of product stored, they were also normalized for weather. An attempt was made to normalize for the amount of product processed (fruits and berries at ambient temperature that are placed in the cold rooms for freezing), but this proved to be infeasible because insufficient data (e.g., product mix, differences in moisture content of products) were available to accurately account for changes in energy consumption for processing. It was found, however, that processing energy consumption accounts for less than 9% of the annual total for BCS, so assuming the same percentage savings from processing and storage will not significantly affect the savings calculations.

After determining that it would be infeasible to separately calculate the savings from processing, PNL's analysis was focused on the savings from the cold storage operations. Two six-month periods that were unaffected by processing energy consumption were selected for comparison: January through June 1988 (before ECM installation), and January through June 1989 (after ECM installation).

For each of the months in the comparison, a number of calculations were done. First, the cooling degree-days (CDDs) were calculated against a -15°F ("average" storage temperature) base. The degree-days, along with the results of the other monthly calculations, are listed in Tables 2.1 and 2.2. Next, the net energy consumption (billed consumption minus energy consumed by the tenants) was calculated for each month. The final calculation for each month was to determine the normalized energy consumption in kWh/ton/degree-day. This figure is calculated by dividing the monthly net energy consumption by its corresponding cooling degree-days and storage inventory. For example, the normalized energy consumption for January 1988 is

$$345{,}200 \text{ kWh} \div 1{,}612 \text{ CDD} \div 21{,}155 \text{ tons} = 0.0101 \text{ kWh/ton/degree-day}$$

After the normalized energy consumption was calculated for each month before and after ECM installation, an average was calculated for each six-month period. Prior to ECM installation, BCS consumed 0.0124 kWh/ton/degree-day. Afterwards, consumption dropped to 0.0095 kWh/ton/degree-day, a savings of 23%. To arrive at a figure for annual energy savings in kWh, the

TABLE 2.1 Normalized Energy Consumption Before ECM Installation

Month	Cooling Degree Days (-15°F base)	Net Energy Consumption (kWh)	Inventory (tons)	Normalized Energy Consumption (kWh/ton/degree day)
January 1988	1,612	345,200	21,155	0.0101
February 1988	1,512	304,000	18,334	0.0110
March 1988	1,891	258,400	14,395	0.0094
April 1988	1,890	286,320	11,542	0.0132
May 1988	2,139	274,400	8,931	0.0144
June 1988	2,160	248,000	7,063	0.0162

TABLE 2.2. Normalized Energy Consumption After ECM Installation

Month	Cooling Degree Days (-15°F base)	Net Energy Consumption (kWh)	Inventory (tons)	Normalized Energy Consumption (kWh/ton/degree day)
January 1989	1,643	258,320	17,424	0.0090
February 1989	1,372	238,880	15,117	0.0115
March 1989	1,767	226,184	13,014	0.0098
April 1989	1,950	214,358	10,884	0.0101
May 1989	2,170	215,115	12,216	0.0081
June 1989	2,250	220,731	11,560	0.0085

percentage savings were multiplied by BCS's pre-installation net energy consumption of 4,800,720 kWh, resulting in annual energy savings of 1,094,402 kWh.

PNL's analysis shows that BCS's energy consumption per ton of product stored has decreased by 23% as a result of installing the energy management control system, which is 3% greater than the savings reported in the Completion Report (20%). We calculated that the ECM saved 1,094,402 kWh during its first year of operation. This is less than the kWh savings in the Completion Report because in that report, the percentage savings were applied to the tenant's load along with BCS's load, which overstates the savings for the ECM's first year. BCS intends to place all of the refrigeration equipment in the facility, including the tenants', under the control of the EMCS in the near future, at which time the total savings may well be even greater than those listed in the Completion Report.

Because BCS operates an electrically powered cold storage plant, fuel switching is not an option. Therefore, no fuel switching resulted from installing this ECM.

2.2 IMPACTS TO THE FIRM

2. If the ECM resulted in improved productivity of the process, did the firm then increase output of the process to take advantage of the productivity improvement? Did the change in output result in a net increase or decrease in energy used by the process? Did the change in output cause changes in output at the firm's other plants in the region?

Bellingham Cold Storage's "output" (amount of goods frozen or held in cold storage) is limited by the size of its facilities and its ability to sell storage contracts to their customers. The increased operating efficiency resulting from installing the EMCS would lead to greater output only if it allowed them to sell more contracts, and even then only if excess storage or freezing capacity were available. Conceivably, the EMCS might allow BCS to increase sales by reducing its operating costs, and hence offering lower storage and freezing costs to customers, who would then purchase more BCS services. No evidence of this market linkage was detected in our research, and in fact other factors beyond BCS's control were found to greatly affect its ability to fill the facility. Two of the largest factors that affect BCS's sales are production levels of its fish-processing tenants, and fruit and vegetable yields of Northwest farmers. When processed fish production increases, BCS is called upon to store more fish, both as input to the process and as finished product. The other factor affecting sales is crop yields--when more crops are produced, demand for storage services increases. Neither of these two factors are affected by energy savings at BCS.

In addition to the Orchard Drive facility where this ECM was installed, BCS also has a larger facility on the Bellingham waterfront. A nearly identical EMCS was installed at the waterfront facility in 1987, so this ECM does not represent an energy cost advantage for the Orchard Drive plant. Therefore, there is no reason to expect output to increase at the Orchard Drive plant at the expense of the waterfront plant.

2.3 IMPACTS TO THE UTILITY

3. What is the net impact to the servicing utility in terms of electrical energy consumption (in kWh) from implementing the ECM?

Because there is no cogeneration or other complicating factors, all of the energy savings from this ECM will be reflected in reduced load at the utility, Puget Power. In the first year of operating the energy management control system, the utility's load was reduced by about 1.1 million kWh. Load reductions per ton of product in the future should be even greater, as more of the equipment at the facility is placed under the control of the EMCS.

2.4 LEVELIZED COSTS

4. What are the levelized costs of the ECM from the perspectives of Bonneville and the region?

Levelized annual costs are used to compare the attractiveness of various projects or investment alternatives. The levelized cost is the annual cost that will be incurred over the life of the project, accounting for the time value of money. (See the Appendix for complete definition and formula.)

Levelized costs provide a single figure of merit for comparing energy conservation alternatives. In addition, levelized costs can be used to compare conservation projects with options for new generating capacity and to optimize the ranking of these options. The objectives of using levelized costs to evaluate these energy conservation measures are as follows:

- to determine the financial impact of each ECM to Bonneville ($/kWh saved)
- to determine the financial impact to the region (Bonneville and BCS combined).

2.4.1 Bonneville Perspective

To determine the levelized costs to Bonneville and to the region, we must know the project costs (incentive paid, capital costs, etc.) and the energy savings, and assume a discount rate and project life. The levelized costs shown in Table 2.3 are based on energy savings calculated by PNL, or about 1.1 million kWh per year for 15 years. With energy savings of this magnitude, the project's levelized cost from Bonneville's perspective is 5.0 mills/kWh. This should be considered the maximum levelized cost of the project over its assumed 15-year life, because it is expected that the energy savings will actually increase as more of the refrigeration equipment at the site is brought under the control of the EMCS, thereby reducing the levelized cost. No data are available to assess the amount of savings that can be expected as the tenants' refrigeration equipment is brought under the control of the EMCS, so no levelized costs were calculated to account for those savings.

Bonneville's levelized cost decreases to 4.5 mills/kWh saved when transmission and distribution losses are considered. Transmission and distribution losses increase the energy savings at the source by 7.5% (see Appendix).

All costs are shown in real dollar terms (without inflation effects). These results include the incentive paid by Bonneville but ignore any program administrative or evaluation costs for the program. Data are not available to calculate these costs on a project-by-project basis, but they will be included in the impact evaluation report on the overall program.

TABLE 2.3. Levelized Costs - Bonneville and the Region

Energy Savings (kWh/yr)	Levelized Cost (mills/kWh saved)				
	Bonneville		BCS	Regional	
	Without Transmission Losses	With Transmission Losses	Without Transmission Losses	Without Transmission Losses	With Transmission Losses
1,094,402	5.0	4.7	7.5	12.5	11.6

2.4.2 Regional Perspective

To calculate the levelized cost to the region, the costs to Bonneville and BCS are combined. The incentive paid by Bonneville is included as a cost to Bonneville and as a reduction in cost to BCS. This approach was taken because the incentives have federal income tax consequences to the firm and, therefore, are not a net zero cost to the region. The incentive paid by Puget Power is included as a reduction in cost to BCS with no effect on Bonneville's cost.

As shown in the table, the levelized cost to the region for acquiring annual energy savings of about 1.1 million kWh is 12.5 mills/kWh. Including transmission and distribution losses, the levelized cost decreases to 11.4 mills/kWh saved.

2.5 IMPACT ATTRIBUTABLE TO E$P

5. How much of the ECM's impact can be attributed to the E$P?

Determining whether Bellingham Cold Storage would have implemented this ECM without the incentive from Bonneville requires an understanding of the company's capital budgeting process and its criteria for investment. It also requires one to analyze the ECM from BCS's perspective prior to actually making the decision to install the ECM (i.e., from the data presented in the Proposal). BCS staff stated that they typically fund energy conservation projects that result in simple payback of three years or less and sometimes fund projects with a payback of up to five years. In the absence of any incentives from Bonneville or the utility, simple payback for this project was expected to be 3.5 years, which is in the "gray area" of BCS's funding criterion. This payback period is based on 1.7 million kWh annual savings, as presented in BCS's Proposal for this project. Dollar savings were expected to be about $51,000 per year[a] including savings from the expected demand reduction, and estimated costs were slightly over $179,000. With the $65,100 incentive from Bonneville and the $21,700 incentive from Puget Power,

(a) Based on $0.0215/kWh and 400 kW peak demand reduction for 8 months/year at $4.20/kW/month.

simple payback for this project was expected to be 1.8 years, which was well within the BCS criterion for funding.

Another factor to consider in determining whether or not this ECM would have been installed in the absence of the E$P is technical risk. Because BCS had already installed a very similar system at its waterfront plant and because that system is considered very successful by the firm, technical risk for this project was minimal from BCS's perspective.

We conclude that BCS would have installed this ECM within the next three years, even without the incentive from Bonneville based on BCS's responses during the process and impact evaluation interviews, its financial evaluation of the project, and its level of risk. Therefore, the impact of the E$P program was to cause three year's energy savings, which is at least three million kWh. The levelized cost to Bonneville for three years' savings is 21.0 mills/kWh if annual energy savings are constant at 1.09 million kWh.

APPENDIX

FINANCIAL EVALUATION DETAILS

APPENDIX

FINANCIAL EVALUATION DETAILS

1. Definitions

Levelized Cost - A single figure of merit that expresses the cost per unit of benefit (in this case, energy savings) accounting for the time value of money. This annualized cost would be constant over the entire project life. An infinite number of cash flow scenarios (costs incurred at different times in the project life) could result in the same annualized cost.

Levelized Cost to Bonneville - The annualized costs to Bonneville, direct and indirect, per unit of energy saved by the conservation measure. Costs included are the incentive paid and the program administrative costs (although no administrative costs are included in this analysis of this ECM at Bellingham Cold Storage).

Levelized Cost to Region - The sum of annualized costs to Bonneville and the firm per unit of energy saved by the energy conservation measure. This would include the same costs to Bonneville as above, plus the initial capital and on-going incremental production costs to the firm.

2. Levelized Cost Formula

$$LC = \{[PVCI + PVICI + (PVOM + PVPT + PVOTE) * (1-itf) - PVD * itf] / (1-itf)\} * (CRF/AES)$$

where LC = levelized cost (real $)

PVCI = present value of initial capital costs

PVICI = present value of interim capital costs

PVOM = present value of operating and maintenance (O&M) costs

PVPT = present value of property taxes

PVOTE = present value of one-time expenses

itf = combined state and federal income tax fraction

PVD = present value of depreciation

CRF = capital recovery factor (spreads the costs over the project life in real dollar terms)

AES = annual energy savings (kWh/yr).

3. General Assumptions

The following general assumptions were made in the levelized cost calculations:

a. All cash flows are expressed in nominal terms (with inflation) and are discounted to present value at a nominal discount rate of 8.15% (combines a real discount rate of 3.0% and an inflation rate of 5.0%). The costs are annualized over the life of the project using the capital recovery factor at a real discount rate of 3.0%.

b. Equal annual energy savings--Savings (kWh) per year--is constant over the life of the project. This assumes no loss in efficiency of the equipment with time.

c. Transmission and distribution losses equal 7.5%, increasing the energy savings at the source by a corresponding 7.5%.

d. In the regional cost calculation, the incentive from Bonneville is treated as a cost to Bonneville and, at the same time, a cash inflow to the firm rather than a net zero cost. This is done because the firm will incur a tax liability due to the incentive, thus a net cost to the region.

4. Bonneville levelized cost calculations

Input: one-time expenses

Incentive paid (year 0) = $65,100

Administrative costs (year 0) = $0

Tax rate = 0%

Energy savings (annual) = 1,094,402 kWh (PNL calculation)

Output: levelized cost = 5.0 mills/kWh saved

5. Regional levelized cost calculations (Bonneville + BCS)

A. BCS

Input: initial capital

Equipment = $169,300 (including installation)

One-time expenses (revenues)

Incentive received = ($86,800) (includes $21,700 from Puget Power)

Annual recurring expenses (O&M)

Maintenance = $500

Tax rate = 33%

Depreciation = 5 year

Energy savings (annual) = 1,094,402 kWh (PNL calculation)

Output: levelized cost = 7.5 mills/kwh saved

B. Regional levelized cost = Bonneville levelized cost + BCS levelized cost

= 5.0 mills/kWh + 7.5 mills/kWh

= 12.5 mills/kWh saved

6. Levelized costs allowing for transmission and distribution losses

Input: transmission and distribution losses = 7.5%.

Bonneville levelized cost = 5.0 mills/kWh ÷ 1.075 = 4.7 mills/kWh

Regional levelized cost = (5.0 mills/kWh + 7.5 mills/kWh) ÷ 1.075

= 11.6 mills/kWh