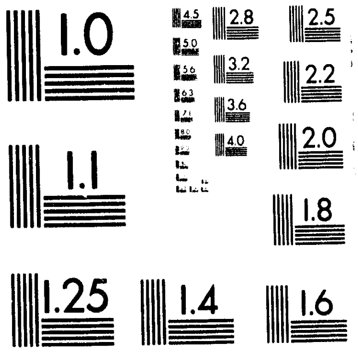
1.0
1.1
1.25
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1.6
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4.0
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5.6
6.3

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Impact Evaluation of Adjustable Speed Drives Installed at Great Western Malting Company Under the Energy $avings Plan

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Prepared for Sheila Riewer
Program Evaluation Section
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Summary

This impact evaluation of adjustable speed drives (ASDs) that were recently installed at Great Western Malting Company (GWM) was conducted for the Bonneville Power Administration (Bonneville) as part of an evaluation of its Energy $avings Plan (E$P) Program. The project consists of four ASDs that are used to control the power to motors driving kiln exhaust fans. The ASDs are being used to control the air flow rate through the compartment house malt drying kilns, which was previously controlled with dampers. The objective of this impact evaluation was to assess how much electrical energy is being saved at GWM as a result of the E$P and to determine how much the savings cost Bonneville and the region. The impact of the project was evaluated with a combination of engineering analysis, financial analysis, interviews, and submittal reviews (GWM's proposal and completion report).

Based on this impact evaluation, energy savings from this project are expected to be 1,140,000 kilowatt-hours per year (kWh/yr). On a unit production basis, this project will save 14.6 kWh/ton of roasted malt. The equivalent savings in average megawatts is 0.13. The project cost $115,632 to install in 1992, and GWM received payment of $92,506 in 1993 from Bonneville for the acquisition of energy savings. The real levelized cost of these energy savings to Bonneville is 8.7 mills/kWh (in 1993 dollars) over the project's assumed 15-year life, and the real levelized cost to the region is 11.6 mills/kWh in 1993 dollars, not including transmission and distribution effects.

Based on the expected project installation costs and energy savings benefits, the ASDs would not have been implemented by GWM without the E$P acquisition payment. The expected acquisition payment reduced the estimated payback period from 8.4 to 3.3 years. Although GWM would usually require an energy conservation project to have a payback period of less than three years, increased corporate interest in reducing energy use made the slightly higher payback acceptable.

Contents

Tables

1.0 Introduction

This report describes Pacific Northwest Laboratory's (PNL's)[a] evaluation of the impact of an energy conservation project installed in 1992 at Great Western Malting Company (GWM) in Vancouver, Washington. The project at GWM is one in a continuing series of industrial energy conservation projects to have its impact evaluated by PNL. All of the projects have received or will receive acquisition payments from the Bonneville Power Administration (Bonneville) under the Energy $avings Plan (E$P) Program.

The E$P is being offered to reduce electrical energy consumption in the industrial sector of Bonneville's service territory. For the GWM project, the acquisition payment offered under the program was equal to the lesser of 10¢/kilowatt-hour (kWh) saved in the first year or 80% of eligible project costs. The general objective of the impact evaluation was to determine how much electrical energy is saved by the project and at what cost to Bonneville and to 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 project in terms of kilowatt-hours, kilowatt-hours per unit of plant output (unit savings), and average megawatts (aMW)? Also, did any **fuel switching** result from implementing this project?

2. If the project improved the 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 serving utility in terms of electrical energy consumption (in kilowatt-hours) from implementing the project?

4. What are the **real levelized costs** of the project from the perspectives of Bonneville and the region?

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

(a) Pacific Northwest Laboratory is operated for the U.S. Department of Energy by Battelle Memorial Institute under Contract DE-AC06-76RLO 1830.

1.1 Approach for Impact Evaluation

Before selecting individual energy conservation projects for impact evaluation, PNL developed a general impact evaluation methodology (Spanner et al. 1988). The major finding of the methodology development was that in the industrial sector, energy conservation projects must be evaluated 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 installing ASDs on the kiln exhaust fans at GWM, four techniques were selected from the general methodology: engineering analysis, financial analysis (see Appendix A), site visit and interview, and review of GWM's submittals. Submetering performed by BRACO Energy Services in accordance with E$P program requirements was relied upon by PNL to determine the project's impact.

Representatives from PNL visited GWM on May 20, 1993 to view the project firsthand and to interview the Process Research Manager.

1.2 Project Description

The GWM plant in Vancouver, Washington produces brewing malt from barley. The malting process consists of three basic steps: steeping, germination, and kilning. The steeping process initiates the germination process by soaking the barley kernels in water for 36-48 hours. After draining excess water, the kernels are transferred to another vessel where germination continues in a controlled environment for another 3-4 days. Finally, moisture is removed by kilning the barley, which stops germination and also develops the malt flavor and color important for brewing.

Malt drying is accomplished in a double deck kiln that reduces the moisture content from 46% to 4% in a 32-hour period. Each batch resides for 16 hours on each deck. During the first 4 hours, the top deck is loaded. Drying may occur on the lower deck during this period, depending on the moisture content of the malt. During the next 8 hours, heated air passes through the upper deck at 100% flow. The temperature of the indirectly-heated air is set at 145°F during the first 4 hours of this period and is raised to 155°F for the next 4 hours. During the last 4 hours of each 16-hour cycle the air temperature is raised to 180°F. Air flow is reduced to 75% of full flow during this period and is directed through both decks.

In the energy conservation project at GWM, electronic ASDs were installed on the exhaust fan motors to control air flow where exhaust dampers were previously used. With the dampers, flow control is achieved by varying the pressure drop of the air. Thus, input motor power is relatively constant. In contrast, the ASDs control the air flow rate by varying the electrical input and fan output directly, thereby eliminating the additional pressure drop losses.

GWM submitted two documents to Bonneville: a proposal and a completion report. The proposal described the energy conservation project and presented GWM's cost and benefit expectations. A completion report was submitted to Bonneville after the project was installed and GWM had verified the resulting energy savings via submetering. This document listed the actual costs of the project along with a calculation of the energy savings that had been achieved. A copy of the proposal cover sheet is included as Appendix B.

Energy savings were verified by metering one of the four identical fan motors for two 96-hour periods. During the first period, flow control was achieved via ASD, while dampers were used to provide flow control during the second test period. Other process parameters (malt moisture levels, deck static pressures, and kiln air temperatures) were also recorded to document operating conditions during the two periods. Energy consumption during the first 4 hours of each 16-hour cycle (when the upper deck is loaded and predrying may occur on the lower deck) was ignored due to the variability of predrying occurrence. Otherwise, the difference in energy consumption measured with damper and ASD control during the two test periods was linearly extrapolated to cover an entire year and all four fans. The resulting energy savings estimate presented in the completion report was 1,173,659 kilowatt hours per year (kWh/yr).

The total cost to GWM for this project was $115,632 and Bonneville paid $92,506 for the energy saved. The acquisition payment was calculated by multiplying the project cost by 80%, which was less than paying 10¢/kWh saved in the first year.

1.3 Summary of Project Impacts

This E$P project is expected to save 1,140,000 kilowatt-hours annually or 0.13 aMW. Over the assumed 15-year life of this project, the levelized cost to Bonneville is 8.7 mills/kWh (1 mill = 1/1000 of a dollar), and the cost to the region is 11.6 mills/kWh. These costs are in real 1993 dollars and do not include additional savings that accrue if transmission and distribution losses are considered. The levelized cost to Bonneville including transmission and distribution losses is 8.1 mills/kWh, and the cost to the region is 10.8 mills/kWh.Without the acquisition payment from Bonneville, this project did not meet GWM's payback criteria; however, payback was satisfactory with the acquisition payment. Therefore, we conclude that the project would not have been installed in the absence of the E$P.

2.0 Impact Evaluation

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

2.1 Energy Savings and Fuel Switching

How much electrical energy is saved annually by the project in terms of kilowatt-hours, kilowatt-hours per unit of plant output, and average megawatts? Also, did any fuel switching result from implementing this project?

Energy Savings

In general, the power required to operate a fan is proportional to the mass flow rate of fluid being moved and the total pressure (velocity pressure plus static pressure) increase imparted by the fan. Where fluid density is constant, or nearly so, volumetric flow rates may be substituted for mass flow rates. Therefore, factors affecting the flow rate and total pressure should be investigated as part of the energy savings evaluation.

As described in Section 1.0, there are three distinct periods during each 16-hour kilning cycle. Each has a unique flow rate and static pressure (velocity pressure is presumed to be constant). During the middle 8 hours, heated air flows through the upper deck. Flow and static pressure are at 100% of the design values. During the latter 4 hours, heated air flows through both decks. Flow is reduced to 75% of design while static pressure is about 65% of design. During the first 4 hours, flow is either 0, or if extra drying is required, heated air is routed through the lower deck only. Flow is reduced to 70% of design while static pressure is about 45% of design.

With ASDs, air flow is reduced (increased) by directly decreasing (increasing) the power to the fan motor rather than by closing (opening) dampers at relatively constant power input. In the GWM application, the percentage energy savings are greatest during the pre-drying period when the required air flow and static pressure is lowest. Pre-drying does not occur every cycle, however, so total energy savings are greatest in the curing period (the last 4 hours of each cycle). Energy savings also occur during the 8-hour drying period because GWM is able to reduce air flow to the minimum required rather than operate at the full design rate.

The PNL evaluation of the GWM energy savings estimate focused on the following factors: 1) variation of process conditions, 2) energy consumption during the pre-drying period, and 3) variation of the length of each operating mode (pre-drying, drying, and curing).

As indicated in Section 1.0, process conditions (malt moistures, static pressures, and air temperatures) were recorded during the two test periods. The data recorded indicated no significant differences between the two periods that would be expected to impact fan energy consumption. In general, there is no seasonal variation in production or process conditions, except for the temperature and humidity of the ambient air drawn into the kilning rooms. The absolute humidity of the entering air has a direct impact on the amount of time required to dry the malt. The higher the humidity, the longer it takes the malt to dry, all else being equal. The additional drying time, when required, is accomplished during the optional pre-drying period at the start of each cycle.

The Process Research Manager at GWM estimated that pre-drying was required about 15% of the time on an annual basis. Energy savings during the pre-drying period were specifically excluded from the completion report due to uncertainty regarding the frequency of occurrence. In fact, during the test period, pre-drying occurred on one-third of the cycles. Pre-drying energy savings were included in the total energy savings estimated developed by PNL based on the estimated average annual frequency noted above and the average energy savings recorded during the test period when pre-drying occurred.

The annual energy savings estimate presented in the completion report implicitly assumes that the conditions occurring during the test period (other than the pre-drying portion) are repeated throughout the rest of the year. Examination of the metered data indicated that the average number of operating hours in each mode (pre-drying, drying, and curing) were different in the two test periods, with neither matching the expected operating hours per mode. Actual operating hours per mode during the two 96-hour test periods and expected average operating hours per mode are presented in Table 2.1.

Table 2.1. Operating Hours Per Mode

	Loading	Pre-Drying	Drying	Curing
Metering w/ASD	19.5	7.75	42.0	26.75
Metering w/o ASD	18.25	6.75	47.0	24.0
Expected Average	20.4	3.6	48.0	24.0

Annual energy savings were estimated by PNL to be 1,140,000 kWh based on the energy consumption per hour metered during the two test periods and the expected annual average operating hours per mode presented in Table 2.1. This is equivalent to 0.13 aMW or 14.6 kWh per ton of malt. Energy consumption, energy savings, and annual operating hours per mode are documented in Table 2.2.

$$284{,}634 \text{ kWh/year per fan} * 4 \text{ fans} = 1{,}138{,}536 \text{ kWh/year}$$
$$\text{Rounded estimate} = 1{,}140{,}000 \text{ kWh/year or } 0.13 \text{ aMW}$$

Fuel Switching

The fan motors require electrical energy for operation. Therefore, fuel switching is not possible.

2.2 Impacts to the Firm

If the project improved the 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?

Installation of this project improved the productivity of the process by reducing electrical energy consumption per unit of malt. No increase in production was possible because the GWM plant in Vancouver was operating at 100% of plant capacity before the project and continues to do so. Therefore, a net decrease in energy use occurred.

Table 2.2. ASD Energy Savings Calculation

	kW w/o ASD	kW w/ASD	kW Savings	Operating Hours/yr	kWh Savings/yr
Pre-Drying	148.9	55.1	93.8	328.5	30,813
Drying	166.3	148.2	18.1	4,380.0	79,278
Curing	157.0	77.3	79.7	2,190.0	174,543
Total					284,634

2.3 Impacts to the Utility

What is the net impact to the serving utility in terms of electrical energy consumption (in kilowatt-hours) from implementing the project?

All of the energy savings from this project will be reflected in reduced load at the serving utility, Clark County Public Utility District. The net impact to the utility from this project is a 1,140,000 kWh/yr reduction in electrical load or 0.13 aMW. The adjoining cogeneration facility, which provides hot water but not electricity to GWM, is no longer owned by GWM. Therefore, GWM does not have the option to substitute self-generated power for power received from Clark County.

2.4 Real Levelized Costs

What are the real levelized costs of the project from the perspectives of Bonneville and the region?

Real levelized annual costs are used to compare the attractiveness of various projects or investment alternatives. The levelized cost is the annual cost that would be incurred over the life of the project, accounting for the time value of money. (See Appendix A for complete definitions 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. Levelized costs are calculated from the perspectives of Bonneville and the region (Bonneville and GWM combined).

In the industrial sector, it is not possible to accurately predict the life of a project because any number of external factors could cause the project to have a longer or shorter life than expected when it is installed. To allow comparisons of levelized costs among projects installed under the E$P, all projects are assumed by PNL to have a life of 15 years for evaluation purposes. Even though some projects will have longer or shorter lives, 15 years is considered a typical life for projects in the industrial sector.

2.4.1 Bonneville Perspective

To determine the real levelized costs to Bonneville and to the region, we must know the project costs (acquisition payment, capital costs, etc.) and the energy savings, and must assume a discount rate and project life. With energy savings of 1,140,000 kWh/yr, the project's levelized cost from Bonneville's perspective is 8.7 mills/kWh in 1993 dollars (see Appendix A). Bonneville's levelized cost decreases to 8.1 mills/kWh when transmission and distribution losses are considered. Including these losses allows comparison of conservation resources with generation that is measured at the point of production rather than at the site of the end user (point of delivery).

The levelized costs calculated in this impact evaluation include the acquisition payment by Bonneville, the metering costs of BRACO Energy Services, and the estimated administrative and evaluation costs associated with this project.

2.4.2 Regional Perspective

To calculate the real levelized cost to the region, the costs to Bonneville and GWM are combined. The acquisition payment by Bonneville is included as a cost to Bonneville and as a reduction in cost to GWM. This approach is taken because the acquisition payment has federal income tax consequences to the company and, therefore, is not a net zero cost to the region.

The real levelized cost to the region for acquiring annual energy savings of 1,140,000 kWh is 11.6 mills/kWh saved. Including transmission and distribution losses, the levelized cost decreases to 10.8 mills/kWh saved.

2.5 Impact Attributable to E$P

How much of the project's impact can be attributed to the E$P?

GWM uses discounted simple payback to economically evaluate energy conservation projects and generally requires a payback period of less than 3 years. When this project was proposed to Bonneville, it was expected to cost $123,338 and result in electrical energy savings of $14,700/yr for a simple payback of 8.4 years. With the expected Bonneville acquisition payment of $74,770, simple payback was reduced to 3.3 years. The discounted simple payback period would be slightly longer. Although GWM would usually require an energy conservation project to have a discounted payback of less than 3 years, increased corporate interest in reducing energy use made the slightly higher payback acceptable. Considering the facts presented above, we conclude that this project would not have been implemented without the acquisition payment from Bonneville and that all of the project's impact can be attributed to the E$P.

3.0 References

Spanner, G. E., D. R. Brown, D. R. Dixon, B. A. Garrett, R. W. Reilly, J. M. Roop, and S. A. Weakley. 1988. *Potential Techniques for Evaluating the Impact of Industrial Energy Conservation Projects under Bonneville's Energy $avings Plan.* Letter Report. PNL-6628, Pacific Northwest Laboratory, Richland, Washington.

Appendix A

Financial Evaluation Details

Appendix A

Financial Evaluation Details

A.1 Definitions

Real 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 (not the "adjusted system real levelized 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.

Real Levelized Cost to Bonneville Power Administration (Bonneville) - The annualized costs to Bonneville, direct and indirect, per unit of energy saved by the energy conservation project. Costs included are the acquisition payment and the program administrative costs, as well as the costs to evaluate the impact of this project.

Real Levelized Cost to the Region - The sum of annualized costs to Bonneville and GWM per unit of energy saved by the energy conservation project. This would include the same costs to Bonneville as above, plus the initial capital and ongoing incremental production costs to the firm. Any non-electrical savings that result from the project are not considered in this analysis.

A.2 Real Levelized Cost Formula

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

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
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).

A.3 General Assumptions

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

1. All cash flows are expressed in nominal terms (with inflation) and are discounted to present value at a nominal discount rate of 7.12% (combines a real discount rate of 3.0% and an inflation rate of 4.0%). The costs are annualized over the life of the project using the capital recovery factor at a real discount rate of 3.0%, resulting in real levelized costs.

2. Annual energy savings (kilowatt-hours/yr) are constant over the 15-year life of the project. This assumes no loss in efficiency of the equipment with time.

3. Transmission and distribution losses equal 7.5%, increasing the energy savings at the source (point of generation) by a corresponding 7.5%.

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

A.4 Bonneville Levelized Cost Calculations

Input:	
Acquisition payment paid	= $92,506
Administrative and evaluation costs	= $23,251
Metering costs	= $5,000
Tax rate	= 0%
Annual energy savings	= 286,500 kWh
Output: levelized cost	= 8.7 mills/kWh

A.5 Regional Levelized Cost Calculations (Bonneville + GWM)

A. GWM

Input:

Equipment installation	= $115,632
Administrative costs (included with installation)	
Acquisition payment received	= $92,506
Tax rate	= 34%
Project life	= 15 years
Depreciation	= 7 years
Annual energy savings	= 1,140,000 kWh
Output: levelized cost	= 2.9 mills/kWh

B. Regional levelized cost = Bonneville levelized cost + GWM levelized cost + GWM levelized cost = 8.7 mills/kWh + 2.9 mills/kWh = 11.6 mills/kWh.

A.6 Levelized Costs Allowing for Transmission and Distribution Losses

Input: transmission and distribution losses = 7.5%

Bonneville levelized cost = 8.7 mills/kWh/1.075 = 8.1 mills/kWh

Regional levelized cost = 11.6 mills/kWh/1.075 = 10.8 mills/kWh

Appendix B

Cover Sheet from Proposal

Appendix B

Cover Sheet from Proposal

Requirement 2.

Cover Sheet

I. Project

Project Title:

Categorically Excluded: (See Attachment 2, Program Description Booklet)

Technologies:	Yes	No
Variable Speed Drives	☒	☐
	☐	☐
	☐	☐
	☐	☐
	☐	☐
	☐	☐

Confidential or Proprietary Information: ☒ Yes ☐ No

Industry

Name: Great Western Malting Co.

Address: Foot of W. 11th Street Vancouver

City:

State: Washington Zip: 98660

Attention: John Cuti

Contact

☐ Same as Industry contact

☐ Utility Representative, if utility-operated program

Name: John Cuti

Phone: (206) 699-9385

SIC Code: 2083

Utility Service Area: Clark PUD

Utility-Operated Program: ☐ Yes ☒ No

II. Project Summary

A Brief Project(s) Description:

Four 200 HP variable speed drives (VSD's) will be installed on four 73" backward inclined centrifugal kiln fans. The drives will be used to regulate kiln airflow in lieu of the existing exhaust dampers which are currently in use.

III. Estimated Energy Savings and Costs

Average Annual Energy Savings:

747,700

Total Project Cost:

$123,338

Estimated Incentive:

74,770

June 15 - 30, 1992

DATE FILMED

4/11/94

END