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IMPACT EVALUATION OF AN ADJUSTABLE SPEED DRIVE
INSTALLED AT BALL-INCON GLASS PACKAGING
CORPORATION UNDER THE ENERGY SAVINGS PLAN

G. E. Spanner
G. P. Sullivan

May 1993

Prepared for
Sheila Riewer
Program Evaluation Section
Office of Energy Resources
Bonneville Power Administration
U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Richland, Washington 99352

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operated by
BATTELLE MEMORIAL INSTITUTE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC06-76RLO 1830

SUMMARY

This impact evaluation of an adjustable speed drive that was recently installed at Ball-InCon Glass Packaging Corporation (Ball-InCon) was conducted for the Bonneville Power Administration (Bonneville) as part of an evaluation of its Energy Savings Plan (ESP) Program. The Program makes acquisition payments to firms that install energy conservation projects in their industrial processes. The objective of this impact evaluation was to assess how much electrical energy is being saved at Ball-InCon as a result of the ESP 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 (Ball-InCon's Abstract, Proposal, and Completion Report). The project consists of switching from inlet guide vanes to adjustable frequency drives for 10 motors that provide cooling air to glass container molds.

Based on this impact evaluation, energy savings from this project are expected to be 1,711,500 kWh/yr, or about 0.20 average megawatts. On a per-ton basis, this project will save approximately 7.8 kWh/ton of glass produced. The project cost \$182,834 to install, and Ball-InCon received payment of \$95,581 from Bonneville for the acquisition of energy savings. The real levelized cost of these energy savings to Bonneville is 5.2 mills/kWh over the project's assumed 15-year life, and the levelized cost to the region is 10.7 mills/kWh in 1992 dollars, not including transmission and distribution effects.

This project would not have been implemented without the acquisition payment from Bonneville, so all of the energy savings can be attributed to the ESP.

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IMPACT EVALUATION OF AN ENERGY SAVINGS
PLAN PROJECT AT BALL-INCON GLASS PACKAGING CORPORATION

1.0 INTRODUCTION

This report describes Pacific Northwest Laboratory's (PNL's)^(a) evaluation of the impact of a project installed in the fall of 1991 at Ball-InCon Glass Packaging Corporation (Ball-InCon) in Seattle, Washington. The project at Ball-InCon 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 Savings Plan (E\$P) Program. This project has installed under E\$P principles in effect prior to October 1992.

The E\$P is being offered to acquire electrical energy savings in the industrial sector of the Pacific Northwest. For the Ball-InCon project, the acquisition payment offered under the program was equal to the lesser of 10¢/kWh saved in the first year x 0.75 or 80% of eligible project costs x 0.75 (the 0.75 factor is applied to the acquisition payment for this project because the serving utility, Seattle City Light (SCL), does not obtain all of its power from Bonneville).

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, 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

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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?

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 replacing inlet guide vanes with adjustable speed drives at Ball-InCon, four techniques were selected from the general methodology: engineering analysis, financial analysis (see Appendix A), site visit and interview, and review of Ball-InCon's submittals. Onsite submetering was performed by Ball-InCon, SCL, and Bonneville in accordance with E\$P program requirements, and this submetering was relied upon by PNL to determine the project's impact.

Representatives from PNL visited Ball-InCon on December 1, 1992 to view the project firsthand and to interview the Plant Engineer and the Assistant Plant Manager.

1.2 PROJECT DESCRIPTION

Ball-InCon manufactures glass containers at its plant in Seattle. The plant includes five furnaces, each supplying molten glass to two container-molding machines (I.S., or individual section, machines). As molten glass at

2,000°F is fed into the molds, heat is transferred to the molds themselves. This excess heat is removed by blowing air over the molds. Each I.S. machine has its own cooling fan, so there are 10 such fans in the plant. Among the 10 motors driving the fans, 2 are rated at 200 horsepower (hp) and 8 are rated at 125 hp. Depending on the specifics of the containers produced, the fans typically operate at 50% to 80% of maximum air flow.

Prior to implementing this E\$P project, the air flow from each fan was regulated by adjusting pneumatically operated inlet guide vanes. This method is an inefficient way to control air flow because the fan speed remains constant as energy is dissipated at the inlet vanes.

This project consists of replacing inlet guide vanes on the 10 cooling fan motors with adjustable speed drives (ASDs, also commonly called variable speed drives, or variable frequency drives). The ASDs regulate air flow by adjusting the speed of the motors, which saves energy because each motor rotates at a speed just sufficient to supply the amount of air required to cool its corresponding molding machine. Energy savings result because the electrical energy dissipated by the ASDs is much less than the excess mechanical energy formerly dissipated by the vanes. The vanes were left in place fully open after installing the ASDs to serve as a backup means to control air flow.

Verifying the savings from this project was a joint effort between Ball-InCon, SCL, and Bonneville. The first step to verify the savings was to assign each motor to one of three groups for analysis purposes. Each of the three groups consists of motors that are the same size and that are operated in similar fashion. To estimate the total savings, it was necessary to estimate the savings for only one motor in each group, multiply this estimate by the number of motors in the group, and then sum the savings for all three groups.

For each motor, the savings estimating procedure was to determine the difference in power consumption for a motor with the guide vanes and with an ASD and then multiply this difference by the number of operating hours to arrive at the annual savings in kWh. Part of this calculation was to estimate the operating characteristics of the motor during a typical year (e.g., air

flow, static pressure) and to determine the difference in power consumption for each set of operating characteristics. The specific operating schedule of each motor group depends on the product mix (e.g., glass thickness, gob weight), and this product mix varies over time. Therefore, the operating schedule for each motor group, which has a significant effect on the savings achieved, is itself an estimate.

To determine the energy consumption of the motors with guide vanes and with an ASD, a variety of approaches was used. For some motors, time-series metering was carried out for several months. Other motors were spot metered, and yet other motors were metered during test sessions in which operating characteristics of the motors were varied while power consumption data were recorded. Manufacturers' data were used for some of the energy consumption estimations because nothing better was available. Even though the Proposal stated that comprehensive, before and after metering would be used to verify energy savings, such metering was not performed for this project.

Ball-InCon submitted three documents to Bonneville, all of which were prepared largely by SCL: an Abstract (in 1988), a Proposal (in 1990), and a Completion Report (in 1992). The Abstract and Proposal described the project and presented Ball-InCon's cost and benefit expectations. Included in each were separate calculations of the project's expected simple payback using two different estimates of project costs, energy savings, and electricity costs.

A Completion Report was submitted to Bonneville after the project was installed and Ball-InCon, SCL, and Bonneville had verified the resulting energy savings. This document listed the actual costs of the project along with a calculation of the energy savings that had been achieved. An addendum to the Completion Report was also submitted that included a revised estimate of energy savings. A copy of the cover sheet from the Completion Report is included as Appendix B.

The total cost to Ball-InCon for this project was \$182,834, and Bonneville paid \$95,581 for the energy saved. The acquisition payment was calculated by multiplying Ball-InCon's expected project cost as stated in the proposal (\$159,302) by SCL's cost-sharing percent (0.75) by 0.80. The 0.75 factor is applied because SCL does not obtain all of its power from Bonneville.

1.3 SUMMARY OF PROJECT IMPACTS

This E\$P project is expected to save 1,711,500 kilowatt-hours annually, or about 0.20 aMW. Over the assumed 15-year life of this project, the levelized cost to Bonneville is 5.2 mills/kWh (1 mill = 1/1000 of a dollar), and cost to the region is 10.7 mills/kWh. These costs are in real 1992 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 4.8 mills/kWh, and the cost to the region is 9.9 mills/kWh.

This project did not meet Ball-InCon's typical funding criteria, therefore, it would not have been implemented without the acquisition payment from Bonneville. The project would not have been implemented in the absence of the E\$P and all of the energy savings can be attributed to the program.

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

1. *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

To verify the energy savings for this project, a combination of time-series and spot metering was used along with ASD manufacturer's data and estimated operating schedules for the three motor groups. After the Completion Report was originally submitted to Bonneville, Bonneville and SCL engineers performed some further metering and energy savings calculations which were submitted in an addendum to the Completion Report. For purposes of energy savings calculations, this impact evaluation uses as its starting point the addendum to the Completion Report.

In the addendum, the assumed operating schedules for the three groups of fans do not all total to the same number of hours per year (two groups totalled 8,640 hours, and one group totalled 8,760). Also, the total energy savings calculated were reduced by 10% to allow for downtime, resulting in reported savings of 1,563,559 kWh/yr. During our visit to Ball-InCon, we were told that all three fan groups operate 8,520 hours/yr (24 hours/day, 7 days/week, with 10 days of downtime/yr). Based on this operating schedule and the metered data and analysis procedure from the addendum, the energy savings for this project are estimated by PNL to be 1,711,500 kWh/yr. This level of energy savings corresponds to 0.20 aMW, or about 7.8 kWh/ton of glass containers produced.

Energy savings reported in this impact evaluation are necessarily an estimate because actual energy consumption, and hence energy savings, are

affected by the exact mix of products (i.e. mix of container sizes) produced at the plant. It is not possible to know years in advance what the product mix will be.

Fuel Switching

Because electric motors are the most economical prime movers for fans, fuel switching was not a feasible option, so no fuel switching occurred.

2.2 IMPACTS TO THE FIRM

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?*

Installation of this project improved the productivity of the production process by slightly reducing the amount of energy required to produce glass containers. The plant already operates at its maximum capacity, however, so this project will not result in any changes in production levels. Ball-InCon has no other plants in the region (the nearest one is in Madera, California), so no impacts will occur at other plants.

2.3 IMPACTS TO THE UTILITY

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

Because the project had no cogeneration or other complicating factors, all of the energy savings will be reflected in reduced load at the serving utility, SCL. The net impact to the serving utility from this project is a 1,711,500 kWh/yr reduction in electrical load.

2.4 REAL LEVELIZED COSTS

4. *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 were calculated from the perspectives of Bonneville and the region (Bonneville, SCL, and Ball-InCon 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 longer or shorter life than expected when it is installed. To allow comparisons of levelized costs among projects installed under the ESP, 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 conservative but likely life for typical 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 1,711,500 kWh/yr, the project's levelized cost from Bonneville's perspective is 5.2 mills/kWh (see Appendix A). Bonneville's levelized cost decreases to 4.8 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 as well as the 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, SCL, and Ball-InCon are combined. The acquisition payment by Bonneville is included as a cost to Bonneville and as a reduction in cost to Ball-InCon. 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. SCL's costs include the cost for preparing program submittals and for performing metering. Because SCL does not explicitly track its costs for participating in the ESP, the utility provided an approximate estimate of its costs.

The calculated, real levelized costs to the region for acquiring annual energy savings of 1,711,500 kWh is 10.7 mills/kWh saved. Including transmission and distribution losses, the levelized cost decreases to 9.9 mills/kWh saved.

2.5 IMPACT ATTRIBUTABLE TO ESP

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

Ball-InCon uses simple payback to select plant improvement projects, with a payback of 1 year or less typically required for project implementation. When this project was initially suggested to Bonneville in the Abstract in early 1988, it was expected to cost \$113,346 and result in electrical savings of \$79,704/yr (based on estimated energy savings of 3,188,160 kWh/yr) for a simple payback of 1.4 years without an acquisition payment from Bonneville. With an expected acquisition payment of \$68,008, the simple payback would have been 0.6 years. Even though the project as originally envisioned met Ball-InCon's payback criterion with the acquisition payment, the project was initially rejected at Ball-InCon's corporate headquarters.

In the Proposal nearly 2 years after the Abstract was submitted, the project was expected to cost \$159,302 and result in electrical savings of \$34,800/yr (1,360,800 kWh/yr usage and 175-kW demand savings combined) for a simple payback of 4.6 years without an acquisition payment and 1.8 years with an acquisition payment of \$95,581. Even though the project by this time was

expected to have a payback length longer than Ball-InCon's typical criterion, the project was finally approved by its corporate headquarters.

During our site visit and interview, we were told that the acquisition payment expected from Bonneville was important to Ball-InCon's decision to implement the project. We were also told that the project would not have been implemented without the acquisition payment. It is not clear why the project was initially rejected by corporate headquarters and then later accepted, even though it became less attractive financially, but apparently the perseverance of the Energy Management Analyst from SCL was the major factor.

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 ESP.

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 Savings 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 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, SCL, and Ball-InCon 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, as well as the costs for the utility to prepare submittals and perform metering. Any non-electrical savings that result from the project are not considered in this analysis.

A.2 REAL LEVELIZED COST FORMULA

$$LC = \{[PVC I + PVIC I + (PVOM + PVOTE) \cdot (1-itf) - PVD \cdot itf] / (1-itf)\} \cdot (CRF/AES)$$

where LC = levelized cost (real \$)

PVC I = present value of initial capital costs

PVIC I = 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 8.15% (combines a real discount rate of 3.0% and an inflation rate of 5.0%). See Section A.7 for levelized costs calculated under alternative discounting assumptions. 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. Equal annual energy savings (kilowatt-hours/yr) is constant over the 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 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 Ball-InCon rather than a net zero cost. This is done because Ball-InCon will incur a tax liability from the acquisition payment, thus a net cost to the region.

A.4 BONNEVILLE LEVELIZED COST CALCULATIONS

Input: one-time expenses

Acquisition payment paid (year 0) = \$95,581

Administrative and evaluation costs (year 0) = \$18,558

Tax rate = 0%

Annual energy savings = 1,711,500 kWh

Output: levelized cost = 5.2 mills/kWh

A.5 REGIONAL LEVELIZED COST CALCULATIONS (BONNEVILLE + SEATTLE CITY LIGHT + BALL-INCON)

A. Ball-InCon

Input: initial capital

Equipment	= \$182,834
One-time expenses (revenues)	
Acquisition payment received	= (\$95,581)
Tax rate	= 34%
Project life	= 15 years
Depreciation	= 7 years
Annual energy savings	= 1,711,500 kWh

Output: levelized cost = 5.4 mills/kWh

B. Seattle City Light

Input: one-time expenses

Administrative costs (estimated)	= \$1,000
Tax rate	= 0%
Annual energy savings	= 1,711,500 kWh

Output: levelized cost = 0.05 mills/kWh

C. Regional levelized cost = Bonneville levelized cost + Seattle City Light levelized cost + Ball-InCon levelized cost

$$\begin{aligned} &= 5.2 \text{ mills/kWh} + 0.05 \text{ mills/kWh} + 5.4 \text{ mills/kWh} \\ &= 10.7 \text{ mills/kWh} \end{aligned}$$

A.6 LEVELIZED COSTS ALLOWING FOR TRANSMISSION AND DISTRIBUTION LOSSES

Input: transmission and distribution losses = 7.5%

Bonneville levelized cost = $5.2 \text{ mills/kWh} / 1.075 = 4.8 \text{ mills/kWh}$

Regional levelized cost = $10.7 \text{ mills/kWh} / 1.075 = 9.9 \text{ mills/kWh}$

A.7 LEVELIZED COSTS USING ALTERNATIVE DISCOUNTING ASSUMPTIONS

A. Not including transmission and distribution effects.

Real levelized cost to Bonneville in 1990 dollars with 5% inflation and 8.15% nominal discount rate = 4.9 mills/kWh.

Real levelized cost to the region in 1990 dollars with 5% inflation and 8.15% nominal discount rate = 10.0 mills/kWh.

Real levelized cost to Bonneville in 1993 dollars with 4% inflation and 7.12% nominal discount rate = 5.4 mills/kWh.

Real levelized cost to the region in 1993 dollars with 4% inflation and 7.12% nominal discount rate = 11.0 mills/kWh.

B. Including transmission and distribution effects.

Real levelized cost to Bonneville in 1990 dollars with 5% inflation and 8.15% nominal discount rate = 4.5 mills/kWh.

Real levelized cost to the region in 1990 dollars with 5% inflation and 8.15% nominal discount rate = 9.3 mills/kWh.

Real levelized cost to Bonneville in 1993 dollars with 4% inflation and 7.12% nominal discount rate = 5.1 mills/kWh.

Real levelized cost to the region in 1993 dollars with 4% inflation and 7.12% nominal discount rate = 10.3 mills/kWh.

APPENDIX B

COVER SHEET FROM BALL-INCON'S COMPLETION REPORT

Cover Sheet

Directions: Complete Sections I through IV and submit with Project Abstract. Photocopy and complete Section V to submit with Project Proposal. Photocopy and complete Section VI to submit with the Completion Report.

I. SPONSOR INFORMATION

Name and Full Address of Sponsoring Entity
Ball-InCon Glass
5801 E. Marginal Way S.
Seattle, WA 98134

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II. PROJECT IDENTIFICATION

Title
Variable Speed Drives for Cooling Fan Motors

Name and Title of Project Manager or Other Contact

Location of Proposed Project

Doug Coburn

Seattle Plant
5801 E. Marginal Way S.
Seattle, WA 98134

Area Code & Telephone No.
(206) 762-0660, Ext. 272

Standard Industrial Classification Code (SIC)
3221 - Glass Containers

Utility Service Area
Seattle City Light

III. PROJECT SUMMARY

Brief Description of Proposed Project

Install variable speed drives on cooling fan motors to replace inlet vanes. This proposed method of modulating air volume will save energy over the existing method.

IV. ESTIMATED ENERGY SAVINGS AND COSTS (submit with Project Abstract)

Average Annual Energy Savings	Total Project Costs	Estimated Incentive	Incentive Type
3,188,160 kWh/yr	\$ 113,346	\$ 68,008	5¢ per kWh x 80% of Project Costs x 75%

V. ESTIMATED ENERGY SAVINGS AND COSTS (submit with Project Proposal)

Average Annual Energy Savings	Total Project Costs	Estimated Incentive	Incentive Type
1,360,800 kWh/yr	\$ 159,302	\$	5¢ per kWh x 80% of Project Costs x 75%

VI. MEASURED ENERGY SAVINGS AND COSTS (submit with Completion Report)

Average Annual Energy Savings	Total Project Costs	Ratio of Actual Savings to Estimated Savings
2,094,076 kWh/yr	\$ 182,835	154 %

1,503,559 kWh per Gaylands 8/6/92 memo

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