PNL-8661
UC-310

IMPACT EVALUATION OF ADJUSTABLE SPEED DRIVES INSTALLED AT HEWLETT-PACKARD COMPANY UNDER THE ENERGY $AVINGS PLAN

G. P. Sullivan
K. K. Daellenbach
G. E. Spanner

September 1993

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

Pacific Northwest Laboratory
Richland, Washington 99352

DISCLAIMER

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

SUMMARY

This impact evaluation of adjustable speed drives (ASDs) that were recently installed at Hewlett-Packard Company (HP) was conducted for the Bonneville Power Administration (Bonneville) as part of an evaluation of its Energy $avings Plan (E$P) 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 HP 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 (HP's Proposal and Completion Report). The project consisted of installing 24 ASDs on 24 variable air volume system supply- and return-fans at HP's Vancouver, Washington manufacturing facility. A secondary benefit to adding the ASDs was the ability to program in a night-setback feature. This feature was always present in the existing central computer system but was not used because of the lack of ASDs.

Based on this impact evaluation, energy savings from this project are expected to be 2,582,900 kilowatt-hours/year (kWh/yr), or 0.30 average megawatts. The project cost $252,068 to install, and HP received payment of $201,654 (1992 dollars) from Bonneville for the acquisition of energy savings. The real levelized cost of these energy savings to Bonneville is 7.0 mills/kWh (in 1992 dollars) over the project's assumed 15-year life, and the real levelized cost to the region is 10.8 mills/kWh in 1992 dollars, not including transmission and distribution effects. This project would not have been implemented without the acquisition payment from Bonneville.

CONTENTS

IMPACT EVALUATION OF ADJUSTABLE SPEED DRIVES INSTALLED AT HEWLETT-PACKARD COMPANY UNDER THE ENERGY $AVINGS PLAN

1.0 INTRODUCTION

This report describes Pacific Northwest Laboratory's (PNL's)[a] evaluation of the impact of an energy conservation project installed in February 1992 at Hewlett-Packard Company (HP) in Vancouver, Washington. The project at HP 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 HP 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?

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

3. What was the net impact to the serving utility in terms of electrical energy consumption (in kWh) 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 installing adjustable speed drives (ASDs) at HP, four techniques were selected from the general methodology: engineering analysis, financial analysis (see Appendix A), site visit and interview, and review of HP's submittals. Submetering of building energy use was performed by HP before and after project installation in accordance with E$P program requirements. PNL relied on the results of this metering to determine the project's impact.

Representatives from PNL visited HP on February 8, 1993, to view the project firsthand and to interview the project manager.

1.2 PROJECT DESCRIPTION

HP's Vancouver, Washington location has two buildings (a third is under construction) separately housing manufacturing and engineering support services for their Desk-Jet® printers and facsimile product lines. Building #1 houses the engineering support services and functions as an office building with typical hours of operation from 6:30 a.m. to 6:30 p.m., 5 days per week, 52 weeks per year. Building #2 is the manufacturing facility which operates 24 hours per day, 365 days per year. This building also contains the cafeteria, which forms a breezeway connecting the two buildings. The two buildings are served by 24 supply- and return-fans which provide proper ventilation and cooling. Both buildings operate in a similar seasonal mode; during the four to five months between mid-October through mid-March, the buildings operate in an "economizer" mode where the system uses outside air for cooling. The buildings typically require cooling from chillers during the remaining months. When required, the buildings are heated by natural gas boiler-heated hot-water perimeter units which were not affected by this project.

The conservation project at HP installed 24 ASDs on 24 variable air volume supply- and return-fans. The ASDs replaced existing inlet-vane control systems on the fans. In addition to the ASDs, a direct digital control (DDC) system was extended for use in Building #1. The DDC system was necessary for proper ASD control. Prior to this project, only Building #2 was controlled by a DDC system. The project also included installing current sensors to measure fan power consumption to determine the amount of energy saved.

The energy savings in this project result from using the ASDs to control fan speed. Without the ASDs, the fans run at full speed and unnecessarily consume electricity (fan power consumption varies with the cube of the speed). With the ASDs, the fan speed is matched to the required airflow, as determined by the duct static pressure set-point, and consumes only the required electricity to meet the load. There are two additional benefits to installing the ASDs and DDC system. First, the system is now capable of night and weekend temperature setback. Second, with this system, the power factor was increased by over 8%, from approximately 0.86 to 0.93.

HP submitted two documents to Bonneville: a Proposal and a Completion Report. The Proposal described the energy conservation project and presented HP's cost and benefit expectations. A Completion Report was submitted to Bonneville after the project was installed and HP 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. A copy of the cover sheet from the Proposal is included as Appendix B.

The total cost to HP for this project was $252,068, and Bonneville paid $201,654 for the energy saved. The acquisition payment was calculated by multiplying the actual project cost by 80%.

1.3 SUMMARY OF PROJECT IMPACTS

This E$P project is expected to save 2,582,900 kWh annually, or 0.30 aMW. Over the assumed 15-year life of this project, levelized costs to Bonneville is 7.0 mills/kWh (1 mill = 1/1000 of a dollar), and cost to the region is 10.8 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 6.5 mills/kWh, and the cost to the region is 10.1 mills/kWh.

Without the acquisition payment from Bonneville, this project did not meet HP's funding criteria; however, it did meet the criteria with the acquisition payment. Therefore, we conclude that it 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

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 energy savings for this project, 20-minute power consumption readings were taken and stored by the current sensors and the DDC control system. These readings were taken for a one-week period before and a one-week period after the project installation. For similar system operation before and after, the difference in these readings represents the savings over a one week period. However, when the actual readings were taken (before-week: January 21-27, 1992; after-week: March 21-27, 1992) similar conditions did not exist. In the before-week scenario the system was operating in the economizer-mode; in the after-week the system was operating in the chiller-mode. The difference is in the supply-air temperature which directly affects the amount of airflow required and, therefore the power consumption. The before-week (economizer-mode) has a warmer supply-air temperature (60°F) and therefore typically has a higher airflow rate. The after-week (chiller-mode) has a cooler supply-air temperature (55°F) and therefore typically a lower airflow rate. This difference in flow rate between the two weeks would skew the results in favor of greater energy savings. To correct for this difference, a ratio of the inside-air temperature to the two supply-air temperatures (economizer supply-air temperature and chiller-mode supply-air temperature) was applied to the larger flow rate. This ratio reduced the before-week flow measurement by 25% and now allows the before-week and the after-week flow measurements to be compared. The corrected before-week flow measurement was then used with a characteristic performance curve for ASDs to arrive at a corrected before-week power consumption reading. Taking the difference in the corrected before-week and the metered after-week power consumption values now represents the savings over a one-week period. These savings were then extrapolated over the entire year to arrive at a yearly savings of 2,582,900 kWh (0.30 aMW). While the methodologies used in the correction and extrapolation calculations are correct, a more accurate analysis would involve power consumption metering at different times of the year to reflect the variable nature of heating, ventilation, and air conditioning (HVAC) system operation.

The yearly savings figure of 2,582,900 kWh represents a 30% increase over expected energy savings as calculated in the Project Proposal. Approximately half of this increase can be attributed to the night- and weekend-setback feature of the DDC system. The remaining portion is attributed to variance in system performance as predicted in the Proposal versus that calculated in the Completion Report.

Fuel Switching

Because this project consisted of installing ASDs on electric motors, fuel switching was not an option. Therefore, 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?*

Because this project affected only the HVAC system, no measurable productivity improvements were noted. HP has no other plants in the region that perform this type of manufacturing, 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 from this project will be reflected in reduced load at the utility, Clark County Public Utility District. The net impact to the serving utility from this project is a 2,582,900 kWh/yr reduction in electrical load.

2.4 REAL LEVELIZED COSTS

4. *What are the levelized costs of the project 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 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 HP 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 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 conservative but likely life for typical projects in the industrial sector.

2.4.1 Bonneville Perspective

To determine the 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 2,582,900 kWh/yr, the project's levelized cost from Bonneville's perspective is 7.0 mills/kWh in 1992 dollars (see Appendix A). Bonneville's levelized cost decreases to 6.5 mills/kWh when transmission and distribution losses are considered. Including these losses allows a 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). Levelized cost under alternative financial assumptions are presented in Appendix A.

The levelized costs calculated in this impact evaluation include the acquisition payment by Bonneville as well as the estimated administrative and evaluation costs associated with this project.

2.4.2 Regional Perspective

To calculate the levelized cost to the region, the costs to Bonneville and HP are combined. The acquisition payment by Bonneville is included as a cost to Bonneville and as a reduction in cost to HP. 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 calculated, real levelized costs to the region for acquiring annual energy savings of 2,582,900 kWh is 10.8 mills/kWh saved. Including transmission and distribution losses, the levelized cost decreases to 10.1 mills/kWh saved.

2.5 IMPACT ATTRIBUTABLE TO E$P

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

HP uses life-cycle cost (LCC) analysis to select plant improvements. The details of HP's LCC analysis were not available. Without the Bonneville incentive, the results of HP's LCC analysis did not meet its funding criteria; with the incentive the results did meet its criteria. Considering these facts, we conclude that this project would not have been implemented without the acquisition payment and that all of the project's impact can be attributed to the E$P.

To place this project in context with other E$P projects, PNL calculated simple payback with and without the Bonneville incentive. When this project was proposed to Bonneville, it was expected to cost $339,240 and result in electrical cost savings of $33,810/yr (1,988,900 kWh/yr X $0.017/kWh = $33,810/yr) for a simple payback of about 10 years based solely on energy savings. With the Bonneville incentive payment of $201,654, the payback was reduced to 4.1 years.

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, Clark County Public Utility District, and Hewlett-Packard Company (HP) 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 LEVELIZED COST FORMULA

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

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 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 cost 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 a real levelized cost.

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 HP rather than a net zero cost. This is done because HP 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 1)	= \$201,654
Administrative and evaluation costs (years 0 and 1)	= \$30,165
Tax rate	= 0%
Energy savings (annual)	= 2,852,900 kWh
Output: levelized cost	= 7.0 mills/kWh

A.5 REGIONAL LEVELIZED COST CALCULATIONS (BONNEVILLE + HP)

A. HP

Input: initial capital (year 0)

Equipment	= $252,068
One-time expenses (revenues - year 1)	
Acquisition payment received	= ($201,654)
Tax rate	= 34%
Project life	= 15 years
Depreciation	= 15 years
Annual Energy savings	= 2,582,900 kWh

Output: levelized cost = 3.8 mills/kwh

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

= 7.0 mills/kWh + 3.8 mills/kWh

= 10.8 mills/kWh

A.6 LEVELIZED COST ALLOWING FOR TRANSMISSION AND DISTRIBUTION LOSSES

Input: transmission and distribution losses = 7.5%

Bonneville levelized cost = 7.0 mills/kWh/1.075 = 6.5 mills/kWh

Regional levelized cost = 10.8 mills/kWh/1.075 = 10.1 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 = 6.6 mills/kWh.

Real levelized cost to the region in 1990 dollars with 5% inflation and 8.15% nominal discount rate = 10.1 mills/kWh.

Real levelized cost to Bonneville in 1993 dollars with 4% inflation and 7.12% nominal discount rate = 7.4 mills/kWh.

Real levelized cost to the region in 1993 dollars with 4% inflation and 7.12% nominal discount rate = 11.3 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 = 6.1 mills/kWh.
Real levelized cost to the region in 1990 dollars with 5% inflation and 8.15% nominal discount rate = 9.4 mills/kWh.
Real levelized cost to Bonneville in 1993 dollars with 4% inflation and 7.12% nominal discount rate = 6.9 mills/kWh.
Real levelized cost to the region in 1993 dollars with 4% inflation and 7.12% nominal discount rate = 10.5 mills/kWh.

APPENDIX B

COVER SHEET FROM HEWLETT-PACKARD'S PROPOSAL

Cover Sheet

I. Project

Project Title:

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

Technologies:	Yes	No
Adjustable (Variable) Speed Drives	☒	☐
	☐	☐
	☐	☐
	☐	☐
	☐	☐
	☐	☐

Confidential or Proprietary Information: ☐ Yes ☐ No

Industry
ELECTRONICS

Name:
HEWLETT-PACKARD CO.

Address:
P.O. BOX 8906

City:
VANCOUVER

State:
WA

Zip: 98668

Attention:
ED CAREN

Contact:
☒ Same as Industry contact
☐ Utility Representative, if utility-operated program

Name:

Phone: 206-944-2767

SIC Code:

Utility Service Area: CLARK COUNTY P.U.D.

Utility-Operated Program: ☐ Yes ☒ No

II. Project Summary

A Brief Project(s) Description:

INSTALL A TOTAL OF 24 VARIABLE FREQUENCY DRIVES ON 24 VARIABLE AIR VOLUME SYSTEM SUPPLY AND RETURN FANS. THE VARIABLE FREQUENCY DRIVES WILL REPLACE EXISTING INLET VANE VOLUME CONTROL.

III. Estimated Energy Savings and Costs

Average Annual Energy Savings:
1,988,910 KW HRS/YR

Total Project Cost:
$339,240

Estimated Incentive:
$198,891

Continue on back, if necessary

END

DATE FILMED

11/22/93