IMPACT EVALUATION OF AN ENERGY SAVINGS PLAN
PROJECT AT ARCO PETROLEUM PRODUCTS COMPANY

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CONTENTS

EXECUTIVE SUMMARY	iii
1.0 INTRODUCTION	1.1
1.1 APPROACH FOR IMPACT EVALUATION	1.2
1.2 PROJECT DESCRIPTION	1.2
1.3 SUMMARY OF PROJECT IMPACTS	1.3
2.0 IMPACT EVALUATION	2.1
2.1 ENERGY SAVINGS AND FUEL SWITCHING	2.1
2.2 IMPACTS TO THE FIRM	2.2
2.3 IMPACTS TO THE UTILITY	2.3
2.4 LEVELIZED COSTS	2.3
2.4.1 Bonneville Perspective	2.4
2.4.2 Regional Perspective	2.4
2.5 IMPACT ATTRIBUTABLE TO E\$P	2.5
3.0 REFERENCES	3.1
APPENDIX A - FINANCIAL EVALUATION DETAILS	A.1
APPENDIX B - COVER SHEET FROM ARCO'S COMPLETION REPORT	B.1

EXECUTIVE SUMMARY

This impact evaluation of an energy conservation measure (ECM) that was recently installed at ARCO Petroleum Products Company (ARCO) 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 measures in their industrial processes. The objective of this impact evaluation was to assess how much electrical energy is being saved at ARCO as a result of the ESP 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, and submittal reviews (ARCO's Proposal and Completion Report). The ECM itself consists of removing one stage of a six-stage compressor so that its inlet control valve can be opened wider, thereby saving the energy that was previously lost at the valve due to pressure drop.

Energy savings resulting from this ECM are expected to be 2,112,800 kWh/yr. The ECM cost \$367,650 to install, and ARCO received a payment of \$158,460 from Bonneville and \$82,902 from its serving utility, Puget Sound Power & Light Company, for the acquisition of energy savings. The ECM would not have been installed without the acquisition payment offered under the ESP Program. The levelized cost of these energy savings to Bonneville will be 6.3 mills/kWh over the ECM's expected 15-year life, and the levelized cost to the region will be 15.8 mills/kWh.

IMPACT EVALUATION OF AN ENERGY SAVINGS
PLAN PROJECT AT ARCO PETROLEUM PRODUCTS COMPANY

1.0 INTRODUCTION

This letter report describes Pacific Northwest Laboratory's (PNL's)^(a) evaluation of the impact of an energy conservation measure (ECM) installed at ARCO Petroleum Products Company's (ARCO) refinery in Ferndale, Washington. The ECM at ARCO is one of about thirty 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 (ESP) Program.

The ESP is being offered to acquire electrical energy savings in the industrial sector of the Pacific Northwest. For the ARCO project, the acquisition payment offered under the program was equal to the lesser of 10¢/kWh saved in the first year or 80% of eligible project costs, multiplied by 75%, up to a limit of \$187,500. The 75% factor is applied to this project because ARCO's serving utility, Puget Sound Power & Light Company (Puget Power), does not obtain all of its power from Bonneville, thereby allowing only a 75% cost share.

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 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 measure in terms of kilowatt-hours and kilowatt-hours per unit of plant output? Also, did any fuel switching result from implementing this ECM?
2. If the ECM 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 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 ESP?

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, the success, or value, of 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 destaging the Naphtha Hydrogen Desulfurizer (NHDS) Recycle Compressor at ARCO, four techniques were selected from the general methodology: engineering analysis, financial analysis (see Appendix A), site visit and interview, and review of ARCO's submittals. Onsite submetering by PNL was not necessary because the metering performed by ARCO in accordance with ESP program requirements is adequate to determine the project's impact.

Representatives from PNL visited ARCO on April 23, 1992 to view the ECM firsthand and to conduct an interview with the ECM's project engineer.

1.2 PROJECT DESCRIPTION

In the energy conservation project at ARCO, a large centrifugal compressor was destaged so that its operating characteristics more closely match the refinery's current needs for compressed hydrogen. The compressor that was modified is the NHDS Recycle Compressor, originally a six-stage machine. This

compressor is used to recycle hydrogen gas in a loop that removes sulfur from naphtha before the naphtha is routed to the reformer unit.

Because of several factors, such as federal regulations that reduce the allowable lead content of gasoline produced at the refinery and the changing sulfur content of feed stocks, the compressor is no longer required to compress as much hydrogen as it was designed for. This reduction in hydrogen flow has occurred gradually over the last 15 years or so, and the excess capacity has been controlled by an inlet control valve, an inefficient way to control flow. In recent years, the valve was typically set at approximately 20% open to control the flow of hydrogen. By removing one of the compressor's six stages (destaging), the control valve can be opened wider, maintaining the net pressure differential across the compressor/valve combination with lower electrical energy consumption. With the compressor destaged, the control valve is set at about 70% open.

ARCO submitted two documents to Bonneville: a Proposal and a Completion Report. The Proposal described the ECM and presented ARCO's expectations with regard to costs and benefits. Included was a calculation of the ECM's expected simple payback. A Completion Report was submitted to Bonneville after the ECM was installed and ARCO had verified the resulting energy savings. This document listed the actual costs of the ECM along with a calculation of the energy savings that had been achieved. A copy of the cover sheet from the Completion Report is included as Appendix B.

The total cost to ARCO for this ECM was \$367,650, and Bonneville paid \$158,460 for the energy saved ($2,112,800 \text{ kWh/yr} \times 10\text{¢/kWh} \times 75\% = \$158,460$). In addition to the acquisition payment from Bonneville, the serving utility, Puget Power, paid \$82,902 to ARCO for energy saved. Puget Power also paid an engineering consulting firm \$6,400 for energy analysis of the project and for writing the Proposal and Completion Report for submittal to Bonneville.

1.3 SUMMARY OF PROJECT IMPACTS

This E\$P project, or ECM, is expected to save 2,112,800 kilowatt-hours annually.

Over the assumed 15-year life of this ECM, levelized costs to Bonneville will be 6.3 mills/kWh (1 mill = 1/1000 of a dollar), and cost to the region will be 15.8 mills/kWh. These costs are in real 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 will be 5.8 mills/kWh, and the cost to the region will be 14.7 mills/kWh.

Without the acquisition payments from Bonneville and Puget Power, this ECM did not meet ARCO's funding criteria; however, it did meet the criteria with the acquisition payments. 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 ECM in terms of kilowatt-hours and kilowatt-hours per unit of plant output? Also, did any fuel switching result from implementing this ECM?*

Energy Savings

Determining the energy savings for this ECM was difficult because some of the process parameters that affect energy consumption (e.g., mole weight, inlet temperature, and flow rate) vary over time. Because of these variations, it is difficult to make valid comparisons between before- and after-installation energy consumption measurements. Fortunately, long-run, average values of the varying parameters are known, and these long-run values can be reliably used in energy consumption calculations. Briefly then, the approach for determining energy savings consisted of taking before- and after-installation measurements of energy consumption to validate compressor performance curves at specific operating conditions, and then calculating energy savings from the performance curves using the long-run values of the process parameters.

Prior to destaging the compressor, operating conditions were recorded for 8 days and mean values were calculated. Data recorded consisted of inlet temperature, inlet pressure, flow rate, and compressor electrical current. After the compressor was destaged, the same measurements were repeated for 11 days and means were again calculated. Because the temperatures, pressures, and flow rates were not identical for the before and after readings, the electrical current consumption readings were not directly comparable. Another complicating factor is that the mole weight of the gas varies from the start of a run to the end of a run, which also affects energy consumption by the compressor.

Prior to calculating energy savings from this ECM, the data measured after destaging the compressor were compared to expected data from the compressor vendor's performance curves. It was found that the measured and predicted data were in close agreement, which validates the predicted performance curves. Energy consumption was then calculated from the vendor's performance curves for the six-stage and five-stage configurations, assuming an average flow rate of 2003.9 thousand standard cubic feet/hour (MSCFH). This average flow rate has been shown to be a good long-run representation of flow through the recycle compressor. Allowances were made in the calculations for motor efficiency (96%) and onstream load factor (90%).

To calculate the energy savings reported in the Completion Report, the calculated power consumption for the five-stage configuration was subtracted from the calculated consumption for the six-stage configuration. Note that the before- and after-destaging metered data were not directly used in the energy savings calculations; the metered data were used only to validate the calculated compressor performance at specific conditions.

According to this verification method, energy savings from this ECM total 2,112,800 kWh/yr. This amount of energy represents about a 14% savings in electricity consumption for the NHDS recycle compressor. Because of variations in process inputs and product mix output, it is not practicable to describe the energy savings in terms of kWh per unit of output.

Fuel Switching

The only viable source of energy to drive the NHDS compressor is electricity, all of which ARCO obtains from its serving utility, Puget Power. Therefore, no fuel switching occurred.

2.2 IMPACTS TO THE FIRM

2. *If the ECM 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 ECM did indeed improve the productivity of the production process by reducing the amount of electricity required to drive the NHDS recycle compressor. However, the energy savings represent only about 0.35% of the energy used to produce gasoline at the refinery. No changes in output from the refinery are expected to result from installing this ECM, so the ECM will lead to a net reduction in energy consumption. ARCO has no other refineries in the region, 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 ECM?*

Because there are no cogeneration or other complicating factors in this project, all of the energy savings from this ECM will be reflected in reduced load at ARCO's serving utility, Puget Power. The net impact to the serving utility from this ECM will be a 2,112,800 kWh/yr reduction in electrical load.

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 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. The objective of using levelized costs to evaluate these energy conservation measures is to determine the financial impact of each ECM to Bonneville (\$/kWh saved) and to the region (Bonneville, Puget Power, and ARCO combined).

In the industrial sector, it is not possible to accurately predict the life of an ECM because any number of external factors could cause the ECM 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 ECMs are assumed to have a life of 15 years. Even though some ECMs will have longer or shorter lives, 15 years is considered a conservative but likely life for typical ECMs 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 ECM life. With energy savings of 2,112,800 kWh/yr, the project's levelized cost from Bonneville's perspective will be 6.3 mills/kWh. Bonneville's levelized cost decreases to 5.8 mills/kWh when transmission and distribution losses are considered. These losses increase the energy savings at the point of generation by 7.5%.

The levelized costs calculated in this impact evaluation include the acquisition payment by Bonneville but ignore any 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 an impact evaluation report on the overall program.

2.4.2 Regional Perspective

To calculate the levelized cost to the region, the costs to Bonneville, Puget Power, and ARCO are combined. The acquisition payments by Bonneville and Puget Power are included as costs to Bonneville and Puget Power and as a reduction in cost to ARCO. 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 levelized costs to the region for acquiring annual energy savings of 2,112,800 kWh is 15.8 mills/kWh saved. Including transmission and distribution losses, the levelized cost decreases to 14.7 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?*

ARCO uses rate of return to select plant improvement projects, typically with a threshold level of 12% to 15% for implementation. When this project was proposed to Bonneville, it was expected to cost \$334,000 and result in electrical savings of \$44,951 (usage and demand savings combined) per year. ARCO assumes a project life of 15 years in its financial calculations, and with this life, the rate of return of this project is less than 10.5%. Without the acquisition payment from Bonneville, then, the project did not meet ARCO's funding criteria.

With the expected acquisition payment from Bonneville of \$158,460, the rate of return is nearly 25%, well above ARCO's implementation threshold. Puget Power was also expected to make an acquisition payment to ARCO of \$82,902, which further increases the rate of return, to about 50%.

During the interview conducted as part of this impact evaluation, ARCO stated that Bonneville's acquisition payment definitely affected the decision to implement this project. ARCO admitted that it is possible that the project would have been implemented some time in the future even without the acquisition payments, although it was not likely, and it would not have been soon.

Considering the facts presented above, we conclude that this project would not have been implemented without the acquisition payments from Bonneville and Puget Power 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 Savings Plan*. Letter Report. PNL-6628, Pacific Northwest Laboratory, Richland, Washington.

APPENDIX A

FINANCIAL EVALUATION DETAILS

APPENDIX A

FINANCIAL EVALUATION DETAILS

A.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 Power Administration (Bonneville) - The annualized costs to Bonneville, direct and indirect, per unit of energy saved by the conservation measure. Costs included are the acquisition payment and the program administrative costs (although no administrative costs are included in this analysis of the ECM at ARCO Corporation).

Levelized Cost to the Region - The sum of annualized costs to Bonneville, Puget Sound Power & Light Company (Puget Power), and ARCO Petroleum Products Company (ARCO) 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 ongoing incremental production costs to the firm. Also, for this project, Puget Power paid an acquisition payment to ARCO, and the utility also paid a third-party engineering firm to perform analysis of the project and to write the Proposal and Completion Report. Any non-electrical savings that result from the ECM are not considered in this analysis.

A.2 LEVELIZED COST FORMULA

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

where LC = levelized cost (real \$)

PVI = 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).

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%). The costs are annualized over the life of the project using the capital recovery factor at a real discount rate of 3.0%.
2. Equal annual energy savings--savings (kilowatt-hours) per year--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 payments from Bonneville and Puget Power are treated as costs to Bonneville and Puget Power and, at the same time, a cash inflow to ARCO rather than a net zero cost. This is done because ARCO will incur a tax liability from the acquisition payments, thus a net cost to the region.

A.4 BONNEVILLE LEVELIZED COST CALCULATIONS

Input: one-time expenses

Acquisition payment paid (year 0) = \$158,460

Administrative costs (year 0) = \$0

Tax rate = 0%

Energy savings (annual) = 2,112,800 kWh

Output: levelized cost = 6.3 mills/kWh

A.5 PUGET POWER LEVELIZED COST CALCULATIONS

Input: one-time expenses

Acquisition payment paid (year 0) = \$82,902

Engineering costs (year 0) = \$6,400

Tax rate = 34%

Energy savings (annual) = 2,112,800 kWh

Output: levelized cost = 3.5 mills/kWh

A.6 REGIONAL LEVELIZED COST CALCULATIONS (BONNEVILLE + PUGET POWER + ARCO)

A. ARCO levelized cost

Input: initial capital

Equipment = \$367,650

One-time expenses (revenues)

Acquisition payment received = (\$241,362)

Tax rate = 34%

Project Life = 15 years

Depreciation = 5 years

Energy savings (annual) = 2,112,800 kWh

Output: levelized cost = 6.0 mills/kWh

B. Regional levelized cost = Bonneville levelized cost + Puget Power levelized cost + ARCO levelized cost

$$= 6.3 \text{ mills/kWh} + 3.5 \text{ mills/kWh} + 6.0 \text{ mills/kWh}$$
$$= 15.8 \text{ mills/kWh}$$

A.7 LEVELIZED COSTS ALLOWING FOR TRANSMISSION AND DISTRIBUTION LOSSES

Input: transmission and distribution losses = 7.5%

Bonneville levelized cost = $6.3 \text{ mills/kWh} / 1.075 = 5.8 \text{ mills/kWh}$

Regional levelized cost = $15.8 \text{ mills/kWh} / 1.075 = 14.7 \text{ mills/kWh}$

APPENDIX B

COVER SHEET FROM ARCO'S COMPLETION REPORT

A. 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

ARCO PETROLEUM PRODUCTS CO.
CHERRY POINT REFINERY
4519 GRANDVIEW ROAD
FERNDAL, WA 98248

II. PROJECT IDENTIFICATION

Title	Name and Title of Project
HDS RECYCLE COMPRESSOR MODIFICATIONS	Manager or Other Contact
Location of Proposed Project	F. M. SHOEMAKER/PROJECT ENGINEER
ARCO PETROLEUM PRODUCTS CO.	Area Code & Telephone No.
CHERRY POINT REFINERY	(206) 371-1500
4519 GRANDVIEW ROAD	
FERNDAL, WA 98248	
Standard Industrial Classification Code (SIC)	Utility Service Area
	Portion of kWh purchased from servicing Utility
	%

III. PROJECT SUMMARY

Brief Description of Proposed Project

REMOVE 1 OF 6 COMPRESSOR STAGES (ROTORS) IN THE NAPHTHA HDS UNIT RECYCLE GAS COMPRESSOR TO REDUCE COMPRESSOR DIFFERENTIAL PRESSURE AND POWER REQUIRED. THIS MODIFICATION WILL BE ACCOMMODATED BY FURTHER OPENING THE COMPRESSOR INLET THROTTLING VALVE.

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

Average Annual Energy Savings	Total Project Costs	Incentive Estimate	Incentive Type	Ratio of Incentive Estimate to Total Project Costs
4,348,000 kWh/yr	\$ 334,000	\$ 217,400	X 5¢ per kWh — 80% of Project Costs	65 %

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

Average Annual Energy Savings	Total Project Costs	Incentive Limit	Incentive Type	Ratio of Incentive Limit to Total Project Costs
2,112,801 kWh/yr	\$ 334,000	\$ 158,460	x 75% of 10¢/kWh = 5¢ per kWh — 80% of Project Costs	47 %

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

Average Annual Energy Savings	Total Project Costs	Ratio of Actual Savings to Estimated Savings
2,112,801 kWh/yr	\$ 367,649.81	100 %
		BASED ON MANUFACTURES DATA

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