Residential Fuel Substitution in Integrated Resource Planning: An Economic Analysis

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The impact of fuel substitution as a demand side resource is currently being investigated as part of Portland General Electric's (PGE) current least cost planning process. PGE is an all electric utility serving approximately 600,000 customers in northwestern Oregon. This paper evaluates the economics of fuel substitution of electric space and water heat loads from the social, participant, and utility rate payers points of view. Using long term marginal cost assumptions, space and water heat conversion programs from electric to gas were found to be cost effective over a wide range of input assumptions. Electric marginal costs and average load impacts were found to be key sensitivities in the analysis of fuel substitution programs. However, many economic and business issues need to be addressed by the electric utility. Unlike standard energy efficiency programs, a fuel substitution program does not allow the electric utility to retain the customer's end use need. The business and customer service implications of removing an end use are beyond the scope of this paper but remain an important consideration from the electric utility's point of view. Since the short term impact on electric customers is negative, PGE is also exploring dual-fuel technologies as an alternative to permanently displacing space and water heat loads with fuel substitution programs.

Introduction

Electric space and water heat have long been the targets of energy efficiency efforts by electric utilities. Large potential savings in energy and demand make these end-uses natural areas to focus utility programs. Recently, however, this focus has taken a new twist. Instead of lowering a household's consumption of electricity for space and water heating, electric utilities are now considering and being asked by our regulators to consider eliminating that load when in the societal interest.

Fuel substitution, as a demand side resource, is increasingly viewed as a viable strategy by regulators in utility-integrated resource planning. This paper presents the approached used by an electric utility in the Pacific Northwest to understand the economics of fuel substitution in residential space and water heating markets.

Background

Portland General Electric (PGE), an electric utility serving approximately 540,000 residential customers in northwest Oregon. Because of historically low rates, about 50% of these customers have electric space heat and 75% have electric water heat. PGE filed its first least-cost plan with the Oregon Public Utility Commission (OPUC) in 1990. As part of its current least-cost planning process, PGE is considering several demand-side options to meet future energy needs, including fuel substitution in electric space and water heat markets.

In 1991, the staff of the Oregon Department of Energy (ODOE) and the (OPUC) prepared a report on fuel switching which included recommendations concerning a sponsoring utility's obligation to demonstrate the reasonableness of proposed fuel switching programs (ODOE and OPUC 1991). Subsequently, the OPUC accepted the staff recommendations and encouraged "reasonable fuel switching program proposals by any utility - natural gas or electric - which demonstrate that such programs are in the public interest, promote energy efficiency and are cost-effective to customers of both affected utilities".[1]

Study Objectives

This research was conducted at PGE to better understand the economics associated with fuel-substitution from the social, participant, and customers of the electric and gas utilities perspective. An important objective of this analysis is to determine the key sensitivities involved in the economic analysis of a fuel-substitution program. Another important objective is to make recommendations based on the results of the sensitivity analysis to formulate strategy to address fuel substitution and subsequent program design.

Approach

Method

Since the chief objective of this work is to determine cost effectiveness of fuel substitution a standard economic analysis approach has been used. There are four basic steps:

- Define analysis method
- Determine base input assumptions
- Conduct sensitivity analysis to determine important variables
- Report findings and implications

The economic model used to calculate program benefits and costs by various perspectives is well documented (California 1987, EPRI 1991). A standard analysis model was used as a matter of conformity, but more importantly because it provides a conventional way to define the various economic perspectives. Table 1 lists the types of impacts that result from fuel substitution and how these impacts accrue to the various economic perspectives. A "+" indicates the impact accrues as a benefit while the "-" indicates a cost. When an impact has no effect on the perspective, the cell in Table 1 has been left blank.

The electric and gas customers perspectives used in this paper refer to the impact on general ratepayers for each utility. This is sometimes referred to as the ratepayer impact test, or the non-participant test. Since there are no tax incentives or externalities considered in the analysis and all perspectives use the same discount rate, the societal perspective is equivalent to the total resource cost (TRC) perspective except for utility taxes paid. The TRC perspective includes as a cost, Federal and State taxes paid by the utilities whereas these costs are a transfer payment from the societal perspective.

Data Sources

The range of likely load impacts for space and water heating were derived from several sources. Analysis of PGE's billing and market research data provides typical end-use consumption data. Bonneville Power Administration's End-Use Load and Consumer Assessment Program (ELCAP), now called the Regional End-Use Metering Project (REMP), served as the basis for the load shape information used to allocate electrical consumption between on- and off-peak and seasonal periods and to drive the demand impact. BPA's REMP data was also an important source for end-use consumption levels. A Washington Water Power study completed in 1991 also provided useful information on the costs and energy impacts of fuel-switching programs (WWP 1991).

The marginal cost for electricity was derived from PGE's long-run marginal cost study which describe the change in

Table 1. The Economic Perspectives of a Fuel Substitution Program

	Perspective			
	Participant	Electric Customers	Gas Customers	Societal
Changes in Electric Bill	+	-		
Changes in Gas Bill	-		+	
Installation Costs/ Program Expenditure	-	-	-	-
Avoided Electric Supply Cost		+		+
Increased Gas Supply Cost			-	-

generation, transmission, and distribution expenses associated with a incremental change in load. This study also breaks out the on and off-peak costs of capacity and energy by season. In this way the impact on system costs is allowed to reflect specific assumptions regarding load characteristics. Marginal energy and demand costs were allowed to vary by four periods: on and off-peak for winter and summer seasons. Uniquely defined periods with variable marginal costs are sometimes referred to as costing periods. Costing periods allow the avoided cost impacts of demand side programs to be more accurately estimated.

The marginal cost of gas service was taken from the Northwest Natural Gas Company's (NNG) 1991 least-cost plan. NNG is the local distribution company (LDC) within PGE's service territory.

Several points need to be mentioned when considering marginal utility costs. First of all, these expenses are based on long term system investments. Some of these investments will not need to be made for several more years. In the case of generation capacity, for example, PGE does not anticipate new plant until the last half of this decade. In the case of transmission and distribution (T&D) costs, there is some difference of opinion within PGE as to whether or not the company will actually be able to forgo planned T&D investments as a result of DSM programs. For these reasons, there is considered to be more downside risk associated with electric utility marginal costs than upside risks.

Just the opposite is true for the marginal cost of supplying natural gas. It has been pointed out that little has been done to establish a standard framework for calculating gas marginal costs and that the costs associated with serving peak loads with gas is probably understated (Chamberlin and Mayberry 1991). For this reason there is probably more uncertainty around marginal gas costs than there is marginal electric costs. Furthermore, there appear to be more upside risks than downside. These factors are reflected in the sensitivity analysis discussed in the next section.

Conversion costs include only those expenses that are incremental as a result of the fuel conversion decision. This includes the cost required to bring gas service into the house (if not already present) and the cost to install gas-fueled water and space-conditioning equipment. Inhouse conversion expenses often involve additional duct work for combustion gas venting and piping.

In this analysis, two types of conversions are considered. (1) Converting only the water heater with the assumption that gas service already resides in the house. Approximately 18% of PGE's single family residential customers, over 60,000 residences, have gas space heat with electric water heat. In this case, the incremental cost is the expense associated with additional piping and venting for the new gas water heater and the remaining value of equipment replaced before the end of its economic life. (2) Space and water heat are both converted. In this case, the additional expense includes both LDC costs to bring gas into the house and customer costs for in house piping and venting. Since it is anticipated that most electric equipment will be replaced near the end of its life, incremental costs do not include the cost of the new space and water heaters. Instead, an expense of $100 and $400 has been added (for water and space heat units, respectively) to the participant perspective to reflect the remaining equipment life foregone.

It is assumed in both conversion scenarios identified above that the equipment removed will be replaced with the level of efficiency most prevalent in the market as reflected by standard practices within the region. Sensitivity analysis reflects the likely variation around the resulting base technology. This may not result in the most efficient technology on the market as the basis for analysis. The economic results discussed below are affected by the assumption regarding base and replacement equipment. For example, comparing an advanced electric heat pump with a conventional gas furnace would yield different results than comparing a conventional electric-resistance furnace with a high-efficiency pulse-combustion gas furnace. These technologies are not addressed in this paper.

In this study, a special scenario was developed to consider the additional cost of ducting a home that is converting from zonal heating. The costs of converting only space heat for customers with existing gas service was not considered because of the low incidence of electrically heated homes with gas service in PGE's service territory.

The marginal gas and electric costs are reported as 30-year real levelized value. These are calculated from regulatory filings. Both of these forecasts assume similar real annual escalation (2% to 3%) in the price of wellhead natural gas. Therefore, it is appropriate to consider sensitivity analyses that vary the relative escalation of gas and electric costs/prices. Due to tighter supply constraints for natural gas, current forecasts suggest that gas prices will rise relative to electric prices in the next 5 to 10 years.[2] Since changing relative prices is considered to be a likely scenario, these price changes need to be considered in the analysis. By adjusting the real price of gas rise in relation to electricity, the analysis is able to consider the impact of changes in relative electric and gas prices.

While program design specifications are beyond the scope of this paper, assumptions about program cost and free riders are specific model inputs. Variable utility program cost of $100 per conversion is charged to the electric utility as a nominal expense, recognizing that the program will have some costs associated with it. Of particular importance to any fuel substitution program is the level of program participation over and above the market induced level of conversions.[3] A high level of free riders could result in a non cost-effective program. The analysis was conducted over a 30-year time frame to reflect the long-term nature of conversion decisions.

Results

Base Case

For each parameter discussed above, each affected variable was given a base value and assigned a range around the base. While subjective, ranges for the parameters were defined to include 80% of the probability distribution around the mean. In other words, there remains a 10% chance of a lower value than the low end of the range and a 10% chance of a higher value than the high end of the range. In this way an analysis of the sensitivity of the results to changes in one parameter while the others are held at their base values can be determined and compared across parameters. Parameters and variable definitions used in the sensitivity analysis are shown in Table 2.

The values in Table 2 were used in the model to calculate the net present value (NPV) from each of the four perspectives considered. Table 3 shows the results of the analysis when all values of the variables listed in Table 2 are set at their base values.

In the case of converting only water heaters, every perspective is left better off as a result of substitution from electric to gas equipment. Reduced electric supply expenses provide benefits to society over and above the conversion costs and increased gas supply expenses. In the long run, revenues lost to the electric utility are more than offset by lower supply costs while the gas utility marginal revenues are in excess of marginal costs. Conversion expenses paid by the participant are recovered in year 6 resulting in an average NPV of $560 per participant.

The results for space and water heating conversions are also shown in Table 3. Participant's have a simple payback on investment of 6 years and an average NPV of $3,100. The one significant difference between space and water heat conversions and water heat only conversions is that with the former the gas utility and it's customers are worse off. This is due to the assumption that homes making space and water heating conversions require the added expense of running gas piping from a street location to the house. This expense is paid by the gas utility in this analysis.

Sensitivity Analysis

The results of sensitivity analysis for water heat only conversions are summarized in Figure 1 for the society and participant perspectives.

The same information is summarized for space and water heat conversions in Figure 2.

The NPV results shown in Figure 1 and Figure 2 were derived by changing one parameter while the others are held at their base values.[4] Since the variables were tested over similar probability ranges, the sensitive parameters can be determined by identifying parameters with a large difference in NPV.

As can be seen from the results shown in Figure 1, the results of water heat conversions are most sensitive to the assumptions regarding load and electric utility marginal costs. The same is true for space and water heat conversions represented in Figure 2. Societal impacts are moderately sensitive to relative price and cost escalations, the incidence of free riders in the program, and measured life assumptions. It should be pointed out that while net present value at the societal level is positive for all ranges of every key sensitivity, this could easily change if more than one variable is allowed to change. For example, if electric marginal costs were actually lower than assumed and space and water load impacts were also lower on the low end of the range, a program with relatively high levels of free ridership would result in a non cost-effective program from society's point of view.

The participant in a water-only conversion is significantly affected by existing level of water heat consumption. Hence many single resident homes may not benefit from fuel switching. Using the base case analysis for the water-only conversion, the participant has an average payback in the sixth year of conversion. Space and water heat conversions are usually cost-effective for the participant. Interestingly, this result is most sensitive to assumptions regarding water load impacts and relative price and cost escalation. In the base case, the participant has an average payback of six years.

Table 2. Parameters and Variable Range for Sensitivity Analysis

Parameter	Cost-Effective Variables Affected	Low	Base	High
Water Load Impacts	kWh Saved	2,400	4,200	6,000
	kW (derived from kWh and load factor)	0.78	1.36	1.94
	Therms Added	174	252	330
Space and Water Load Impacts	kWh Saved	8,000	15,000	20,000
	kW (derived)	3.31	6.25	8.27
	Therms Added	420	725	940
Electric Marginal Costs	LRIC/kW Summer, Peak	$36.00	$51.42	$61.70
	LRIC/kW Summer, Off-Peak	$0.00	$0.00	$0.00
	LRIC/kW Winter, Peak	$39.94	$57.06	$68.47
	LRIC/kW Winter, Off-Peak	$0.00	$0.00	$0.00
	LRIC/kWh Summer	$0.021	$0.030	$0.036
	LRIC/kWh Winter	$0.023	$0.033	$0.040
Gas Marginal Costs	LRIC Gas (Therms)	$0.38	$0.48	$0.62
Installation Costs	Water Only - In House(a)	$200.00	$300.00	$400.00
Installation Costs	Space and Water Heat:			
	In-House Conversion	$ 800.00	$1,200.00	$1,600.00
	Street to House Costs	$ 500.00	$1,000.00	$1,500.00
	Ducting	$ 800.00	$1,200.00	$1,600.00
	Total - Ducted House(b)	$1,700.00	$2,600.00	$3,500.00
	Total Unducted House(b)	$2,500.00	$3,800.00	$5,100.00
Relative Price and Costs Escalation	Gas Prices over Electric	-1.0%	0.0%	2.0%
	Gas Costs over Electric	-2.0%	0.0%	4.0%
Program Costs	Variable Utility Program Costs	$50.00	$100.00	$200.00
Free Riders	Net to Gross Ratio	20%	30%	50%
Life		15	30	45

(a) Includes $100 for value of remaining life of existing water heater.
(b) Includes $400 for value of remaining life of existing space heater.

From the point of view of the electric utility ratepayers, fuel substitution sometimes fails. This is due to the loss of revenue from the sales compared to the reduced cost. The key sensitivities causing a negative impact are the assumptions regarding load and electric utility costs.

While not apparent in Figure 1 or Figure 2, an important observation is that the NPV to PGE ratepayers is negative at the low end of electric marginal costs for both water heat and water and space heat conversions. This means that if the avoided costs of serving the converted load were actually 30 percent lower than in the base case

Table 3. Net Present Value of Fuel Substitution by Perspective - In Millions of 1991 Dollars

(Based on 1000 conversions using base values from Table 2)

Perspective	Water Heat Only	Space and Water Heat
Society	$1.5	$6.0
Participant	$0.6	$3.1
Electric Customers	$0.4	$2.2
Gas Customers	$0.3	($0.3)

analysis, then the electric utility and its ratepayers would be left worse off due to higher rates passed on to existing customers to offset the net loss in revenues.

From the societal perspective, fuel substitution is almost always cost-effective in the long run. Space and water heat conversions are cost-effective over the entire range of single-parameter variability in the analysis. In the short term, however, marginal electric costs are roughly only a third of long term marginal cost because generation, transmission, and distribution capacities are currently adequate. This implies that near term fuel substitution will result in negative economic impacts to society and electric utility customers.

The issue of variability of marginal cost of supplying space and water heat loads is an important issue to electrical utilities engaged in demand-side management programs. There has been much discussion concerning the actual realization of transmission and distribution savings from demand-side management programs. This discussion is no different in the case of fuel substitution. The important question is, are actual transmission and distribution investments able to be foregone due to the fuel substitution program? Informal discussions at Portland General Electric have resulted in differences in opinion as to whether or not these types of system investments can

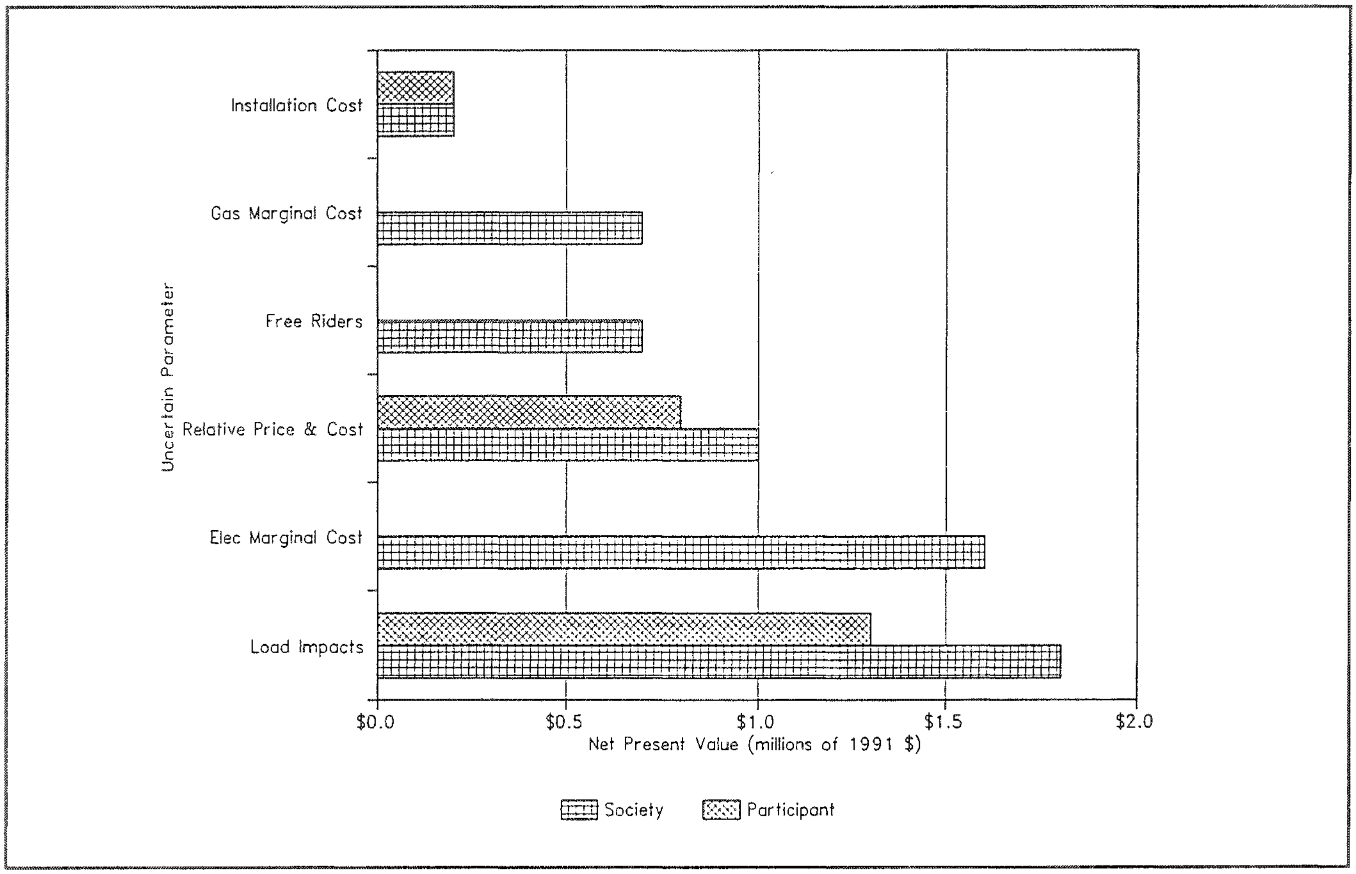

Figure 1. Sensitivity Analysis Results, Water Heat Only Conversions. Bar length indicates the magnitude of the change in NPV corresponding to low and high ranges of model parameters.

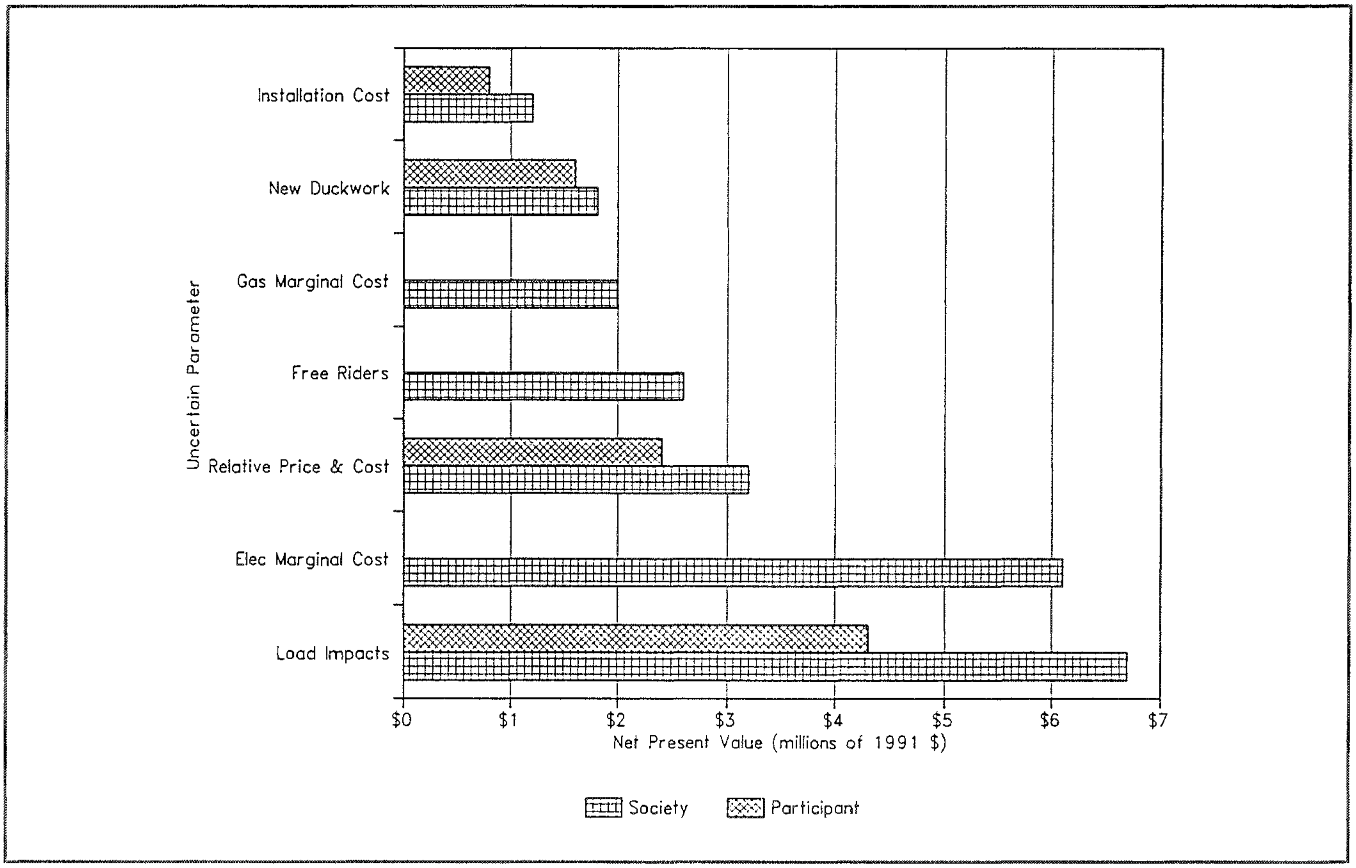

Figure 2. Sensitivity Analysis Results, Space and Water Heat Conversions. Bar length indicates the magnitude of the change in NPV corresponding to low and high ranges of model parameters.

actually be foregone. It is recognized, however, that an important determinant of whether or not these expenses can be avoided is the concentration of the load impact within a geographical area. This is especially true if the concentration occurs in areas experiencing high rates of existing growth. This has important implications for designing a fuel substitution program that targets specific areas within a utility's, gas or electric, service territory. Since utility marginal costs are found to be a highly sensitive determinant of the economic benefit to the utility and its ratepayers, it makes sense that any fuel substitution program should focus its efforts on areas where transmission and distribution benefits are most likely to occur.

The gas utility's ratepayers are often negatively affected by a space and water heat fuel substitution program even though gas rates are higher than gas marginal supply costs. This is true across almost all ranges of sensitivities tested in the analysis. The main driver in this result is the assumption regarding the required investment by the gas utility in lines from the street to the residence. If this investment were not required, the gas utility and its ratepayers would be made better off by space and water fuel substitution programs. In the case of water conversion programs in homes with existing gas lines, the gas utility and its ratepayers are left better off by conversion because utility lines are already in place.

Business Issues

Unique to fuel substitution is the considerable transfer of business to the LDC. Selling less of one's product in the interest of societal good is not a natural free market consequence. Many states, including Oregon, have enacted regulatory changes that overcome the negative consequence of lost revenue associated with implementing energy efficiency programs. Fuel substitution programs will also require careful regulatory consideration to leave all ratepayers at least as well off.

But selling less of one's product through energy efficiency programs and selling less of one's product via fuel substitution create very different customer-supplier relationships for the electric utility. The former preserves the customer relationship. Energy efficiency programs allow the utility to provide the same level of end-use service at a lower cost to the participant. Fuel switching, on the other hand, severs the customer-supplier relationship.

Despite favorable economics to support fuel substitution programs, there is a business issue at stake that fails basic principles of consumer choice; namely the right to win a customers's purchase through the offer of a competitive product. Because of this, PGE is currently seeking creative solutions to the problem of gaining the societal benefits of fuel switching without compromising the right to provide customer service. For example, we are examining dual-fuel heating technologies that could be offered to our customers as a regulated product with fixed and variable charges unique to the product offer. This product would not look like a standard kWh offering. Since these systems would be primarily gas-fueled, most if not all the societal benefits would be realized. The societal benefits might even be greater because of 1) load control opportunities, 2) retaining benefits of non-firm hydro in the Northwest, and 3) real time flexibility to respond to fluctuations in spot market gas and electric prices.

Regulatory Issues

The issue of how to share fuel substitution program effort and expenses, including lost revenue, is a important regulator concern. If it were a matter of incremental gas sales alone, gas ratepayers would always see a positive effect since marginal revenue is greater than marginal cost. If new gas pipe must be put in place to serve the load and if this cost exceeds about $700 (typical extension costs are estimated to be around $1,000) then the non-participants will see a rate increase. Discussions around the right way to share costs and benefits among utilities and customers and the right way to structure regulation are just beginning to appear in the literature. (Weinstein and Pfeifenberger, 1992)

Should a fuel substitution program be permitted if the expected result has a significant societal benefit, yet introduces a small negative impact on the existing gas customers? The following observations would indicate such a program, might be acceptable. Because of high insulation in new homes, new gas homes have less connected load than old homes that would be switched to gas. In other words new gas customers have a greater negative impact to existing customers than hooking up old electric customers. In electric utility regulation, the entire premise of permitting demand-side options rests on the test of positive societal impact. This premise holds despite the typical result of negative impact on non-participant electric customers. Consistent principals in both electric and gas regulation would indicate a modest negative impact on existing gas customers is reasonable in the interest of societal good. After all, existing gas customers are also non-participant electric customers, and this group generally sees a positive effect.

In Oregon, gas and electric utilities are not regulated on a consistent basis. Not only are long run incremental costs calculated by two different methods, but also criteria for no-loser tests are not the same. There is no policy in place regarding inter utility equity transfers among customers. It would be prudent to resolve these issues, and others that might arise, through public hearings before sanctioning fuel substitution programs from any utility.

Conclusions

The results of this analysis have demonstrated that electric marginal costs and average load impacts are key determinants in the economics of any fuel substitution program. Long term economics show favorable results from fuel switching. However the short run incremental cost to the utility is perhaps one-third of the long run cost. At such a low avoided cost, the sensitivity analysis shows that the utility perspective is negative.

Because of:

1. unresolved regulatory issues,
2. unresolved business issues,
3. negative short term effects, and
4. potential for more favorable dual-fuel technologies,

further research and regulatory discussions in the near term are indicated before launching into fuel switching programs.

Endnotes

1. OPUC letter, "To Natural Gas & Electric Utilities Regulated by the Public Utility Commission", October 1, 1991.

2. In the previously referenced Oregon study, for example, natural gas rates are projected to rise one to two percent per year faster than electric rates (ODOE and OPUC 1991).

3. PGE and NNG records indicate that the historic rate of water heater conversions over the last five years has been around 3,000 per year. Space heater conversions have been around 1,000 per year.

Table 4. Results of Sensitivity Analysis By Perspective

Net Present Value in Millions of 1991 Dollars (based on 1000 conversions)

Sensitivity for Water Heat Conversion Only

Uncertainty Parameter	Society High	Society Low	Society Diff	Participant High	Participant Low	Participant Diff	Electric Rate Payer Impact High	Electric Rate Payer Impact Low	Electric Rate Payer Impact Diff	Natural Gas Rate Payer Impact High	Natural Gas Rate Payer Impact Low	Natural Gas Rate Payer Impact Diff
Water Load Impacts	$2.4	$0.6	$1.8	$1.2	($0.1)	$1.3	$0.6	$0.2	$0.4	$0.3	$0.2	$0.1
Electric Marginal Costs	$2.1	$0.5	$1.6	$0.6	$0.6	$0.0	$1.0	($0.6)	$1.6	$0.3	$0.3	$0.0
Gas Marginal Costs	$1.1	$1.8	($0.7)	$0.6	$0.6	$0.0	$0.4	$0.4	$0.0	($0.1)	$0.6	($0.7)
Installation Costs	$1.4	$1.6	($0.2)	$0.5	$0.7	($0.2)	$0.4	$0.4	$0.0	$0.3	$0.3	$0.0
Relative Price & Cost Escalation	$0.7	$1.7	($1.0)	$0.0	$0.8	($0.8)	$0.4	$0.4	$0.0	($0.2)	$0.4	($0.6)
Free Riders	$1.0	$1.7	($0.7)	$0.6	$0.6	$0.0	$0.2	$0.4	($0.2)	$0.2	$0.3	($0.1)

Sensitivity for Space and Water Heat Conversion

Uncertainty Parameter	Society High	Society Low	Society Diff	Participant High	Participant Low	Participant Diff	Electric Rate Payer Impact High	Electric Rate Payer Impact Low	Electric Rate Payer Impact Diff	Natural Gas Rate Payer Impact High	Natural Gas Rate Payer Impact Low	Natural Gas Rate Payer Impact Diff
Space & Water Load Impacts	$8.8	$2.1	$6.7	$4.9	$0.6	$4.3	$2.9	$1.1	$1.8	($0.1)	($0.6)	$0.5
Electric Marginal Costs	$8.5	$2.4	$6.1	$3.1	$3.1	$0.0	$4.6	($1.4)	$6.0	($0.3)	($0.3)	$0.0
Gas Marginal Costs	$4.9	$6.9	($2.0)	$3.1	$3.1	$0.0	$2.2	$2.2	$0.0	($1.4)	$0.6	($2.0)
Installation Costs	$5.4	$6.6	($1.2)	$2.7	$3.5	($0.8)	$2.2	$2.2	$0.0	($0.8)	$0.2	($1.0)
-with New Ductwork	$4.3	$6.1	($1.8)	$1.1	$2.7	($1.6)	$2.2	$2.2	$0.0	($0.8)	$0.2	($1.0)
Relative Price & Cost Escalation	$3.6	$6.8	($3.2)	$1.4	$3.8	($2.4)	$2.2	$2.2	$0.0	($1.5)	$0.0	($1.5)
Free Riders	$4.3	$6.9	($2.6)	$3.1	$3.1	$0.0	$1.5	$2.5	($1.0)	($0.2)	($0.3)	$0.1

4. The complete results of the sensitivity analysis are listed in Table 4 at the end of this paper. The high and low values of NPV are listed along with the difference between the two extremes for each of the four perspectives considered.

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