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RESIDENTIAL FUEL CHOICE IN THE PACIFIC NORTHWEST

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EXECUTIVE SUMMARY

In 1983, the Northwest Power Planning Council (Council) issued Model Conservation Standards (MCS) designed to improve the efficiency of electrically heated buildings. Since then, the standards have been adopted by numerous local governments and utilities. The Bonneville Power Administration (Bonneville) has played an active role in marketing residential energy efficiency improvements through the Super Good Cents Program (SGCP) and encouraging the adoption and implementation of the MCS as local codes through the Early Adopter Program (EAP). Since the inception of the MCS, however, questions have arisen about the effect of the code and programs on the selection of heating fuels for new homes.

Recently, Bonneville has proposed a gradual reduction in the incentive levels under these two programs prior to 1995 based on several assumptions about the market for MCS homes: 1) builder costs will decline as builders gain experience building them; 2) buyers will seek out MCS homes as their appreciation for their lower energy costs and greater comfort increases; and 3) the resale market will increasingly reflect the greater quality of MCS homes.

The growing availability of data from several jurisdictions where the MCS have been implemented has recently made it possible to begin assessing the effect of the MCS programs on residential fuel choice and evaluating assumptions underlying the programs and Bonneville's plans to revise them. This study is the first such assessment conducted for Bonneville.

Pacific Northwest Laboratory (PNL) has collected and analyzed several types of data from EAP jurisdictions for this study. A survey of attitudes and behavior related to fuel choice was conducted in the EAP jurisdictions in the Tacoma area and Southern Idaho. Builders in Tacoma, principally of electrically heated homes, were interviewed to determine their experiences and attitudes. Housing characteristics and sales provided by the county assessor were collected for Tacoma. These data have provided initial information about builders' considerations in selecting heating fuels and their construction practices; home buyers' perceptions about different fuels and their propensity to change fuels; the economic value buyers attach to different fuels and MCS

features; and the effect of attitudes, costs, and demographics on fuel preferences.

The major findings of this study follow. They are based primarily on information from builders of electrically heated homes in Tacoma and households in EAP jurisdictions, so they cannot be generalized with confidence to the overall region, all households, or builders who typically install gas heating. These are the findings:

(1) Builders who predominately install electric heating prefer it because of its ease of installation, relatively low installation costs, widespread use and acceptance, and associated MCS incentive programs.

(2) The builder's fuel choice decision is influenced most by buyers' preferences and market demand.

(3) MCS incentives have been effective in encouraging builders to construct energy-efficient electrically heated homes. Though builders choose what fuel to install partly on the basis of relative fuel prices, modest incentives tied to specific fuel types could offset the effect of higher fuel prices.

(4) Some builders have found that meeting MCS requirements does not have to raise the cost of construction significantly. The SGCP and EAP have increased the application of many energy-conservation measures in new housing and, as a result, many associated construction techniques have now become standard with the builders.

(5) Builders of electrically heated homes believe buyers of custom homes and higher-priced homes are likely to play a larger role in selecting the heating fuel and are more likely to prefer fuels other than electricity.

(6) Cost and safety dominate other fuel attributes in predicting home buyer fuel preferences and choices. Home buyers also indicate that levels of reliability, efficiency, comfort, convenience, pollution, and odor, as well as cost and safety, are all considered to be very important when fuels are compared.

(7) Natural gas is the heating fuel most preferred by the buyers studied, followed by electricity, wood, and oil. Buyers perceive natural gas to be the most economical fuel and perceive natural gas and electricity to be equal as the most efficient fuels. Electricity, however, is perceived to be safer, less polluting, and more convenient than natural gas. Electricity is also ranked preferable in terms of odor.

(8) Electricity is the most used appliance fuel and the appliance fuel most preferred by buyers.

(9) There is more of a potential for households that use electric heat or electric appliances to switch to natural gas for these applications than

from natural gas to electricity. There is evidence, however, that expressed preferences overpredict fuel switching when compared to observed behavior.

(10) Though the share of the existing housing stock that switches fuel during any year is small, the number of homes that switch is comparable to the number of new homes built during a year. The magnitude of the effect, therefore, is likely to be similar to the effect of a pronounced change in preferences for fuel in new homes.

(11) In Tacoma, the share of new single-family homes having electric heating has fallen from around 95% in the early-1980s to about 55% currently. This trend has been coincident with the introduction of the MCS.

(12) In Tacoma, buyers were willing to pay about $4,000 more for existing gas-heated homes than they were for existing electrically heated homes in 1987, controlling for the age of the home. The increased value of gas-heated homes appears to be related to recent large increases in the relative price of electricity. The electricity price increases appear largely responsible for the recent decline in electric heating's share in the new housing market.

(12) In Tacoma, buyers have been willing to pay $4 to $5 more per square foot for an MCS electrically heated home than for a conventional electrically heated home, controlling for the age of the home. This premium exceeds estimates of the additional cost of constructing MCS homes and more than offsets the current differential between the price buyers are willing to pay for gas-heated and electrically heated homes.

(13) In Tacoma, we estimate that builders receiving the EAP incentive made a larger profit in 1987 if they built electrically heated homes instead of gas-heated homes. Without the incentive, electrically heated and gas-heated homes were about equally profitable.

(14) In Tacoma, buyers' willingness to pay more for MCS homes suggests that demand for new, electrically heated homes is higher than it otherwise would have been without the EAP and MCS requirements.

These results are, of course, limited by the scope of the data available and the preliminary nature of this study. They do suggest, however, that the interaction between energy efficiency requirements and the various means to implement them, such as codes and marketing programs, is a complex one that may prove to be different than first appearances suggest. This study serves as a basis for further investigations that could address issues such as how valid the findings for Tacoma are in other parts of the region, how crucial incentives are and what other effective alternatives exist, how effective code implementation is compared to other approaches (such as marketing

programs) for increasing penetration levels of the MCS, and what obstacles and opportunities arise in conjunction with code programs.

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APPENDIX A.1

1.0 RESIDENTIAL FUEL CHOICE IN EARLY ADOPTER JURISDICTIONS

In 1983, the Northwest Power Planning Council (Council) issued the Model Conservation Standards (MCS), designed to improve the efficiency of electrically heated buildings. Since their issuance, the standards have been adopted by numerous local governments and utilities. The Bonneville Power Administration (Bonneville) has played an active role in encouraging the adoption and implementation of the MCS through its customer utilities. Since the inception of the MCS, however, questions have arisen about the effect the MCS may have on the selection of heating fuels for new buildings.

Since the standards apply only to new, electrically-heated buildings and they reduce long-term heating costs, typically at the expense of increased first costs, many planners and policy-makers have speculated that the MCS may affect the decision about which fuel to select for new buildings. In the residential sector, the MCS have been estimated to add about $4,000 to $6,000 to the price of a new single-family home (Northwest Power Planning Council 1986); in some cases this represents a price increase of as much as 10%. Since homes heated with fuels other than electricity are not required to meet the MCS unless local code agencies adopt equivalent requirements for all new homes, the construction cost of an MCS home will exceed costs of other comparable new homes heated with different fuels. Though the buyer will benefit from reduced heating bills in the long run, builders, lenders, and potential buyers must all reckon with the higher construction cost of electrically heated MCS homes.

The growing availability of data from several jurisdictions where the MCS have been implemented has recently made it possible to begin assessing the effect of the MCS on residential fuel choice. This study is the first such assessment conducted for Bonneville.

1.1 DESCRIPTION OF SUPER GOOD CENTS AND EARLY ADOPTER RESIDENTIAL PROGRAMS

Bonneville has initiated the Super Good Cents Program (SGCP) throughout its service region to encourage the construction and purchase of homes meeting the MCS. The SGCP is a marketing program operated by local utilities. As of February 1988, 106 utilities were participants in the SGCP. The program combines advertising, technical information, builder training, and financial assistance

to encourage buyers to purchase MCS homes and builders to build them. Local utilities participating in the SGCP provide assistance to designers to help them build to the MCS requirements without giving up amenities important to buyers. Bonneville has created a regional marketing and technical assistance network to assist utilities, builders, and buyers. Bonneville also provides, through the participating utilities, builder or buyer incentives that range from $1,000 to $1,500 for single-family homes, plus $500 if a heat recovery ventilation system is installed. The incentive levels are higher in the more extreme climate zones, where the MCS requirements are more stringent.

The Early Adopter Program (EAP) focuses on achieving MCS levels through building codes. It is designed to upgrade local building code requirements to MCS levels. It aids governments that are raising their residential building codes to MCS levels, and it aids utilities adopting legally enforceable utility service requirements that are consistent with the MCS. The program provides a one-time lump sum payment for costs associated with code adoption and start up. It provides several other payments to the local jurisdiction or utility to defray program costs. In addition, it provides builder incentives that range from $1,500 to $2,900 for single-family homes, plus $500 if a heat recovery ventilation option is installed.

The study discussed in this report focuses on several jurisdictions where the EAP has been in effect for a year or more. Since the EAP results in mandatory requirements for all electrically heated homes in an enforcing jurisdiction, assessing trends, behavior, attitudes, and fuel choices in EAP jurisdictions provides an initial indication of the fuel-choice consequences of adopting the MCS on a larger scale.

1.2 CHARACTERISTICS OF STUDY JURISDICTIONS

As of March 1988, about 20 regional jurisdictions were EAP participants, with the majority located in Washington. Tacoma was the both the first adopter and the EAP jurisdiction with by far the largest number of residential units constructed to the MCS. The jurisdictions we analyzed were limited to those for which the code had been effect since at least January 1987 and for which Bonneville had collected preliminary residential construction data. Table 1.1 shows that we included seven jurisdictions in our study, with MCS going into

effect after June 1986 in all except Tacoma, where it was effective in June 1984. Milton was originally covered under the Tacoma EAP but subsequently elected to administer its program separately. Nearly 70% of the homes built in the EAP jurisdictions were electrically heated. Ninety-four percent of the non-electric homes and 80% of the electric homes were located in Tacoma.

The EAP jurisdictions available for analysis represented basically two geographic regions: the Tacoma area (Bonneville's Puget Sound Area) and the Idaho Falls area (Bonneville's Idaho Falls District). Table 1.2 shows that the former is located in the least extreme MCS climate zone, zone 1, and the latter is located in climate zone 2. The table also indicates that the two participating Idaho cities are located in counties that are EAP participants. Washington Natural Gas has a franchise to serve all of Pierce County, though gas is currently unavailable in Fife. A single gas company serves the Idaho jurisdictions. Tacoma Public Utilities (TPU) and Milton are participants in

TABLE 1.1. Characteristics of EAP Jurisdictions Analyzed

Jurisdiction	Date MCS Went Into Effect	Approximate # Homes Since MCS Went Into Effect, by Fuel Type[a]	
		Electric	Gas/Other
Tacoma, WA	Jun 1984	600	311
Fife, WA	Jan 1987	2	0(b)
Milton, WA	Jun 1986	42	3
Bingham County, ID	Jan 1987	25	4
Blackfoot, ID	Mar 1987	2	1
Bonneville County, ID	Jan 1987	30	10
Idaho Falls, ID	Dec 1986	48	3

(a) Numbers do not include multi-family dwellings and are not exact because final data were not available in all cases. In some cases, data are based on building permits issued rather than completions.
(b) Natural gas is not available in Fife.

TABLE 1.2. Additional Information on EAP Jurisdictions

Jurisdiction	MCS Climate Zone	County	Electric Utility	Natural Gas Utility
Tacoma, WA	1	Pierce	TPU	WNG(a)
Fife, WA	1	Pierce	TPU	WNG
Milton, WA	1	Pierce	TPU	WNG
Bingham County, ID	2	--	Utah P&L	Intermountain(b)
Blackfoot, ID	2	Bingham	Idaho P&L	Intermountain
Bonneville County, ID	2	--	Utah P&L	Intermountain
Idaho Falls, ID	2	Bonneville	Idaho Falls	Intermountain

(a) WNG is Washington Natural Gas Co.
(b) Intermountain Gas Industries, Inc.

Bonneville's SGCP. In Idaho, Utah Power & Light and the City of Idaho Falls participate in the SGCP.

Traditionally, homes in all these regions have been built with electric heating. Electricity has been competitively priced for many years and has been the fuel of choice for heating. Recent data, however, indicate that this historical predominance may be changing. Table 1.3 presents residential fuel choice data from the 1980s.

In Tacoma, the share of new homes using electric heating declined gradually in the early 1980s. In mid-1984, it declined sharply and fell until 1986, when it appeared to level off at about 55%. We did not have detailed heating equipment types for all years. However, data for January 1981 to May 1984 indicated that from one-third to one-half of all new homes in Tacoma had baseboard electric heat and that the share of heat pumps rose from 9% in 1981 to 14% in early 1984. For January 1981 to May 1984, virtually all non-electrically heated new homes in Tacoma were heated with natural gas.

Though a slight trend is evident in Tacoma prior to 1984, the sharp change in 1984 suggests strongly that introduction of the MCS for electrically heated homes significantly reduced the proportion of new homes built with electric heating. While the initial evidence supports this hypothesis, we note that we

TABLE 1.3. Heating Fuel in New, Single-Family Residences[a]

Year	Fuel Type Installed, % Electricity	Gas	Other
1981			
--Tacoma	95	5	<1
--Idaho Falls	81	19	
1982			
--Tacoma	92	6	2
--Idaho Falls	85	15	
1983			
--Tacoma	91	9	<1
--Idaho Falls	90	10	
1984			
--Tacoma (Jan-May)	88	12	(b)
--Tacoma (Jun-Dec)	65	35	(b)
--Idaho Falls	97	3	
1985			
--Tacoma	66	34	(b)
--Idaho Falls	93	7	
1986			
--Tacoma	57	43	(b)
--Idaho Falls	91	9	
1987			
--Tacoma	55	45	(b)
--Idaho Falls	92	8	

(a) Shares of electrically heated homes in Idaho Falls were estimated as the difference between total construction and share of gas-heat ed homes.

(b) No data were available that separated natural gas and other fuels. All non-electric fuels are included with natural gas. The number of electrically heated homes was based on completed construction, whereas the number of non-electrically heated homes was based on permit data.

would expect relative fuel prices to affect the fuel selection as well. Figure 1.1 shows how fuel prices have varied in Washington since 1960. Until about 1975, electricity was clearly less expensive than either gas or oil, and relative prices were fairly constant. Since 1973, however, all prices have increased, and since 1981, electricity has been more expensive than natural gas. Given that relative fuel prices certainly influence buyer demand, one would expect that the relative share of homes heated with electricity would have declined since the early 1980s; this probable effect of changing prices, therefore, makes it impossible to ascertain what effect the MCS may have had on the residential fuel choice without further analysis.

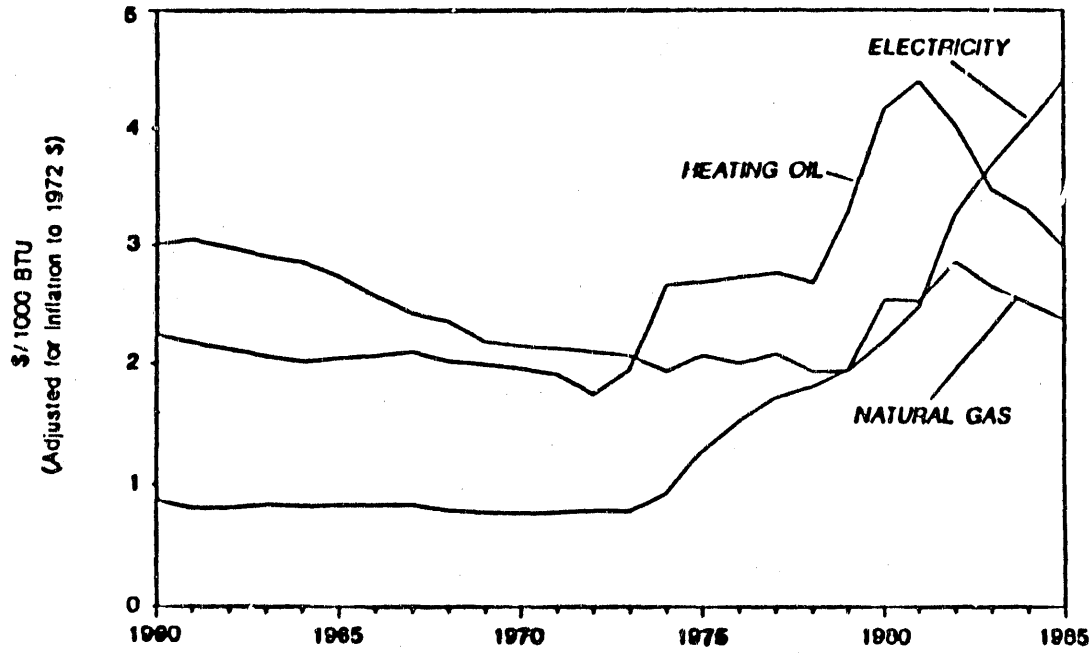

FIGURE 1.1. Average Energy Prices in Washington by Fuel (Source: 1987 Biennial Energy Report, Washington State Energy Office)

The data for Idaho Falls are less indicative of any trends. Natural gas captured a larger share of the market in the early 1980s and has stabilized at about 5 to 10% since 1983. The MCS was in effect during all of 1987, and no effect on the proportion of new homes using electric heating was apparent in that year.

1.3 POLICY AND RESEARCH OBJECTIVES AND ANALYTIC APPROACH

The EAP jurisdictions offer an ideal starting place for analyzing the effects of adopting codes based on the MCS. Bonneville assumes for planning purposes that MCS-level codes will be adopted in all parts of the Bonneville region by 1995 and, at that time, the EAP and SGCP incentives will no longer be needed. Significant planning and policy questions remain, however, about what will happen prior to 1995, how buyers and builders will react to the MCS, and how adoption of the MCS will affect residential fuel-choice decisions.

Bonneville has proposed a gradual reduction in the incentive levels prior to 1995 based on several assumptions about the market for MCS homes: 1) builder costs will decline as builders gain experience building them; 2) buyers will seek out MCS homes as their appreciation for MCS homes' lower energy costs and greater comfort increases; and 3) the resale market will increasingly reflect the greater quality of MCS homes. In addition, Bonneville anticipates finding more effective ways to invest the funds now going to incentive payments.

From Bonneville's and the Council's perspectives, understanding the impacts of the MCS on fuel choice in new housing is very important. Specifically, the additional costs of MCS homes affect the ability of buyers to afford new electrically heated homes and the propensity of lenders to provide mortgages. Builders factor the added construction costs into their decisions about fuel choice. Buyers' perceptions about fuel costs, fuel-cost trends, and other fuel attributes also affect their preferences. From the planning and program side, buyer and builder attitudes and preferences affect the selection of an appropriate incentive level, selection of an incentive mechanism, and the likelihood that builders will construct MCS homes and buyers will choose them.

This study is a first attempt to address some of these issues based on the experience gained in the EAP. It has been conducted in conjunction with the Phase III survey PNL administered for Bonneville to a regionally representative sample of households. The survey instrument developed for the Phase III project incorporates numerous questions related to occupant attitudes toward different fuel types, preferences, and behavior. Our study has administered essentially the same survey instrument to a sample of households in the EAP jurisdictions shown in Table 1.1. These survey data provide the basis for characterizing EAP households and comparing them with households throughout the region. Because of the longevity of the Tacoma EAP, it provides a good basis for in-depth analysis of the impacts of the EAP. We conducted builder focus groups in Tacoma to gather information on builder attitudes and actions. The Tacoma builders also participated in a conjoint analysis to identify the importance of different factors in their fuel choices. Housing characteristics information from Tacoma provide data that we use here to estimate the effect of fuel type and MCS features on the value of new homes. These data, together with the EAP survey results, provide an initial basis for modeling buyers' fuel choices.

The results for Tacoma and the other EAP jurisdictions provide initial indications about the interactions between the MCS and fuel-type selections. The scope of this study, however, is rather limited, and one major purpose of the study is to identify what issues merit further analysis. Based on the results from this preliminary study, we have also identified further avenues for exploration that would provide more general and comprehensive responses to the policy and planning issues facing Bonneville and the Council.

Section 2 of this report discusses the information collected from Tacoma builders. Section 3 presents the results from the EAP households survey and briefly compares the data with those from the Phase III survey of the region. Section 4 examines how different fuel types and the MCS features are valued in Tacoma and analyzes buyers' fuel choices. Section 5 reviews the findings and discusses implications and profitable directions for further analysis. An appendix presents the details of the survey data and conjoint and survey methodologies used in the study.

2.0 PERSPECTIVES OF TACOMA BUILDERS OF ELECTRICALLY HEATED HOMES

Builders play a major role in making fuel choices for new homes, and they are influenced by many factors. Clearly, potential buyers' preferences and the costs of procuring and installing different equipment affect their choices. In the EAP and SGCP jurisdictions, the builders' decisions have been complicated by the requirements of these programs.

This section presents the results of two focus groups conducted with Tacoma builders. We held discussions with builders on specific issues related to the fuel-choice decision and asked builders specific questions that were the basis for a conjoint, or tradeoff, analysis.

The builder information we collected is indicative of builder perspectives. Because of the small sample size, characteristics of the participating builders, and the uniqueness of the Tacoma situation, however, the results cannot be used to statistically infer perspectives and behavior throughout the Bonneville region. The objective of this analysis was to provide qualitative information which could suggest possible research areas and hypotheses to be studied more fully in future quantitative studies. The last section of this study discusses research areas and hypotheses illuminated by this activity.

2.1 BUILDER SELECTION PROCESS

A list of Tacoma area home builders was provided by Tacoma Public Utilities. The list of residential builders included builders producing a variety of residential structures (single-family, duplexes, multi-family complexes) and using different types of heating fuels. Builders on this list were contacted and asked to participate in focus groups discussing the fuel-choice decision in residential homes. All of the participants were either company presidents or general managers. The attendees were paid a $35 honorarium and travel allowance.

The two focus groups were held on consecutive evenings at the Tacoma Dome Quality Inn in mid-February. Though we had anticipated 20 people would attend the focus groups, a total of only 11 people attended, four the first evening and seven the second evening. The first group consisted of small builders who exclusively used electricity in their homes. The second group consisted of a mixture of small and large builders who primarily used electricity; one builder

had also built homes using natural gas. The characteristics of the people attending the two focus groups are described in the appendix to this report.

Though half of the builders who agreed to attend were builders of gas-heated homes, the builders that actually attended were essentially builders of electrically heated homes. One builder built about 5% of his homes with natural gas heat. The lack of participation by builders of gas-heated homes was unfortunate for our purposes because it further reduced the representativeness of the perceptions expressed by the builders. Most new residences in Tacoma are electrically heated, but recent trends indicate that a growing share of new homes are gas-heated. The opinions expressed at the focus groups, therefore, did not reflect experiences of builders who have traditionally built gas-heated homes and may not have captured perceptions of builders who have recently begun to build more gas-heated homes instead of electrically heated homes.

2.2 FOCUS GROUP AND TRADE-OFF ANALYSIS FINDINGS: AN OVERVIEW

The focus groups provided information through discussions and trade-off analysis measurement techniques on what factors influence the fuel-choice decisions made in new residential construction. Because of the small and fairly homogenous sample of builders participating, the results cannot be generalized to other builder types or the Bonneville region in general. Most importantly, they cannot be assumed to apply to builders of gas-heated homes.

Information gathered at the sessions suggested that the following factors were most important to the participating builders of electrically heated homes: individual buyer's heating fuel preference, the overall market demand for a specific heating fuel, the builder's heating fuel preference, the price-range of the home, the type of home, the presence of incentives for installing electric heating, and the relative price increases of heating fuels.

Both the focus group discussions and the trade-off analysis indicated that owner's preference (at the individual, or micro-, level) and market demand (at the macro-level) were the most important factors influencing fuel choice. The builders suggested that market demand was affected by the Federal Housing Administration (FHA) and banks, through lending practices; by realtors; by consumers' and builders' past experience with the predominant fuel (electricity); by utility advertising and programs; and by information provided through agencies

such as Bonneville. These builders indicated a strong preference for installing electricity as the primary heating fuel. Its ease of installation, relatively low installation costs, widespread use and acceptance, and associated incentive programs were factors that promoted its acceptance among the participants.

The conjoint analysis also investigated trade-offs among the factors that influenced these builders' fuel choices. The results indicated 1) that if electricity prices were increasing faster than gas prices, the builders would be more likely to install gas heating equipment, but this tendency could be offset by a modest monetary incentive for installing electric heating, and 2) that in custom homes and higher-priced homes, where owners have more influence on the fuel-choice decision, the likelihood of installing electricity as the primary heating fuel was lower.

The findings of the focus groups and the trade-off analysis are discussed in detail in the following sections.

2.3 HOME BUILDERS DISCUSS THE FUEL CHOICE ISSUE

Six general topics were addressed by the participants in the focus groups: past behavior, decision-making roles, fuel choices and relative benefits, the role of incentives, role of market characteristics, and expectations for future trends. Each of the six topics is summarized below. Included in the summaries are the questions that were used to begin the discussions.

2.3.1 Topic: Past Behavior

Questions: What is the history of the installation of different fuels?

How has it changed over the past 5 years?

All of the participants in both focus groups indicated a history of and preference for all-electric homes. This behavior is based on the following factors:

-availability: Builders stated that natural gas is only available within the Tacoma city limits. The builders attending the focus groups built both within the city limits and in surrounding areas.

-incentive programs (SGC and EAP): The program assists with rebates and with marketing assistance. (Advertising helps sell homes.)

-experience: Both builders and consumers in the area have experience with electricity but none or very little with gas.

-construction costs: Installation of electricity is simpler and less expensive than installion of gas piping.

As we noted earlier, the builders in the focus groups built electrically heated homes almost exclusively. Recent data suggest that a large share of new homes in the area are heated with natural gas, so the comments by the participating builders cannot be taken as representative of all of Tacoma's builders. Nevertheless, the comments are indicative of the attitudes of those builders who have historically built and continue to build electrically heated homes.

2.3.2 Topic: Decision-Making Roles

Questions: What responsibilities are retained by your firm and which are subcontracted?

Who participates in decision-making for each step in the choice of fuels? What are their relative roles? When are decisions made?

How constant are the decisions over time and between projects? What are the major causes of changes in the decision-making process?

The participants, for the most part, were small-scale builders (of less than 20 units per year). As noted before, they were the key decision-makers in their companies and handled all decision-making functions themselves. The builders indicated that they retain decision-making responsibilities when using subcontractors. "They work for us" was the general theme of the discussion.

In most cases, the fuel-choice decision is made by the builders. The exceptions occur when the home is built specifically for a buyer who specifies the type of heating fuel. The builders mentioned several other outside influences that may affect their choices, including:

-the FHA and banks, which indirectly affect the selection of fuel type through their effect on market price ranges when they determine who qualifies for loans.

-real estate agents who act as conduits for consumer demand (although there was much skepticism about their information value).

-Tacoma City Light (now part of Tacoma Public Utilities, sponsor of the SGCP and EAP) which determines requirements for electrically heated homes, including several design features.

-Bonneville and others who publish research and guidelines on cost-effectiveness, energy conservation, etc.

2.3.3 Topic: Fuel Choices Available and Relative Benefits and Costs of Each

Questions: What are the benefits and drawbacks for natural gas? Electricity? Propane? Wood? Solar?

What are the most important benefits and drawbacks?

The comments of the participants regarding the various heating fuels can be summarized as follows:

- Electricity - universally available, relatively cheap to install and operate, units much more salable, appliances easier and cheaper to obtain and install

- Natural Gas - limited availability, more expensive to use than electricity in Tacoma City Light area and comparable in the Puget Power area, limited market appeal, main-line and appliances much more difficult and costly to install, some mention of negative consumer perception (smelly)

- Propane - relatively available, only useful where gas desired but not available (rarely an issue), otherwise same as natural gas

- Wood - although relatively cheap and more available in Tacoma than in other parts of the country, not a serious choice because of operational difficulties and higher costs than are associated with electric heat

- Solar - not practical in the "gloomy" environment of Tacoma, payback period much too long due to low cost of electricity and lack of sunshine, no consumer demand.

The lack of participation by builders of gas-heated homes prevented us from exploring differences in builder perceptions depending on the type of heating fuel they installed. The participating builders indicated that they thought electric heat was less expensive to operate than gas heat in Tacoma, but recent utility prices suggest that electric heat has become more expensive than gas heat during the past three years. The participants also indicated that natural gas was available only within the Tacoma city limits, but the gas utility has stated that areas outside the city are also served by gas.

2.3.4 Topic: The Role of Incentives

Questions: What incentive programs are you aware of, and how have these figured in your firm's fuel choice decisions?

How do you expect these to change? How would you like to see these change?

The only program mentioned was the Tacoma City Light SGCP that offers rebates for energy-conservation construction techniques, as well as for installing an air-to-air heat exchanger. This program was the major topic of conversation for much of both sessions.[a] All of the builders had built under this program, many exclusively. A number of builders expressed the view that they were able to build to the requirements without increasing their construction costs. It was very clear that the program had instigated application of most of the energy conservation measures (e.g., 2"x6" walls with extra insulation, triple-pane windows, passive solar siting), that these techniques are now standard with the builders, and that these measures will remain after the program ends.

Participant comments indicated that the only change expected if the program ended, and most assumed that it would, would be that they would no longer install electric heating exclusively. Many stated that without the incentives they would investigate gas and other fuels; they also stated that they would probably continue to install electric heating exclusively until other factors, such as the cost of electricity, the installation cost of electric heat, and market demand changed, as well.

2.3.5 Topic: Knowledge and Role of Market Characteristics

Questions: How much do you know about the people who will, and will not, buy your homes? What factors are important in their buying decision? Where do you get this information?

How important is the customer market information in making fuel choice decisions?

The builders seemed to have a simple view of their consumers: buyers are concerned primarily with the cost of the unit. Subsidiary concerns include

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(a) It is interesting that the builders did not emphasize the EAP or distinguish it from SGCP.

size (square feet of floor area), energy-conserving characteristics, and location (utility service area due to the differing costs of electricity). No mention was made of other design elements, such as number of bedrooms, number of bathrooms, relative size of kitchen or other rooms, type of roofing and siding materials, etc.

Customer fuel preference is perceived by the participants to be almost exclusively electricity. One builder who was moving into a new area where the existing homes mostly have gas heating planned to continue building and selling all-electric units because he believes that they will sell.

2.3.6 Topic: Expectations for Future Trends

Questions: What changes do you expect over the next five years:

-In characteristics of your residential construction projects relating to fuel choice? Does this reflect the changes that will occur in the industry in general?

-In the fuel choices for different appliances?

-In your decision making processes and roles?

-In fuel choice availability, characteristics, and relative benefits/costs?

-In characteristics and roles of market demand?

What are your general opinions and predictions for overall changes in fuel choices in residential construction?

The participants didn't mention many expectations for changes except one: the cost of electricity will go up. Some expect more fuel-efficient appliances, and most expect more conservation knowledge among consumers. However, as far as choosing a heating fuel, the major factors that make electricity the predominant choice will not change significantly.

Based on the discussions in the two focus groups, both builders and consumers have preferred electricity in the past, presently prefer it, and will continue to prefer it in the future. Only a drastic increase in the cost of electricity relative to other fuels would change this, and that change would result from consumer demand, since installation costs would still be lower for electric heat.

2.4 TRADE-OFF ANALYSIS OF THE FUEL CHOICE DECISION

Trade-off analysis, sometimes referred to as conjoint analysis, is a method of comparing the relative importance of factors influencing a decision. By having respondents rank or rate a series of profiles made up of various factors, the relative importance of the alternate choices for each of the factors is examined. The methods and statistical techniques available for collecting and analyzing conjoint data vary, and a complete description of these techniques is beyond the scope of this report (see Green and Srinivasan 1978; Green and Rao 1971; and Green and Wind 1975). An overview of methods and statistical techniques, as well as the specific method and statistical technique utilized for this study, are provided in the appendix.

2.4.1 Fuel Choice Factors Analyzed

For this study, the same residential builders participating in the focus groups were asked to consider six factors thought to influence the fuel-choice decision in residential construction. The factors and the alternate levels within each factor were suggested by previous discussions with builders. The builders were presented 25 profiles of the residential fuel-choice decision that varied the combinations of the choices within the factors. They were asked to rate the likelihood of electricity being installed as the primary heating fuel in each of the profiles. In rating the situations, the builders were told that all home-heating fuels were equally available and that they should rate the situation as if they were going to do the construction. They rated the likelihood of electricity being the primary heating fuel on a scale from 1 (very unlikely) to 10 (very likely).

The results reported here must be qualified, because the same limitations apply as applied to the generalizability of the focus group results. Namely, the builders were essentially all Tacoma-based builders of electrically heated homes and their perceptions could not be generalized to those builders who construct gas-heated homes or who were located in other parts of the region. The results, however, should be indicative of the behavior and responses of builders of electrically heated homes.

2.4.2 Relative Importance of the Factors

Figure 2.1 illustrates the relative importance of five factors influencing fuel choice. Among the focus group participants, the owners' heating fuel preference was the largest single influence on the decision about the home heating fuel. The type of housing and the price of the residential units were relatively equal in their influence on fuel choice, as were the builders' incentives and relative price changes in heating fuels.[a]

The utility values shown in Table 2.1 are an indication of the relative importance of each influencing factor level in increasing the likelihood of electricity being installed as the primary heating fuel. (Note that the utility values for a particular factor are constrained by the statistical technique used so that they must add up to zero. Consequently, a negative

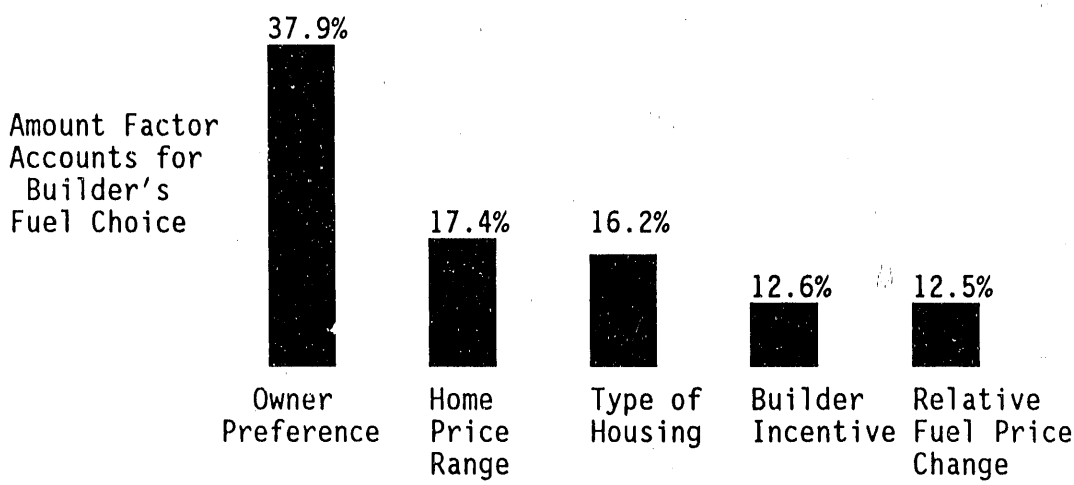

FIGURE 2.1. Relative Importance of Fuel Choice Factors

(a) From previous discussions with commercial builders (Watts et al. 1985), it was hypothesized that the construction contract mode would play a vital role in determining who the decision-makers were in the fuel choice decision (building owner, contractor, subcontractors, architects, etc.) and, consequently, what fuel was selected. Probably because the participants all indicated they were the main decision-makers and our situation involved residential construction, this factor was relatively unimportant compared to the other factors considered, and we do not discuss it further.

Relative Importance of Tradeoff Levels by Fuel Choice Factor		Type of Housing	
		Single-Family, Tract	0.637
		Single-Family, Custom	-0.778
		Multi-Family Complex	0.257
		Du-, Tri-, Quad-plex	-0.115
Home Price Range		Owner Heating Fuel Preference	
High-End	-0.902	Electricity	1.926
Moderate	0.623	Natural Gas	-1.392
Low-End	0.279	Wood	-0.534
Builder Incentive		Relative Fuel Price Changes	
High ($300)	0.606	Elect. Increasing Relative to Gas	-0.448
Low ($50)	-0.500	Gas Increasing Relative to Elect.	0.645
None	-0.106	Similar Price Changes	-0.197

TABLE 2.1. Relative Utility Values of Factor Levels[a]

utility for a given factor level does not mean that the builder would choose something other than electricity, but only that the probability of selecting electricity is lower relative to levels that are positive.) Relatively large positive or negative utility values indicate that the level has more influence on the likelihood of electricity being the primary heating fuel than levels with smaller positive or negative utility values.

The range (from lowest to highest) of the utility values for a particular factor indicates the relative importance of that factor. The greatest range exists for owner heating fuel preference and, as previously mentioned, this factor accounts for most of the relative importance of all the factors considered. Since this tradeoff analysis assumes linearity and little or no correlation between the factors, the overall utility for a profile can be

(a) Upon examining the builders' responses, it was noticed that one builder's ratings of the profiles did not vary across the 25 profiles. To eliminate this acquiescence response bias, his responses were not included in the analysis.

estimated by adding the utility values for each factor level in the profile of interest.[a] For example, the profile with the greatest likelihood for installing electricity consists of a single-family, tract home in a moderate price range, where the owner prefers electrical heat, the builder is receiving a high incentive for installing electrical heat, and the price of natural gas is increasing relative to the price of electricity (total utility = 4.437). The profile with the lowest likelihood for installing electricity is that of a single-family, custom home in the high-end price range, where the owner prefers natural gas, low incentives are available for installing electricity, and electricity prices are increasing relative to gas prices (total utility = -3.52). Comparing utility values of these profiles to the value for other combinations of factor levels would allow us to rank various combinations, but it would not provide a cardinal measure of the value of different combinations.

We can make some observations about the relative importance of different factors in the builder's fuel choice decision. We caution the reader, however, that the results here are based on a small group of builders of electrically heated homes in a single area, and they cannot be generalized to other builders or the Bonneville region without additional information.

2.4.3 The Importance of the Owner's Heating Fuel Preference

Within the owner heating fuel preference factor, as expected, perceived owner preferences for electricity over natural gas or wood increase the probability a builder would install electric heating. Considering the utilities for natural gas (-1.392) and wood (-0.534), in a situation where the owner prefers natural gas it is less likely that the builder would choose to install electricity than in a situation where the owner prefers wood heat. In part, this result is due to the fact that other heating systems are often used to back up wood heating systems, and the back-up system might as well be electricity.

(a) We examined the correlation between the effects of the factors and levels and found no evidence that the analysis needed to include interactions.

2.4.4 The Importance of the Type of Housing and Home Price Range

An examination of the levels within the type of housing and home price range factors reveals an interesting trend. The lowest utilities for these two factors are associated with high-end and custom homes. Comparing these two levels with the other levels for these factors, they are quite a bit lower and would be expected to significantly reduce the probability of installing electric heat.

The fuel decision in custom homes is influenced in several ways. The buyer of a custom or semi-custom home clearly has more involvement in all decisions made about the home. Custom homes tend to be more expensive, and our results suggest that high-end homes are less likely to be equipped with electricity. A custom, high-end home has a utility value of -1.68 due to these two factors alone, suggesting a relatively low likelihood for the builder to install electric heat. It is illuminating, however, that even under these circumstances a buyer's preference for electricity (utility value = 1.926) would be large enough to offset the effect of these two factors.

The market for high-end, custom homes may merit special attention because of these effects. For example, incentives that reduce the cost of new housing using a specific fuel type may have less effect than a well-designed promotion that addresses other characteristics of more importance to the custom-home buyer.

2.4.5 The Importance of Incentives and Relative Fuel Price Changes

In the real world, the amount and type of incentive for installing a specific heating fuel should determine the extent to which it offsets the effect of expected fuel price increases. For this tradeoff analysis, builder incentive levels were fixed at the following: high incentive for installing primary electric heat, $300 per unit; low incentive for installing primary electric heat, $50 per unit; and no incentive present. The relative fuel price changes were only in terms of which fuel price was increasing faster.

The utility values associated with the builder incentive factor and the relative fuel-price change factor suggest that builder incentives may be effective in protecting electricity's market share in periods of increasing electricity costs. As Figure 2.1 shows, the two factors have about the same magnitude of effect on fuel choice. From the values in Table 2.1, the utility

for the high incentive level (.606) is large enough to offset the lower utility for the price of electricity increasing relative to natural gas (-0.448).

The utility values also suggest another illuminating effect of incentive levels. The low incentive level is less likely to convince the builder to select electricity than no incentive at all. While this seems inconsistent, it is possible that builders anticipate that certain costs would be incurred in applying for an incentive (additional paperwork, time, etc.), and an incentive of $50 would be inadequate to cover these costs. A trade-off study on incentives, using a statistically representative sample, could provide more insight into incentive effects.

3.0 THE ATTITUDES OF EARLY ADOPTER PROGRAM HOUSEHOLDS AND THEIR FUEL CHOICES

The material presented in this section is based on a telephone survey of households in the Early Adopter Program (EAP) jurisdictions identified in Section 1. The objectives of this section are to describe the demographics of these households and their attitudes towards heating fuels, as well as to identify potential influences and trends in fuel choices.

The survey methodology and documentation are described in the appendix. Documentation of the statistical tests and assumptions used for the interpretations presented in this section is also located in the appendix.[a]

3.1 DESCRIPTION OF THE EARLY ADOPTER HOUSEHOLDS

Homeowners are of primary interest in this study. Of the 238 households surveyed, 217 are homeowners and 21 are renters. Four segmentation schemes were used to describe the EAP households that were surveyed: geographic region (Western Washington or Southern Idaho), primary heating fuel, choosers of primary heating fuel, and lifecycle segments.

Tables 3.1 and 3.2 show the geographic distribution and the primary heating fuel distribution of the EAP households. About 27% of our sample households are located in Southern Idaho and 73% are in Western Washington. Though the specific counties or cities are not represented in our sample in proportion to their contribution to each region's share of the population, the sample shares in each region are quite consistent with the region's share of the total population.

(a) Out of the universe of EAP households available, we were able to obtain valid phone numbers and complete interviews for 238, or 28%. Of the 324 qualified households we were able to contact, 52 were initial refusals and 34 were midway terminates. The refusal rate was 16%; the termination rate was 10%; and the response rate was 74%. Given the proportion of the universe we were able to contact and the response rate, our results should be adequately representative of the EAP population surveyed.

TABLE 3.1. Geographic Distribution of EAP Population and Surveyed Households When Survey Was Conducted

Region	Households in EAP Region	Surveyed Households	Percent of Sample in Region
Bingham County	33	9	3.8%
Bonneville County	38	14	5.9%
Blackfoot, ID	3	1	0.4%
Idaho Falls, ID	70	40	16.8%
S. Idaho	144	64	26.9%
Fife, WA	2	0	0%
Cheney, WA	3	0	0%
Milton, WA	16	10	4.2%
Tacoma, WA	449	164	68.9%
W. Washington	470	174	73.1%

TABLE 3.2. Distribution of Primary Heating Fuel Use[a]

Region	Primary Heating Fuel							
	Electricity		Natural Gas		Wood		Oil	
S. Idaho	49	20.6%	8	3.4%	6	2.5%	0	0.0%
W. Washington	97	40.8%	64	26.9%	10	4.2%	1	0.4%
Totals	146	61.4%	72	30.3%	16	6.7%	1	0.4%

(a) Fuels not listed comprise 0.8%

New home buyers may have some say in the type of fuel in the home they purchase. As Section 2 indicated, builders typically expect buyers of custom homes or higher-priced homes to express a fuel preference. We asked respondents to the EAP survey to indicate whether they were the "chooser of primary heating fuel" and used their responses as one segmentation scheme. The perceptions and attitudes towards heating fuels are important to consider when examining these "choosers." The proportion of homeowners that reported an active role in choosing their primary heating fuel is 57.6%.

The lifecycle segmentation schemes were created using household demographics. Families and singles have different consumer behaviors and attitudes at different stages in their lives. The lifecycle segmentations

describe the EAP households using combinations of the following demographic variables: household size, age of household members, total years of formal household education, household income, and sex of household members. A cluster analysis was used to group the households that are most alike on these variables into four lifecycle segments. The four lifecycle segments are:

Early Family Stage Households (11.8%) - The large majority of these households consist of a couple between the ages of 23 and 35 with young children. Approximately 78% of the households have pre-school and primary school-aged children. Only 14% of the households have secondary school-aged children. The average annual household income is between $30,000 and $44,999 and 50% of the households are single income. The average adult in this category has completed some college.

Low Income - Late Family Stage Households (3.8%) - These households consist of couples between the ages of 36 and 64. A few of the households have older children (18 - 22 years old). None of the households have children in the preschool and primary school ages. Approximately 89% of the households are dual income. The average annual household income is between $15,000 to $29,999. Most of the households have members who have completed high school or some college.

Medium Income - Small Family Households (72.3%) - These households have few children. Only 5.2% have one pre-school child, 7.0% have at least one primary school-aged child, and 3.5% have one child of secondary school age. The majority of these households have adult couples (78%) while the rest are made up of single adults. The ages of the adults in the household range from 23 to 64. Approximately a third fall into the 23 to 35 age range, a third into the 36 to 64 age range, and the last third is made up of young adults (18 - 22 years old) and elderly adults (65+ years). Their average annual household income is between $30,000 to $44,999. A large majority of the couples have dual incomes (72%). The average adult in this category has completed some college.

High Income Couples - Few Children Households (12.2%) - This lifecycle segment has the highest education and annual household incomes. Approximately 30% of the households have at least one adult that has completed graduate-level degrees, and most have completed a college degree. The average annual household income is at the high end of the $45,000 to $59,999 category. The segment consists mostly of couples in the 36- to 64-year age range. A few of these couples still have some older children at home. Approximately 45% of these households have adults in the 23- to 35-year age range. If the households have younger children, they only have one. Most households do not have children.

3.2 HEATING FUEL

Understanding what heating fuel characteristics are important to consumers and how consumers perceive different heating fuels is important in trying to understand fuel choice. This section explores these issues, along with fuel-switching and available incentives that may influence the choice of heating fuel.

3.2.1 Importance of Heating Fuel Attributes

The importance consumers place on eight fuel attributes are examined in this section. The respondents were asked how important they felt it was for a heating fuel to be economical, efficient, dependable, convenient to use, safe, non-polluting, comfortable, and without an offensive odor. Their responses are summarized in Table 3.3.

It appears that the large majority of respondents felt that it is important for a heating fuel to possess each of the eight attributes. The attributes are ranked in order of importance assigned to them by the respondents. Very little difference separates the rankings of each attribute, and the respondents' ratings on the importance of the eight attributes were consistent across all segmentation schemes.

TABLE 3.3. Percent of Respondents Rating Fuel Attributes at Each Level

Mean Importance Rating	Attribute	Importance of Attribute: Not at all Important	Not Very Important	Somewhat Important	Very Important
3.95	Dependable	0.0%	0.4%	4.2%	95.4%
3.93	Economical	0.0%	0.0%	7.2%	92.8%
3.92	Efficient	0.0%	0.0%	7.6%	92.4%
3.92	Safe	1.3%	0.0%	4.2%	94.5%
3.90	Not have an offensive odor	0.8%	1.3%	5.5%	92.4%
3.87	Provide comfortable heat	0.4%	0.4%	11.4%	87.8%
3.82	Convenient	0.0%	0.8%	16.0%	83.1%
3.77	Non-polluting	0.8%	1.3%	19.0%	78.5%

3.2.2 Perceptions of Different Heating Fuels

In the previous section, the importance consumers associated with different heating fuel attributes was examined. It was noted that a large majority of respondents felt that each of the attributes presented was important for a heating fuel to have. This section investigates how each of the fuels is perceived by the households. It examines respondent ratings on each of the eight previously discussed attributes, as well as their responses to open-ended questions investigating fuel perceptions.

The respondents were asked to rate four different heating fuels - electricity, natural gas, wood, and oil - on each of the attributes. For each of the fuels, four of the attributes were worded in the positive and the other four in the negative. The analysis involved reverse-coding the negatively worded attributes and examining the difference between the perceptions of the fuels on each of the eight attributes, as well as how positively each fuel is perceived overall. Friedman's two-way analysis of variance of ranked data is used to test the statistical significance of the differences between the fuels (see the appendix).

Table 3.4 is a pair-by-pair comparison of the mean scores for each fuel by attribute on a scale from 1 (Poor Descriptor) to 4 (Good Descriptor). Comparing the overall positive perception (the sum of the other scores) of the fuels, electricity ranks the highest, followed by natural gas, wood, and oil. Comparing the individual attributes of household fuel perception, electricity and natural gas consistently score higher than wood and oil. Natural gas is perceived as the most economical fuel and shares the highest dependability ranking with electricity. Table 3.3 indicated that these were the two most important fuel attributes. Electricity is perceived to be safer, less polluting, and more convenient than natural gas. Natural gas is also perceived as having an unpleasant odor, relative to electricity.

Since this technique does not assign weights to the attributes, the overall positive image rating does not take into account different values consumers attach to the attributes. In several cases, one fuel is rated superior to another fuel across all the attributes and, therefore, we can conclude that the fuel is rated superior overall to another fuel. For all attributes, gas is rated higher than wood and oil, and electricity is rated higher than oil.

TABLE 3.4. Comparison of Means of the Positive Perception Scale by Fuel Attribute

Fuels	Low Cost	Depend-able	Safe	Non-Polluting	Comfort-able Heat	Efficient	Con-venient	No Offensive Odor	Overall Positive Image
Gas	3.2*	3.1	3.1*	2.7*	3.4	3.0	3.2*	2.7*	23.5*
Elect.	2.4	3.1	3.5	3.2	3.4	3.1	3.4	3.5	25.4
Gas	3.2*	3.1*	3.1*	2.7*	3.4*	3.0*	3.2*	2.7	23.5*
Wood	2.6	2.6	2.3	2.1	2.9	2.6	1.7	2.6	19.3
Gas	3.2*	3.1*	3.1*	2.7	3.4*	3.0*	3.2*	2.7	23.5*
Oil	1.9	2.7	2.7	2.6	2.9	2.6	2.6	2.3	18.2
Elec.	2.4	3.1*	3.5*	3.2*	3.4*	3.1*	3.4*	3.5*	25.4*
Wood	2.6	2.6	2.3	2.1	2.9	2.6	1.7	2.6	19.3
Elec.	2.4*	3.1*	3.5*	3.2*	3.4*	3.1*	3.4*	3.5*	25.4*
Oil	1.9	2.7	2.7	2.6	2.9	2.6	2.6	2.3	18.2
Wood	2.6*	2.6	2.3*	2.1*	2.9	2.6	1.7*	2.6	19.3
Oil	1.9	2.7	2.7	2.6	2.9	2.6	2.6	2.3	18.2

* < .05 level of significance

Electricity is rated the same as or higher than gas on all attributes except cost and dependability, but these are the two most important attributes, as shown in Table 3.3. We cannot, therefore, conclude based on these results whether gas or electricity is perceived more favorably. Section 3.2.3 presents data that shed light on overall preferences.

A number of fuel attributes were perceived differently across the segmentation schemes. For the overall positive perception, however, only the rating of natural gas was found to be different across one segmentation scheme, that of region. Tables 3.5 and 3.6 show the importance scale means (1-Not important, 4-Very important) of attributes that are perceived differently at a statistically significant level across the various segmentation schemes.

Of the eight attributes tested for natural gas, six were found to be perceived significantly differently between the two regions. The Southern Idaho households perceived natural gas to be more polluting, less efficient, and more odorous than did the Western Washington households. In addition, the Southern

TABLE 3.5. Attributes That Are Perceived Differently Across Regions

	Western Washington	Southern Idaho
NATURAL GAS		
Safe	3.2	2.9
Non-Polluting	2.8	2.4
Provides Comfortable Heat	3.5	3.2
Efficient	3.1	2.8
Convenient	3.3	2.8
No Offensive Odor	2.8	2.5
ELECTRICITY		
Low-Cost	2.3	2.7
FUEL OIL		
No Offensive Odor	2.5	3.0

TABLE 3.6. Attributes That Are Perceived Differently Across Heating Fuel Type

	Primary Heating Fuel		
	Electricity	Natural Gas	Wood
NATURAL GAS			
Low-Cost	3.1	3.4	3.1
Safe	2.9	3.5	2.7
Provides Comfortable Heat	3.3	3.7	3.1
Convenient	3.0	3.5	2.9
WOOD			
Low-Cost	2.7	2.3	3.6
Provides Comfortable Heat	2.7	3.1	3.9
Efficient	2.5	2.3	3.3
ELECTRICITY			
Low-Cost	2.7	1.9	2.1

Idaho households perceived natural gas to be less safe, less comfortable, and less convenient than did the Western Washington households. In all these cases,

the Western Washington households' perceptions of natural gas were more favorable than the Southern Idaho households' perceptions. Some of the regional differences are undoubtedly due to the effect that familiarity has on perceptions.

Electricity's share of the new-home market in Tacoma has declined substantially in recent years, whereas it has continued to dominate the Southern Idaho market. Our results suggest that residents who have a particular fuel tend to rate it higher than alternative fuels, and the increasing familiarity with gas heat in the Tacoma area may account for some of the regional differences shown in Table 3.5. Although there were differences between the two regions, both regions tended to perceive natural gas in a positive manner.

The degree to which electricity is perceived to be a low-cost fuel varies from Western Washington to Southern Idaho. Although both regions perceive electricity to be fairly low-cost, Tacoma households have a less positive perception of the cost of electricity, probably partly because of rate increases recently announced in the area.

Table 3.6 presents the fuel attributes that are perceived differently by users of different primary heating fuels. Natural gas users perceive natural gas in a more positive light than electricity and wood users across four attributes: low cost, safety, comfort, and convenience. Respondents consistently perceived their fuel in a more positive light than did respondents who used another primary heating fuel. Most notably, wood-heat users often rated their fuel more than one point higher than other primary fuel users rated wood.

The findings presented in Tables 3.5 and 3.6 can be used to describe patterns related to perceptions about the various fuels and their attributes. This information could be used to target programs related to fuel choice.

From the discussion on the respondents' rankings of fuel attributes (Table 3.4), one would expect that the majority of respondents perceive oil to be the most expensive heating fuel, followed by electricity, wood, and natural gas. Table 3.7 shows the percentage of respondents, based on answers to open-ended questions, who perceive different fuels to be the most expensive and least

TABLE 3.7. Percentage of Respondents Reporting Perceived Expense by Fuel Type

	Type of Heating Fuel			
	Natural Gas	Electricity	Wood	Oil
Most expensive fuel	7%	54%	2%	36%
Least expensive fuel	50%	22%	24%	4%
Most expensive fuel in 5 years	11%	55%	6%	28%

expensive now and the most expensive in 5 years. These results are fairly consistent with the fuel ratings related to economy. Table 3.7 indicates that electricity is perceived to be the most expensive fuel, with oil following at a close second. Natural gas is perceived to be the least expensive fuel, followed by wood. The perceptions of the relative expense of oil and electricity are reversed here compared with the economic ratings presented earlier, while natural gas and wood retain their same ranking. The results for electricity are unique in that the proportions of respondents perceiving electricity to be the most expensive (54%) and least expensive (22%) fuel were both relatively large. It is possible that this disparity is due, in part, to differences in electricity prices between the two regions. This hypothesis is consistent with the results in Table 3.5, which show electricity gets a better rating on the "low-cost" scale in Southern Idaho than it does in Western Washington.

The respondents were also asked the reasons why they were using their present type of heating fuel. Of those respondents living in electrically heated homes, about 64% stated reasons other than it was the type of fuel that came with the house. Approximately 32% of these respondents felt that electricity was less expensive than other fuels, or they had received a cash incentive to heat primarily with electricity. Twelve percent of the respondents living in electrically heated homes stated that the availability of electricity and their familiarity with it were the reasons for their use of electricity. Other reasons mentioned were convenience, efficiency, and cleanliness.

The largest proportion of respondents in natural gas-heated homes (55%) reported using natural gas because they thought it was less expensive than other fuels or they had received a cash incentive to heat primarily with natural gas. Eighteen percent of the respondents mentioned that the comfortable heat natural

gas provided was their reason for using the fuel. Around 27% of the respondents stated that natural gas was what came with the home.

For wood-heated homes, the primary reason stated for wood use was that wood is less expensive than other fuels. Around 31% of the respondents stated the comfort or coziness of the heat as a reason for their use of wood heat.

3.2.3 Fuel Preferences and Fuel Switching

The questionnaire included several questions addressing heating fuel preferences and fuel switching. The following paragraphs examine the relationship between present heating fuel and preferred heating fuel and trends in fuel switching among the surveyed households.

Table 3.8 compares the respondents' present heating fuel type with their preferred heating fuel type and breaks down the responses based on whether or not the respondent reported that natural gas was available in their area. About half of the households prefer natural gas heating and about 40% prefer electric heating. Those households that use natural gas are the most satisfied with their present heating fuel (95% prefer gas). For all fuels, households express the highest preference for their present fuel.

Assuming that households had the resources available, there is more of a potential for households using electric heat to switch to natural gas than for households using gas heat to switch to electricity. However, it appears that for a number of electricity users, the "grass is always greener" syndrome is influencing their preference for heating fuels. We draw this conclusion based on the fact that the percentage of electricity users preferring natural gas decreases and the percentage preferring electricity increases in areas where natural gas is available and the option to switch to natural gas is a realistic one.

TABLE 3.8. Percentage of Respondents Preferring a Specific Fuel Type by Present Fuel Type[a]

Present Heating Fuel	Preferred Heating Fuel				
	Electricity	Natural Gas	Wood	Fuel Oil	No Preference
	(All Respondents)				
Electricity	58%	30%	3%	2%	2%
Natural Gas	4%	95%	0%	0%	0%
Wood	25%	19%	56%	0%	0%
All Fuels Combined	39%	48%	6%	1%	2%
	(Respondents Living Where Natural Gas Is Available[b])				
Electricity	71%	17%	4%	4%	1%
Natural Gas	4%	95%	0%	0%	0%
Wood	40%	20%	40%	0%	0%
All Fuels Combined	38%	52%	5%	2%	1%

(a) Percentages do not add to 100 because of roundoff and exclusion of other heating fuel types.
(b) 35.3% of respondents reported natural gas was available in their area.

While Table 3.8 suggests that there is a potential for residential customers to switch to natural gas from electricity, there may be significant obstacles that prevent extensive fuel switching, such as the cost of installing gas piping. When asked how likely it was for the household to switch heating fuels in the next two years, only 3% of the respondents reported they would consider switching in the next two years. In the past two years only 7% of the respondents had switched their heating fuels, and of those, half did so only because they changed residences. Of those respondents who had switched their heating fuel in the past two years for reasons other than changing residence, five had switched from gas to electricity, two from electricity to gas, and one from fuel oil to gas.

These results indicate that, while there may be considerable potential for fuel switching due to fuel preferences, only a small proportion of existing households switch in the short-term. It appears that other factors, such as the cost of making the change, reduce fuel switching below levels anticipated based strictly on stated fuel preferences.

From a planning and policy perspective, however, the potential impact of fuel switching in existing households in a single year may be quite important because the impacts may be comparable to those due to new housing starts. The share of households switching fuel in any given year without changing houses was around 1.8% ($\frac{1}{2}$ x $\frac{1}{2}$ x 7%). This is equivalent to the most probable estimates of housing stock growth rates of 1.4-1.9% per year (Northwest Power Planning Council 1986, p. 2-20).

3.2.4 Incentives for Installing Heating Equipment or Energy Improvements

One factor that probably influences fuel choice is the presence of incentives for using a specific fuel type. The questionnaire asked the respondents if they had received any incentives for using their particular heating equipment and, if so, what incentives they had received. Respondents frequently interpreted this question broadly and mentioned incentives that applied to a number of energy-related improvements, not just fuel or equipment type.

Nineteen percent of the homeowners in the survey indicated that they had received some type of incentive for installing their present heating system. Incentives related to electric heating systems accounted for 83% of the incentives reported. About 7% of the incentives were identified as associated with gas-heating equipment. The respondents reported that the incentives were for a Super Good Cents home (27% of respondents indicating they had received some incentive), furnace equipment (5%), windows (5%), added insulation (17%), a heat pump (7%), water heater (2%), air exchanger (15%), and for other equipment not mentioned (22%). Based on these responses, only 12% of the respondents receiving incentives reported incentives tied directly to the heating system. Of course, incentives for Super Good Cents homes and air exchangers were implicitly related to the selection of electric heating. The amount of the incentives ranged from a reported high of $5,000 for a Super Good Cents home to a low of $300 for a fireplace insert.

The questions about incentives were intended to help reveal the effect of incentives on fuel choice. The confusion apparent from the open-ended responses indicated, however, that the basic question asking respondents if they had received a fuel incentive was not worded properly to elicit the desired

information. The open-ended responses were very helpful in qualifying the initial response.

While most of the households utilizing incentives were located in Western Washington, a larger proportion by region was located in Southern Idaho. Of the households in Western Washington, 15% reported taking advantage of incentives for their heating system, whereas 23% of Southern Idaho households reported receiving incentives.

3.3 APPLIANCE FUELS

We also investigated residential fuel-choice for appliances that can be fueled by either electricity or natural gas. These appliances are the cooking stove, water heater, and clothes dryer. Similar to the section on heating fuels, this section covers the respondents' present appliance fuels, preferred appliance fuels, and appliance fuel switching.

Electricity is the most used appliance fuel and the most preferred appliance fuel among the surveyed households. Table 3.9 indicates the proportion of surveyed households which have electricity or natural gas for each of the three

TABLE 3.9. Percentage of Households Having and Preferring Given Appliance Fuels

	PRESENT APPLIANCE FUEL			
Appliance	Electricity		Natural Gas	
Stove/range	93%	85%*	6%	15%*
Water Heater	75%	57%*	25%	43%*
Clothes Dryer	97%	92%*	3%	8%*
	PREFERRED APPLIANCE FUEL			
Appliance	Electricity		Natural Gas	
Stove/range	76%	74%*	21%	24%*
Water Heater	58%	53%*	39%	46%*
Clothes Dryer	85%	92%*	13%	8%*

* Percentage of Households in Cases Where Respondents Report Natural Gas Is Available

appliances and which fuel they prefer for their appliances. Since the table shows, as with heating fuels, that the shares of respondents who have gas-fueled appliances are less than the shares that prefer gas-fueled appliances, there is a potential for households using electricity to switch to natural gas for all three appliances. As was observed with the heating fuel preferences, however, there may be a notable difference between expressed preferences and actual selections. Where natural gas is available, 8% of the households have gas clothes driers, but for the entire sample 13% indicate a preference for natural gas. Since occupants typically purchase their own clothes dryer, they have considerable control over the choice of fuel for clothes driers. As a result, respondents should be able to select gas for clothes driers to the extent that they prefer gas.[a] There is, therefore, an unexplained gap between stated preferences and actual choices when both fuels are available.

The respondents were also asked if they had ever switched their cooking fuel or water heater fuel. Thirty-five percent of the homeowners surveyed had switched their cooking fuels. Of those who switched, 80% switched from natural gas to electricity, while 11% switched from electricity to natural gas. Those switching from natural gas to electricity mentioned "electricity was already in the home" as the primary reason for switching. Other reasons mentioned more frequently were that electricity was cheaper and did not smell. Those that switched from electricity to natural gas mentioned, as the primary reason for their switch, building a new home that used natural gas.

Forty-two percent of the homeowners surveyed had switched water-heating fuels. Of those who switched, 60% switched from natural gas to electricity and 40% from electricity to natural gas. Those that switched from natural gas to electricity most often mentioned moving or building a new home and faster recovery as the reasons for their switch. The top three reasons for switching from electricity to natural gas as a water heating fuel were the fuel was already in the home, faster recovery, and lower fuel costs. The fact that people who switched to both electricity and natural gas stated a major reason was faster recovery suggested that a lack of reliable information existed.

(a) The cost of connecting to the gas supply system and installing gas piping may provide a significant cost penalty for conversion.

Electricity was both the most used and the most preferred appliance fuel. Electricity was the preferred fuel for all three appliances, having the largest advantage over natural gas for clothes driers and the smallest advantage for water heaters. Fuel switching occurred frequently, but was due primarily to moving into a new home that was equipped with a different fuel. Performance and cost also contributed to fuel switching.

The most appliance fuel switchers are in Western Washington, but a larger proportion of the Southern Idaho households have switched their appliance fuels (47% switched water heating fuels; 34% switched cooking fuels). The majority of the appliance fuel switchers are classified as "fuel choosers."

3.4 HEAT PUMPS

Besides questions concerning the perception of fuels, fuel choice, and fuel switching, the questionnaire also obtained information about heat pumps and household awareness of heat pumps. This section describes the households with heat pumps, the fuel type for these heat pumps, the general familiarity of the homeowners with heat pumps, and attitudes towards heat pumps.

Only 11 of the households surveyed had heat pumps, 4.6%. Of the 11, eight households had electric heat pumps; the other three had gas heat pumps. Ten of these households (91%) were located in Western Washington. Nine out of the eleven households were classed as "fuel choosers" and actively chose their current heating fuel.

Those respondents reporting that they were familiar with heat pumps were asked about their heat pump likes and dislikes (Table 3.10). The percentage of respondents reporting that they were familiar with heat pumps was 53%; 19% reported being very familiar with heat pumps. The most mentioned advantage of heat pumps was that heat pumps are efficient and heat the home faster. A second advantage mentioned was that heat pumps are used for full-year operation: they both heat and cool. Sixteen percent of the respondents mentioned that heat pumps were more economical to operate than standard heating and cooling systems. Other advantages mentioned were that heat pumps were clean, quiet, and controllable or convenient to use.

The most mentioned disadvantage to heat pumps was that they are not economical. Also, respondents complained that the heat pump does not work well in extreme conditions and needs a backup system. Out of the 115 respondents who owned or stated they were familiar with heat pumps, 36% stated they would purchase a heat pump system if they were to buy another heating system. Out of the homeowners in the entire sample, only 7 (3%) reported being very likely to purchase a heat pump system in the next two years. Sixteen (7%) reported being somewhat likely to purchase a heat pump in the next two years.

The fact that the economics of heat pumps were considered both an advantage and disadvantage was particularly interesting. Because the survey did not probe further on responses to these questions, it was unclear whether this apparent inconsistency was due to misinformation, different interpretations of the questions, or differences of experiences. Both first costs and fuel costs affect the economics of heat pumps, as does the presence of a significant cooling load. A better understanding of these responses would require further data.

TABLE 3.10. Percent of Respondents Who are Familiar with Heat Pumps Mentioning a Specific Advantage or Disadvantage

Advantages of Heat Pumps		Disadvantages of Heat Pumps	
efficient/delivers better heat/heats faster	33%	expensive/not economical	28%
full year operation/ both heats and cools	31%	noisy/ugly/allows no fresh air	17%
less expensive/more economical	16%	needs a backup system/doesn't work well in extreme conditions	17%
convenient/programmable/ controllable	7%	high maintenance/short life span	7%
environmentally sound/ clean/quiet	5%	complicated/hassle to install	2%
		there's nothing I don't like about it	12%

3.5 COMPARISON OF EAP HOUSEHOLDS WITH REGIONAL SAMPLE

The questionnaire used in the survey of EAP households was basically the same one used in another Bonneville-sponsored residential survey, the Phase III

survey. The Phase III sample consisted of 1,000 households selected to be representative of the Bonneville region. The results of that survey are presented in another report (Harkreader and Hattrup 1988). The results of the regional survey can be compared with those from our survey directed at households in the EAP jurisdictions.

For the most part, the EAP households' perceptions of the importance of the eight fuel attributes and the perceptions of the different heating fuels were no different than perceptions based on the regional sample. One notable difference was that the regional respondents were about evenly split in their preferences for natural gas and electricity. In Western Washington, the preferences were about 45% for gas and 35% for electricity; in the rest of the region, however, the proportion preferring electricity was substantially higher than that preferring gas. There was no appreciable difference between the fuel switching behavior and potential in the two samples. In terms of household characteristics, the EAP households also matched the regional sample of households quite well.

4.0 HOW TACOMA HOUSEHOLDS VALUE AND CHOOSE HEATING FUELS

Previous sections of this report have provided evidence that builders seek to satisfy the preferences of potential buyers, and that buyers have preferences for particular fuels. Buyer fuel preferences depend largely on perceptions about relative fuel costs, but they also depend on other factors such as safety, convenience, and efficiency.

The Tacoma EAP jurisdiction provides an excellent test bed for analyzing some of the factors that affect buyer fuel choices. The EAP has been in effect there for several years, allowing one to observe trends and the effect of the EAP on fuel choices. Being that Tacoma is a major metropolitan area, data on its housing stock are readily available. A substantial number of homes in both the pre-EAP and post-EAP housing stock have been surveyed.

This section addresses how home buyers in Tacoma value different fuels, how they value homes built to the Model Conservation Standards (MCS), and how fuel preferences are related to characteristics of the home buyer. The first two issues are analyzed using hedonic price analysis, and the last is addressed using discrete choice analysis.

4.1 THE VALUE OF DIFFERENT HEATING FUELS AND MCS FEATURES

Numerous studies have used the hedonic property value technique to evaluate the characteristics of housing. The hedonic technique is a fairly straightforward approach for assessing the impact of house attributes on the selling price. The motivation for applying the technique is to estimate the dollar value of a characteristic which is not openly observable. One of the classic applications has been to estimate the dollar value of air pollution damage.[a] Other applications have included valuing local parks, airport noise, and not surprisingly, conservation programs.[b]

(a) Freeman (1979) discusses 12 different studies that have examined air pollution valuation using the hedonic technique.

(b) Laquatra (1987) gives an overview of several energy-related applications. Other applications include Laquatra (1986), Palmquist (1984, 1985), and Zaki and Isakson (1983). Rosen (1974) discusses the theoretical underpinnings of this technique.

Applications of the technique start from the assumption that the price of the house is a function of the attributes of the house. This line of logic suggests that the incremental value of any particular attribute can be statistically estimated from knowledge of the selling prices of houses and the amounts of the attributes in each house. The incremental value is the dollar value of the characteristic under study. In this study, we are interested in the dollar value of different fuels and the package of MCS features.

Operationally, the technique is implemented by using regression analysis. The selling price is regressed on the quantities of the attributes in each of the houses sold. The method disaggregates the selling price to find the contribution of each attribute to the selling price. Each housing sale is an observation. Equation (4.1) shows this relationship:

$$\text{Selling Price} = F(\text{attributes}) \tag{4.1}$$

The contribution of each attribute to the selling price depends on the demand for the attribute by home buyers, the quantity available, and the ease and expense with which the supply of the attribute can be increased.

While the function F() can take different forms, most researchers have found the linear or logarithmic linear forms to fit the best. An example linear function is shown in Equation (4.2):

$$\text{Selling Price} = a_0 + a_1 * x_1 + a_2 * x_2 + \ldots + e \tag{4.2}$$

In the linear form illustrated by Equation (4.2), the incremental value of an additional unit of x_1 in the selling price of the house is a_1. If, for example, x_1 measured the square footage of the house, a_1 would be the incremental effect of an additional square foot on the selling price of the house; a_1 is the value of an additional square foot. From a buyer's perspective, a_1 is what he or she is willing to pay for an additional square foot. From a seller's or builder's perspective, a_1 is the price at which they can sell an additional square foot.[a]

(a) The incremental value associated with the attributes estimated in Eq. (4.2) reflects the demand and supply of each x_i in the region and time-period studied. Inference about the effects of changing supply and demand requires additional information.

Note that the estimated coefficient, a_1 is the capitalized effect. The coefficient captures the discounted value of the equipment and the expected cost of running the equipment. Decomposing the estimated coefficient depends on understanding expectations about home heating fuel prices. Abelson and Markandya (1985) describe this problem in detail. In this study there will be no attempt to decompose the estimated effects of the equipment and expected annual operating expense.

Clearly, this approach is dependent on the accuracy with which houses can be described. Some housing attributes cannot be measured at all, and others cannot be measured continuously and so must be measured with a zero-one dummy variable. If the object of the analysis is to estimate a particular a_i, then omitting a variable which is a determinant of the housing price, but is uncorrelated with the variable of interest will not bias the estimate of a_i. The effect of the omitted variable will be to change the constant and lower the R-squared of the estimates.

The application of this technique to analyzing residential fuel choice is straightforward. If x_1 indicated electric space heating and x_2 indicated gas heating in Eq. (4.2), then a_1 and a_2 would measure the effect of the fuels on the price of the home. The difference between a_1 and a_2 is the amount the price of the house would vary in the local housing market given the fuel type. The implications for the new home market are fairly direct. Builders would want to build the house which had the greatest difference between the cost of installing the fuel and the price at which they could sell. Home buyers would, given their attitudes towards each fuel, want to spend the least for their preferred fuel.

Three factors which complicate the relationship between new housing and fuel choice are 1) the nature of existing housing available on the market, 2) expectations about fuel price changes, and 3) the dynamic nature of the housing market.

Conventional applications of the hedonic technique consider new housing and existing housing to be substitutes for each other. The applications assume that buyers of new homes compare existing homes with the new homes on an equal footing. The profitability of various features in new homes is affected by the availability of those features in the current stock of housing, as well as in

competing new homes on the market. Of course, this assumption can be tested using the data in this study.

Current fuel prices and future fuel price changes, either announced or simply expected, are major factors in how much home buyers are willing to pay for a house with a particular fuel. Each home buyer must trade off the equipment cost of the fuel against the operating cost (fuel price). The amount they are willing to pay for a home with a given fuel will depend on their expectations for the future prices of the fuel. If they expect that the cost will be less for one fuel than another, they will be willing to pay more up-front for a house with equipment using the less expensive fuel. In this way, the future price of fuels, in addition to current prices, affects the incremental price builders can receive for a house.

Finally, the role of fuel type in housing prices is dynamic. As fuel prices change over time the effects of fuel type on housing prices will also change; the analysis of a single year alone cannot always capture these effects. The dynamic effects, however, can occur in a relatively short time period. For example, abrupt changes in relative fuel prices can produce sudden shifts in the market clearing prices of houses heated with different fuels because the supply of homes with a given fuel type is fairly constant in the short-run. If the price difference is sufficient to change the relative profitability of installing different heating fuels, both retrofit changes in existing homes and changes in the fuel type mix of new homes will occur. How quickly these effects occur and how long it takes to reestablish a long-run equilibrium is an empirical issue.

4.1.1 Data

Application of the hedonic price technique requires knowledge about the sales prices and characteristics of both new and existing houses sold during specific time periods. These data can be found at county assessors' offices. Tacoma housing sales and house characteristics are maintained in the Pierce County Assessors Office. The county maintains these records to allow it to properly assess property taxes. These records are public information and are available to anyone who requests them. To allow this analysis, the complete listing of residential properties and historical data in Pierce County was obtained in a computer-readable format.

This pilot study focuses on a neighborhood in Tacoma. The particular neighborhood was chosen at random in the Phase III survey design process. It consists of three ZIP codes, 98465, 98466, and 98409. Although use of the data from a neighborhood limits the generalizability of the descriptive statistics for the data, the values of electric, gas, and oil heat and the MCS package that are estimated in this study should closely apply to the rest of the Tacoma area, since the neighborhood is a fairly typical one.[a]

Since the MCS code was implemented in mid-1984, the time period of interest is from 1984 onward, plus enough time before 1984 to provide some historical perspective. The time frame of 1981 to 1987 was selected, three-and-a-half years on either side of the decision to implement MCS. Seven smaller data sets were generated from the complete set. These seven included all residential sales in the study area for each year between 1981 and 1987.

Pierce County collected fuel type data only until the late 1970s. While the assessor data covering the time period we analyzed did not specify fuel type, it did include detailed information on heating equipment type. Two equipment types, however, had ambiguous fuel types; these were forced-air heat, which could be fueled by gas, oil, or electricity and floor/wall heating units, which could be fueled by either gas or electricity. We augmented the assessor data in the following way: First, each year's sales were randomized, and then the listed phone numbers for the first 500 houses which had an unknown heating fuel type were obtained. Next, these houses were called in order and the occupants were asked their main heating fuel type and if it was the type in the house when purchased. Attempts to call each of the five-hundred houses were made in order. Houses where the calls were not answered were called again in future passes through the listing. Finally, these observations were added to

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(a) Also, most prior applications of hedonic analysis have found that, given free movement by home buyers, an entire city will share a common hedonic price structure. This is true despite the fact that location is an important determinant of housing type because location and other attributes are typically uncorrelated.

those for which the heating equipment data indicated unambiguously the fuel type (e.g., baseboard heating).[a]

The raw assessor's data contain a rich description of both the attributes of each house and the property around the house. Land descriptors include amenities such as waterfront and views, as well as indications of lot size, the quality of road access, and the condition of the land itself. In general, the neighborhood we analyzed is sufficiently homogeneous that there is little variation in these attributes. For example, none of the houses were on swampy land or had waterfront. The study area is basically a city neighborhood. The available house descriptors were even richer. These included age of the house, quality of construction, house type, the kind of interior and exterior walls, porches, number of bedrooms, number and kind of baths, square footage of basements and garages as well as living areas. The data also included information about the fireplaces, heating equipment, and other built-in appliances. Together, the property and house data provided a fairly complete picture of each property.

The data were "cleaned" to obtain a sample which was appropriate to the analysis. For example, numerous buildings were actually businesses which were zoned both residential and commercial. Another difficulty was the assessor's practice of listing the selling price for a lot and then the characteristics of the house which was subsequently built on the lot. The latter problem was addressed by including only houses which had ages greater than or equal to zero and sold for more than $35,000. A final difficulty was that some houses were clearly sold for some purpose other than as housing units. It appeared that these houses had been purchased as part of a group. Approximately 20 plots were removed on a case-by-case basis using this criterion. The result of this was that the remaining house sales were conventional structures sold as housing units.

4.1.2 Housing Characterization

The neighborhood under study is shown in Figure 4.1. Much of the housing in the neighborhood is post-World War II construction. During the recent past,

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(a) See Snedecor and Cochran (1978, pp. 523-525) for a justification and explanation of this cost-constrained sample design.

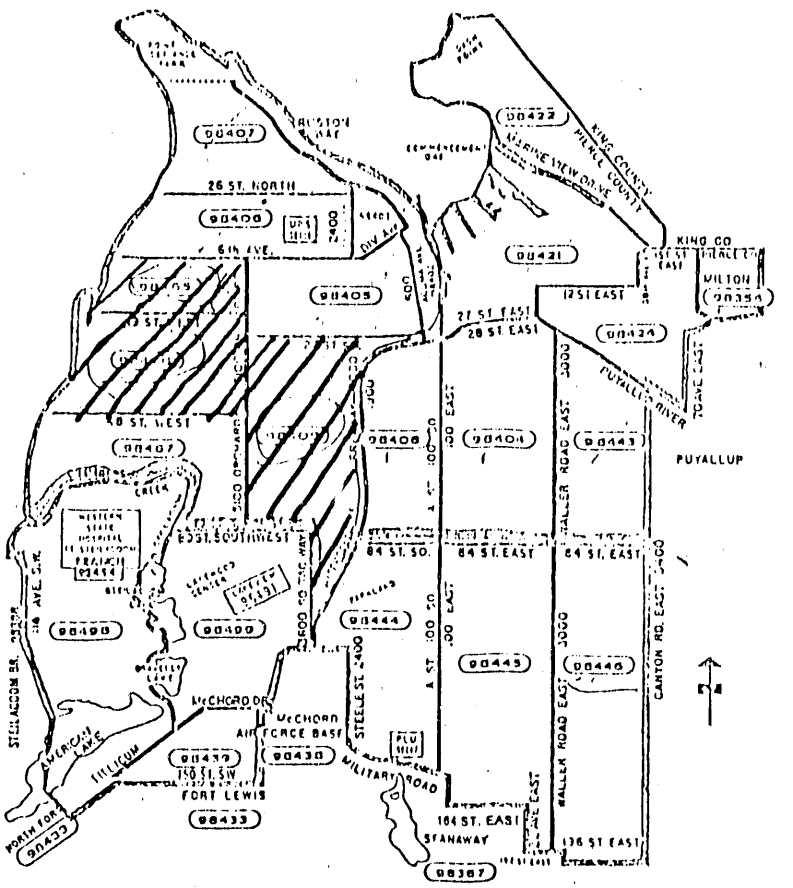

FIGURE 4.1 Tacoma Neighborhoods Sampled

about 20 to 25 electrically heated homes have been added each year. In general, the area is fairly homogeneous, with similar neighborhood amenities found equally dispersed throughout the area. Access to the downtown city center is roughly equal across the three ZIP code areas. One concern was that part of the area borders the Puget Sound. As it turned out, there were not any properties which

had waterfront access in any of the final samples. The mean levels of each of the variables used in the final regressions are shown in Table 4.1.

As can be seen from the table, there is not a substantial variation in the characteristics of the houses sold between 1981 and 1987. This is consistent with a fairly mature neighborhood which slowly adds houses over time. The average house had a lot around 9,300 sq ft, was 20 to 25 years old, had 3+ bedrooms and 1-3/4 baths, and had about 1,500 or 1,600 sq ft of floor space. The average MCS house in the sample was between 1,496 and 1,761 sq ft. In this analysis, the square footage is split into first- and second-floor square footage. This approach seems to pick up the differential in construction cost between upper and lower floors, and later in the hedonic analysis, to usefully control for housing style.

TABLE 4.1. Means of Housing Characteristics

	Year						
	81	82	83	84	85	86	87
Price, $	74,765	71,104	78,361	76,593	73,832	76,000	72,331
Land area, sq.ft.	9,000	9,380	9,726	9,341	8,892	9,044	9,403
Age, yr.	20.7	21.6	23.9	23.4	23.2	22.3	27.9
Fair construction, %	44.0	41.3	40.5	32.1	39.1	28.8	35.7
Average const., %	50.5	56.9	47.8	58.5	44.9	70.4	64.1
Good const., %	5.5%	2.8%	11.7%	9.4%	6.8%	.8%	.2%
1st floor sq.ft.	1,301	1,246	1,300	1,219	1,227	1,221	1,220
2nd floor sq.ft.	329	374	424	399	350	359	302
Bedrooms	3.5	3.5	3.5	3.3	3.2	3.2	3.2
Baths	1.9	1.8	1.9	1.8	1.6	1.7	1.7
Wood shakes	16.5%	12.8%	15.3%	22.6%	15.8%	23.2%	12.7%
MCS							
1st floor sq.ft.	---	---	---	977	1,110	1,065	1,067
2nd floor sq.ft.	---	---	---	519	651	559	490
Total sq.ft.	---	---	---	1,496	1,761	1,624	1,557
Oil forced-air, %	12.6	14.4	10.9	9.2	5.1	7.2	13.9
Gas forced-air, %	36.0	21.5	39.4	34.2	39.2	45.7	26.7
Elec forced-air,%	18.0	32.3	20.7	40.9	27.2	24.3	38.3
Elec baseboard, %	33.4	31.8	29.0	15.7	28.5	22.8	21.1
Total Observations	126	125	133	159	163	109	109

Most of the construction is either fair or average. The Pierce County Assessor's Manual makes a point of noting that care must be taken in listing a house as "excellent" or "poor" in construction. This admonition seems to have

had the effect of tightly bunching the assessments around average construction. A variable which was significant in several regressions was the presence of hand-split wood shakes. This feature was assumed to be an indicator of quality and other unmeasured characteristics.

The space heating in the houses was of four types: electric baseboard or one of three types of forced-air. Forced air could be electric, gas or oil.

4.1.3 Analysis

We used the hedonic analysis technique to estimate the incremental effect of fuel type and MCS on the sale price of houses in Tacoma. The strategy followed was to examine the fuel effects for each of the seven years and the MCS effects for each of the last 3.5 years in our sample.

This approach has several advantages. One is that it does not constrain the estimated effects of a housing attribute to be constant across years. The value of lot size could change, for example, as the local economic outlook was changing. A second is that it helps prevent biased estimates of the coefficient on fuel type or MCS as the result of collinearity between an omitted variable which is changing over time and either space heating type or MCS. For example, interest rates could have been falling over a five-year period. If interest rates were correlated with the number of MCS homes, then the coefficient on the MCS variable would pick up some of the effect of interest rates as well as the effect of MCS. Separate regressions for each year help minimize the effects of these sorts of mis-specification biases.

Halvorsen and Pollakowski (1981a) use time dummy variables in concert with fuel-type variables to estimate the effect of the 1973 oil embargo on housing prices between 1971 and 1975. They control for a time trend using dummy variables. Edmonds (1985) has suggested that this approach may have limitations. Since Halvorsen and Pollakowski pool their data they impose several assumptions about the housing market over that time period. Among these is that the contribution of other housing structural characteristics, such as square footage, lot size, etc, were equally valuable throughout the time period. By estimating a single independent regression for each year, this study allows the incremental effect of structural housing attributes to vary from year to year. This will

also help minimize mis-specification bias due to uncontrolled intertemporal effects.

Estimating a separate regression for each year does require substantially more data than the Halvorsen and Pollakowski method. Our study estimates hedonic regression on the basis of 109 to 163 observations per year. Halvorsen and Pollakowski use 269 observations in a single regression. Other investigators have used as few as 84 (Brown and Pollakowski 1977) and as many as several thousand observations. The primary trade-off in deciding the number of observations to use is between homogeneity of the sample, in variables other than the one of interest, and the statistical improvements possible with more observations. In the case of hedonic property value analysis, limiting the data to a small locality reduces the chances of an unobserved effect contaminating the estimated coefficient for the variable of interest. Researchers who have used many observations generally have drawn from a wide geographic area, or across wide swaths of time, and had to devise various neighborhood indexes or simple dummy variables (e.g., Johnson and Kasserman 1983) to account for neighborhood or intertemporal differences. These kinds of variables were not required here because the data were drawn from a small, homogeneous area.

Several methods are available to develop the regression specification when there are repeated samples. Basically, the analyst can 1) fit each year individually[a], 2) choose a specification and functional form which fits the group as a whole, or 3) fit selected years and apply that specification to the entire sample. Since much of the analytical interest is centered around the events in recent years, it seemed most appropriate to use the third approach to yield the most fruitful analytical results. This analysis is based on a specification which fit 1987 and 1986 well, and was then applied to the years from 1981 to 1985. Examining the fit of the specification to other years helps to understand the robustness of the specification.

A variety of specifications for the hedonic regressions was examined. The basic model which other researchers have found to be successful includes lot

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(a) Halvorsen and Pollakowski (1981b) discuss the use of Box-Cox transformations to fit a specific functional form to data for an individual year.

size, square footage, quality of construction, number of baths, age and number of bedrooms. This analysis augmented this specification in a variety of ways in an attempt to fully exploit the information available in our data. One set of variables examined were seasonal dummy variables (winter, spring, summer, and fall). These worked moderately well in explaining housing prices, but they were not consistently positive or negative. More importantly, the rest of the parameter estimates were not sensitive to their inclusion or exclusion. Since the seasonal dummy variables were making only a marginal contribution to the model, they were dropped. There was also an examination of the land quality variables. Again, they proved to be unimportant. Occasionally, a particular year would show that one or another of these experimental variables was significant, but they were never consistently significant across the years.

The final specification is a simple description of the house and property that is consistent with what other researchers have found, and it performs well here. The land area is simply measured as total square feet. The building is measured as area upstairs and downstairs, number of bedrooms and bathrooms, age, quality, heating type, and wood shake roofs. The only atypical variable is wood shake roofs. This variable seems to work well in describing more expensive housing in this neighborhood. It is significant in five of seven regressions.

The search for functional form was limited to the linear and the semi-logarithmic forms. Most researchers have found these to be the most successful. They performed almost equally well in this study. The semi-logarithmic form fit slightly better in six out of seven regressions. The parameter estimates were robust with respect to the functional form chosen and only the semi-logarithmic form is reported in this section.[a]

(a) The semi-logarithmic approach was also examined for heteroskedasticity. Both the Glejser and modified Glejser tests (see Glejser 1969) were used to examine each regression equation independently. There were no consistent patterns of heteroskedasticity apparent in the data. See Kennedy (1985) pp. 104-105 for a complete discussion of these tests.

4.1.4 Results

Table 4.2 presents the results from the regressions. The regressions generally perform well. Adjusted R-squareds in these regressions range between .57 and .83, with most around the .80 range. Most regressions have seven or eight significant coefficients.[a] The coefficient of age is always negative, indicating that older homes are worth less, and nearly always significant. It is somewhat more variable than the square footage coefficients, however, but is about the same magnitude across years.

The primary assessor's data also include a house-type variable. There is considerable belief among realtors that different styles of home (e.g. split-level, two-story etc.) have different salability. In this study, including a house style dummy variable in addition to upper and lower square footages was not successful. The house style dummies were not significant at conventional levels and were inconsistent in sign. Splitting the square footage into upper and lower area seems to capture the house type effects. The first- and second-floor square footage coefficients are always positive, significant, and of about the same size.

Houses of below-average quality are less valuable than average or good quality houses. As noted earlier, the Pierce County Assessor's Manual indicates that the high and low subjective quality codes should be used with great caution. This shows up in the data, because few homes are ranked good or above or of low quality. Therefore, all houses are lumped into the three middle categories, with the excellent and good quality homes moved into the above-average category and the poor quality homes moved into the fair category.

Two variables which cause some interpretation difficulties are the lot size and number of bedrooms. In general, it seems clear that both are important determinants of housing price. However, lot size is significant in only three regressions. It is, however, positive and of about the same magnitude in all

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(a) Since the regression uses the logarithm of sales price as the dependent variable, the coefficients of the variables do not indicate the incremental value of each variable directly. To calculate the incremental value associated with the independent variables the coefficient is multiplied by the mean selling price for the year of interest. For example, the oil heat effect in 1981 is $74,765 * 0.17244 = $12,892.

TABLE 4.2. Hedonic Price Regression Results[a]

	1987	1986	1985	1984	1983	1982	1981
Constant	10512	10654	10707	10656	10463	10660	10505
	(134)	(152)	(125)	(146)	(124)	(103)	(147)
Land Value	-0.00152	0.00838	0.00708	0.01039	0.01194	0.00258	0.00465
	(-0.38)	(2.26)	(1.26)	(3.72)	(2.75)	(0.74)	(0.90)
Building Age	-2.15	-5.0	-3.11	-3.51	-1.62	-3.06	-2.53
	(-2.70)	(-5.66)	(-3.00)	(-4.36)	(-1.74)	(-2.51)	(-2.35)
Below Avg.	-151.9	-59.8	-170.3	-119.4	-108.4	-78.1	-155.9
	(-3.98)	(-1.68)	(-3.95)	(-3.26)	(-2.86)	(-1.34)	(-3.51)
Above Avg.	153.9	216.9	170.8	109.3	-32.9	195.4	99.3
	(1.45)	(3.85)	(1.63)	(1.87)	(-0.40)	(1.21)	(0.96)
1st Floor Square Feet	0.301	0.285	0.265	0.299	0.218	0.287	0.302
	(4.76)	(4.58)	(3.63)	(5.60)	(3.75)	(3.74)	(4.80)
2nd Floor Square Feet	0.173	0.250	0.202	0.239	0.156	0.218	0.262
	(3.31)	(5.95)	(2.98)	(5.00)	(2.97)	(3.07)	(4.68)
Bedroom	19.57	-17.28	-11.80	-41.07	49.11	-1.95	-6.34
	(0.93)	(-0.90)	(-0.44)	(-1.91)	(2.47)	(-0.05)	(-0.28)
Baths	120.18	52.99	51.30	90.44	50.85	13.29	106.36
	(3.19)	(1.60)	(1.25)	(2.38)	(1.46)	(0.22)	(2.46)
Wood Shakes	47.19	102.9	127.8	123.6	384.4	149.9	133.0
	(0.95)	(2.41)	(1.63)	(3.03)	(5.99)	(1.78)	(2.09)
MCS sq ft	0.0706	0.0491	0.0465	-0.00857	--	--	--
	(2.17)	(1.76)	(1.22)	(-0.25)	--	--	--
Oil Forced Air	36.44	64.68	-96.96	98.34	9.82	125.12	172.44
	(0.66)	(0.85)	(-0.79)	(1.39)	(0.14)	(1.31)	(2.19)
Gas Forced Air	131.05	112.7	86.55	25.44	-20.95	85.88	66.73
	(2.90)	(3.11)	(1.62)	(0.60)	(-0.48)	(1.05)	(1.25)
Electric Forced Air	71.55	80.63	27.82	41.86	90.91	104.65	-14.50
	(1.77)	(1.87)	(0.46)	(1.10)	(1.69)	(1.50)	(-0.20)
Observations	126	125	133	159	163	109	109
R-Squared	0.79	0.85	0.73	0.81	0.79	0.62	0.83
Adj R-Squared	0.76	0.83	0.70	0.80	0.77	0.57	0.81

(a) Note that all coefficients have been multiplied by 1000 for presentation purposes and t-statistics are shown in parentheses.

seven regressions. The likely cause of the lack of precision in estimating the coefficient is a lack of variation in lot sizes. Most lots in a given neighborhood are very close in size, and so identifying the contribution of lot size to house value is difficult in some years. The coefficient for the number of bedrooms variable was inconsistent. One possible reason for this unanticipated result is a lack of variation in the houses sold, but this argument is less compelling than in the case of lot size. A more plausible explanation is that the assessors are not consistent in the application of the term "bedroom." Bedrooms could include any room which is not a living or dining room or only rooms currently used as bedrooms. In either case, it would be difficult to identify the precise contribution of such a diverse variable.

Finally, since the focus of much of the policy relevance of this work is on the construction of new homes, there was an examination of whether or not new homes were distinct from existing homes. A distinction between new and existing homes was introduced into the regression model in two ways. The first was simply as a dummy variable. The dummy was one if the home was new, zero otherwise. The second was to introduce the square footage of new homes as a dummy variable. If the home was an existing home, the square footage was zero. Neither approach yielded a consistent pattern across the regressions. As a result, no distinction between new and existing homes is made in the final regression model. In this sample, age appears to adequately capture vintage effects on the price of housing.

The fuel and equipment choice variables are of primary interest to Bonneville from a programmatic and analysis point of view. The heating choice variables in the hedonic regressions include four options: electric baseboard, electric forced-air, gas forced-air, and oil forced-air.[a]

(a) Several other heating types are present in the overall Tacoma area, including floor/wall gas and electric units, gas and electric heat pumps, wood heating systems, and solar designs. These systems are either present in very small numbers or not represented in our final housing sales sample. The floor/wall units present were typically about 1% of the total, and they were effectively grouped with baseboard systems. The neighborhood sampled has very few houses with wood heating or solar systems, and none were in our sample. Heat pumps were present for a small number of our observations, but these observations were eliminated because they corresponded to cases where the assessor's price data were for the lot

Therefore, we included dummy variables for the three forced-air heating types and they are coded zero-one. The excluded variable was electric baseboard heating. The system dummy variables, therefore, measure the difference between having that type of forced-air heat and having electric baseboard heat. Table 4.3 shows the estimated dollar effects for each of the years and forced-air heating types.

TABLE 4.3. Hedonic Price of Forced-Air Heat By Fuel[a]

	Oil	Gas	Electric
1981	$12,892*	$4,989	-$1,084
1982	$9,355	$6,421	$7,824
1983	$734	-$1,567	$6,797*
1984	$7,352	$1,902	$3,130
1985	-$7,249	$6,471	$2,080
1986	$4,836	$8,426*	$6,028*
1987	$2,724	$9,798*	$5,350*

(a) Estimates based on coefficients significantly different from electric baseboard heat at the 90% level or beyond are starred.

The coefficients for each forced-air system and fuel type provide the basis for estimating the value of that combination relative to baseboard electric heat. The hedonic prices associated with fuel and heating type vary from $12,892 for oil heat in 1981 to -$7,249 for oil heat in 1985. The differences between the coefficients allow us to calculate the difference in value for the different fuels. In all cases, the forced-air systems had either a higher value than the baseboard system or were not different at a statistically significant level. The relative value of an oil furnace was statistically significantly higher than a baseboard system only in 1981 and, applying weaker criteria, 1984. The value of an electric furnace was higher than the value of a baseboard system in all years except 1981, when the value was negative but not different from zero

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where a home was to be built rather than the finished house.

at a statistically significant level. The values for gas forced-air heating are generally positive, though they are not statistically significant at conventional levels until 1985-87.

The most useful comparison is made by subtracting the effect of electric forced-air heat from gas forced-air heat. Since both systems are forced-air systems, this difference estimates the pure fuel hedonic price effect. In 1987 the pure price difference between gas and electricity showed that gas had a value $4,448 higher than electric heating.[a] In 1986 gas was also favored, but by only $2,398. Interestingly, in 1983 electricity was favored by $8,364. In 1984 and 1985, the results were mixed but neither the electric nor gas furnace values were significantly different from electric baseboard heat.

The incremental value of homes built to MCS was estimated on a per-square-foot basis. This specification, rather than the total incremental value, was used for a couple of reasons. First, the cost of building to the MCS would be expected to vary with the size of a home, since larger homes would require the installation of more insulation, larger areas of upgraded windows, etc. Second, the incentive paid under the EAP varies with floor area (up to certain limits) and would therefore offset the incremental cost by an amount related to the area. The incremental MCS value per square foot is estimated in regressions for new, electrically heated homes sold from June 1984 through 1987. The parameter estimate is negative and insignificant in 1984, positive but not quite significant at conventional levels in 1985, and positive and significant in 1986 and 1987.

The ambiguous results for 1984 are probably attributable to data uncertainties. We assumed all electrically heated homes sold after May 1984 were MCS homes; however, most could have been permitted prior to MCS code implementation and grandfathered in. Without a house-by-house matching between

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(a) Our estimates of the difference in the value of specific fuels is an unbiased estimate using the data available for this study. Based on these data, the greater value for gas heating in 1986 and 1987 is significant at nearly the 90% level. The estimated differences are consistent with expectations and the probable effect of fuel prices on the hedonic prices. The precision of our estimates of this difference, however, depends on sample size and increasing the sample size in future analyses would improve the precision of our estimates.

MCS incentive records and the assessor's data, it was not possible to be certain whether a house built in 1984 was an MCS house. This mis-classification of some 1984 non-MCS homes as MCS homes is probably responsible for the difficulty in isolating the effect of MCS on 1984 home prices.

The 1985 regression is a better indicator of the value of MCS homes. The 1985 coefficient is positive and has a t-statistic of 1.2. While significant at only about the 75% level, the coefficient is of the same order of magnitude as the 1986 coefficient, which is significant.

Two years of significant MCS effects are found in the hedonic analysis. In the 1986 regression, the coefficient is significant at the 90% level. The incremental price of MCS (evaluated at the mean) implied by the coefficient is $3.73 per square foot. This means that an MCS house in Tacoma sold for $3.73 more per square foot than an otherwise identical non-MCS house. The 1987 regression locates the expected effect more precisely. In this regression the t-statistic is 2.16, significant at the 95% level. The price of MCS (evaluated at the mean) is estimated to be $5.10. The premium commanded by MCS in 1987 had grown by 36%.[a]

4.1.5 Discussion of Fuel and MCS Values

One of the important issues which has been raised in the context of residential fuel choice has been the role of the MCS. There has been considerable discussion about the fact that the Tacoma MCS was implemented at the same time that an increased number of new homes were being built with gas rather than electric heat. Several observers speculated the decline in electric heating was due to a causal link between the implementation of MCS and fuel choice. This study has found considerable evidence that this is not the case. Indeed, our results suggest far fewer electrically heated homes would have been built in Tacoma without the EAP.

Section 1 pointed out the dramatic change Tacoma has experienced in the share of new housing equipped with electric heating. From levels over 90% in

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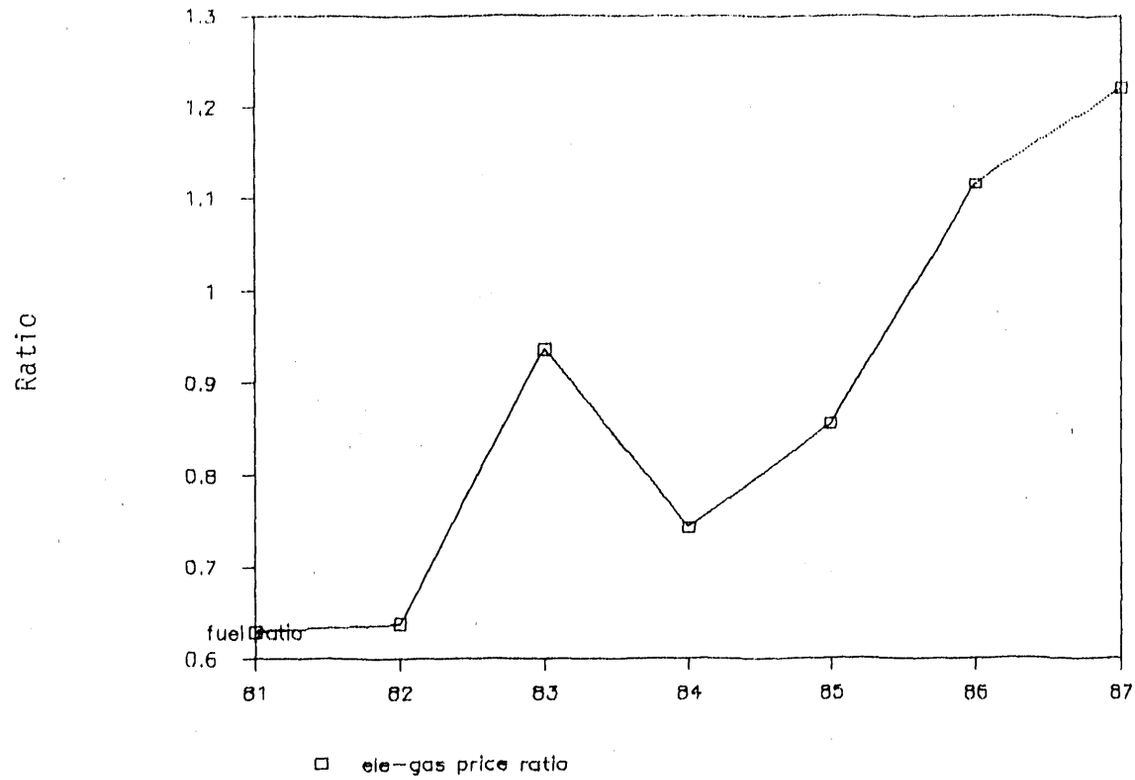
(a) The hedonic prices associated with being an MCS home indicate the premium that builders received for MCS houses. In general, it is not reasonable to believe that either $3.73 or $5.10 are the exact measures of the MCS premium, but it does appear that the premium is in the $3.00 to $5.00 range.

the early 1980s, the share of new homes in Tacoma equipped with electric heating had declined to around 55% by 1987. Section 3 noted that occupants of new homes rate cost as the major factor in their evaluation of different fuels and that over half considered electricity to be the most expensive fuel. Our hedonic price estimates are consistent with the heating-fuel trends, and it appears from Figure 4.2 that trends in heating-fuel prices may largely explain the shift to natural gas. The figure shows the difference in the hedonic prices (electric value minus natural gas value) and the ratio of electricity prices to natural gas prices (the ratio was adjusted to an equivalent energy basis by assuming 70% efficiency for natural gas furnaces) from 1981 to 1987. Though the correspondence between the price ratio and the difference in fuel values is not perfect, there is a clear trend toward higher electricity prices and a lower valuation of electric heating. The pivotal period is around 1983. Between 1982 and 1983, the ratio of electric-to-gas prices jumped over 50%, and suddenly electricity was about the same price as natural gas. It has since increased to a level over 20% higher than gas. From 1983-on, the relative value of electric heating declined until 1985 through 1987, when gas-heated homes commanded a premium of about $4,000. Though not the only factor affecting residential fuel choice, it appears that relative fuel cost has played a major role in determining the shares of homes equipped with electricity or gas heating fuels.

In mid-1984, the Tacoma EAP began, and all new electrically heated homes were built to the MCS. If the MCS code had not been in place, our results suggest that the differential in housing value simply due to fuel type would have approached $4,500 in 1987. The effect of MCS has been to make electric houses about $4-$5 per square foot more valuable than they would have been without the code. Because they are more efficient, buyers are willing to pay more for MCS homes than otherwise comparable homes. The premium buyers are willing to pay for MCS homes more than offsets the reduction in their value due to their being electrically heated. This offset translates into a higher demand for MCS homes than would have been observed for new electrically heated homes if the EAP were not in effect.

The regression results indicate that the shift in advantage from electricity to gas is the result primarily of pure differences in fuel values; the introduction of MCS was merely coincident with this shift and did not cause it.



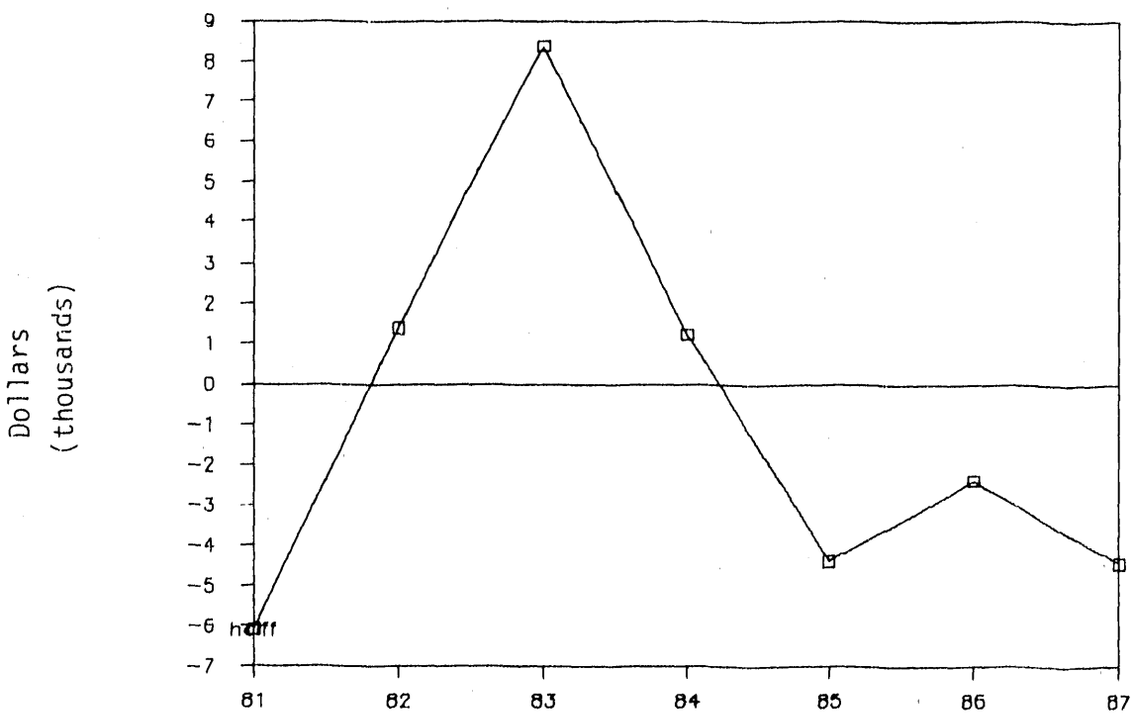


FIGURE 4.2. Fuel Price Ratio (Electricity/Gas) and Difference in Hedonic Prices (Electricity - Gas)

If anything, introduction of the MCS has helped maintain electricity's share of the new-home heating market.

Our results also can be interpreted from the builder's viewpoint. One way to use these results is to analyze the builders "accounting" sheet for the fuel choice. A builder who could estimate reasonably well how much buyers were willing to pay to have different heating fuels (Section 2 suggests that builders are quite sensitive to the demands of buyers) could calculate what the profit margin would be for either gas or electric housing in any particular year. A useful example is 1987. Table 4.4 shows the calculations for 1,000 and 1,500 square foot houses.

The results indicate that in 1987, houses around 1,500 square feet were most profitable if they were built with electric, rather than gas, forced-air heat and received the MCS incentive. If the incentive had been dropped, electrically heated homes would have been about as profitable as gas-heated houses. On the other hand, smaller houses were somewhat less profitable to build with electric heat. If the MCS incentive had been dropped, small electrically heated houses would have returned about $1,300 less profit than gas-heated houses. Calculations for 1986 show similar results.

4.2 EFFECT OF HOME BUYER ATTITUDES ON FUEL CHOICES

There are many goods - usually durable goods - which are purchased one at a time by individual consumers. In these cases, the choice is not how much of the good to purchase, but rather which brand and model best fits the consumer's needs. There are a large number of different types of discrete choice models in the econometrics literature that have been applied to model this process. The most common approach is the logit regression technique. This is the approach to modeling fuel choices by individual consumers that is used in this analysis.

4.2.1 Modeling Attitudes, Prices, and Fuel Choice

Fuel choice by Tacoma early adopters is primarily a discrete choice. Once they have chosen a particular fuel, it is quite costly to change. Of course, the analysis of discrete choices is not limited to fuel choices. It has wide applicability. As a result, there is a considerable body of research developing tools appropriate to this problem.

TABLE 4.4. Sample Builder Financial Calculations[a]

	Gas	Electric	
1987 Calculations		1500 sq.ft.	1000 sq.ft.
Fuel hedonic price differential	$4,448	0	0
MCS hedonic price differential	0	$7,650	$5,100
MCS construction cost effect	0	-$3,000	-$2,000
MCS incentive	0	$1,500	$1,000
Total net profit	$4,448	$6,150	$4,100
1986 Calculations			
Fuel hedonic price differential	$2,398	0	0
MCS hedonic price differential	0	$5,595	$3,730
MCS construction cost effect	0	-$3,000	-$2,000
MCS incentive	0	$1,500	$1,000
Total net profit	$2,398	$4,095	$2,730

(a) The calculations assume MCS homes cost an additional $2 per sq.ft. to build and that incentive levels are $1 per sq.ft. The difference between electric and gas forced-air system coefficients represent a pure fuel effect if the mechanical portion of the electric and gas forced-air systems are equal in cost.

The most common tool is a technique known as logistic (or logit) regression. Logit regression models have two useful features in the context of this study. The first is that they allow the roles of each attitude and the various measures of cost in the individual's decision to be quantified. Once quantified, these can be compared in a meaningful way. Even though the attitude measures are ordinal, their parameter estimates can be compared to the cost measures parameter estimates and their relative importance to the decision-maker compared. Second, fuel choice actions and desires can also be compared in this approach. This is accomplished by comparing the parameter estimates for one logit regression

estimated for the fuel actually used and a second model estimated based on fuel preferences.

In the context of this study,the model was applied to the EAP jurisdiction survey in Tacoma. This application assumed that the discrete choice of fuel depended on both external factors (fuel cost and hedonic price) and internal factors (fuel attitudes). The specification of the model included the attitudes towards the fuels as described in the questionnaire and the costs of the fuels. Two specifications of the cost of fuels are included. The first was the average residential price, and the second was the hedonic prices discussed in Section 4.1.

The logit regression model was applied in two different ways. The first was to apply the model to explain the relationship between attitudes, costs, and the fuel in the house. The second was to relate attitudes and costs to the preferred fuel which, of course, was not necessarily the fuel in the house.

4.2.2 Data

The data for the analysis came from three sources. The first was the EAP questionnaire. The complete questionnaire is discussed in Section 3. The second source of data was the hedonic price results. These are documented in Section 4.1. Finally, the residential natural gas and electricity prices for the last 4 years were collected from the utilities.

In the context of this analysis, the important parts of the questionnaire were those concerning attitudes towards fuels. Attitudes towards eight different characteristics of fuels were obtained on a fuel-by-fuel basis in the questionnaire. To insure the integrity of the answers, the attitudes were asked as positives in some cases and as negatives in other cases. In each case, the respondents answered 1 if it was a poor description to 4 if it was a good description. The eight characteristics which respondents were asked to rate are listed below:

- fuel is low cost
- fuel is efficient
- fuel is unreliable
- how hassle-free the fuel is to use
- the safety of the fuel

- how polluting the fuel is
- the heating evenness and comfort of the fuel
- fuel has an unpleasant odor

These questions were asked with regard to both electric and natural gas.

The raw attitudinal data were used to create a new set of relative attitudinal variables. The new variables were constructed by subtracting the electrical score from the gas score.[a] For example, if individual i ranked electric comfort at 3 and gas comfort at 2, the adjusted comfort score would be -1. This composition of the attitudinal data allows the number of variables which need to be considered to be reduced considerably. It also allows the analysis to focus more tightly on the differences between the fuels. Since the raw rankings are ordinal, focusing on the differences also allows simpler interpretation of the results.

The fuel prices were obtained from the respective utilities. The fuel prices were put on a common footing by converting therms into kWh using a factor of 29.3. The electric prices were further adjusted downward by 70% to account for the combustion efficiency of natural gas when used for heating. These fuel prices were combined with the attitudinal data in the estimation procedure.

4.2.3 Analytical Results

The model was applied in two cases. The first was to examine the actual fuel in the house and the relative prices and individual attitudes. The second was to examine the individual's preferred heating fuel. This approach allows the factors influencing the actual fuel and the preferred fuel to be compared.

Table 4.5 shows the final results. A number of other specifications were examined. These included all of the differenced attitudinal variables, as well as other demographic variables and other housing characteristics. The reported regressions predict choices well and seem to conform to reasonable prior expectations about model specification.

(a) The best way to handle ordinal variables of this type is to create a set of dummy variables, one for each category of response for each question. However, this would have created forty variables in this application. Since there were less than 100 observations, this approach could not be supported by the data.

TABLE 4.5. Logit Regression Results[a]

Dependent Variable = 1 if gas; 0 if electricity

Independent Variable	Actual Fuel	Preferred Fuel
Constant	-6.698*	-1.363
	(-2.041)	(-0.442)
Low cost difference	0.516*	0.900*
	(2.327)	(3.487)
Safety difference	0.946*	0.791*
	(2.901)	(2.824)
Male education	-0.271	-0.111
	(-1.547)	(-0.623)
Male age	0.04286	0.01986
	(1.581)	(0.695)
Female age	0.2996	0.272
	(1.467)	(1.253)
Number of bathrooms	1.678*	-0.151
	(2.562)	(-0.248)
Adjusted fuel price	-0.0239	0.02008
	(-0.577)	(0.456)
Pure hedonic fuel price	52.930	-23.351
	(0.804)	(-0.555)
Pure hedonic fuel price squared	-0.0786	-80.0336
	(-0.968)	(-0.133)
log likelihood	-41.8	-38.6
number of observations	92	82
percent correctly predicted	81.52	79.27

(a) Starred coefficients are significant at the 90% level or beyond.

The individual's perceived cost is always a statistically significant factor in fuel choice. The difference in perceived safety is also an important factor in both regressions. The three demographic variables, male and female ages and male education, while significant at only about the 85% level, also are important indicators of fuel choice. The number of bathrooms is important in the actual fuel-choice equation. Its statistical significance and parameter estimate are fairly robust with respect to model specification, and it is included, therefore, without strong prior expectations about its role in fuel choice. The statistical significance of this parameter is interesting, however, given that the coefficient suggests that gas water heating is preferred when the number of

bathrooms increase, and survey results (Section 3) indicated that many respondents preferred gas water heaters because of a perceived quicker recovery rate.

The final set of variables in the choice regressions are price variables. The price variables are specific to the year the house was bought. These include the adjusted fuel prices, the hedonic price of the fuel, and the hedonic price squared. The hedonic price squared is included to capture non-linearity in the effect of the hedonic price on the fuel choice.

The adjusted fuel price difference is negative in the actual fuel choice regression and positive in the preferred choice regression. The size of the parameters is about equal. In general, this result holds true with changing model specifications. The negative coefficient in the actual choice regression is the expected one: as gas becomes more expensive relative to electricity, the likelihood of choosing gas goes down. The difficulty this application faces is that only four price differences (for the years 1984 to 1988) are represented. The lack of precision of the parameter estimates and the apparent wrong sign of the coefficient in the preferred fuel case are most likely due to the lack of variation in the data. An expanded sample, either cross-sectionally or inter-temporally, would increase our ability to discern the effect of fuel prices on individual choices.

A second set of fuel prices, the hedonic prices from the previous section, are also entered in the equation. These variables do not seem to perform well either and they also suffer from a lack of variation in the data.

The regression for actual fuel conforms to expectations about the hedonic price effect. The pure hedonic price effect is positive, and the squared term is negative. Although both are measured with modest levels of precision, the results are robust with respect to model specification. In the regression for the preferred fuel, the results differ from expectations and are less satisfactory. Both coefficients are negative, and both have markedly reduced levels of significance.

Overall, the model based on the actual fuel choice has the theoretically preferred signs for the variables of interest and predicts choices quite well. When the model is developed based on the stated fuel preferences, however, the

model seems to be reduced. Basically, the only variables which perform well in the preferred fuel model are the self-held beliefs about fuel safety and cost. One explanation for this lies in the way in which the data were gathered and organized. The regression using the actual fuel choice related the actual prices in the year the choice was made to the choice. The preferred fuel model, however, related the preferred choice to the prices when the owner bought the current house. Since many of these interviewees bought their homes two, three, or four years ago, fuel prices from those years need not be particularly good indicators of what people would choose today.[a] On the whole, and restricting our observations to the actual fuel choice, the estimation results conform with reasonable expectations about the effect attitudes and prices would have on fuel choice.

4.3 OBSERVATIONS

This chapter has presented two exploratory analyses of fuel choice behavior in Tacoma. The first addressed the role of fuel type and the MCS on the selling price of homes in the housing market. The second addressed individual choices and preferences.

The analysis reported in Section 4.1 indicated that heating fuel type affects selling price and its effect appeared related strongly to relative fuel prices: when the relative price of a given fuel was low, home buyers were willing to pay more for a home heated with that fuel.

The analysis also showed that buyers were willing to pay a premium for homes built to the MCS. MCS homes cost about $3 to $5 more per square foot than conventional electrically heated homes.

Though the share of new homes in Tacoma heated with electricity has fallen substantially in recent years, the trend appeared to be dominated by the effect of recent increases in electricity prices. Rather than being a contributing factor to the decline, our results suggested that adoption of the MCS has made

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(a) Of course, the best approach is to relate today's fuel prices to the preferred fuels. However since this study examines only Tacoma, there would be only a single set of prices and estimation is impossible.

new electrically heated homes more economically attractive to buyers and has probably helped maintain electricity's share of the new home heating market.

The analysis of individual choices and preferences incorporated attitudinal survey data to determine the effect of attitudes and cost factors on home buyers' behavior. Fuel costs were the overriding factor in both choices and preferences. Safety considerations also played a statistically significant role.

Because these findings are based on limited data, they should be considered preliminary, but they are indicative of the relative importance of different factors in home buyers' fuel choice. The hedonic analysis has shown that the impact of Bonneville programs can be identified and their effect on housing markets quantified. Both the precision and generalizability of the initial findings can be improved by increasing the sample size and extending these analyses to other areas in the region. The individual choice analysis provided results that were in accordance with prior expectations, but the results were not as statistically significant as would be desirable. Increased sample size in future analysis would improve the validity and reliability of these results as well.

5.0 IMPLICATIONS FOR POLICIES, PROGRAMS, AND FUTURE RESEARCH

The primary purpose of this study was to provide an initial assessment of the residential fuel choice in the Early Adopter Program jurisdictions and identify research issues that merit further exploration. To fulfill this purpose, our study has collected household attitudinal and behavioral data, builder perceptual information, and housing economics data.

Recent Bonneville programmatic decisions have been based on several assumptions about the response of the housing market and fuel choices to implementation of MCS programs. Bonneville has assumed that the costs of building MCS homes will decline as builders become more familiar with constructing to the standards. Bonneville has assumed also that buyers will seek out MCS homes as familiarity with their cost and comfort benefits increases and that the benefits will be increasingly reflected in the resale market.

Our study does not provide a definitive test of these assumptions. It has shed light, however, on their validity.

The household survey suggests that homeowners pay attention to fuel type in buying homes and appliances. Cost appears to be the overriding factor in determining fuel type. Results for Tacoma suggest that relative fuel prices are reflected in home selling prices, and the value of homes with different heating fuels can change dramatically in a relatively short period of time as relative fuel prices change. Though all factors posed to the survey respondents were considered important in their fuel choice, safety and dependability, along with costs, were the most important considerations.

Though MCS homes both entail a specific fuel (electricity) and increased energy efficiency, the effect of MCS on the selling price can be separated from the effect of fuel type. In Tacoma where the experience with MCS homes is the longest, buyers of new homes are willing to pay substantially more for an MCS home than a lower efficiency, electrically heated home.[a] It appears that buyers are willing to pay even more for MCS homes than the additional

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(a) We were unable to estimate the contribution of market supply and demand separately to the observed price differential, but the estimated value represents the premium being paid by buyers.

construction cost would imply. We did not attempt to determine how the resale market responded to the increased efficiency of MCS homes.

Information from builders suggests that they are already finding ways, over a period of 3 to 4 years, to minimize the costs of complying with the MCS. It is likely that builders who have adapted to the MCS requirements could continue building MCS homes profitably without substantial incentives.

Based on regional data, households typically prefer electricity for heating and appliance use. Electricity rates better than natural gas in safety, pollution, convenience, and odor. Households in the EAP areas analyzed in this study, however, prefer gas to electricity for heating. Gas rates better in terms of cost, and cost appears to be the preeminent factor affecting fuel preference.

Other results suggest that home buyer fuel preferences and behavior may respond quickly and significantly to outside forces. Household survey responses indicate a substantial potential for changes in fuel preferences in new homes. Fuel choice trends in Tacoma show that where the historical cost advantage of electricity has eroded, the market may shift toward a significantly larger share for gas heating in new homes. And builders indicate that when a buyer or the market expresses a fuel preference, the builders are more responsive to that preference than other factors in deciding which fuel to install. In existing homes, the share of homes likely to switch fuels in a given year is small, but the number of homes that switch fuels is comparable to the number of housing starts.

The potential for switching from electricity to gas, given current fuel prices and trends, is also illuminated by the fact that households with gas heat appear far more satisfied with that fuel than households that have electric heat. Over the region surveyed, 30% of the households with electric heat indicate a preference for natural gas, whereas only 4% with gas heat indicated they preferred electric heat.

Our study results are necessarily limited by the constraints of the study. The survey instrument we used was designed for the companion study (Harkreader and Hattrup 1988), so it was not tailored to answer some potential questions

related to residential fuel choice.[a] For example, how buyers would respond to different types of incentives or what sources they rely on for fuel information were not examined. The builder information was limited, unfortunately, to builders of electrically heated homes because builders of gas-heated homes did not follow through on their plans to attend the focus groups. Consequently, the perceptions and attitudes attributed to builders only reflect part of the industry. The analyses of energy-efficiency and MCS effects on housing prices are based on data from Tacoma only; we do not assume that they are valid for other parts of the region.

Both the study findings and the limitations affecting the study suggest areas for fruitful additional investigation. The fundamental objective of additional research would be to provide Bonneville with the information that can be used to understand and predict the relationship between adoption of the residential MCS and residential fuel choice. This information will provide a foundation for Bonneville program decisions related to structure, incentives, and timing.

Additional research should focus initially on extending the analysis in two areas: attitudes and preferences of builders and buyers and the economics of the housing market. The results presented here indicate that buyers are the key decision-makers in residential fuel choice. Though builders play a major role also, they are driven primarily by buyers' preferences, either as expressed through the market or as expressed by individual buyers.

The results of the current study can be used to identify issues related to buyer fuel preferences and attitudes that should be further examined. Information sources relied upon by buyers should be identified and their importance in shaping buyer perspectives should be determined. These issues and apparent inconsistencies in the responses to the survey should be addressed further. Other factors that buyers associate with a fuel being economical, such as expectations about fuel price trends and operating costs, should be addressed. Since more than half the households questioned indicated that they played a role in fuel selection, more information on how buyers of custom and

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(a) Since the survey instruments were identical, however, the results could be compared directly, and this provided clear benefits.

semi-custom homes view different fuels would be essential. Finally, information collected from homeowners should be used to assess the tradeoffs they make among fuels and their preferences for different types of incentives and promotions tied to the MCS. Data for this study have suggested that buyers' fuel preferences are quite responsive to fuel prices and, therefore, operating costs; as a result, incentives that reduce monthly operating costs, rather than lump sum payments, might be more attractive to buyers.

The economics of the housing market should be analyzed further. One focus should be on improving the reliability of the initial findings for the Tacoma market. Indications from the present study were that buyers paid about $4 to $5/sq.ft. more for MCS homes. Additional areas within Tacoma should be analyzed to verify this estimate and increase the precision of the estimate. The analysis in Tacoma should be expanded to also address the effect of new custom homes on the value estimated for MCS homes. The effects of fuel prices in Tacoma and other areas should be investigated, since the present study suggests that relative fuel prices have a large effect on the sales price of homes. These analyses should be extended to other locations, in addition to Tacoma, distributed across the Bonneville service area.

Other issues need to be addressed to provide Bonneville an adequate capability for assessing and predicting responses and impacts of MCS on residential fuel choice. The limited information now available on builder perspectives and roles needs to be expanded. Specifically, the behavior of builders who typically install gas heating should be determined. This initial study suggests that builders may respond favorably to incentives related to fuel type, but a better understanding is required of the actual response to such incentives and issues related to implementing such an approach. Builders also have some influence over buyer fuel preferences, and this role and its effect should be investigated. Buyer perceptions about heat pumps may be very important in future programs by Bonneville or the utilities that address the selection of heat pumps as the heating system. Our current results suggest that inconsistencies exist in household perceptions of heat pump costs. The market for heat pumps, consumer cost considerations, and consumer experiences need to be characterized to permit better program design and predictions. Initial comparisons with the results of the regional survey were conducted for

this study; more detailed analysis of the regional data should be made to determine if fuel preferences and choices behave in the same way they do in the EAP jurisdictions. This study's results indicate there may be considerable potential for fuel switching in the residential sector as households select new homes, appliances, or heating equipment. Modeling of fuel choices should be expanded and refined to increase the predictive ability of models for estimating what fuel consumers prefer and choose.

In general, this study and additional research can provide the basis for Bonneville to develop the capability to assess and predict fuel choices and programmatic impacts. Ideally, research in this area would lead to quantitative and qualitative tools that could form a modeling capability to predict the penetration of different fuels in the residential sector under different circumstances. Such a capability would have considerable benefits for Bonneville, planning groups in the region, and utilities who have a need to assess and forecast energy demand, resource needs, and programmatic impacts.

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APPENDIX

CONJOINT ANALYSIS AND SURVEY INFORMATION

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CONJOINT ANALYSIS AND SURVEY INFORMATION

FOCUS GROUP PARTICIPANT CHARACTERISTICS

The characteristics of builders attending the focus groups and participating in the conjoint analysis are summarized in Table A.1. All builders were from the Tacoma area.

TABLE A.1. Participating Builder Characteristics

Participants' ID	01	02	03	04	05	06	07	08	09	10	11
No. of '87 Units	140	100	3	4	34	28	2	8	7	2	16
% Single Family Tract Homes	0	95	100	100	0	70	100	75	100	50	63
% Single Family Custom Homes	4	5	0	100	0	15	0	25	0	0	0
% Multi-Family	96	0	0	0	100	15	0	0	0	50	37
% Electric Heat	100	100	100	100	100	95	100	100	100	100	100
% Electric Water Heater	36	100	100	100	100	95	100	100	100	100	100
% Gas Heat	0	0	0	0	0	5	0	0	0	0	0
% Gas Water Heater	64	0	0	0	0	5	0	0	0	0	0
Position in Company	Pres	Pres	Pres	Pres	Pres	Pres	Pres	Pres	Mgr	Pres	Mgr

CONJOINT ANALYSIS

Conjoint analysis is a method of comparing the relative importance of the factors influencing a decision. Conjoint studies assume that behavior can be described, in most cases, by simple additive models involving estimated values called utilities. (Conjoint studies also can include interactions among the factors.) Also, these utilities can be estimated by presenting respondents with compound stimuli which force them to tradeoff various levels of the influencing factors. Each factor influencing a decision can have several different attribute levels. For example, one factor that may influence the fuel choice decision is the price of the home. This factor can have several different levels (e.g., $50,000, $75,000, etc.).

There are two general methods to present the respondents with stimuli for conjoint analysis: the trade-off presentation and the full profile presentation. The trade-off presentation allows the respondents to rank or rate their preferred attributes through a pair by pair comparison of the influencing factors. For example, the respondents could be asked to consider what features they prefer for an apartment. The features and feature levels are presented to the respondents in matrix format (see Figure A.1) and they are asked to rank their preferred combinations in each matrix.

The full profile presentation combines all of the features for the respondents' consideration into one profile and each profile is created with different combinations of the feature levels. The respondent is then asked to rate or rank each individual profile. For the above example, 27 profiles would be created; each having a different combination of levels for the three features. The respondent would then rank (sort by preference) or rate (assign a relative preference value to) each of the 27 profiles. This method increases the burden

		No. of Bedrooms 1	2	3
No. of Bath-rooms	1	9	5	6
	2	7	1	3
	3	8	2	4

Rankings

		No. of Bedrooms 1	2	3
Rent	300	5	6	9
	350	1	3	7
	400	2	4	8

Rankings

		No. of Bathrooms 1	2	3
Rent	300	5	1	2
	350	6	3	4
	400	9	7	8

Rankings

FIGURE A.1. Trade-off Analysis for Apartment Features (Hair et. al 1979, p. 306)

on the respondent as the number of features and attribute levels increases. A full profile design using the number of factors and attribute levels in this fuel choice study would require the respondents to consider 972 profiles. For this reason, fractionated designs are used to reduce the number of profiles to a manageable number. In fractionated designs, the sample of profiles is randomly selected via statistical designs called orthogonal arrays that assume independence between factors and allow the least amount of error in estimating the utilities ("Conjoint Analyzer, Version 2" 1987).

The algorithms used to analyze the data collected in a conjoint study vary depending on the assumptions the analyst is willing to make about the statistical power of the data. Originally, conjoint data were analyzed using non-metric techniques (i.e., they required no assumptions about the properties of the distribution of the data) such as monotone regression, MONANOVA, (Kruskal 1965) or LINMAP (Srinivasan and Shocker 1973). The non-metric nature of the data was assumed due to the ranking procedures of data collection.

Over the past 20 years, the assumptions of conjoint analysis have taken a pragmatic turn. Having respondents rate attribute levels and using metric techniques of analysis are the prevailing methods for conjoint analysis today. Using a rating scale, as opposed to a ranking task, permits one to generate predicted choices with equivalent reliability but requires fewer respondent judgments, thus simplifying the task for the respondent. Assuming quasi-metric data allows use of metric techniques that take advantage of the quasi-interval properties of the data that non-metric techniques would treat as statistical "noise." "Non-metric routines may be losing popularity simply because they do not appear to help predictions" (Huber 1987).

The method used in this study is a fractionated profile presentation. The respondents were asked to rate 25 profiles. The utilities for each of the factors and attribute levels were estimated using an ordinary least squares regression technique using a type of dummy coding called effects coding. The effects coding constrains the levels of each feature to sum to zero.

EAP FUEL CHOICE SAMPLE AND SURVEY METHODOLOGY

The EAP fuel choice survey is a telephone survey of EAP households. The sample was drawn from lists of addresses of new single-family dwellings in eight EAP regions. The list from each region included the homes built since the adoption of the EAP building guidelines. Names and telephone numbers for the addresses were supplied by area utilities and county assessor offices. Not all addresses were occupied. The sampling plan called for contacting all the homes in every region except Tacoma. From the Tacoma lists, a random sample of electrically heated homes and a separate sample of gas heated homes was to be drawn. Enough of these homes were to be contacted to fill the quotas for the survey. The total number of completed surveys was to be 350; 250 electrically heated homes and 100 gas heated homes. After exhausting the lists from all eight regions, 238 interviews were completed. Table A.2 shows the breakdown of households by primary heating fuels by region.

The total number of EAP households from the lists is approximately 800. Table A.3 shows the number of EAP homes that completed the survey from each region. The number of completed interviews is about 28% of the entire number of EAP households.

TABLE A.2. Primary Heating Fuel Use by Region

Region	Electricity	Natural Gas	Wood	Oil
S. Idaho	20.6%	3.4%	2.5%	0.0%
W. Washington	40.8%	26.9%	4.2%	0.4%
Totals	61.4%	30.3%	6.7%	0.4%

TABLE A.3. Number of Completed Surveys by EAP Region

	Number of Completed Surveys	Percent of Sample
Bingham County, ID	9	3.8%
Bonneville County, ID	14	5.9%
Blackfoot, ID	1	0.4%
Idaho Falls, ID	40	16.8%
Fife, WA	0	0.0%
Cheney, WA	0	0.0%
Milton, WA	10	4.2%
Tacoma, WA	164	68.9%

ANALYSIS OF VARIANCE TECHNIQUES

Friedman's analysis of variance is used to test the hypothesis that consumers have different perceptions of the various heating fuels. Friedman's two-way analysis of variance by ranks is an appropriate test for the analysis of variance between matched samples when the data are in at least an ordinal scale. It is a nonparametric test that approximates a Chi-square distribution (Siegel 1956, p. 168).

The respondents rated eight heating fuel attributes for each of four separate heating fuels. The respondents were asked to rate how well the attribute described the fuel in question on a four-point scale ranging from a poor description (1) to a very good description (4). The respondents' ratings of each attribute for each fuel and the summation of ratings across all attributes for each fuel were tested for statistically significant differences.

The Kruskal-Wallis one-way analysis of variance by ranks is used to test for differences between perceptions of the importance of the fuel attributes and the perceptions of the different fuels across segmenting variables (fuel type, region, etc). The Kruskal-Wallis one-way analysis of variance by ranks is used to test whether k independent samples are from different populations. The Kruskal-Wallis analysis of variance technique requires at least ordinal level data and approximates a Chi-square distribution. For segmentation schemes that involve only categorical data the Chi-square test of independence and the lambda test for association are used.

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