The Economics of Residential Space Heating

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This paper reports on the evaluation of a residential fuel switching program undertaken jointly by B.C. Hydro and the natural gas utilities in British Columbia. This program provided incentives for the installation of natural gas space heating in new multi-family residential construction. The paper focusses on three key issues: the determinants of space heating fuel choice; the costs and benefits of the program in terms of customer value and economic efficiency; and the impact of the program on environmental sustainability. Key findings include the following. First, the main determinants of space heating fuel choice include relative capital costs of space heating equipment, fuel costs and dwelling type. Second, participants benefitted from the program since the present value of additional natural gas costs plus customer net capital costs was less than the present value of reduced electricity consumption. Third, the program had a positive net present value on a total resource cost basis, ie. the program met the key utility planning test for British Columbia. Fourth, the program had significant negative external effects due to the green house gases and local pollutants associated with the use of natural gas space and water heating. The program failed the societal test due mainly to the costs associated with additional CO_2, SO_2 and NO_x.

INTRODUCTION

In recent years, natural gas has become the favoured fuel for space heating and water heating in single family dwellings in British Columbia. However, natural gas has achieved more limited penetration in apartment units. This limited penetration of natural gas in apartments appears to be due to a variety of market barriers. To address these market barriers, B.C.Hydro and the gas utilities in British Columbia implemented a pilot fuel switching program called Residential Natural Choice. The Residential Natural Choice pilot subsidized installation of natural gas space and water heating in new multi-family residential construction.

This paper provides selected results from the evaluation of this pilot. The paper is structured as follows. The next section provides a description and overview of the pilot. The succeeding four sections cover the approach of the study, space heating fuel choice, costs and benefits, and environmental impacts. The final section provides a conclusion.

BACKGROUND

Background and Rationale for the Pilot

In British Columbia, natural gas has a number of advantages as a heating fuel over electricity. First, although natural gas requires higher initial or capital costs, life cycle costs for natural gas are often lower than electricity. Second, if natural gas is used as the incremental fuel source to produce electricity, it is usually more efficient to use natural gas directly as a heating fuel rather than using it indirectly by first producing electricity. Third, burning natural gas directly for heating may reduce harmful emission volumes.

Although it has these advantages, natural gas has made only limited inroads as a heating fuel in multi-family dwellings. There appear to be market barriers preventing a higher rate of market penetration for natural gas in multi-family heating applications. These barriers include the difficulty that developers have in recouping higher capital costs for natural gas space and water heating through higher selling prices or higher monthly rents and possibly lower levels of knowledge of energy efficiency among first-time and off-shore buyers who make up much of the market for multi-family units.

Pilot Description

The goals of the Residential Natural Choice pilot were to promote natural gas as a space and water heating fuel and to gain an understanding of the impact of alternative incentive levels on heating fuel choice. The pilot began in September 1991 and remained open for subscription until March 1992. Pilot design emphasized the following features. First, incentive costs were shared between B.C.Hydro and the gas utilities. Second, the pilot was not narrowly limited with respect to location to get as wide a range of experience as possible. Third, incentive levels offered were deliberately varied to gain an understanding of take-up at varying incentive levels. Fourth, the program was targeted at apartment developments, although rowhouse developments were also eligible.

Because of the pilot nature of the initiative, there was no initial widespread advertising. Instead, major developers were individually approached and informed of the nature and purpose of the pilot. Participating buildings had to use natural gas for both space heating and water heating, although incentives were offered only for the incremental capital costs of space heating. Any natural gas fireplaces installed had to have an efficiency of at least 65 percent. When a proposal from a developer was received, it was carefully reviewed to gain an accurate understanding of the likely reduction in electricity consumption, the increase in natural gas consumption and the incremental capital costs involved. Following this review, a decision was made on whether or not to offer an incentive for the project, and, if an offer was made, the level of the incentive. An initial interest was expressed for some 30 developments. Offers were made for 21 of these developments and agreements concluded for 15 projects. These included 14 apartment projects and one rowhouse project.

METHODOLOGY

This paper examines three main issues: first, the determinants of space heating fuel choice; second, the costs and benefits of the Residential Natural Choice pilot; and, third, the environmental impact of the pilot in terms of greenhouse gases and local emissions. It should be noted that although the pilot affected both space heating and water heating decisions, only the impact on space heating is considered here.

Multiple lines of evidence approach were used in the study. In other words, for each issue, several data sources were used since no single data source provided adequate information on the issue. These data sources included program records, preprogram baseline surveys which included information on fuel choice in new housing developments, client surveys, site audits and previous environmental impact studies. The main data analysis techniques used were discrete choice modelling, cost benefit analysis, and engineering algorithms. Table 1 summarizes the key evaluation issues, together with the data sources and methodologies employed in examining the issues. These are discussed in detail in the following sections.

SPACE HEATING FUEL CHOICE

Model and Data

Fuel choice in residential households has been examined in several previous studies. These include Cambridge Systematics (1982 and 1984), Dubin and McFadden (1984), Gately (1980), Goett (1978), and Tiedemann (1994). These studies have generally fitted logit or multinomial logit models to national samples of household data on appliance saturations, fuel prices and fuel choices. Samples have generally been restricted to single family dwellings because of data limitations. These studies have found that the major determinants of fuel choice include fuel prices and capital costs for relevant alternatives.

In modelling space heating fuel choice, a discrete choice model is needed since builders and developers have a discrete number of alternatives from which they can choose. In the case at hand, natural gas and electricity are the only energy sources used to any significant extent in new residential construction in the areas where the program was marketed. Fuel oil, propane and wood are not used to any significant extent in new dwellings. The dependent variable is thus a simple binary one, ie. a ‘‘1’’ if natural gas space heating is used and a ‘‘0’’ if electric space heating is used.

A review of the papers cited above together with interviews with developers suggested that there were a number of possible determinants for space heating fuel choice. These included five variables which are used in the statistical modelling. These include: the incremental per unit capital cost

Table 1. *Major Evaluation Issues, Data Sources, Methodologies*

Evaluation Issues	Data Sources	Methodologies
Determinants of space heating fuel choice	Program records Client survey Baseline surveys	Discrete choice modelling
Costs and benefits of the program	Program records Survey of developers Site audits	Cost benefit analysis
Environmental effects of the program	Program records Site audits Bridges report	Engineering algorithms

of natural gas space heating; the price of natural gas; the price of electricity; whether the development was a rowhouse development; and whether the development was a single family home development. In preliminary work several other possible determinants of space heating fuel choice were also considered. These included: owner occupied versus rental housing; market housing versus social (ie. subsidized) housing; number of housing units in the development; and average size of the units in the development in square feet. None of these proved to be significant, so they were omitted from further regressions. The sample consisted of 194 housing developments for which suitable information was available from a series of B.C.Hydro surveys of developers. These housing developments were completed in the years 1990, 1991, 1992, 1993 or 1994. Variables included in the model and sample characteristics are shown in Table 2.

Model Estimation and Results

The model was estimated using both a logit model and a probit model. When the dependent variable is a discrete one, both the logit model and the probit model possess superior statistical properties to ordinary least squares (Amemiya 1981, Johnston 1984). The logit model and the probit model differ in their assumptions about the nature of the residuals. The probit model assumes that the residuals have the standard normal distribution with mean 0 and standard deviation 1, while the logit model assumes that the residuals have the standard logistic distribution with mean 0 and standard deviation about 1.7. The models were estimated by maximum likelihood using the Newton-Raphson method. In each case, the model converged in five iterations.

The regression results are reported in Table 3. The asymptotic t-ratios are shown below the regression statistics. Since maximum likelihood estimation is used, the familiar F-statistic is replaced by a likelihood ratio statistic which is equal to [-2 times (log likelihood restricted minus log likelihood unrestricted)]. The likelihood ratio statistic has the chi-squared distribution with degrees of freedom equal to the number of restrictions, in this case five. The coefficients all have the expected signs, and all coefficients except the constant are statistically significant. An increase in the incremental capital cost of natural gas space heating or an increase

Table 2. *Definition of Variables and Sample Characteristics (n = 194 developments)*

Variable	Definition
Space	Natural gas heating = 1, electric heating = 0
Capcost	Incremental per unit capital cost of natural gas space heating in 1992 C dollars
Gaspric	Price of natural gas in 1992 Canadian dollars per GJ
Elecpric	Price of electricity in 1992 Canadian cents per kW.h
Row	Rowhouse development = 1; other = 0
Single	Single family = 1; other = 0

Source: Tiedemann 1995, 388.

Table 3. *Space Heating Choice Model (dependent variable is natural gas space heating = 1, electric space heating = 0)*

Variable	Logit Model	Probit Model
Constant	1.1957 (.1180)	.4542 (.078)
Capcost	−.0092*** (−4.625)	−.0055*** (−4.963)
Gaspric	−3.8939** (−2.140)	−2.2303** (−2.174)
Elecpric	4.9217** (2.363)	2.8997** (2.461)
Row	2.4361*** (5.049)	1.4611*** (5.263)
Single	3.9641*** (6.444)	2.3728*** (6.979)
Log-like	−91.46	−91.14
Log-like con only	−133.63	−133.63
Chi-sq	84.35 (.0000)	84.99 (.0000)

Source: Tiedemann 1995, 391.
Figures in parentheses are t-ratios for regression coefficients and probability values for the chi-squared statistic.
**Significant at 5% level.
***Significant at 1% level.

in the price of natural gas reduce the probability of natural gas space heating. An increase in the price of electricity, presence of a rowhouse development or presence of a single family dwelling development all increase the probability of natural gas space heating.

COSTS AND BENEFITS

Cost Tests and Data

The purpose of the cost benefit analysis was to determine the impact of the pilot from the perspective of various stakeholders. Five cost tests were considered in the analysis. These were the utility test, the rate impact measurement test, the participant test, the total resource cost test and the societal test. A variety of data sources were utilized. Estimates of increased natural gas consumption and reduced electricity consumption were based on a combination of engineering and site visit data, using standard ASHRAE methods. Capacity savings were based on typical load shape information. Marginal costs of electricity and natural gas were based on information from B.C.Hydro and B.C.Gas. Incentives paid and utility program costs were based on program records. Revenue gains (ie. for natural gas) and revenue loses (ie. for electricity) were based on projected rates for the utilities. Incremental capital costs were based on discussions with developers. Tax credits were based on present sales tax schedules. The only externalities included were environmental costs as discussed in the next section.

Cost Benefit Results

Cost benefit analysis was undertaken using COMPASS software. The following key assumptions were used in the modelling. First, a 30 year time horizon was used with an assumption that major gas servicing would be required after 20 years. Second, a discount rate of eight percent was used reflecting B.C.Hydro's long-term marginal cost of capital. Results of the COMPASS runs are shown in Table 4. The Residential Natural Choice pilot had a benefit cost ratio of 1.25 using the utility test perspective. The pilot was thus a success from the utility perspective, given avoided costs at that time. From the rate impact perspective, the benefit cost ratio was just below one at 0.96. The pilot thus had a slight negative impact on energy rates. For the participant test, the benefit cost ratio was 1.10. In other words, participants gained from the pilot. From a total resource cost perspective, the key test used in British Columbia, the pilot was a success. Here, the benefit cost ratio was again over one at 1.06. Finally, from a societal perspective (taking into consideration environmental externalities), the benefit cost ratio was less than one. This is examined in the next section.

Table 4. *Benefit Cost Analysis*

Test	Benefit Cost Ratio
Utility	1.25
Rate Impact	0.96
Participant	1.10
Total Resource	1.06
Societal	0.82

ENVIRONMENTAL IMPACT

The production, transmission, distribution and utilization of various fuels leads to different environmental costs and impacts. For electricity, these include recreational, agricultural and forestry losses due to dam construction and reservoir flooding and release of carbon if trees and other vegetation are killed. For natural gas these include emissions for the gathering, processing,transportation and combustion of the fuel.

In British Columbia, most electricity is produced from hydro-electric power, supplemented with some thermal production. B.C.Hydro's social costing framework includes externalities in the marginal cost of electricity supply used in the above analysis.

The main externality that needed to be costed was that associated with additional natural gas consumption. External impacts or external costs were calculated using the following formula: external costs ($/GJ) = emission factor (kg/GJ) * unit emission cost ($/kg). The main emissions associated with natural gas include the following: carbon dioxide; sulphur dioxide; nitrous oxides; methane; carbon monoxide; volatile organic compounds; and particulate matter. The emission costs for these seven classes of emissions are shown in Table 5. The emission costs are based on a consultant's study (Bridges, 1991) which used the estimated cost of controlling the pollutant as a proxy for emission damage costs.

The key point is that incorporation of these environmental costs reverse the conclusions of the benefit cost analysis. On a societal basis, ie. adjusting total resource costs by the emissions externalities, the benefit cost ratio is reduced from 1.06 to 0.82. Although the pilot appears cost effective on a total resource cost basis, it is not cost effective when environmental externalities are considered.

Table 5. External Cost for Natural Gas

Emission	External cost (C$/GJ)
CO_2	.812
SO_2	.323
NO_x	.103
CH_4	.009
CO	.001
Volatile organics	.018
Particulates	.001
Total	1.267

CONCLUSIONS

This paper illustrates how discrete choice modelling and cost benefit analysis can be employed in the analysis of a fuel switching DSM program. There are four main findings. First, the relative costs of space heating equipment, fuel costs and dwelling type are major determinants of space heating fuel choice. By reducing the relative capital cost differential, larger incentives can encourage the installation of natural gas space heating equipment. Second, pilot participants benefitted from the program. The present value of additional natural gas costs plus customer net capital costs was less than the present value of reduced electricity consumption. Third, the pilot had a benefit cost ratio greater than one on a total resource cost basis. The pilot met the key utility planning test for British Columbia. Fourth, the program failed the societal test. This was due to the negative external effects associated with greenhouse gas and local emission production due to increased natural gas consumption.

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