THE SOCIAL COST OF NEW CONSTRUCTION RESIDENTIAL SPACE HEATING IN BRITISH COLUMBIA

by

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Abstract

Two potential policy approaches and subsequently four policy options are analysed for their potential to reduce the social cost of electric space heating in British Columbia. A fuel neutral, as opposed to a fuel switching policy approach is recommended based on marginal economic costs, greenhouse gas emissions intensities, consumer costs, and the political/policy context. No market failure and, as such, no justification for policy intervention in fuel choice is found. A standardized heat pump installation program, subsidies for high efficiency heating equipment, a mandatory Energuide for Houses rating, and regulating heating equipment efficiency are policy options assessed by their effectiveness, economic/financial cost, equity, administrative ease, and political feasibility. I construct a demand model to forecast the potential electricity savings, analyse private payback periods, and conduct qualitative assessment. A market-based policy, the Energuide for Houses standard is the policy option that best addresses issues of equity and political feasibility.

Keywords: Fuel switching, demand side management, space heating, heat pump, energy policy

Executive Summary

Residential electric space heating demand on Vancouver Island presents significant challenges to BC Hydro and provincial policymakers. Vancouver Island is a key area of concern due to its high levels of electric space heating, growing residential sector, aging capacity infrastructure, and higher bulk transmission costs. This study examines how policymakers can reduce the social cost of electric space heating on Vancouver Island.

Using economic, environmental, private cost, and political feasibility criteria, I analyse whether fuel switching from electricity to natural gas or a fuel neutral policy option best addresses the energy concerns on Vancouver Island. Subsequently, I propose four policy options and assess their capacity to reduce the economic cost of electric space heating on Vancouver Island. I construct a forecasting model to assess the effectiveness of each policy's potential electricity savings and peak energy demand. Payback analysis and qualitative assessment supply the measures for the economic and financial criterion. Equity, administrative ease, and political feasibility criteria are also considered.

Key Findings and Recommendations

- I found insufficient evidence of market failure as a justification for policy intervention in fuel choice. Lower space heating loads and higher rates for natural gas distribution (compared to the Mainland) explain Vancouver Island's higher market shares of electric space heating. Regression analysis reveals consumer fuel choice on Vancouver Island is sensitive to natural gas prices. Natural gas does not prove to have the lowest greenhouse gas emissions intensity, or costs to consumers; therefore, a provincial fuel neutral policy approach is recommended. The marginal economic cost analysis is inconclusive as no incremental cost study was available for natural gas. Natural gas has a higher marginal economic cost compared to electricity when using variable distribution charges (adjusted by load and coincident factors) as a proxy for marginal cost.

- A mandatory Energuide Rating of 80 for residential houses, a sector-specific market-based regulation, proves to be the best policy option to reduce electric space heating load; although significant equity issues are raised. Residential rate redesign is likely the most efficient way to address equity issues.

- Studies reveal heat pumps can meet performance expectations, even in colder weather, if installed properly. A standardized heat pump installation program, to maximize the efficiency potential of the technology, is recommended.

- The payback periods for the capital cost of high efficiency heating devices in an average new home on Vancouver Island, when compared to electric baseboard heating, are high. Raising electricity rates, to reflect more closely marginal costs, would reduce payback periods and increase the diffusion of high efficiency heating equipment.

- Regulating heating device efficiency may increase the electricity demand on Vancouver Island, as electric baseboards represent an almost perfect substitute that is lower cost. Consumers may switch to baseboard heating if natural gas furnaces and heat pumps cost more due to greater efficiency requirements.

Dedication

To my Dad and Mom, Dennis and Lynn Gorecki, for all their love and support. Dad, thank you for your constant encouragement to excel in academia and whatever I do. Mom, thank you for patiently listening to all of my troubles, celebrating my achievements, and helping me flourish with your love and prayers.

Acknowledgements

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List of Acronyms

AFUE – Annual Fuel Utilization Efficiency

BCH – BC Hydro

BCUC – British Columbia Utilities Commission

CCGT – Combined Cycle Gas Turbine

CO_2e -- Carbon Dioxide Equivalent or Greenhouse Gas Equivalent

COP – Coefficient of Performance

EGH – Energuide for Houses

GHG -- Greenhouse Gas

GJ – Gigajoule

GWh -- Gigawatt Hour

HSPF – Heating Seasonal Performance Factor

IEP – Integrated Electricity Planning

IPCC – Intergovernmental Panel on Climate Change

KWh -- Kilowatt Hour

LTAP – Long Term Acquisition Plan

MJ – Megajoule

MW – Megawatt

MWh – Megawatt Hour

NRCan – Natural Resources Canada

RDDA – Revenue Deficiency Deferral Account

TGVI – Terasen Gas Vancouver Island

TJ – Terajoule

WECC – Western Electricity Coordinating Council

Glossary

Term	Definition
Annual Fuel Utilization Efficiency	The ratio of heat output to the total energy consumed.
B.C. Clean Electricity	Alternative energy technologies that result in a net environmental improvement relative to existing energy production. Examples may include hydro, wind, solar, photovoltaic, geothermal, tidal, wave and biomass energy, as well as cogeneration of heat and power, energy from landfill gas and municipal solid waste, fuel cells and efficiency improvements at existing facilities (Ministry of Energy Mines and Petroleum Resources, 2002).
Bulk Transmission	The transfer of electricity on the major high-voltage *transmission system* from the generators to the lower-voltage *distribution systems* (BC Hydro, 2005a).
Carbon Dioxide Equivalent/ Greenhouse Gas Equivalent	A unit that expresses the radiative forcing of a given GHG in terms of carbon dioxide with equivalent radiative forcing
Coefficient of Performance	The ratio of the useful heating energy delivered to the electricity used to run the heating system.
Combined Cycle Gas Turbine	The combination of combustion and steam turbines to generate electricity from two thermodynamic cycles. Exhaust heat from the combustion turbine is recovered to produce steam to power a steam turbine, resulting in higher thermal efficiency.
Demand Side Management	An effort to decrease, shift or increase electricity demand on the demand side of the revenue meter that results in a change of electricity sales and revenues.
Dependable Capacity	For BC Hydro long term planning purposes, dependable capacity is the "maximum capacity that a plant/unit can reliably provide for 3 hours in the peak load period of weekday during the continuous two weeks of cold weather" (BC Hydro, 2005a). Factors external to the plant affect its dependable capacity.
Dispatchability	How easily the generation can be adjusted to match short-term variations in load.

Firm Energy	The energy that is available 100 per cent of the time (BC Hydro, 2005a).
Free Riding	Individuals benefiting from energy efficiency incentive programs even though they would have purchased energy efficient equipment without the incentive.
Global Warming Potential	The global warming potential (GWP) is a measure of the radiative effect of a greenhouse gas as compared to CO_2. The associated GWP is multiplied by the quantity of each greenhouse gas to produce an equivalent measure that can be used as the total greenhouse gases called carbon dioxide equivalents (CO_2e). GWPs are available for different time horizons but the IPCC uses the one hundred year time horizon (International Panel on Climate Change, 2001).
Greenhouse Gases	Natural and anthropogenic constituents in the atmosphere that absorb and re-emit infrared radiation (Government of Canada, 2005).
Heating Seasonal Performance Factor	The total heating output of a heat pump during its normal annual heating usage period divided by the total electric power input for the same period, the quantity of heat produced in a season is compared to the quantity of electricity consumed
Joule	A unit of heat.
Levelized	Levelizing is a method of converting a non-uniform stream of costs, prices, or greenhouse gases into a present value equivalent uniform series.
Load Factor	The ratio of the annual energy consumption (adjusted for the number of hours in a year) to the peak demand.
Local Transmission	Electricity transfer between the lower end of bulk transmission and the lower voltage distribution systems.
Megatonne	One million tonnes.
Peak Capacity	The maximum amount of electrical power that generating stations can produce in any instant.
Peak Demand	The maximum instantaneous demand on a power system.
Petajoule	10^{15} joules.

1 Introduction

As Canada struggles to meet its Kyoto obligations and energy prices rise, residential space heating concerns citizens and policymakers alike. Partly as a consequence of the cold climate, in the average Canadian household, space heating encompasses approximately 60 percent of household energy use (Office of Energy Efficiency, 2001). Total annual residential energy demand from space heating is 873 petajoules (PJ) resulting in approximately 52 megatonnes (MT) of greenhouse gas emissions.[1] Electric space heating has always been of concern to BC Hydro (BCH) due to its seasonal nature, strain on the system's capacity, and the quantity of energy it consumes; in fact, peak electricity demand in British Columbia is driven by the residential space heating load (BC Hydro, 2004).[2] The region of the Province with the greatest market share of electric space heating and, at the same time, a growing gap between capacity and demand is Vancouver Island.

Electric space heating demand on Vancouver Island poses a challenge for provincial policy makers. The Island represents 27 percent of BC Hydro's new residential growth in demand and promises a continued level of growth.[3] Significant transmission challenges result from Vancouver Island's costly submarine connection, aging transmission infrastructure, and the fact that it receives 70 percent of its electricity from the Mainland.

BC Hydro's Power Smart program focuses on shifting new electric to natural gas space heating load.[4] Electric space heating imposes a high marginal cost on BC Hydro due to its low load and high coincidence factors.[5] In addition to the strain on BC Hydro's system, some say using electricity for space heating has greater environmental impact than using natural gas as an end-use.

This study aims to first scrutinize whether fuel switching to natural gas or fuel neutrality is a better policy approach to space heating, based on economic, environmental, private cost, and

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[1] A megatonne is one million tonnes. A joule is a unit of energy and with the prefix peta it is 10^{15}.
[2] Space heating load is the energy required to heat a house per year.
[3] Percentage of residential demand is based on REEPS forecast figures for 2005/6 and 2006/7.
[4] BC Hydro also has programs focused on more efficient furnace blowers.
[5] A load factor is the ratio of the annual energy consumption (adjusted for the number of hours in a year) to the peak demand (D_P). Coincidence demand is the demand of a particular end-use measured at the time of total system peak.

political criteria. Policy options to reduce the electric space heating load are then analysed. The policy analysis is taken from a provincial perspective rather than from the perspective of British Columbia Power Authority (a crown corporation) or Terasen Gas Incorporated (a publicly owned regulated utility).[6] The Province has the responsibility to make decisions from the perspective of all British Columbians; therefore, I base policy recommendations on optimising full social benefits and minimising social costs.

1.1 Policy Problem

The policy problem is *electric space heating in new single family dwellings on Vancouver Island imposes too great a social cost on British Columbians*. The financial costs are currently being borne by residents, ratepayers, and BC Hydro. The economic costs, including environmental externalities, are borne by all British Columbians; hence, I direct policy recommendations in this study primarily at the provincial government.[7] The study examines the following questions:

- Should space heating policies and programs favour fuel switching from electricity to natural gas or pursue efficient heating technologies regardless of fuel choice?

- What space heating policies/programs should the Province/BC Hydro use to reduce electric space heating demand?

Reducing the impacts of space heating can occur in three different ways: 1) thermal efficiency improvements in the building shell (including doors and windows); 2) increased efficiency of heating equipment, and 3) improved heat delivery efficiency.[8] To narrow the scope of this study, the focus is on heating appliances through either fuel switching or increasing their efficiency.

1.2 Study Outline

This first section introduces the policy problem studied. Section two reviews the most common heating appliances and their characteristics – distinguishing low from high efficiency heating devices. Heat pumps are a particular focus as they are an unfamiliar technology to many,

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[6] Henceforth referred to as BC Hydro and Terasen Gas.
[7] The role of the British Columbia Hydro and Power Authority's is to ensure policy decisions do not pose great economic costs on ratepayers.
[8] The third category includes blower motor efficiency, radiant floor heating, and thermal storage heat sinks to improve heat pump performance.

although growing in popularity on Vancouver Island and in the Southern Interior.[9] Section three describes why policymakers should focus on electric heating in new single family homes on Vancouver Island. Section four outlines the theoretical arguments on the fuel switching debate including efficiency and environmental impacts. Section five outlines the market failures associated with heating devices choice in new construction that make the case for public policy intervention. Section six summarizes the methodological practices. Section seven determines whether space heating policies should favour natural gas or whether a fuel neutral policy approach should be adopted. Finally, the policy options, criteria, analysis, and recommendations are outlined in the final section of the paper.

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[9] Heat pumps in this study refers to air-source heat pumps, unless specified as ground source.

2 Residential Space Heating Technology

2.1 Technical Characteristics of Heating Devices

Electricity and natural gas are the two main fuel choices for primary space heating. Common heating devices on Vancouver Island can be categorized as low and high efficiency devices (see Table 1 below). The term efficiency, in this paper, is a relative term. Low efficiency implies, for a given heating fuel, a home can be heated more efficiently. Collectively, these heating devices make up 79 percent of what is used in single family dwellings on Vancouver Island (Habart & Associates Consulting Inc., 2004). The sections below describe the characteristics of each device.[10]

Table 1 Common High and Low Efficiency Heating Devices

High Efficiency Heating Devices	Low Efficiency Heating Devices
Condensing furnaces natural gas furnaces	Mid efficiency natural gas furnaces
High efficiency natural gas boilers	Mid efficiency natural gas boilers
Air-source heat pumps	Electric furnaces[11]
	Electric baseboard heaters[12]

Electric baseboards and electric furnaces are both electric resistance heating; the difference lies in their heat delivery. Electric resistance heating is 100 percent efficient, that is, they convert nearly 100 percent of the electricity that reaches the device into heat. They are low

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[10]This study excludes less common heating devices such as reverse cycle chillers (similar to an air source heat pump), boilers for a radiant floor heating system, a type of efficient heat delivery, and, ground source heat pumps. Radiant floor heating is a system typically consisting of liquid filled tubes in the flooring that are used to heat a home; radiant heat can be zoned to provide heat only in the required rooms. Ground source heat pumps are similar to air source but use the heat storage ability of the earth and/or the groundwater to heat and/or cool a building. They can reach efficiencies between 300 and 400 percent but currently have high payback times for the average single family dwelling (Compass Resource Management Ltd. & MK Jaccard and Associates, 2005).

[11] Some may argue electric resistance heating should only be considered low efficiency heating if powered by fossil fuel fired generation. If powered by hydro or wind power the efficiency of the energy system is much greater. See Section 4.1 for further discussion on this topic.

[12] Ibid.

efficiency because heat pumps would use less electricity to provide the same amount of heat per home.

Baseboard heaters have thermostats located in each region allowing zonal heating – an advantage that can provide energy savings. These heaters are inexpensive to install, as they do not require a centralized ducting system and each heater is inexpensive compared to centralized heating equipment. Due to their straightforward design, these heating devices typically last a long time.

Electric furnaces use a ducting system, like heat pumps and natural gas furnaces. They are more expensive to operate than baseboard heaters because of efficiency losses through the ducting system and they require blowers (a large electric fan) to distribute the heat throughout the house. Any centralized heating system that uses ducting can lose a lot of energy, as high as 35 percent, if installed inefficiently. Electric furnaces have one advantage over natural gas in that they have no heat losses through the chimney.

Natural gas furnaces burn fuel to heat air that is distributed throughout a home with an electric blower. Furnace efficiency is measured by the annual fuel utilization efficiency (AFUE) or the ratio of heat output to the total energy consumed. Three categories exist for furnace efficiency: standard (65-70 percent AFUE), mid efficiency (78-80 percent AFUE), and high efficiency (90-94 percent AFUE). Standard efficiency is no longer is sold due to regulation. Mid-efficient furnaces are currently the most common natural gas heating system on Vancouver Island. High efficiency or natural gas condensing furnaces extract more heat from the combustion by condensing the water vapour. Furnaces have an average expected lifetime of 15 years.

2.1.1 Heat Pumps – Breaking the Laws of Thermodynamics?

An electric air-source heat pump can achieve high efficiency levels. Using a unique heating technique, heat pumps do not generate heat (with the exception of back-up heating components). Instead, heat pumps move heat from outside to inside a home where a blower distributes the heat in a central ducting system. True to their name, air-source heat pumps transfer heat from the cold air outside a home to the warmer air inside - an ability to move heat in a sense "uphill". The efficiency of a heat pump is directly related to the temperature within which it operates - the smaller the difference between outdoor and indoor temperatures, or the "lift", the greater the efficiency.

Heat pumps operate exactly like refrigerators; in fact, all refrigerators are heat pumps running in reverse moving heat from inside to outside the appliance. Consider an air-source heat pump, its coil, containing refrigerant, (generally) spans the inside and outside of a house. Outside, the refrigerant is colder than air. The refrigerant vaporizes from the heat it absorbs due to the temperature differential. The refrigerant vaporizes at a low temperature. On its way into the house, a condenser compresses the gas causing the temperature to rise. Once inside, the gas is now hotter than the air inside the house and heat is released over the large surface area of the indoor coil and is distributed throughout the house using a blower. It then condenses on its way back outside, as the refrigerant passes through an expansion or metering device, once again returning it to its cold liquid form. Essentially, pressure changes caused by the compressor and the expansion valve enable the gas to evaporate at outdoor low temperatures and condense at higher indoor temperatures. It takes very little energy to run these valves compared to the heat transferred into the house. The efficiency gain causes the appearance that a heat pump is breaking the laws of thermodynamics by producing more energy than it uses, but a heat pump is merely moving heat not generating it.

When run in reverse, heat pumps can act as air conditioners. Heat pumps are therefore quite popular in the arid climate of the Southern Interior where winters tend to be mild and summers hot and dry. Concern has been raised about utilities promoting heat pumps as an energy efficient way to heat your home when air conditioning use in the summer may reduce their annual energy savings. On Vancouver Island, this is likely not an issue due to its mild summer temperatures.

Heat Pump heating performance has two common measures. The coefficient of performance (COP) is the ratio of the useful heating energy delivered to the electricity used to run the compressor, fan, and any back-up resistance heating that is required. An average COP of 2 indicates a heat pump is 200 percent efficient. Heating Seasonal Performance Factor (HSPF) is the total heating output of a heat pump during its normal annual heating usage period divided by the total electric power input for the same period, the quantity of heat produced in a season is compared to the quantity of electricity consumed. Because heat pumps have different performance at various temperatures, different HSPF ratings are provided for different heating zones.[13] In heating region IV, a zone that much of Vancouver Island falls into, new heat pumps range in efficiency from 7.2 to over 10.5 HSPF or 2.12 and 3.09 COP. The average life of a heat pump is approximately 14 years.

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[13] To estimate the average COP from a HSPF rating one should divide by 3.4.

Air source heat pumps lose efficiency below certain temperature for two reasons. At certain temperatures, heat pumps can simply not provide enough heat to warm the house to comfortable temperatures and back-up heat is required. Electric resistance back-up heat significantly lowers a heat pump efficiency and can cause peaking problems for electric utilities already experienced in states such as Alabama and Florida (Bouchelle, 2000). Heat pumps also need to defrost their outdoor coils periodically, by running the refrigerants backwards, again reverting to resistance heating. While cold climate heat pumps are emerging on the market, air source heat pumps work best in mild climates such as on Vancouver Island and the Lower Mainland. Heat pumps also experience cycling losses from stopping and starting a heat pump. When the movement of the refrigerant is halted, heat absorbed by the refrigerant cannot travel into the house.

3 Growing Demand on Vancouver Island

Why should energy policy focus on space heating in new single family dwellings (SFD) on Vancouver Island? This section justifies to policymakers why this is an important area in residential energy policy. The nature of space heating and its costs, population growth, and consumer choice all legitimise a focus on space heating on Vancouver Island.

3.1 The Costs of Space Heating

Electric space heating will place a significant demand on the BC Hydro system. Space heating's energy intensive nature and seasonal demand impose greater costs on a utility by requiring expanded transmission and distribution capacity for only short periods of the year. If fuel choice does not significantly change, in twenty years, the additional electric space heating load from Vancouver Island will be approximate 560 GWh or an additional 273 MW on peak demand.[14]

Not only does residential heating consume a great deal of energy, space heating represents a higher cost to a utility due to its low load and high coincidence factor. A low load factor indicates that space heating has a high peak demand in relation to its average consumption throughout the year. A high coincident factor indicates that the period of high demand coincides closely to the total utility peak, that is, how much demand it adds to the utility's peak.[15] High demand at peak times requires a utility to expand its capacity for peak periods. High peak demand coupled with low consumption during low demand periods, generates insufficient revenue to cover the increased capacity costs and rates must increase. These characteristics of space heating, do not change with fuel choice; the low load factor/high coincidence factor adds additional costs to both electric power and natural gas utilities. On Vancouver Island, two different utilities bear these costs – Terasen Gas Vancouver Island Incorporated (TGVI) and BC Hydro.

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[14] See Section 6.3 for methodology on how this number is derived, based on a demand forecast I constructed.
[15] See Appendix A for an explanation of how load and coincidence factors are calculated.

3.2 New Construction Single Family Dwellings

Residential space heating policy should first focus on new construction, as it is far easier to influence space heating choice in new construction than the retrofit market for existing houses. Literature on residential heating choice focuses primarily on household retrofit decisions, yet space heating from new construction market is an easier market to induce energy changes. The decision-making process for heating equipment in new construction is different from retrofitting decisions. Consumers demonstrate preferences for remaining with the same type of space heating fuel and heating device currently installed despite potential lifecycle cost savings (Sadler, 2003). Retrofit choices made in existing housing are often limited by existing infrastructure; for example, it is much more expensive to install a natural gas condensing furnace into a home that is currently being heated with electric baseboards due to the need for ducting. Existing housing also has a share of rental properties; these households have little to no incentive to upgrade heating appliances to save operating costs. In British Columbia, approximately 14 percent of housing is rental properties.[16] In terms of marketing, it is much easier/less costly to reach new construction decision-makers. Developers are a smaller demographic to target and either decide what space heating to install in a home or influence homebuyers in their decision. If existing homes begin reverse fuel switching (from natural gas to electricity), this building archetype may warrant greater policy focus but this does not appear to be the case despite concerns at Terasen Gas and BC Hydro.[17]

Single family dwellings (SFD) is the focus building archetype as they have the greatest demand in terms of space heating. SFDs comprise 75 percent of the total space heating load in British Columbia. To provide perspective, the total 2001 residential electric space heating load for BC Hydro, was 3,211 GWh or 21% of total residential electricity use. Between 2000 and 2003, new homes added roughly 206 GWh of residential electric space heating load to the BC Hydro system; of this total demand, the top five regional building archetypes with the highest demand include:

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[16] From the perspective of the renter, there is little to no incentive to purchase capital-intensive durable goods that have higher energy efficiency, as renters generally remain at the property for a short time period and do not have to pay for the initial device. From the owner's perspective, they do not have to pay the energy bills therefore there is little incentive to purchase more efficient yet more expensive durable goods.

[17] There appears to be little movement away from natural gas to electric space heating in existing homes. Based on the BC Energuide for houses database, there has been a low frequency of fuel switching from a natural gas furnace to electricity. Since 1998, of 3451 Energuide assessments on Vancouver Island only 5.4% switched from another fuel to electricity, only 0.5% of the total made a switch from natural gas to electricity; this suggests is that existing users are not moving towards electric heating. [17]

1. SFDs on Vancouver Island (28% or 57.9 GWh)

2. SFDs in the Lower Mainland (21% or 42.5 GWh)

3. SFDs in the Interior (21.9%, or 42.6 GWh)

4. Apartments in the Lower Mainland (24% or 23.6 GWh)

5. Row dwellings in the Lower Mainland (11%, or 23.2 GWh)

3.3 Why Focus on Vancouver Island?

Vancouver Island has the highest market share of electric space heating in new construction SFDs when compared to other regions in the Province. Fifty-six percent of single family dwellings on Vancouver Island use electric space heating as compared to 15 percent on the Lower Mainland, and 13 percent in the Interior (see Figure 1 below) (Habart & Associates Consulting Inc., 2004).[18] Fuel choice on the Island also has shifted over time.

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[18] Vancouver Island numbers are not taken directly from the Habart study. They are determined by a combination of the Habart database and BC Energuide for Houses as it allows a larger sample size.

Figure 1 Single Family Dwelling New Construction Fuel Choice in Different BC Regions between 2000-2005
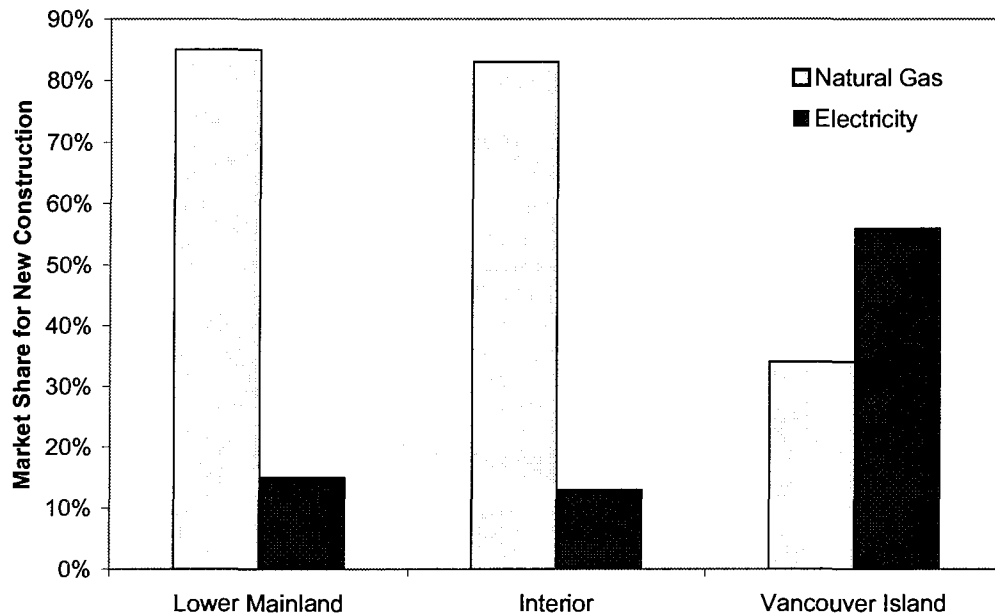
Source 1 Habart Fuel Choice Survey

Vancouver Islanders seem to be moving away from using natural gas for space heating. A significant shift in new SFD fuel choice was seen between 1994-1999 and 2000-2005 (see Figure 2 below). Electric heating constituted 38 percent and natural gas approximately 59 percent of the new construction space heating for the period of 1994-1999.[19] Between 2000 and 2005, the predominant fuel choice shifted from natural gas to electricity; 56 percent of SFDs were primarily heated with electricity and 34 percent with natural gas.[20] [21]

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[19] Percentages do not add up to 100 percent as there is a third category – do not know/alternate fuels.

[20] Caution should be exercised in using these numbers, as sample sizes are not extremely robust. See Appendix B for sample size and other descriptive stats.

[21] Historical fuel and heating device choice compare two time-periods, 1994-1999 and 2000-2005. Natural gas service on the Island began in 1991, so the time for analysis was chosen couple of years after to allow for market adjustment to this "new" energy source. In analysing heating device choice, numbers for electric radiant and portable electric as primary heating devices are extremely low and therefore aggregated into the baseboard category. Ground source heat pump numbers are also low and combined with air source heat pumps. When examining descriptive statistics caution should be exercised, as sample sizes are not extremely robust.

Figure 2 Single Family Dwelling New Construction Fuel Choice on Vancouver Island
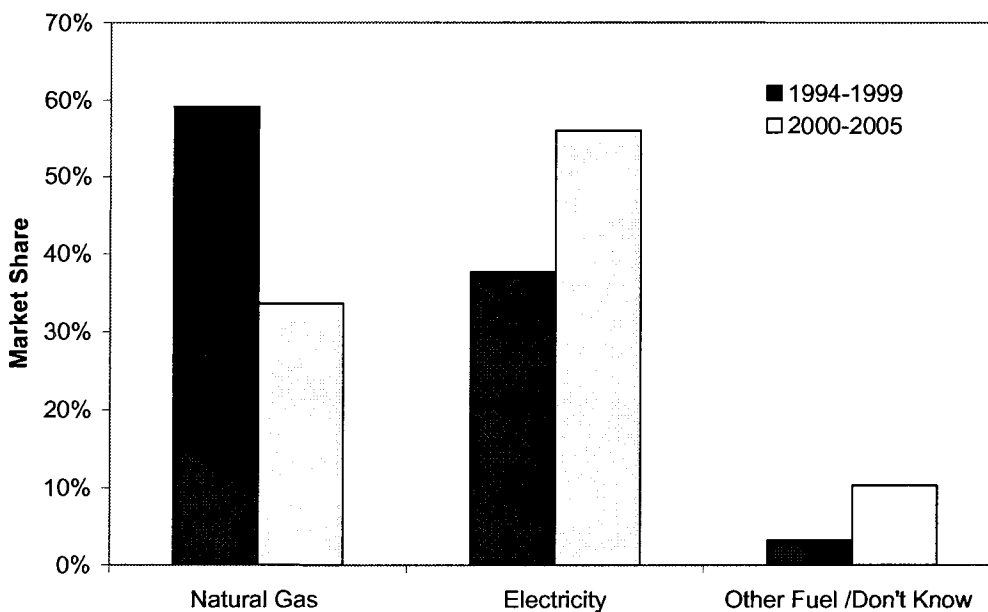
Source 2 BC Fuel Choice and BC Energuide for Houses Database

The high percentage of electric heating on Vancouver Island is of additional concern to BC Hydro given the Island's projected population growth. Due to its mild climate and appeal for retirees, growth rates on Vancouver Island are projected to be higher than the Canadian average over the next twenty years. The growth will primarily be in residential and commercial sectors. In addition to high growth rates, increased energy demand will also come from more intense use of electricity-based technologies in homes and businesses and a higher proportion of value-added manufacturing (Vancouver Island Energy Corporation, 2003).

Vancouver Island's transmission capacity is already capacity-constrained. A combination of on-Island generation and transmission from the Mainland meet the current electricity demand. Generation on the Island supplies about 30 percent of peak load and the remaining 70 percent comes from the Mainland via submarine transmission. The southern corridor connects Delta/Tsawwassen to Duncan via Galiano and Salt Spring Islands; this connection is old and for planning purposes will no longer be functional by 2007 leaving a ~300 MW peak short fall in meeting Vancouver Island's needs (British Columbia Transmission Corporation, 2005). The challenge of meeting Vancouver Island's demand growth is exacerbated by the fact that a high proportion of residential customers are choosing electric space heating.

3.4 The Challenge of Meeting Demand – Is Fuel Switching a DSM Solution?

Demand side management (DSM), through BC Hydro's Power Smart program, is one method proposed to reduce BCH's current shortfall between supply and demand. BC Hydro is currently pursuing a modest fuel switching program as part of a load displacement demand side management measure. Part of BCH's energy efficiency plan includes incentives for BC Hydro customers to fuel switch from electric to natural gas furnaces, water heaters, and ranges on Vancouver Island.[22] The cumulative savings from the residential fuel switching program is estimated to be 164 GWh between 2003 and 2012 or less than five percent of the DSM goal to save approximately 3,600 GWh.

The only residential fuel switching program currently in effect is BC Hydro's contribution to Terasen Gas Vancouver Island's "Home Builders Grand" program. The program provides a $1,000 incentive to builders and developers to install Energy Star qualified natural gas high efficiency furnaces or boilers in combination with natural gas domestic hot water in residential new construction applications.[23] Financial incentives are also available through provincial and federal governments. Energy Star qualified natural gas furnaces and boilers purchased from February 16, 2005 to April 1, 2007 are exempt from the provincial sales tax (PST). Subsidies for high efficiency space heating are also available though Natural Resource Canada's Energuide (EGH) program although only for existing homes.

To date, BC Hydro has chosen not to pursue fuel switching more aggressively, "because it is questionable whether the electricity savings are permanent" (BC Hydro, 2005a). In the past, natural gas offered a significant operating cost advantage but in recent years, natural gas has a reduced operating advantage. BCH is concerned that if natural gas prices rise, customers may partially or completely switch back to electricity use. While the Energuide database has shown that reverse fuel switching of primary heating equipment does not appear to be occurring, secondary heating may be problematic. Portable electric heaters or installed electric baseboard heaters are inexpensive to purchase and easy to install.[24]

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[22] Base year fiscal 2003 otherwise known as the Power Smart Two portfolio.

[23] Terasen Gas Inc. offers further incentives beyond the "Home Builders Grand" program but BC Hydro currently does not participate.

[24] Currently, 25 percent of BC households and 33 percent of new homes on Vancouver Island use electricity as a secondary heating source (Habart & Associates Consulting Inc., 2004:; Itron, 2005). Based on numbers from the 2002 Conservation Potential Review, secondary space heating (electric space heating in houses with a non-electric fuel source as their primary heating fuel) comprises 49% of the space heating load or 1550 GWh. Eighty-one percent of the secondary space heating is contributed by SFDs.

Historically, BC Hydro has participated in several different residential fuel substitution programs with BC Gas, the natural gas utility prior to its current form Terasen Gas. Rebates have been offered to homeowners in all BC regions who replace their electric water heater with a gas-fired one. Large apartments with central water heating have also been offered incentives to use natural gas water heaters, and clothes dryers (Chung, 1993).[25] The Residential Natural Choice pilot approached major developers directly to offer incentives (Tiedemann, 1994:, 1995).

It is unknown to what degree future Power Smart portfolios will possess fuel switching initiatives as the details of Power Smart 3, 4 and 5 have yet to be determined. These Power Smart portfolios have a target of 7,274 GWh of annual energy consumption avoided. A financial disincentive against electric space heating has been discussed (Marbek Resource Consultants, 2006).

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[25] BC Hydro's non-integrated diesel customers have been offered subsidies to use propane furnaces.

4 Electric versus Natural Gas Residential Heating

Is switching to natural gas the way to solve the electric space heating load problem? Is natural gas the preferred fuel for space heating? This section examines the issues of energy system efficiency, and environmental impact of each type of heating fuel from a theoretical perspective. I examine data specific to Vancouver Island in subsequent sections.

4.1 The Efficiency Argument

The efficiency argument for using natural gas heating came to the forefront in the 1970s with Amory Lovins' work. In his seminal piece, " Energy Strategy - the Road Not Taken," he argued for efficient use of energy matched in scale and energy quality to end-use needs (Lovins, 1976). Energy varies in quality or its ability to do useful work and Lovins asked why use high-grade energy to perform a task that only requires medium or low-grade energy?[26] He likens our inappropriate energy use to "using a chainsaw to cut butter." An illustration of Lovins' thesis is from an efficiency perspective, designing a building to take advantage of dispersed solar energy for heating purposes is preferred to using high-grade electricity for heat.

The first law of energy efficiency can be used to explain the total efficiency of an energy system (Miller, 1980).

$$\text{First law energy efficiency} = \frac{\text{Useful energy output}}{\text{Total energy input}}$$

This law broadens our perspective on appropriate energy sources for different end-uses. For example, the conversion of electricity to heat is 100 percent efficient, but electricity generation from fossil fuels experience a number of efficiency losses in its production and transportation. A fossil fuel fired electricity plant has significant energy losses when burning fuel to produce heat that then runs a turbine to produce "high grade" electricity; further efficiency losses occur through transmission. New natural gas powered combined cycle gas turbine (CCGT) plants can at

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[26] High grade or quality energy is highly concentrated energy such as oil, gas, uranium, and electricity. Low grade or quality energy is more dispersed or dilute such as solar energy.

best achieve approximately 60 percent efficiency.[27] Local transmission and distribution losses are approximately seven percent, and peak bulk transmission losses depend on the distance travelled. In British Columbia, bulk transmission losses range between zero and 18 percent – the average is 5 percent (Marbek Resource Consultants, 2003).[28]

Technologies that are more efficient could reduce some of these losses, but some level of energy loss is unavoidable based on the second law of thermodynamics. In combusting fuel to perform work, some of the energy degrades to a dispersed and less useful form. If society continues to use high-grade fossil fuels to produce electricity, from an efficiency perspective it makes more sense to avoid these energy losses and burn natural gas at the location where heat is needed – burn natural gas in a furnace in a home to achieve efficiencies between 80 and 94 percent. Hence, for space heating, fuel switching from fossil fuel fired electricity to natural gas seems rational from an energy efficiency perspective.

Exceptions to the fuel-switching efficiency argument do exist. Electricity generation can use sources and end-use technologies that cause electric heating to be a more efficient choice than natural gas end-use heating such as hydro, geothermal, or wind power to produce electricity and/or heat pumps as an end-use. Converting moving water to produce electric heat has a total system energy efficiency of 80 percent compared to natural gases system efficiency of at best approximately 65 percent (Miller, 1980). Ground source heat pumps and air-source heat pumps, as end-use technologies in certain climates also have a system efficiency superior to natural gas when combined with electricity generated by a CCGT plant.

4.2 Environmental Impacts

Fuel switching is often preferred from an efficiency perspective, but what if one also considers air emissions? The lower emitting fuel depends on the marginal electricity generation source. When coal or natural gas is the marginal electricity source 100 percent of the time and electric resistance heating is the end-use, natural gas furnaces have a lower environmental impact. If a heat pump is the end-use equipment and/or thermal generation is the marginal electricity source less than 100 percent of the heating season, there are mixed results for the lowest emitting space heating fuel (see Section 7.1.3). If hydro, wind, geothermal, or biomass is the marginal generation source, electric heating is preferable from an efficiency and emissions perspective. At

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[27] Natural gas combined cycle plants achieve one of the highest levels of efficiency for fossil fuel electricity production by using exhaust gases to produce additional electricity.

[28] Miler introduces two more energy calculations – the second law of energy efficiency and net useful energy. From a societal perspective, these concepts provide additional insight to the debate on appropriate end-uses but are beyond the scope of this study.

the same time, green power has its limitations. Comparing the impacts of green electricity and natural gas as heating fuels is difficult when land and water impacts are taken into consideration. Large hydro dams affect the environment by flooding large areas and altering water flows. Small hydro, for the most part, does not flood areas but, depending on the project, impacts water flows. Wind energy allows multi use in its impacted area but may adversely affect avian wildlife. Transmission lines change vegetation patterns, introduce non-native species, and potentially the use of pesticides.

In British Columbia, there has been debate on the environmental impact of fuel substitution programs. If the marginal electricity source is thermal, fuel substitution programs offer environmental benefits (G.E. Bridges and Associates Inc., 1991). When non-emitting electricity supply sources are included in the mix, fuel switching could have a neutral or negative impact from an air emission perspective. The future environmental impact of fuel switching programs is dependent on how green BC Hydro future electricity resources will be.

When the provincial space heating load is considered, it is apparent that natural gas heating is a necessary part of a provincial energy strategy. Advocates for electric space heating must consider the entire provincial energy picture. If electricity were the only fuel source for all residential space heating, a significant amount of electricity generation capacity would be required. Based on space heating load estimates in BC Hydro's 2002 Conservation Potential Review, the residential non-electric space heating load in BC Hydro's service area is almost 10,500 GWh/year. It would take the Site C dam, 42 small hydro projects, two 200 MW wind farm (100 2 MW turbines), and a 200 MW geothermal project to meet this space heating load requirements. The total land and water impacts would be equivalent to over 11,500 hectares. Recall, that residential space heating load is growing significantly with British Columbia's population growth and requires additional electricity sources to meet this demand.

Future carbon capture and sequestration could eliminate the environmental reason for fuel switching away from fossil fuel sourced electricity generation for heat. If near 100 percent carbon sequestration is pursued for new electricity generation, electricity would become a zero carbon heating fuel – superior to burning natural gas for end-use. Using fossil fuels in a centralized, rather than dispersed, manner would be preferred, as it would enable centralized carbon sequestration.

5 The Case for Policy Intervention

Before engaging in policy analysis, I identify five market failures that provide the basis for public policy intervention in space heating on Vancouver Island. These market failures can result in a lower than optimal market penetration of energy efficiency equipment. Analysis in Section 7 investigates whether these market failure are also present in fuel choice. I also identify non-market failures that are also often present that lower the diffusion rates of high-efficiency technologies. These non-market failures are important to take into account when analysing if policy intervention should occur.

In an ideal world, the price of a space heating fuel reflects its true social cost if there are perfectly competitive markets with no externalities. Rates reflect marginal costs borne by the economic agents and the externality costs borne by society; but this ideal world is not reality. Not only are many environmental costs external to those who benefit from energy use, a perfectly competitive market does not exist for electricity or natural gas and rates do not reflect marginal costs. Under-provision of information, the principal-agent problem, and lack of access to capital could produce a deficiency of energy efficiency in the market.

1) The principal-agent problem between developers and homeowners

Developers often choose the heating device installed in a new home (unless it is a custom-built house). The developer or contractor does not pay the energy bills a heating appliance generates over its lifetime but does face the initially higher capital costs to install an energy efficient device. Only if they feel that they can recover the extra costs and effort associated in a higher sale price, will developers install more a more energy efficient heating device or make a fuel choice that will save a consumer operating costs.

2) Utility rates do not reflect the marginal cost of energy

The Province of British Columbia and the BC Utilities Commission generate a market failure by setting energy rates below their marginal cost. While natural gas commodity costs are based on market prices, distribution costs do not reflect seasonal or time of day changes in capacity costs. In addition, on Vancouver Island, the soft cap on natural gas rates and contribution of royalties from the Province add an additional distortion to prices. Because of the large debt

load associated with the natural gas pipeline built to the Island in 1991, the Provincial government provides a fuel royalty credit to Terasen Gas to help offset these costs. The British Columbia Utilities Commission (BCUC) also allows Terasen to place a soft cap on their residential and commercial rates until at least 2012.[29] The soft cap essentially allows Terasen's rates, including a commodity charge, to be set below BC Hydro's electricity rates.[30]

Due to the legislated heritage contract, that states that all British Columbians should benefit from inexpensive heritage hydrological resources, residential electricity rates are based on average embedded not the incremental cost of generation and transmission. Electric space heating customers also do not face price signals that reflect the seasonal/daily dynamics of supply and demand. For example, during the winter when space heating demand is the highest and water levels in the reservoirs are low, consumers pay the same price for electricity as when generation is cheaper in the spring with an abundance of water and lower electricity demand.

If consumers face constant average cost pricing, they will not behave efficiently with regard to energy consumption. If peak demand exceeds supply, more capacity must be built, or electricity imported from other jurisdictions. Consumers would face higher average prices over time as capacity is added or if imports cost more than domestic production, but they will not link these average prices to their consumption levels at peak periods. Without higher rates at peak periods, consumers have no incentive to change behaviour to reduce consumption during these periods.

To strive for economic efficiency in a regulated market, regulators should ideally strive for price signals that reflect the marginal cost of the fuel. Marginal cost pricing is difficult to do practically, so a second-best would be to have increasing block prices based on average costs, average-cost prices that reflect seasonal or time-of-day peaks, or regionally differentiated rates depending on the cost of transmission.

3) Environmental Externalities

As outlined in Section 4.2, the prices of electricity and natural gas do not reflect their environmental impacts. All technologies that use energy indirectly produce pollution or impact the environment; therefore, energy efficiency devices result in lower environmental impact. Consumers will choose heating devices with efficiencies lower than what is socially optimal if prices do not reflect the costs energy places on the environment. Both BC Hydro and Terasen

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[29] The fuel royalties paid by the Province financially enable the soft cap
[30] The soft cap mechanism allows Terasen to recover its cost of service, sometimes including an amount to pay off their debt, while maintaining competitive (compared to electricity) and stable rates over time. Rates are adjusted in the long-term as expectations for recovery of the debt-load change.

rates do not incorporate an estimate for external environmental costs. Even when planning for demand side management programs, both utilities do not incorporate an environmental cost into their pricing therefore some technologies that should be included in DSM programming do not pass a cost benefit analysis. The true social cost of pollution is a highly contentious subject but it remains within the realm of good public policy to identify low cost opportunities for reduction of environmental impacts.

4) Under provision of information

Taking into account transaction costs, many consumers have incomplete information about the options for different heating devices, their potential energy savings, their reliability, and other attributes. Information has public good attributes; once it is created, many can use it at little or no additional cost. Therefore, information on energy efficiency is often under-supplied in the market unless provided by the government.[31] Related to the lack of information on energy efficiency is the positive externality generated when early adopters install a technology new to the market. The reliability and operating cost savings are often uncertain without many trials; therefore, consumers are often reluctant to use new technologies. A role for government intervention is to reward early adopters for making an investment and "testing" new energy efficient heating devices.

5) Limited credit

For a number of reasons, individuals who wish to purchase capital-intensive energy efficient goods may not have access to capital. Even if a loan to finance the purchase is available, interest rates will reduce the energy-related financial savings and thus reduce the benefits of such purchases.[32] Access to more capital (or capital at a lower price) may allow new homebuyers to pay for a high efficiency heating device.

Jaffe and Stavins were, perhaps, the first to clearly distinguish between market and non-market failures related to the so called "energy efficiency gap" (1994b) - that is, the gap between actual and optimal levels of energy use whether that be defined by financial or full economic costs. Non-market failures related to energy efficiency include:

- Uncertainty in a technology (for example its durability or efficiency performance);

- The risk of making irreversible investment decisions;

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[31] A pure public good is non-exclusive and non-rival; that is, one cannot prevent another from consuming the good and for any given level of production, the marginal cost of an additional consumer is zero.
[32] The opportunity cost of capital should always be considered in capital-intensive purchases.

- Transaction costs for acquiring energy efficient information or adopting a technology; for example, the cost of learning how to operate a more complicated thermostat;

- Characteristics that are viewed to be less valuable; for example, reduction of comfort levels due to uneven heating patterns;

- An energy efficient technology may be cost effective for the average consumer, but there is heterogeneity among the market in terms of costs and use patterns. For example, different homes have different space heating loads that may or may not warrant the purchase of a more expensive high efficiency heating device; and

- Finally, a level of inertia often exists in consumer adoption behaviour.

As expressed by Jaffe and Stavins (1994b), the "technologist's optimum" is to ignore market failures and strive for a 100 percent market penetration of energy efficiency devices. A "true social optimum" takes into account non-market failures and only focuses on policies that can be defended from a cost benefit perspective.

These non-market failures create intangible costs that need to be assessed when determining the optimal rate of energy efficient market penetration; these costs can elevate the average discount rate for adoption of energy efficient technologies. Implied discount rates for heating and cooling appliances have been found to be as high as 30 and 60 percent (Dubin, 1984:; Sadler, 2003). Policies in this study will not focus on the "technologists' optimum" level of market penetration that ignores these intangible but relevant costs or attempts to overcome non-market failures. Policies, instead will be directed at achieving the "true social optimum"; focusing on eliminating or counteracting the market failures listed above with policies that could pass a cost benefit test (Jaffe, A. B., & Stavins, R. N., 1994:; Jaffe, 1999).

6 Methodology

In previous sections, I make the case that electric space heating in SFDs on Vancouver Island imposes too great a social cost on British Columbians. The response by utilities and the Province to date has been to encourage natural gas over electric baseboard heating. My methodology is structured to first analyse whether a fuel switching policy is appropriate, or whether the province should take a fuel neutral approach to reducing space heating load. The criteria assessed to determine the policy approach are private costs/ determinants of fuel choice, marginal cost analysis, air emission impacts, and current political and policy context. Once the policy approach is determined, policy options to reduce electric space heating load are assessed using effectiveness, economic/financial, equity, political feasibility, and administrative ease criteria. Policy effectiveness is analysed by using a demand forecast model I built, private cost analysis, and qualitative assessment based on academic and industry literature.

6.1 Methodology for Policy Approach Analysis

6.1.1 Determinants of Fuel Choice/Private Cost Analysis

Analysing historical space heating choices against a backdrop of energy prices, and capital costs gives insight into determinants of new construction fuel choice. I use historical rates, private costs, and regression analysis to indicate whether market failures are at play in fuel choice. If fuel choice appears to be driven by cost, it is less likely the principal-agent market failure has a great influence on space heating fuel choice. Private costs can also demonstrate what costs might be imposed on consumers by a fuel switching agenda.

6.1.1.1 Regression Analysis

I use regression analysis to examine the influence of energy prices and the percentage of tract homes in the market on fuel choice. Two databases are combined and analysed. The first database contains space heating related interview results obtained by Habart & Associates

Consulting Incorporated for Terasen Gas Inc. and BC Hydro.[33] The second database is the Natural Resources Canada Energuide for Houses database. [34] Forced entry binary logistical analysis is used on the dependent variable of fuel choice – one if natural gas is the primary fuel choice and zero if electricity is used for space heating. All 263 cases were included in the model. The time-period analysed, 1994-2005, provides a sufficient length of time to demonstrate variation in behaviour and sufficient number of data points.

Annual average natural gas price (for the heating season – November to March) and new construction housing starts for Vancouver Island are the independent variables in the model. A superior model would measure the relative contribution of capital costs (including subsidies available), energy prices, a developer's previous building patterns, custom and model home ratios (a measure of the primary decision-maker), and income (a measure for access to capital) on fuel and heating device choice – unfortunately, data limitations prevented optimal model analysis. **See Appendix A for a discussion on fuel and heating equipment choice determinants.**

New construction housing starts are used as a measure of the state of the housing market to give an indication of the level of tract home building. In the new construction market, consumers and developers are heating equipment decision-makers. In custom-built homes, a consumer can select heating fuel and equipment. The developer makes heating choice in model built homes. The housing starts independent variable tests the theory that higher levels of electric space heating is partially a result of more model homes being built. I hypothesize that baseboards are the heating choice of tract homebuilders due to its low capital cost. When the market is doing well (as in the last five-seven years on Vancouver Island), there are more tract homes being built.[35] The best measure for the state of housing market is the number of construction starts per year. Therefore, the increase in baseboard heating may be partially due to an increase in model home building and a potential measure is the state of the housing market.

Due to constant electricity prices, I theorize, natural gas fuel prices also act as a driver in fuel choice. Since deregulation of natural gas as a commodity in 1985, natural gas prices are established through open markets. Customers now experience price signals from excess demand or constrained supply in today's integrated North American market. A tight demand/supply balance and the higher costs of new marginal supplies have resulted in price fluctuations over the

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[33] The interviews were conducted on Vancouver Island homeowners whose homes were constructed between 2000 and 2005 (Habart & Associates Consulting Inc., 2004).
[34] It contains information on all Energuide retrofits undertaken in British Columbia until November 8, 2005. The database only contains houses that have requested and conducted an Energuide evaluation.
[35] Personal Communications, Prill, Peggy, Canadian Mortgage and Housing Corporation, Senior Market Analyst, March 21, 2006.

past seven years (see Figure 3 below) (Canadian Gas Association, 2005). However, electricity rates are regulated by the BCUC and based on average embedded pricing.[36] Consumers will therefore expect fluctuating natural gas prices, while electricity will be seen as a stable charge even in colder than normal winters.

Sumas natural gas prices are used to represent energy prices. Both Terasen Gas Vancouver Island rates and Sumas natural gas prices were tested in the regression analysis. A consumer would pay Terasen rates, but natural gas market prices is what is predominantly in the media and therefore have more interface with the general public. Sumas heating season prices (between November and March) are used to represent public perceptions around natural gas prices.[37] Natural gas prices are lagged by two years, as a significant time delay can exist between when a house is designed (when the heating fuel choice is made) to when it is completed. Different heating fuels have different BC Building Code requirements therefore fuel choice is likely made in the design phase and thus, a time lag is appropriate.

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[36] Based on the Provincial Energy Plan's focus on maintaining low electricity rates, it is reasonable to assume that electricity rates will remain stable rising only with inflation (Ministry of Energy Mines and Petroleum Resources, 2002).

[37] As a distribution utility, Terasen passes natural gas commodity and transmission prices directly on to its consumer, yet natural gas commodity costs are not based on the prices from one market hub. Terasen use a variety of tactics to obtain the price for residential consumers including: purchasing gas from a variety of sources, locking in the price of gas through contracts, and putting gas in storage for use at a later date. Therefore, Sumas prices are not perfectly reflective of Terasen commodity costs.

Figure 3 Sumas Gas Monthly Gas Prices 1990-2005 (2005 $CDN/GJ)
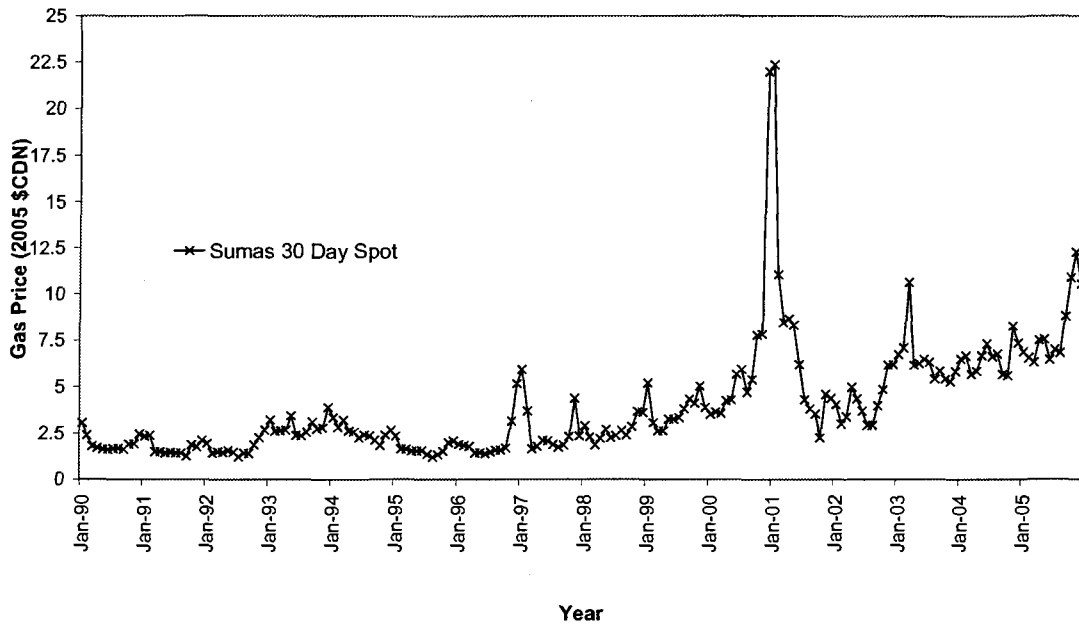
Source 3 National Energy Board

6.1.1.2 Private Costs

Data for private cost analysis are from various sources. Terasen Gas and BC Hydro provided historical rates. Innes Hood consulting, funded by BC Hydro, provided average space heating load; details are found in Appendix A. These space heating loads are based on the Energuide for Houses Database. Andy Kesteloo of Thornley BKG Consultants Incorporated (who provide construction project and cost management services) provided capital costs for heating devices (see Table 5 below).

Capital costs are based on pricing conducted on March 31, 2006, for a 2000 square foot house in Victoria or Vancouver with a space heating load of approximately 12,000 kWh.[38] Pricing is quite volatile in the construction industry and variation should be expected. Ducting, installation, the heating appliance costs, taxes, and hook-up fees are included in the cost assessment. Electricity hook-up fees include the cost to upgrade a home from a 200 to 400-amperage service. High efficiency natural gas furnaces are assumed exempt from Provincial Sales Tax based on current provincial policy.

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[38] The same space heating load was used for electric and natural gas houses; in reality, the BC Building Code requires electrically heated homes to have a higher level of insulation. Electrically heated homes would be more efficient, benefiting their operating costs, but have a great capital cost. These additional costs/savings would have conflicting effects on payback periods and are assumed not to substantively change the analysis.

Table 2 Heating Appliance Capital Costs in Victoria March 2006

	Total Cost	Incremental Cost to Baseboard Heating
Electric baseboard heating	$5,454	$0
Electric Furnace	$10,470	$5,016
Air Source heat pump – HSPF 9.9	$15,600	$10,146
ASHP HSPF 8	$12,419	$6,965
ASHP HSPF 7.3	$11,040	$5,586
Mid efficiency furnace	$8,850	$3,396
High efficiency furnace	$13,461	$8,007

Source 4 TBKG Consultants Incorporated

To examine private costs for homeowners, a critical value for natural gas rates is calculated for a 15-year payback period (natural gas furnaces are assumed to have an average 15 year lifespan). The critical value is the natural gas rate (including commodity, transmission, and distribution costs) required for a homeowner to have lifecycle costs equivalent to electric baseboards. Lifecycle costs are calculated using the following formula:

$$LCC = CC * \left(\frac{r}{1-(1+r)^{-n}} \right) + \frac{SHL}{FE} * E$$

LCC = Lifecycle Costs

CC = Capital Costs

r = Discount Rate

SHL = Space Heating Load

FE = Furnace Efficiency

E = Energy rate

A discount rate of 6 percent is used to be consistent with the amortized payback period calculations in subsequent sections. As natural gas commodity prices are volatile and it is

uncertain how BCUC will regulate rates, a critical value on savings is preferred to testing various price forecasts and their impact on payback periods.

Using the above method does not necessarily reflect how developers perceive purchasing choice nor would it accurately reflect revealed discount rates for replacement purchases. Discount rates, or the implicit rate of return that a developer or consumer requires to make an investment decision can be quite high.[39] Tiedemann (1995) found developers to use an implied discount rate of thirty percent. Consumer discount rates in revealed preference studies reflect time preference, consumer preferences, outcomes from lack of information, the effects of principal/agent problems, constrained borrowing, and inertia. These discount rates are therefore often in excess of borrowing rates. The United States Environmental Information Administration calculates personal discount rates often in excess of 30 percent.

At the same time, new construction likely has lower discount rates due to lower levels of inertia, transactions costs, and time preference rate, especially when consumers, not developers, are the decision-makers. When compared to the cost of a house, the incremental cost of a heating system is quite small. Increasing a mortgage by a $3,000-10,000 likely presents fewer tradeoffs than paying the capital cost of a heating system upfront. Consumers with access to information on energy savings and capital costs have been shown to have significantly lower discount rates. Sadler (2003) found stated preference survey discount rates between eight and nine percent. Any market failures that raises the discount rate but does not impose greater costs to consumers, such as lack of information, could also be ignored in payback analysis. In this policy assessment, payback analysis is used to assess costs to consumers not to estimate market penetration of heating equipment.

6.1.2 Economic Cost Analysis

The marginal cost of natural gas and electricity is measured by the price of an additional gigajoule of heat. The cost of providing a gigajoule of heat differs depending on when that heat is required. Heat required during peak hours on the coldest day of the year is far more costly than off peak winter heat requirements, and even more costly than off peak requirements in the fall or spring. Capacity related costs depend on the space heating influence on peak. A marginal cost averaged over the heating season spanning November through March is calculated. **Details on how marginal costs are calculated can be found in Appendix A.**

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[39] A discount rate is defined as the rate at which the public sector must pay the private sector in order to induce the private sector to forego consumption today.

Consistent marginal cost estimates are important in determining which fuel type is the least cost approach. Unfortunately, Terasen Gas Vancouver Island Inc. either does not have a forwarding looking incremental cost study or will not make it publicly available. Instead, I must use a proxy for natural gas distribution on Vancouver Island.

6.1.3   Environmental Impact

Greenhouse gas emission intensities of electric baseboards, mid and high efficiency natural gas furnaces, and low and high efficiency heat pumps are compared as a measure of environmental impact. In this analysis, high efficiency heat pumps are considered to have an efficiency of 291% (HSPF of 10) and low efficiency of 229 percent (7.8 HSPF). The "best" and the "worst" case scenario for electricity air emissions are considered. In the "worst" case scenario, fossil fuel fired thermal generation, either a pulverized coal supercritical 560 MW plant or a 500 MW combined cycle gas turbine is considered the generation source on the margin. In the best-case scenario, marginal sources are assumed at least 50 percent BC Clean Energy, based on the Provincial Energy Plan.[40] [41] It is unlikely that all new BC Hydro generation will be BC Clean or Green. Even the Low Air Impact and Diverse Portfolios generated for the 2005 Integrated Electricity Planning Process contain substantial natural gas fired generation especially in the near term.[42] Site C has such a long lead time, 11 years, that the project will have little impact on levelized emissions over the next twenty years (BC Hydro, 2005a). **See Appendix A for an explanation of why greenhouse gases and marginal generation emissions are used as an environmental indicator in this study.**

Emissions intensities for electricity supply are obtained from BC Hydro's 2005 Resource Options Report (ROR) (with the exception of CCGT lifecycle emissions) and adjusted by 12.9704 percent for transmission losses. The global warming potentials used to convert different greenhouse gases to carbon dioxide equivalents are those listed in the Intergovernmental Panel on Climate Change (IPCC) 2001 Scientific Assessment (International Panel on Climate Change,

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[40] B.C. Clean Electricity is defined as alternative energy technologies that result in a net environmental improvement relative to existing energy production for facilities of 50 MW or more (Ministry of Energy Mines and Petroleum Resources, 2002). Examples may include hydro, wind, solar, photovoltaic, geothermal, tidal, wave and biomass energy, as well as cogeneration of heat and power, energy from landfill gas and municipal solid waste, fuel cells and efficiency improvements at existing facilities.
[41] This is a low estimate as the Clean Energy acquired in fiscal 2005 was only 35 percent. In order to achieve the target over 10-year period marginal sources must exceed 50 percent to reach the target.
[42] The 2005 Integrated Electricity Plan (IEP) outlines how BC Hydro will meet their forecasted electricity load over the next 20 years.

2001).[43][44] CCGT lifecycle emissions are the same lifecycle emissions used for natural gas furnaces. Using the same lifecycle emissions for natural gas and electric space heating ensures consistency in comparison, as natural gas carbon dioxide (CO_2) emissions intensity changes significantly from year to year (see Figure 4).[45] These losses are based on the assumption that new generation will be close to the Lower Mainland load centre.

Natural gas emissions at various lifecycle stages are obtained from a variety of sources. Natural gas lifecycle emissions intensity is obtained from the Canadian Association of Petroleum Producers (CAPP). Terasen Gas and Duke Energy provided 2002 data for CO_2e from transmission and distribution. End-use is based on the average daily composition of gas supplied to the Lower Mainland and Vancouver Island in 2005 from the Duke system at Huntingdon station. N_2O and CH_4 end-use emissions are from Canada's Greenhouse Gas Inventory (Matin, 2004).

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[43] CO_2e = Carbon dioxide or greenhouse gas equivalent is a unit that expresses the radiative forcing of a given GHG in terms of carbon dioxide with equivalent radiative forcing (Government of Canada, 2005).

[44] Global warming potential is a measure of the radiative effect of a greenhouse gas as compared to CO_2. By definition the GWP of carbon dioxide is 1. The GWP values for all other greenhouse gases are greater than 1 (Government of Canada, 2005). The associated GWP is multiplied by the quantity of each greenhouse gas to produce an equivalent measure that can be used as the total greenhouse gases called carbon dioxide equivalents (CO_2e). GWPs are available for different time horizons but the IPCC uses the one hundred year time horizon (International Panel on Climate Change, 2001).

[45] It should be noted that BC Hydro's natural gas lifecycle emissions used in BC Hydro's ROR are much higher than those provided by CAPP – 37 t/GJ and 7 kg/GJ respectively. Time restrictions prevented an analysis of BC Hydro's methodology but natural gas emissions may be a low estimate in comparison to coal emissions. Natural gas lifecycle emissions are greater than coal lifecycle emissions in the ROR but by using CAPP numbers natural gas gains the advantage.

Figure 4 Average CO2 Concentration for All B.C. Gas Production 1954-2004
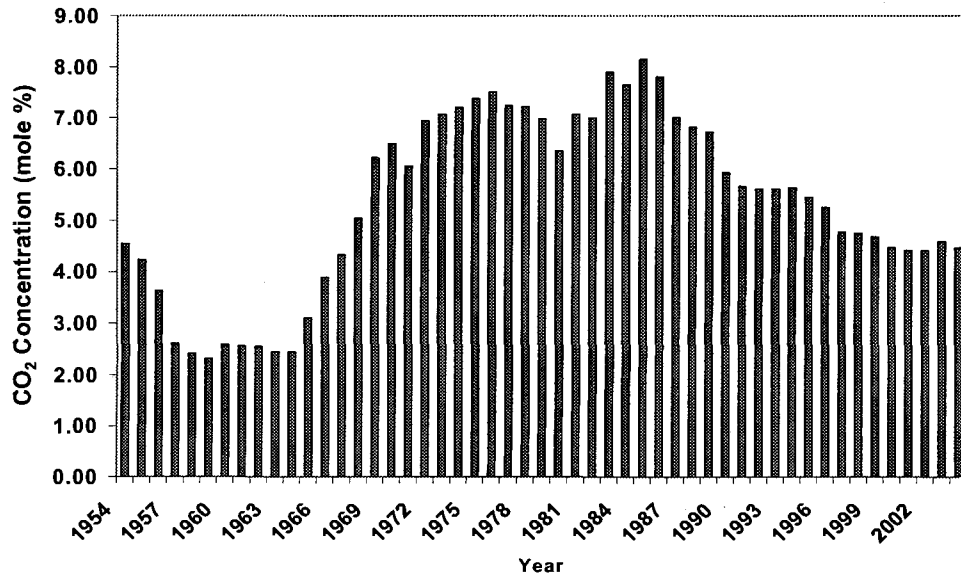
Source 5 Irwin, Tony. Duke Energy.

6.2 Demand Forecasting

This section outlines the method I use to construct a model to estimate energy conservation potential for different policy options. It also outlines private and marginal cost payback methodology used in policy analysis.

Initial market shares for fuel and heating equipment choice is based on 2000-2005 data obtained from the Habart and Energuide combined databases. Fuel choice is then adjusted yearly based on the probability of choosing natural gas found in the regression analysis and the yearly natural gas prices associated with the high natural gas price forecast. Changes in heating equipment are adjusted based on the yearly differences found in the BC Hydro forecast generated by the Residential End-Use Energy Planning System model (REEPS). [46]

To obtain the total space heating load energy consumption/savings, market shares are multiplied by the predicted annual number of new SFDs and the average space heating load for new construction.[47] Space heating load is dependent on a number of factors including: weather, airtightness (or energy efficiency) of a building shell, area and exposure of a building envelope,

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[46] REEPS May 13, 2005 forecast is used. Fuel and equipment shares are not used as they are based on electric space heating shares as reported by billing data. Depending on the region, the billing data can be significantly different from end-use surveys. In addition, fuel choice adjustments are not made based on the forecast price of natural gas.

[47] New construction numbers are taken from the BC Hydro forecast.

basement style, and square footage of a building. Space heating load is the energy required to heat a house per year. The load and the efficiency of the heating devices determine the energy consumption required to provide a given heating service. Heat pump efficiencies used in demand modelling are based on the U.S. Department of Energy's HSPF rating for region IV. **See Appendix A for an explanation of how I verify HSPF performance.**

The average annual space heating load is adjusted downwards on the assumption that thermal efficiency of new building shells will improve over time and decrease the absolute amount of space heating load. Figure 5 demonstrates an increase in Energuide for Houses rating, a measure of energy efficiency of homes, over time in British Columbia (see Section 8.5 for description of the Energuide for Houses rating system).[48] Natural energy savings are estimated to increase by 204 kWh per year. Distribution, and transmission losses at a rate of 12.9704 percent are included in the electricity savings calculations.[49]

To obtain peak consumption/savings the annual electricity consumption is divided by 1000 (to convert from GWh to MWh) and by a load factor, and multiplied by a coincident factor (see Load and Coincidence Factors in Appendix A). Levelized savings, using a discount rate of eight percent, are calculated for 1, 5, 10, and 15-year increments. At twenty years, levelized savings are only slightly higher; therefore, they are not presented in the results. Cumulative savings at 10 and 20-year periods, with no discount factor, are also presented.

Modelling the Energuide for Houses policy option required additional assumptions. **See Appendix A for a full description of assumptions made regarding the Energuide for Houses policy option.**

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[48] At the same time, increases in housing floor space and volume could offset building shell energy efficiency improvements. SFD square footage has increased in the Lower Mainland and the Southern Interior but not Vancouver Island between 1994-1999 and 2000-2005.
[49] Natural energy savings are savings that would have happened in the absence of policy intervention.

Figure 5 Average EGH Rating Change for Houses by Year Built
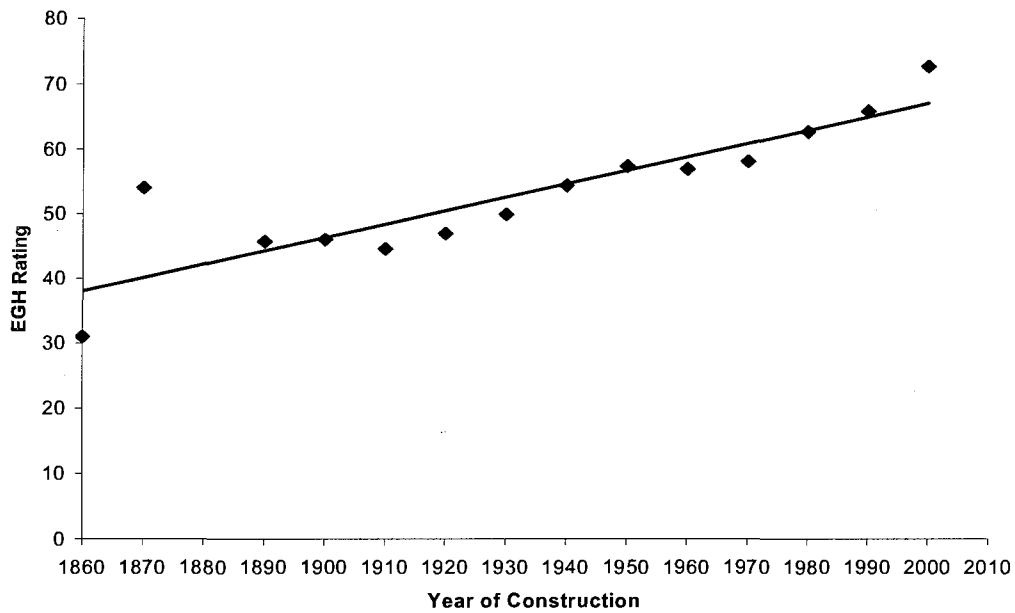
Source 6 BC Energuide for Houses Database

6.2.1 Private Costs of Policy Options

Private payback period are calculated for three of the four policy options. See Table 2 for capital cost of different heating equipment. Different bundles of energy efficient technologies were modelled in *Lifecycle Cost Analysis Energy Standards for New Low Rise Buildings* (Cooper, 2004). Two bundles are chosen to analyse private payback periods. Details on these bundles can be found in Appendix A.[50] Bundle number two includes an air source heat pump.[51]

I assume that incremental capital costs of different heating systems are added to a new homeowner's mortgage. The payback period is therefore based on a monthly-amortized mortgage at an annual interest rate of six percent.[52] Electricity rates are used for operating cost savings. EIA and High gas electricity forecasts are then used for payback based on the marginal cost of generation (see Appendix A for a description of these forecasts). EIA prices proved to be close to current rates; therefore, it was dropped from payback analysis. Accurate marginal cost estimates for transmission and distribution are only available for 10 years into the future therefore a proxy estimate of $6/MWh is used for transmission and distribution costs obtained from internal analysis done by BC Hydro. A $15/ton for greenhouse gas external cost is added to the marginal

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[50] Bundle number one increases a homes' EGH rating from 76 to 80 and bundle number two from 76 to 81.
[51] The efficiency of the heat pump is not indicated in the report.
[52] See Section 6.1.1.2. for an explanation of why a 6 percent discount rate is used.

cost of electricity to obtain an estimate for the social cost of electricity. The electricity source is assumed 50 percent 500 MW CCGT and 50 percent non-emitting generation source such as wind, or hydro. It is assumed that the energy advisor fee of $300 to $350 is already incorporated into the capital costs of these energy bundles.

To avoid forecasting natural gas rates on the Island, a critical factor for natural gas savings is calculated for a 15-year payback period (natural gas furnaces are assumed to have an average 15 year lifespan). The critical value is the amount of savings per unit of heat ($/GJ) a homeowner would have to incur for a 15-year payback on a monthly mortgage at an annual rate of 6 percent. As natural gas commodity prices are volatile and it is uncertain how BCUC will regulate rates, a critical value on savings is preferred to testing various price forecasts and their impact on payback periods.

7 Policy Approach and Analysis

This section seeks evidence for market failure in fuel choice thus justification for public policy intervention to shift space heating load from electricity to natural gas. Section 5 outlines potential market failures but it must be determined that these market failures are applicable to fuel choice on Vancouver Island. The burden of proof lies in demonstrating that natural gas is the socially optimal heating fuel; without proof of natural gas superiority over electricity for space heating, it is difficult to justify interference in consumer choice.

The policy options analysed in this study can be modified to fit either a fuel neutral or fuel switching policy approach (see Table 3 below). Fuel neutral policies encourage high efficiency heating appliances irrespective of the fuel type. Fuel switching policies discourage the use of electricity and encourage the use of natural gas. Policy options range from low levels to higher levels of policy intervention. These policy options are discussed in Section 8.

Table 3 Policy Options for each Policy Approach

Policy Approach	Fuel Switching Policies	Fuel Neutral Policies
Policy Options	• Natural gas subsidy	• High efficiency heating device subsidy
	• Disincentive for higher residential amperage	• Mandatory EGH standard
	• Regulate HSPF for heat pumps[53]	• Regulate heating appliance efficiency
		• Program for standardized heat pump installation

To assess which policy approach to take, I examine the following criteria:

• Private costs / evidence for consumer choice

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[53] HSPF regulation is categorized under fuel switching because regulating a higher HSPF would increase the cost of heat pumps relative to natural gas and likely favour the selection of natural gas over electricity.

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- Marginal cost of space heating/economic issues

- Air emissions

- Political feasibility/policy context

These criteria are chosen to examine costs from a homeowner's, utility's, and society's perspective.

7.1 Analysis

7.1.1 Private Costs - Why Islanders are Choosing Electric Heating

Private costs (costs a homeowner must pay) reveal what costs fuel switching may impose on consumers. Private costs can also indicate why heating choices are made - whether developers and consumers make choices based on costs and benefits or whether there are market failures at play preventing efficient choices.

BC Hydro has various theories on why electric heating is the predominant choice on Vancouver Island. The principal-agent problem is seen to play a predominant role, that is, developers are making choices based on capital costs and not taking into account future operating savings a homeowner could gain from natural gas (see Section 5 for further description of the principal-agent market failure) (British Columbia Utilities Commission, 1991). Another theory is if a developer is familiar with specific building practices, they have a tendency to have little variance in their building design – again ignoring potential lifecycle cost savings for homeowners. Utility representatives also postulate that as natural gas is new to the Island residents have a greater mistrust in natural gas – a market failure in information provision on natural gas safety.

Historical energy rates, and payback analysis reveals that the average consumer/developer seems to be choosing heat equipment with the lowest lifecycle costs and fuel switching would impose greater costs on Islanders. Electric baseboard heating is likely chosen because it is has the lowest lifecycle costs. Natural gas savings, required to payback the incremental capital costs in a 15-year timeframe, are not realistic; natural gas rates are not sufficiently low to provide cost savings to reimburse the purchase of the furnace within its lifetime. If the principal-agent problem were a major factor, you would expect the average lifecycle costs of natural gas to be lower than electricity.

When comparing fuel rates, electricity is more expensive to heat your home due to the soft cap on natural gas rates on the Island.[54] Figure 6 below shows despite rising natural gas prices, heating with electric baseboards is more expensive per gigajoule than heating with natural gas. Heating with different efficiency heat pumps is less expensive than heating with natural gas. These rates only reflect operating costs, capital costs must also be considered to provide a full lifecycle perspective.

Figure 6 Electricity and Fuel Rates between 1996-2006 for Different Heating Device Efficiencies (Nominal CDN$)
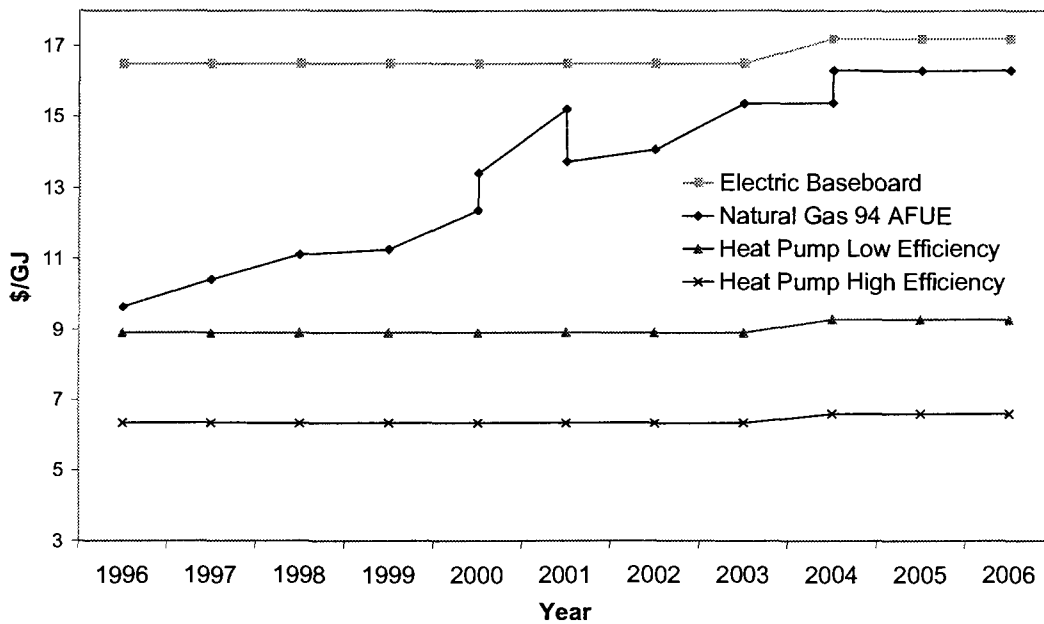
Source 7 Terasen Gas rates and BC Hydro rates

When compared to electric baseboards, natural gas furnaces require extremely low rates to provide sufficient payback to legitimise their purchase in a new home from a consumer monetary perspective (for the average single family home on Vancouver Island). Table 5 demonstrates the rate per gigajoule required so the 15-year lifecycle costs are equivalent to electric baseboard. The required rate is very low - under $7/GJ for mid efficiency furnaces; it is unrealistic to expect rates to drop to this level.[55] The incremental capital cost of high efficiency

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[54] The soft cap is designed to maintain natural gas rates lower than electricity rates.
[55] Recall that rates include commodity, transmission, and distribution costs.

natural gas furnaces (without the lifetime energy costs) is higher than the entire lifecycle costs for baseboard heating (including energy costs!).

Recall that the space heating loads used for private cost analysis are **average** space heating loads; a range of housing size and thermal efficiency exist on Vancouver Island, which can justify higher capital costs to be within the realm of savings to legitimise their purchase. The BC Energuide for Houses database demonstrates that houses heated with natural gas on average have a higher space heating load than houses heated with electricity.[56]

Table 4 Private Costs for Electric Baseboard in Average New Construction on Vancouver Island

	Space Heating Load (GJ)	Cost per GJ	Capital Costs	Lifecycle costs
Electric Baseboard Operating Cost	40.1	$16.81	$5,454	$1,234.91

Table 5 Private Costs for Mid and High Efficiency Natural Gas Furnaces in Average New Construction on Vancouver Island

	Space Heating Load (GJ)	Rate to equal baseboard lifecycle costs (GJ)	Capital Costs	Lifecycle costs
Mid efficiency Natural Gas Furnace	50.1	$6.46	$8,850	$1,234.91
High efficiency Natural Gas Furnace	42.6	$0.00	$13,461	$1,385.98

Source 8 Capital costs - TBKG Consultants Cost Assessment and space heating loads - BC Hydro

This study's regression analysis demonstrates that between 1994 and 2005 consumer fuel choice appears to respond to natural gas prices; in other words as the perceived lifecycle costs of natural gas heating go up there is less chance consumers will choose natural gas. The logistical

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[56] Although, this could be in part a result of different Building Code requirements. Houses built with electric heating are required to be built with a higher level of insulation. In addition, because of different Building Code requirements natural gas is less expensive to build. These cost differences were not taken into account in the natural gas assessment.

regression model has a Nagelkerke R square of 11 percent, or natural gas prices can only explain 11 percent of the variation in fuel choice. Sumas natural gas prices lagged by two years improve the predictable capability of the model to a significant degree ($p<0.0001$) - by 8 percent. Based on the literature and discussions with experts, other variables play a role in fuel choice (see Appendix A for Heating Choice Determinants in New Construction) so the limited power of the model is to be expected. A dollar increase in Sumas natural gas prices decrease by 15.8 percent the odds that a house completed two years later will use natural gas for primary space heating. This variable is highly significant.

While not extremely robust, the results from this model suggest that natural gas price fluctuations impact fuel choice in new single family construction or consumers are responding to prices visible in the media.[57] While Sumas prices do not reflect Vancouver Island natural gas rates due to the soft cap, consumers may not be aware of the soft cap.[58] Alternatively, they may realize that higher natural gas prices will result in higher rates overtime even with the soft cap - the costs of service and debt repayment simply occur over a longer time frame (see discussion associated with Figure 7).

New construction starts, a measure to determine the importance of the percentage of tract home building in the market, did not prove to be significant. The lack of significance could indicate that the principal-agent problem in tract homes may not be present to a significant degree. On the other hand, new construction starts may not be a good measure for the principal-agent problem.[59] Natural gas capital costs and commodity prices are not significantly different elsewhere in BC.

So why do other regions in the province predominantly choose natural gas heating? The answer is likely colder climates (resulting in higher space heating loads) and lower natural gas distribution rates result in greater cost savings and less sensitivity to price. The average space heating load for a SFD in the North is almost three times that of the average on the Island (see Appendix A Summary of Regional Space Heating Loads). Higher space heating load means operating cost savings accrue more quickly over time legitimising higher capital costs. Table 6 and Table 7 show that natural gas rates required to equal baseboard heating lifecycle costs are consistent with average historical prices especially considering the lower transmission and

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[57] Fuel choice could be leaning even more heavily towards electric space heating as the lag effect found in the regression analysis means the impacts of recent high gas prices would not be seen in the data analysed.
[58] Recall that Vancouver Island natural gas rates do not fluctuate in a pronounced way with Sumas natural gas prices due to the soft-cap.
[59] Regression analysis on Northern Interior, Southern Interior, and the Lower Mainland demonstrate no significant change in new construction fuel choice based on natural gas price.

distribution costs for the Northern Interior. Vancouver Island's lower space heating load yields lower operating costs therefore less opportunity for energy efficient savings and less justification for a homeowner to spend more money on capital-intensive space heating devices. Colder climates also increase the desire for the comfort of centralized space heating. In addition, air-source heat pumps do not perform as well in colder climates.

Table 6 Private Costs for Electric Baseboard Heating ion Average New Construction in Northern Interior BC

	Space Heating Load (GJ)	Cost per GJ	Capital Costs	Lifecycle costs
Electric Baseboard	$106.30	$16.81	$5,454	$2,347.99

Source 9 Capital costs - TBKG Consultants Cost Assessment and space heating loads - BC Hydro

Table 7 Private Costs for Mid and High Efficiency Natural Gas Furnaces in Average New Construction in Northern Interior BC

	Space Heating Load (GJ)	Rate to equal baseboard lifecycle costs (GJ)	Capital Costs	Lifecycle costs
Mid efficiency natural gas	$132.88	$10.81	$8,850	$2,347.60
High efficiency natural gas	$113.09	$8.50	$13,461	$2,347.21

Source 10 Capital costs - TBKG Consultants Cost Assessment and space heating loads - BC Hydro

High market shares of natural gas in Interior BC might be justified by the colder climate but why does the Lower Mainland build with natural gas when the climate is similar to that on Vancouver Island? Natural gas rates in the Lower Mainland have historically have been lower than those on Vancouver Island. Figure 7 (below) reveals that not only do Lower Mainland customers have lower rates, but also during periods of lower commodity costs the rates drop lower than those on Vancouver Island. Higher cost of distribution and the necessity to pay off the

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Revenue Deficiency Deferral Account (RDDA) means that Vancouver Island customers do not benefit to the same extent from periods of low gas prices as Mainland customers.[60] [61]During periods of lower commodity costs, Vancouver Island rates include amounts to pay off the debt from establishing the utility on the Island.

The Lower Mainland also has a higher average space heating load from larger homes and lower levels of insulation that may to an extent warrant the investment in natural gas furnaces. The BC Energuide for Houses database demonstrates that the Lower Mainland has higher space heating loads – on average 12 GJ higher for electrically heated homes and 23 GJ for homes heated with natural gas. Again, higher space heating loads result in a greater opportunity for accruing enough savings to legitimise higher capital costs.[62] These heterogeneous costs between Vancouver Island and the Lower Mainland, again, represent a non-market failure in heating choice and do not legitimise policy intervention.

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[60] RDDA = Revenue Deficit Deferral Account, or the debt accrued from initial investment in the natural gas pipeline to the Island.

[61] As a new utility, it has high distribution costs, since the large fixed costs of a utility are not spread across a large number of customers.

[62] At the same time, there will be higher costs for ducting and furnace size with larger homes and larger space heating loads.

Figure 7 Terasen Gas Lower Mainland and Vancouver Island Variable Rates 1996-2006
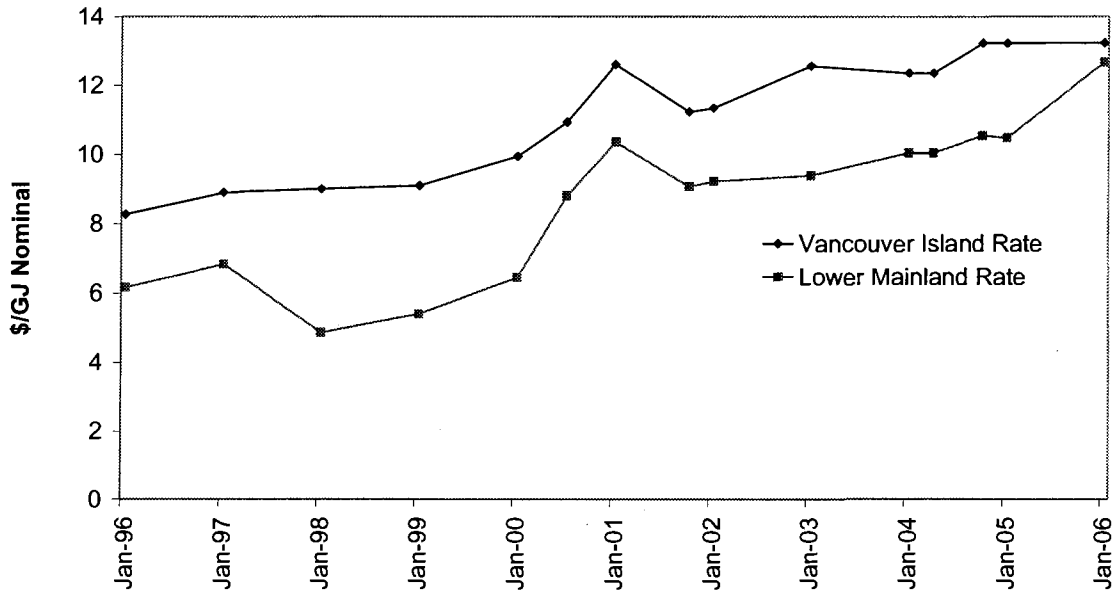
Source 11 Terasen Gas Historical Rates

In sum, there has been a shift to electric heating in new construction on Vancouver Island likely due to the combination of higher natural gas prices, already high distribution rates, and low space heating loads. Capital cost differences between electric baseboard, and natural gas furnaces are significant.[63] Regression results suggest that developers/consumers are watching natural gas prices to determine whether rates will remain low enough to allow enough savings to legitimise the capital investment. New construction housing starts, the variable to measure the principal-agent problem, did not prove to be significant; therefore, the principal-agent is may not be present in a substantial way.[64] There appear to be legitimate cost difference driving heating choice, therefore less of a chance that market failure is driving fuel choice.

7.1.2 Marginal Cost/Economic Issues

This section compares the economic cost of using natural gas or electricity for space heating in new construction on Vancouver Island. Electricity prices do not reflect marginal costs but neither do natural gas rates on Vancouver Island. Comparing their marginal economic costs

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[63] Additional costs for higher insulation requirements for electrically heated homes are not included in these figures but operational costs from the increased insulation and potential for tonal heating are also not included; therefore, the missing costs are assumed not to dramatically change this cost assessment.

[64] At the same time, this variable may be a poor measure for the level of model home building in the market.

can demonstrate what fuel imposes a lower cost on society (excluding environmental impacts). Marginal economic costs of electric space heating must be higher than natural gas heating for this criterion to favour fuel switching policies.

This marginal cost analysis favours a space heating fuel neutral approach, as based on the data available, natural gas space heating does not have the lowest marginal economic cost. Incremental cost data for distribution of natural gas is not available, and the proxy distribution costs available show natural gas marginal cost is higher than electricity. As the burden of proof lies in demonstrating that the fuel switching approach is socially optimal, this criterion therefore favours a fuel neutral approach. Future marginal costs may be lower due to economies of scale in distribution to a larger number of customers.

Table 10 through Table 13 demonstrate that, based on the methodology used and the information available, the levelized marginal cost of natural gas is higher than electricity.[65] Depending on the natural gas price forecast, the marginal cost of electric space heating for new construction on Vancouver Island ranges between $83 and $132 per MWh (see Table 8 and Table 9 below) or $23 and $37 per gigajoule (see Table 10 and Table 11). The marginal economic cost of natural gas is between $38 and $45 per gigajoule.

Table 8 Levelized Marginal Cost of Electric Space Heating High Gas Price

High Gas Price			
	1 year	5 years	10 years
Generation ($/MWh)	$109.47	$116.43	$121.17
Transmission and Distribution ($/MWh)	$3.47	$7.53	$10.52
Total Electricity Cost ($/MWh)	$112.94	$123.96	$131.69

Source 12 Calculations based on figures in (Horii, 2004) and 2004 IEP Electricity Price Forecasts

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[65] The levelized cost can be thought of as the average price over the select timeframe at the same net present value. The discount rate used for this exercise is 8 percent.

Table 9 Levelized Marginal Cost of Electric Space Heating EIA Gas Price

EIA Gas Price			
	1 year	5 years	10 years
Generation ($/MWh)	$80.27	$75.31	$78.41
Transmission and Distribution ($/MWh)	$3.47	$7.53	$10.52
Total Electricity Cost ($/MWh)	$83.74	$82.84	$88.93

Source 13 Calculations based on figures in (Horii, 2004) and 2004 IEP Electricity Price Forecasts

Proper marginal cost analysis is required to determine the lowest incremental cost for fuel substitution on Vancouver Island. Distribution is the highest natural gas cost and it bears the greatest uncertainty. Since the marginal cost for distribution is not available, the variable cost of residential delivery is used, adjusted for load and coincident factors. Although this cost does not include the Revenue Deficiency Deferral amount (from the revenue deficiency for the cost of service prior to 2003) or the current soft cap on rates, it is unknown to what degree this represents the marginal cost, especially into the future. As a new utility, Terasen Gas Vancouver Island's (TGVI) distribution costs are high when compared to the variable delivery costs on the Lower Mainland. TGVI expects that these costs would go down with time especially if they continue to increase their number of customers to further spread out their fixed costs. Therefore, the actual levelized marginal cost is likely lower than the variable delivery cost. It is also unknown to what degree this average variable cost includes fixed costs so again the costs may be lower than presented.

Table 10 Levelized Marginal Cost of Electric Space Heating per GJ High Gas Price

Electricity - High Gas Price - Total Electric Heating			
	1 year	5 years	10 years
Generation ($/GJ)	$30.41	$32.34	$33.66
Transmission and Distribution ($/GJ)	$0.96	$2.09	$2.92
Total Electricity Cost ($/GJ)	$31.37	$34.43	$36.58

Source 14 Calculations based on figures in (Horii, 2004) and 2004 IEP Electricity Price Forecasts

Table 11 Levelized Marginal Cost of Natural Gas Space Heating per GJ High Gas Price

Natural Gas - High Gas Price - 94% AFUE			
	1 year	5 years	10 years
Commodity ($/GJ)	$14.14	$15.08	$15.63
Midstream ($/GJ)	$2.97	$3.51	$3.70
Distribution ($/GJ)	$20.98	$24.83	$26.15
Total ($/GJ)	$38.09	$43.43	$45.48

Source 15 Calculations based on figures in 2004 IEP Electricity Price Forecasts

Table 12 *Levelized Marginal Cost of Electric Space Heating per GJ EIA Gas Price*

Electricity - EIA Gas Price - Total Electric Heating			
	1 year	5 years	10 years
Generation ($/GJ)	$22.30	$20.92	$21.78
Transmission and Distribution ($/GJ)	$0.96	$2.09	$2.92
Total Electricity Cost ($/GJ)	$23.26	$23.01	$24.70

Source 16 Calculations based on figures in (Horii, 2004) and 2004 IEP Electricity Price Forecasts

Table 13 *Levelized Marginal Cost of Natural Gas Space Heating per GJ EIA Gas Price*

Natural Gas - EIA Gas Price - 94% AFUE			
	1 year	5 years	10 years
Commodity ($/GJ)	$14.14	$11.58	$11.90
Midstream ($/GJ)	$2.97	$3.51	$3.70
Distribution ($/GJ)	$20.98	$24.83	$26.15
Total ($/GJ)	$38.09	$39.93	$41.75

Source 17 Calculations based on figures in 2004 IEP Electricity Price Forecasts

7.1.3 Air Emissions

Another criterion to compare space heating fuels is greenhouse gas (GHG) emissions per unit fuel consumed. The fact that environmental externalities are not internalised in heating fuel prices constitutes a market failure from a public policy perspective. Natural gas must prove to have a lower level of environmental externalities, for this market failure to favour fuel switching policy intervention.

GHG emissions intensity is dependent on the fuel used and heating device efficiency. The marginal generation source depends on future resource decisions made by BC Hydro (see Appendix A for discussion on why marginal generation sources are used). Burning natural gas in one's home for heat makes more efficiency sense but this is dependent on the marginal generation source being 100 percent fossil-fuel generated. This section examines GHG emissions resulting from various combinations of thermal generation and electric heating devices, as compared to natural gas space heating. Policies and commitments made by BC Hydro are also examined to postulate what future resource decisions may be made.

Table 14 Greenhouse Gas Lifecycle Emissions for Natural Gas End-use, CCGT, Coal, and Burrard Thermal Power Plant[66]

Natural Gas Furnace Lifecycle Emissions		Fossil-fuel Powered Electricity Generation Lifecycle Emissions			
			CCGT 500 MW	Coal 560 MW	Burrard Thermal Power
	CO_2e (kg/GJ)		CO_2e (kg/GJ)	CO_2e (kg/GJ)	CO_2e (kg/GJ)
Upstream/ Transmission	8.2	Generation	109.8	285.6	163.2
Transmission	1.6	Upstream/ Transmission	8.2	16.5	8.2
Distribution	0.8	Total	118.1	302.0	171.4
End Use	50.2	Baseboard	118.1	302.0	171.4
Total	60.8	**Heat Pump - Low Efficiency**	**51.3**	**131.3**	**74.5**
Furnace – 80% AFUE	**76.0**	**Heat Pump - High Efficiency**	**40.6**	**103.8**	**58.9**
Furnace – 94% AFUE	**64.7**				

When we assume thermal generation represents 100 percent of electricity generation, electric resistance space heating has higher emissions intensity than natural gas used as a direct

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[66] Includes transmission losses for distribution, local transmission, and for bulk transmission from the Mainland to the Island.

end-use (see Table 14 above). Electric resistance space heating lifecycle CO_2e emissions range between 118 to 302 kg/GJ depending on the source of thermal generation. A high-efficiency natural gas furnace, even a mid-efficiency furnace, has lower emission rates by at least 42 kg/GJ - a logical finding considering efficiency losses from electricity generation (see Section 4.1) and the fact that coal is more carbon intensive. Fuel switching proponents use these arguments as environmental justification for favouring natural gas over electric space heating. However, CCGT may not be the marginal source for 100 percent of the heating season. Electric resistance heating sources have a lower GHG emissions intensity (as compared to high efficiency natural gas furnaces) if CCGT is the marginal source for less than 56 % (levelized) of the heating season.

Figure 8 Comparison of Combination Heating Device/Fuel Source GHG Intensity
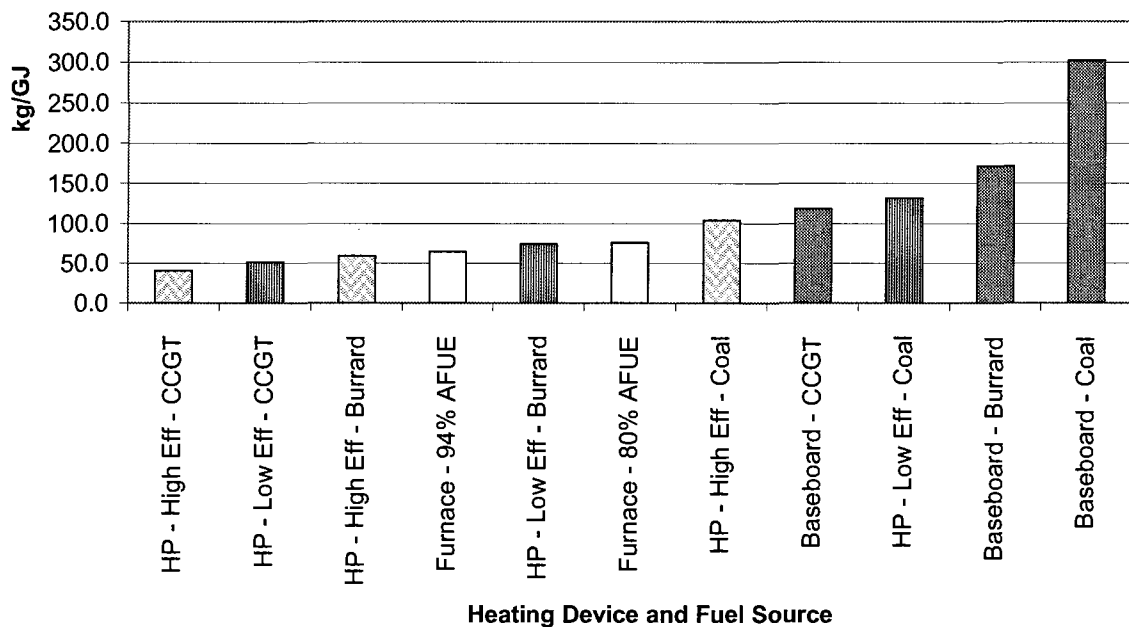
Note: HP= Heat Pump

Heat pumps run contrary to the supposition that fuel-switching programs have an environmental justification. If CCGT is on the margin, high and low efficiency heat pumps have lower emissions intensity (see Figure 8 above). A heat pump, running on CCGT generation, requires an average COP of at least 1.77 to out perform a natural gas fired furnace. If coal-fired power is the incremental generation for 100 percent of the heating season, natural gas furnaces have lower emissions intensity than even high efficiency heat pumps. A heat pump, running on coal-fired generation, has to have a seasonal COP of at least 4.5 to outperform high efficiency natural gas furnace emissions intensity, which is not possible for air-source pumps based on

current technologies. Associated with these coal emission intensities is the assumption that BC Hydro will not engage in carbon sequestration. If thermal electricity generation produces no net carbon (i.e., 100% sequestration), emissions intensity could be as low as zero.

It is clear that BC Hydro's future supply sources will determine what heating device is preferable from an emissions intensity perspective but no plan currently exists that lays out future generation sources. BC Hydro has recently completed the 2005 Integrated Electricity Planning (IEP) process that presents a range of future resource options including coal, natural gas, run of the river and hydro dams, and wind as having good potential for generation options.[67] No decision has yet been made on what generation options to pursue.[68] BC Hydro will also file a Long Term Acquisition Plan (LTAP), which outlines the proposed mix of resources it plans to use to meet the forecasted demand for the next 10 years.

As no resource plan is available, policy must be analysed to speculate on future marginal electricity emissions intensity. BC Hydro has stated concern about the impact of their operations on the environment. BC's *Governance Framework for Crown Corporations* maintains that crown corporations should have a commitment to "fiscal, social and environmental responsibility and ethical conduct" (Province of British Columbia, 2002:6). BC Hydro has two long-term environmental goals that may guide future supply decisions. One goal is to have no net incremental environmental impact in the future (BC Hydro, 2005b). The Electricity Intensity Reduction goal is to develop and foster a conservation culture in B.C. that leads to customers choosing to make a dramatic and permanent reduction in electricity intensity. It is unknown to what degree these goals will affect future supply decisions. Perhaps, the most marked commitment is for BC Hydro to acquire 50 percent of new resources from BC Clean Energy Sources.[69]

Marginal resources (therefore incremental GHG emissions) in the medium to long-term will likely conform to BC Hydro's commitment to acquire 50 percent of new resources from BC Clean Energy Sources.[70] The Clean Energy target follows the directive in the 2002 Provincial Energy Plan to pursue a voluntary goal of acquiring 50 percent of new supply from BC Clean Electricity between 2003 and 2013 (Ministry of Energy Mines and Petroleum Resources, 2002).

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[67] The IEP is a long-term plan that will outline options to meet anticipated customer electricity needs over the next 20 years. The BC Utilities Commission will vet the IEP and their decisions, in combination with directives from the Province of BC, to act as the basis for how the province meets electricity demand.
[68] The Integrated Energy Plan was released on March 30, 2006. An IEP can be completely rewritten every two years depending on market conditions or other factors.
[69] See glossary for the definition of BC Clean Electricity.
[70] See glossary for the definition of BC Clean Electricity.

BC Hydro has to date indicated their intention to achieve this target if the cost does not prove to be too great.

With a medium to long-term perspective on expansion and purchase plans and as BC Hydro reduces its supply deficit, 50 percent of marginal resources as BC Clean generation is realistic. If marginal electricity production is assumed to be 50 percent BC Clean, all types of heat pumps and CCGT using electric resistance heating has lower emission intensity than natural gas furnaces (see Figure 9).[71]

Figure 9 Comparison of Combination Heating Device/Fuel Source GHG Intensity if 50 % of New Supply is from BC Clean Energy
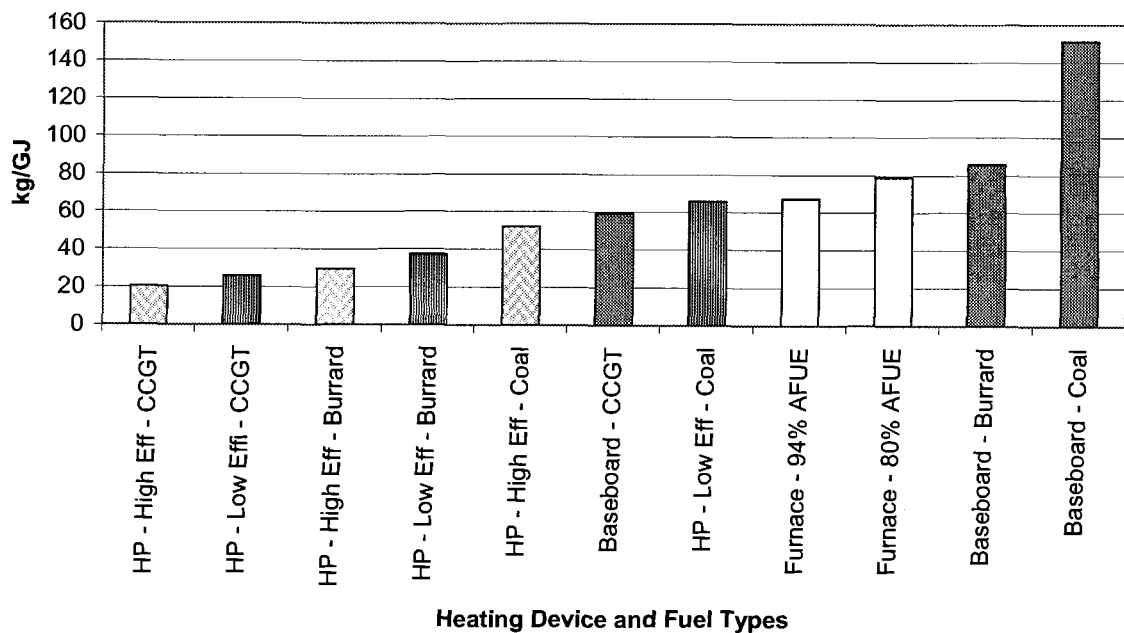
At the same time, cost may influence what resource allocation decisions BC Hydro makes. The Provincial Energy Plan stated that the Clean Energy target "may raise electricity rates by 0.1 to 0.2 percent per year over the next decade". BC Hydro has interpreted this statement as a cap on the maximum rate impact due to this target. If demand increases beyond forecasted levels or sufficient Power Smart savings are not achieved, the cost of generation may influence BC Hydro to reduce their commitment to Clean Energy.

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[71] Note: An assumption is that no cogeneration is included in the 50 percent BC Clean mix, even though cogeneration fits under the definition of BC Clean Energy. Cogeneration has approximately 69 percent the GHG emission intensity of CCGT, although CCGT has 20 percent the NO_x emissions of cogeneration as it is assumed because of economies of scale that cogeneration does not use selective catalytic converters (BC Hydro, 2005a).

Based on BC Hydro's commitment to 50 percent BC Clean Energy, a fuel switching policy approach has little justification from an environmental perspective – even with marginal generation of 100 percent CCGT, heat pumps have a lower emissions intensity. The above GHG analysis therefore favours taking a fuel neutral policy approach. The first principle of BC Hydro's Energy Efficiency Plan is to, "justify and manage the business from an overall portfolio "bottom line" perspective". If BC Hydro continues to abide by its 50 percent Clean Energy commitment, fuel substitution programs will not fill the environmental criteria of triple bottom line analysis. If BC Hydro uses coal for 100% of future marginal generation with no carbon sequestration, fuel switching would have environmental justification; with the abundance of green electricity resource in British Columbia and poor public opinion of coal, this is an unlikely scenario. [72]

7.1.4   Political Feasibility

While not linked to market failures per say, policymakers are concerned with the political feasibility of policy intervention. The provincial government, at minimum, must consider whether new policies are consistent with current policies and acts. Based on legislated acts and past BCUC rulings, a fuel switching policy approach is not consistent with the current policy context.

Implementing a financial disincentive against electric space heating has regulatory barriers. The Utilities Commission Act section 39 states that public utilities have an obligation to provide service without discrimination, "a public utility must provide suitable service without undue discrimination or undue delay to all persons" (Province of British Columbia, 1996:39). A financial disincentive based on end-use would likely be considered discriminatory; in addition, in areas on the Island where natural gas not available, it would be ineffective and unwarranted. The approved tariff BC Hydro would have to be amended, as there is currently no provision to discriminate against the use of any specific type of heating system. The legislated heritage contract states that all British Columbians should benefit from inexpensive heritage hydrological assets, in other words, benefit from lower electricity rates. It is contradictory to have a legislated heritage contract that guarantees access to low-cost electricity to all British Columbians but introduces a financial penalty to discourage residential space heating.

Higher extension and/or connection fees have been suggested as a mechanism for electric space heating financial disincentives.[73] Under a proposed extension policy, BC Hydro will contribute to customer's extension fees based on the average wires cost it receives from all

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[72] In a 2005 BC Hydro survey, 74 percent of respondents are opposed to coal.
[73] Extension fees are upfront payment to BC Hydro for extending the distribution system to a new customer. A connection fee is the cost for a line drop and meter to connect a new home to the distribution system.

customers through electricity rates. Electrically heated homes will pay more wires-related costs through rates and non-electrically heated homes will pay less than their share.[74] If the proposed extension policy were approved, any additional extension fee for different types of space heating would be unwarranted based on costs. For connection charges, there are already different rates for different amperage sizes based on wires, connection, and labour costs that cover the costs of service. Without a total cost basis for a financial disincentive against space heating, the BCUC will likely consider the charge discriminatory.

Based on past rulings from the BC Utilities Commission, it is not likely that financial disincentives against electric space heating would be accepted. In 1991, BC Hydro attempted to introduce an extension fee levy of $1150 for SFD, $1000 for row, and $650 for apartments. In their 1991 decision, the BCUC wrote, "the Commission believes that, in attempting to correct market failure, B.C. Hydro should not force the fuel choice; in fairness that choice properly remains the prerogative of the end-user in a well informed market" (British Columbia Utilities Commission, 1991:18). In the above decision, BCUC did not question the desirability of fuel substitution, rather the most desirable way to send the price signal to the market. If higher connection charges were to be pursued, the Commission wanted to see a non-discriminatory, full cost approach. Compared to when this decision was made, the cost savings of natural gas for consumers are no longer as apparent, especially when heat pumps are considered.[75] In addition, BCUC accepted the principal-agent problem as a dominant market failure in fuel choice; yet, this study has not found evidence in market failure in fuel choice.

7.1.5 Fuel Substitution from Utility Perspectives

This study has not identified market failure that legitimises policy intervention in fuel choice, but from the perspective of Vancouver Island's utilities, fuel switching makes sense. BC Hydro's rate structure and the economic benefits to BC for trading electricity, favour cost effective demand-side management electricity conservation. Terasen Gas has an incentive to increase its customer base to gain economies of scale for their large fixed costs and to generate

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[74] The current extension charge policy provides a contribution to a customer's extension costs based on historic profitability analysis benefiting customers with a larger expected load (including customers using electric space heating).
[75] At the same time, the Commission has accepted financial incentives for natural gas space heating paid in part by BC Hydro. The BCUC has approved the negotiated settlement related to BC Hydro's 2005 Resource Expenditure and Acquisition Policy that included a residential fuel substitution program under Power Smart Two initiatives. Based on this approval, the BCUC accepts fuel switching programs at least partially funded by BC Hydro, likely from a least cost planning perspective.

profits. By encouraging natural gas space heating, BC Hydro reduces the need to pursue more costly generation sources and Terasen Gas gains a larger customer base on Vancouver Island.

Terasen Gas Vancouver Island Inc. is a subsidiary of Terasen Gas Inc. owned by Kinder Morgan, a publicly traded entity, but is regulated by the British Columbia Utilities Commission (BCUC). As a new utility, Terasen Gas has relatively high distribution costs and therefore a strong incentive to increase its number of residential customers. More customers can generate economies of scale and reduce the distribution costs. In addition, Terasen generates profits for its shareholders based on the amount of gas it distributes - the higher number of customers for a given infrastructure, the greater profits it generates.

Due BC Hydro's rate structure, there is significant incentive for the utility to reduce demand in certain regions, times of the day, periods of the season, and from specific end-uses. BC Hydro's postage stamp rates means customers and end-uses that are more costly to BC Hydro do not have the incentive to conserve. Instead, BC Hydro has an incentive to encourage "costly" electricity use to be reduced through demand-side management. As space heating is what drives BC Hydro's peak load and is primarily used when hydrological resources are low and electricity prices may be high, there is significant incentive for BC Hydro to engage in demand-side management to reduce this space heating load. From BC Hydro's perspective, the most effective way to reduce electric space heating load is by having customers switch to natural gas; therefore, there is significant economic incentive for BC Hydro to pursue space heating fuel switching programs.

In addition, BC is part of the integrated western electricity market, but British Columbians do not face price signals that reflect the opportunity cost of electricity in this market. BC Hydro's large dams provide the ability to purchase electricity on the market when prices are low (by constraining hydro flows) and sell electricity when prices are high. This gives rise to the potential for Powerex, BC Hydro's energy trading subsidiary, to generate revenue from electricity trading. However, if domestic consumers face prices below the net price that Powerex receives for trading, then the utility is foregoing rents. These rents help keep domestic prices lower than they otherwise would be or go into provincial revenue. BC Hydro and Powerex's net income (above their allowed rate of return) flow to the province and hence can be used to benefit British Columbians by paying for services such as health care. The potential benefits to the Province for rents through electricity trading are an additional incentive to pursue fuel switching from electricity to natural gas.

Given Terasen's incentives to increase their number of customers and BC Hydro's incentives to shed space heating load both utilities have motivation to work together to have customers fuel switch to natural gas space heating. But these incentives do not necessarily encourage space heating with the lowest social cost. Based on this study's findings there is little evidence demonstrating natural gas is the socially optimal fuel, therefore despite each utility's incentives the Province should pursue a fuel neutral space heating policy.

7.2 Socially Optimal Fuel?

Considering the evidence presented in this section, the logical conclusion is the space heating policy problem should take a fuel neutral approach to reducing electric space heating loads. There is an absence of evidence that natural gas has the lowest marginal cost; heat pumps (and even under some circumstances baseboard heaters) offer potential environmental benefits; it would be political difficulty to defending disincentives for electric space heating; and there is evidence that fuel switching may impose higher prices on consumers.

Evidence does not support the theory that there is market failure in fuel choice. Smaller space heating loads, result in high payback periods for natural gas furnace investments when compared to electric baseboards. Without justification, customers should not be obligated to face the risk of insufficient payback for natural gas furnaces on Vancouver Island. The GHG analysis also indicates that favouring fuel choice cannot be justified from an environmental perspective. Depending on BC Hydro's marginal source of generation, natural gas heating may not have the lowest environmental impacts especially if BC Hydro meets their commitment of 50 percent of new incremental generation as BC Clean. Favouring one fuel choice therefore could run counter to BC Hydro's environmental commitments. In addition, under the legislated heritage contract and the BC Utilities Act, discouraging the use of electric space heating is not consistent with the current policy context.

Based on the analysis in this section, I cannot conclude that natural gas is a superior fuel choice for space heating. Therefore, I recommend the Province should take a fuel neutral stance on space heating policy. The focus should be on energy efficiency, which will have positive effects regardless of fuel choice. Without evidence of market failure, there is no justification to restrict consumer fuel choice. A fuel neutral policy approach is beneficial to both utilities by reducing peak costs. While eliminating all space heating costs is more appealing to BC Hydro, heat pumps, as an option for high efficiency space heating, at least provide a degree of "permanency" to energy conservation. Reversion to electric secondary heat in times of high gas

prices is a real possible. Consumers also have the flexibility to choose their preferred space heating fuel. Heat pumps offer a high efficiency alternative for consumers who prefer electric space heating.

8 Policy Options and Analysis

While fuel switching may not be the optimal policy approach, the problem remains – electric space heating imposes too great a social cost on British Columbians. How best to reduce this space heating load? I propose four policy options that may reduce the social cost of electric space heating in new single family dwellings on Vancouver Island. Given the fuel neutral approach, the policy options examined are:

1. Standardized Heat Pump Installation Program

2. Subsidies for High Efficiency Heating Devices

3. Mandatory Energuide for New Houses Standard

4. Regulating Heat Pump and Natural Gas Efficiency

This range of policy options moves from a low to higher levels of intervention; an installation program for heat pumps being the least compulsory and regulating heating appliance efficiency being the highest.

Section 5 identifies market failures associated with heating device choice that lead to problems with space heating load being too costly from a social perspective. Based on analysis in Section 7.1.1, the principal-agent problem is perhaps not as evident as previously believed; at least in fuel choice, it appears developers/ consumers are making efficient choices based on private costs. Yet, remaining market failures, especially lack of marginal cost pricing, a failure to internalise environmental externalities, and under-provision of information, warrant intervention to encourage high efficient heating.

All of the policy options presented address market failure to some degree. Under-provision of information on energy efficiency, can be addressed by providing staff with financial incentives to educate consumers on the benefits of energy efficient appliances. By increasing the diffusion or the effectiveness of energy efficient technologies, all policy options attempt to reduce energy consumption thereby reducing environmental externalities. Subsidies or financing options reduce the problem of capital constraints preventing energy efficiency purchases. The mandatory EGH rating increases the chances developers will disseminate information on the benefits of

energy efficient heating appliances; especially with the marketing materials already accessible through the EGH program. Developers have incentive to market the benefits of a new versus existing home from an energy efficiency perspective.

As outlined in Section 1, policy options will focus on the efficiency of heating devices. The goal is to increase the rate of technical diffusion of high-efficiency natural gas furnaces and heat pumps. While space heating load can also be reduced by increasing the thermal efficiency of a home and the efficiency of heat delivery, heating equipment efficiency is the chosen focus to create a manageable study. Policy option three, the Mandatory Energuide for New Houses Standard, still fits within the heating efficiency scope but allows flexibility on how efficiency can be achieved. The policy will increase the incentive for developers to use high efficiency equipment, to achieve a better Energuide rating, but does not prescribe how space heating load should be reduced.

Depending on the policy, implementation could be provincial or regional. Vancouver Island could act as a pilot for the mandatory EGH rating program, or if equity is a concern, implementation could be on a provincial scale. From a utility cost perspective, the subsidy for high efficient heating units likely only has justification on Vancouver Island. The heat pump installation/maintenance program should likely be available province wide as there is also growth in heat pump usage in the Southern Interior.

8.1   Other Policy Options

The policy options chosen for study are not the only possible solutions to reduce space heating demand on Vancouver Island. Price signals are an important tool in energy conservation. Appropriate pricing helps to create socially efficient consumer behaviour. Energy tariffs are perhaps the most effective tool in sending appropriate price signals. Econometric analysis on space heating has found an almost unitary price elasticity in the long run; that is, consumers that pay 1 percent more for fuel prices will reduce their fuel consumption by 1 percent (Douhitt, 1989). Creating more efficient demand response for end-users through rate redesign to capture time, seasonal, and regional costs is a topic that has implications beyond residential space heating on Vancouver Island. It is beyond the scope of this study and thus, is not included in the analysis.

At the same time, private cost analysis in this section demonstrates rates set closer to marginal costs reduce payback periods for high efficiency heating appliances, heightening incentive for energy efficient purchases. One step toward marginal cost pricing is a regional differentiation of rates. Islanders could pay for their increased cost of transmission but still

benefit on the generation side. Regional differentiated rates allow all British Columbians to benefit from the heritage generation assets while having to pay for higher transmission costs they impose. One could argue regionally differentiated rate are far more equitable than concentrating demand-side management programs in areas that impose higher costs. DSM benefits Vancouver Islanders who are already being subsidized by other ratepayers through average embedded wires costs in rates. Regional equity may soon prove a greater focus of debate given the residential protest against bulk transmission upgrades to Vancouver Island in the Tsawwassen area. Again, further debate is warranted as this shift in policy may have implications for other remote communities – depending on the rate structure proposed. This study's policy options will likely complement rate redesign endeavours.

8.2 Criteria

The criteria used for policy analysis in this study are as follows:

- Effectiveness

- Economic/Financial Impacts

- Equity

- Administrative Ease

- Political Feasibility

When possible, the criteria are compared quantitatively. In the summary assessment, I rank criteria as high, medium, and low relative to each policy option.

When calculating the energy savings of each policy, only electricity conservation is estimated. Both Terasen Gas and BC Hydro will experience energy savings but the policy problem is the impacts of electric space heating. Calculating the natural gas energy and cost savings will likely improve the attractiveness of these policy options and potentially engage Terasen in cost sharing of policy implementation.

8.3 Standardized Heat Pump Installation Program

8.3.1 Heat Pump Peaking and Performance Problems?

BC Hydro is wary of promoting air-source heat pumps in single-family dwellings partly due to studies that reveal mixed performance, yet, for the most part problems are largely due to

improper installation and operation, not faulty technology. A study of the Bonneville Power Administration in 1987-1991 found the implied COP was only 1.23 (Andrews, 1989). In Florida, Bouchelle *et al* (2000) found the implied COP of installed heat pumps during system peaks was only 1.3; heat pumps reduced both energy and peak demand but by less than half the predicted amount. Consumer behaviour and problematic installation were deemed the causes for poor performance.[76] Reichmuth *et al.* found, of five heat pumps studied, the performance problems mainly resulted from poor installation practices and uninformed homeowner's actions (2005).

Reoccurring issues in sub optimal installations include:

- Undersizing heat pump units;

- Oversizing electric resistance back-up heating;

- Thermostat and heat pump installation location problems;

- An absence of staged auxiliary heat so full back-up resistance heating operates when it is not needed;[77]

- Low airflow across heating coils[78] and control of auxiliary heat;

- Compressor "cut-out" temperatures set too high, so compressor does not operate even when COP is well above 1.0.

- Duct system leakage;

- Undercharging refrigerant[79]; and

- Absence of adaptive recovery thermostats to reduce the frequency of strip heat during set-up periods.

Assuming heat pumps will have performance problems based on the above studies is somewhat misleading. Due to utility intervention, in some areas installation practices have improved. Many of the studies citing heat pump performance problems were conducted ten to twenty years ago. In addition, new higher efficiency heat pumps increase performance levels

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[76] The major causes for the difference in actual and predicted performance was thermostat setback/set up (a change in thermostat temperature setting of 1.1°C on most thermostats causes resistance heat to activate); time delays between the thermostat and resistance heating causing its prolonged and unnecessary operation; and finally misinformed customers operation of "emergency" back-up heat at improper times.

[77] Staged heat is back-up resistance heating that operates

[78] Found in approximately 25 percent of Baylon *et* al's (2005) field cases.

[79] Undercharged refrigerant problem may not be as problematic as originally thought, as heat pumps under laboratory condition only begin to experience efficiency losses at 20 percent undercharging (Baylon, 2005).

above what was found in the above studies. The Oregon Department of Energy estimates that heat pump efficiency has increased by up to 40 percent from models sold five years ago.

A more recent study found heat pumps to be performing at or near expected levels under a subsidy program that required standardized installation practices and third party verification. A consortium of utilities and conservation entities in the Pacific Northwest States commissioned a study that assessed:

- Heat pump performance under conservation programs by analysing billing analysis;

- Installation practices through a field review and billing analysis;

- Heat pump performance under laboratory conditions; and

- Installer's approach through interviews. [80]

Heat pump savings through a subsidy program, Conservation and Renewables Discount, were found to be about 85 percent of those expected (Baylon, 2005). In homes that did not use the heat pump incentives (thereby did not have a required installation protocol), many of the same problems delineated by previous studies were found, such as use of night time thermostat setback.

Baylon *et al* (2005) also found that while contractors in the Pacific Northwest U.S. understand trade-offs in heat pump installation, unfortunately, they favour comfort and lower capital costs over efficiency. Contractors tend to oversize electric resistance back-up heating which reduces the efficiency of heat pumps. All systems in the Reichmuth (2005) study found that electric resistance heating installed could have been reduced by at least 50 percent. Heating contractors also tend to undersize systems by approximately 30 percent, to reduce capital costs for customers (Baylon, 2005). A larger system can meet a greater percentage of the heating load with the refrigerant cycle, avoiding back-up heat activation.

8.3.2 Policy Option

The above studies reveal that installation and behavioural practices reduce heat pump efficiency, not a failure in the technology. Improvements in installation and technology to guide/prevent inefficient consumer behaviour can help avoid performance problems. This first policy option proposes installation standards and a monetary incentive for heat pump contractors/developers to use the standards and educate homeowners.

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[80] The consortium included Bonneville Power Administration, the Northwest Energy Efficiency Alliance, the Energy Trust of Oregon, the Northwest Power and Conservation Council, Idaho Power, and other regional utilities.

The program is modelled after programs in the United States. For example, Energy Star Homes and the State of Oregon incentive programs require heat pumps to be performance tested by certified technicians using approved methods such as CheckMe!®, Enalasys ®, and Honeywell's Service Assistant ®. Essentially, trained technicians use inspection, diagnostic equipment and computer software to assess and make modifications to improve heat pump's performance. The required installation protocols are designed to ensure proper refrigerant charge, air flow over the indoor coil, and control set-up and programming. The Energy Trust of Oregon has a lower level of quality assurance, due to the higher costs of the above methods. A State of Oregon tax credit of $50-100 (one quarter of the cost of the service) helps pay for testing heat pumps and servicing them for optimal performance. The State maintains a list of certified technicians who follow standardized installation techniques. Certified companies have demonstrated proficiency with the prescribed test protocols. To ensure quality assurance for heat pump installations, the Northwest Energy Efficiency Alliance conducts random site inspections and follow up on customer complaints. These examples demonstrate the possible range of stringency in quality assurance for this policy option.

If implemented, the Province would subsidize a range of quality control procedures to encourage proper heat pump installation. Under this policy option, certified technicians are tested to ensure competence and complete a report for each installation to compliance to standards. Once technicians become certified, they are added to a Provincial list of certified technicians. An incentive for submission of technician's report to signify compliance is provided. The stringency of such a program will be tailored to a British Columbian context. Required level of quality control will be based on reported findings and working with trades people to ensure that program specifications do not impose onerous costs or are overly stringent. The use of diagnostic techniques, and perhaps even third party verification, are potential options.

This policy option targets both developers and consumers. Developers have a financial incentive to use certified contractors or have their contractors certified. Consumers have an incentive to seek certified technicians to ensure optimal energy savings. The Province would have to work with contractors to ensure approved diagnostic techniques were effective but appropriate in a Canadian context. Licensing of current performance tests used in the United States, such as CheckMe!® or Enalasys ®, may introduce significant costs for technicians. Working with heat pump trades people can help identify the most appropriate quality control methods at a decent cost. Advice from utilities engaging in such programs in the Unites States can help focus standards on areas where the greatest energy savings can be achieved.

This policy option focuses specifically on heat pumps, as opposed to being fuel neutral, for good reason. Even if no policy in this study is adopted that would increase the diffusion of heat pumps, trends indicate heat pumps will likely continue to be installed on Vancouver Island. This study demonstrated approximately 10 percent of new homes are installing heat pumps and anecdotal accounts from heating contractors says this number will be increasing (see Appendix B for market shares of electric heating devices). If these heat pumps are performing at below optimal levels due to installation problems, there are potential space heating energy savings that are not being fully realised, and potential peak problems for BC Hydro.

One way to reduce the administrative cost and complexity of a heat pump installation program is to link it to the existing EnerGuide for Houses (EGH) program (see Section 8.5 for more details). As part of the EGH program, energy advisors are already installing heat pumps or assessing the energy efficiency of homes after a heat pump has been installed. Also available is the option for a contractor to become certified without becoming an energy advisor. Standardized installation methods for heat pumps could be part of the energy advisor requirements. The energy efficiency recommendations, given by an energy advisor, for new construction could also relate to heat pump installation. Incorporating this policy option into the EGH program integrates energy efficiency performance testing into one package reducing administration complexity and costs. Already, the *Energuide for Houses: Administrative and Technical Procedures* have requirements for ventilation and combustion spillage tests, adding heat pump performance requirements simply extends an already established framework.

8.3.3 Effectiveness

8.3.3.1 Certainty

Ranking = Low-medium

In theory, fewer heat pump installation problems would result from a standardized heat pump installation program, thereby optimising heat pump efficiency. Independent billing analysis of the CheckMe!® service in the Pacific Northwest U.S. revealed an average savings of 360 kWh/yr. Correction of severe problems in a limited number of cases was found to produce the energy savings - 85 percent of the savings came from 15 percent of the customers (Baylon, 2005). Bouchelle *et al* (2000) recommended a new construction heat pump installation programs to address installation problems found in Florida and greatly enhance the efficiency of heat pumps.

While results have been demonstrated in the United States, no field studies of heat pumps have been conducted on Vancouver Island (or the Southern Interior where heat pumps are also becoming more popular). Without field data, it is not possible to assess the methods and trends for heat pump installation in Canada. Prior to this policy option being pursued, a field study of heat pump performance could be conducted as a collaboration between the Ministry of Energy, Mines, and Petroleum resources, BC Hydro, Fortis, and perhaps supported by the consortium of energy conservation entities in the Pacific Northwest U.S. A field survey of heat pump efficiency and installation practices can reveal problems in current installation practices on Vancouver Island/ in British Columbia. Such a study may be costly but can also confirm the need for a heat pump installation/maintenance program (Reichmuth, 2005).

Without information on efficiency performance of heat pumps on Vancouver Island, it is difficult to determine whether such this policy option will have certain energy reduction benefits. Based on U.S. results/studies, it appears such a program is warranted. Along with increased efficiency, the latest heat pumps are also more complicated, thereby requiring high levels of quality assurance to achieve optimal performance. Field studies and consultation with trade contractors can provide more certainty on whether such a program is warranted in British Columbia.

8.3.3.2   Reduction of Annual Electricity Consumption and Peak Demand

Because of the lack of field data for British Columbia, energy conservation can only be estimated and might range from 0 to a high of 37 GWh over twenty years. The potential energy savings in Table 15 (below) are based on estimates for different levels of heat pump performance problems; each total assumes 100 percent market participation of heat pumps in my demand forecast. The most probable level of savings is based on findings in an Oregon field study on the CheckMe!®; the average savings per heat pump was 360 kWh/year (Baylon, 2005). Based on the estimated number of heat pumps installed over the next twenty years, the cumulative impact would be 2.93 GWh. A program with lower levels of quality assurance compared to the CheckMe!® may not achieve this higher level of savings.

If on average heat pumps were to improve performance from one HSPF below their current average to their labelled performance (as found by Reichmuth *et al* (2005)), the energy savings over twenty years would be 9.3 GWh (see Table 15 Below Normal Heat Pump

Performance).[81] If heat pump installation practices are extremely inadequate and representative of the performance found in Florida (see Table 15 Poor Heat Pump Performance), the difference between actual and stated performance is 37 GWh over twenty years. It is unlikely that heat pump performance is this low as the heat pumps in the Florida study are older than those that would be found in new construction. The potential savings are also presented in levelized amounts between one and twenty years (see Table 16).

Table 15 Potential Savings From a Heat Pump Installation Program

	Below Normal Heat Pump Performance (GWh)	Poor Heat Pump Performance (GWh)	CheckMe! Results (GWh)
10 yrs	6.1	24.4	1.53
20 yrs	10.4	41.9	2.91

Table 16 Levelized Potential Savings From a Heat Pump Installation Program

	1 Year	5 Years	10 Years	15 Years
Below Normal Heat Pump Performance (GWh)	1.2	2.1	2.4	2.4
Poor Heat Pump Performance (GWh)	4.8	8.4	9.5	9.6
CheckMe! Results (GWh)	0.21	0.45	0.52	0.53

While not all heat pump systems experience problems related to the use of the back-up resistance elements, a significant enough fraction of systems in the U.S. Pacific Northwest studies showed potential for peak demand reductions that utilities should expect at least some system peak demand reductions from an effective program.[82] One could compare peak performance of an electric furnace to that of a heat pump. If peak efficiency is reduced so electric resistance is fully activated, performance is essentially reduced to that of an electric furnace; this comparison is found in section 8.4.1.2, Table 45 and Table 46.

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[81] Recall the estimated average HSPF being installed in the Southern Interior is 7.2-7.4. Personal Communications, Parent, Brian, Fortis BC, Manager of Energy Efficiency Services, March 17, 2006.

[82] Reichmuth *et al* found different problems led to efficiency reductions at different temperatures (2005); for example, for some heat pumps, performance at low temperatures was functioning while operation at warmer temperatures was reduced.

8.3.3.3 Market Oriented

Ranking= No

This policy option involves the provision of information and heat pump installation improvements arguably are underprovided by the market. Yet, government provision of information does not engage the market to more effectively deliver a policy.

8.3.3.4 Free Ridership

Ranking= None

Free riding under this program is considered zero. This program will simply increase the efficiency of heat pumps that would have been installed in the absence of the program. Free-riding with energy efficiency programs is traditionally seen as individuals benefiting from incentive programs even though they would have purchased energy efficient equipment without the incentive. The concern raised with free-riding is public dollars are spent without incremental energy savings, as savings would have been part of the baseline energy efficient improvements. As no program of this type currently exists, one could assume that any energy savings from this program exceed the current baseline.

8.3.4 Economic/Financial Impact

Ranking = Medium

One downside of heat pump maintenance program is its potential cost depending on the stringency of quality control. Sixty percent of contractors interviewed in the Pacific Northwest found that the CheckMe!® program was a "hard sell" due to the substantial increase in cost for a site visit (Baylon, 2005). The Northwest Energy Efficiency Alliance found there was little market penetration for such diagnostic techniques (through third party certification) as the costs for contractors are too high. The challenge of this policy option will be to determine the stringency of quality control required for energy savings employed at a reasonable cost. The smaller market for heat pumps on Vancouver Island and the investment in equipment and training, may present high costs for contractors.

The economic costs for the Provincial government are also dependent on the degree of coordination with other programs. Conducting field research on the efficiency of installed heat pumps can be costly but can give a better indication whether spending public dollars on the program is legitimate. Working with other entities can reduce economic costs. Installation

standards have already been established in the United States and quality assurance procedures are continually being updated. For example, Energy Trust is currently working with Proctor Engineering to adapt CheckMe! to their needs and develop a program to deliver the service for free. [83]

If EGH regional delivery agents provide the training and quality control procedures through their already established programming channels, the administrative costs of such a program would be greatly reduced. The costs and benefits of gaining the knowledge-based capital needed for the proper delivery of the program would also be spread across Canada. Expanding the standardized installation program to also assess heat pump operation in existing housing could provide further savings and produce "economies of scale" in program development and implementation.

8.3.5 Equity

Ranking =Medium-high

The heat pump installation program introduces some equity concerns, as only some homeowners will be eligible for the program. Horizontal equity issues exist for those who cannot afford housing to take advantage of the program. On the other hand, subsidies that effectively reduce electricity consumption maintain a downward pressure on rates that benefit all ratepayers, including those who do not or cannot take advantage of energy efficient subsidies.

8.3.6 Administrative Ease

Ranking = Medium-low

This policy option has a low to moderate level of administrative ease depending on whether or not parts of the program are integrated into the regional or national level of the EGH rating system, and the degree to which information is used from already existing programs in the U.S. When creating installation standards, administrative procedures, and other program details the Province can benefit from working with utilities and conservation entities in the Pacific Northwest U.S. and their wealth of heat pump expertise. These organizations already have years of experience that can significantly reduce the administrative complexity of establishing such a program. They have had years of experience in promoting, providing incentives, and implementing installation programs and commission studies to continually improve their

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[83] Personal Communications, Lester, Corban, Energy Trust Inc., Trade Ally Coordinator, March 27, 2006.

programs; this knowledge base should be tapped. Administration for this policy option could be set up similar to current procedures for natural gas furnaces installation to ensure safety, except the heat pump program would be to ensure efficient installation.

8.3.6.1 Political Feasibility

Ranking = High

As long as trades people do not become opposed to this program, it has a high level of political feasibility. The program is mostly voluntary in nature and benefits consumers. If trades people are involved in the establishment of this program there is less chance they are opposed to the stringency of quality control and will likely support the program. Their participation and support for the program is imperative for it to be effective.

8.4 High Efficiency Heating Device Subsidy

Another policy option with the potential to reduce electric space heating load is a financial incentive for heat pumps to accompany the current natural gas space heating subsidy. Developers on Vancouver Island are currently offered $1000 for high efficiency natural gas furnace with contributions from Terasen Gas, BC Hydro, and the Province; a financial incentive for high efficiency heat pumps also be offered. A financing program, as an alternative to the heat pump subsidy, could also be offered. FortisBC offers a cash rebate of $250 or a $5,000 loan at a rate of 4.9 percent. About half of the program participants choose the financing option.

In order of priority, subsidies should be targeted at developers currently installing electric furnaces and electric baseboard heating to induce them to switch to heat pumps or high efficiency natural gas furnaces. Convincing developers or consumers to move away from electric baseboard heating cannot focus solely on costs but must emphasize the comfort of centralized heating based on the high capital costs of heat pumps when compared to electric baseboard. Electric furnaces have higher capital costs than baseboard heaters, due to higher installation, ducting and appliance costs. It should be, therefore, an easier sell to convince developers to upgrade from an electric furnace to a heat pump or high efficiency natural gas furnace, as opposed to electric baseboards.[84]

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[84] Electric furnaces also use more electricity than electric baseboards, as they require a blower motor to distribute the heat, have efficiency losses through their ducting, and do not have the advantage of offering zonal heating as does electric baseboards.

Electric furnaces potentially still occupy up to 8 percent of the market (see Appendix B State of High Efficiency Heating); their presence indicates a preference for centralized electric heating.[85]

Different levels of incentives could be offered for heat pumps with different efficiencies. The State of Oregon offers different tax credit incentives for heat pumps with different HSPFs and Energy Efficiency Ratings (EER) (see Table 17).[86] Incentives for only higher efficiency heat pumps would not only increase the average efficiency of heat pumps but also likely reduce the impact of free riding. Individuals that would have installed a lower heat pump in the absence of the subsidy may choose to upgrade heat pump efficiency to take advantage of the incentive. If a quality control installation program accompanies the subsidy program, further efficiency gains can be made (as outlined in Section 8.3.3.2).

Table 17 State of Oregon Tax Credit Incentives for Heat Pumps ($US)

	12 EER	12.5 EER	13 EER
9.0 HSPF	$300	$320	$340
9.5 HSPF	-	$360	$380
10.0 HSPF	-	-	$430

Creating a provincial heat pump technician certification program is also recommended as part of this policy. Certifying technicians and establishing installation standards could act as the quality assurance to ensure heat pump subsidies optimise energy savings. Utilities in the United States require that homeowners/developers who access heat pump subsidies must have certified technicians use performance diagnostic techniques such as CheckMe!® to assess heat pump performance. The efficiency of heat pumps installed under the incentive program had greater efficiencies and than those without the incentive program (Baylon, 2005).

A focused promotion technique could be used to target developers similar to what was employed by BC Hydro's Natural Choice program in the early nineties. This pilot contacted developers building with low efficiency heating directly avoiding costly marketing campaigns. Developers can act as the conduit to communicate with homeowners about the benefits of high efficiency heating equipment and available subsidies.

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[85] Anecdotal evidence from heat pump trades people finds few electric furnaces remain in the Vancouver Island market.
[86] EER is an energy efficiency rating for the air conditioning mode of heat pumps. As low levels of air conditioning are required on Vancouver Island, this rating has not been a focus of this study nor is it recommended to vary subsidy levels based on EER.

Working directly with developers is also conducive to gathering more information on improving heating equipment policies and programs. Interviews with developers and consumers can help delineate to what degree capital costs, operating costs, subsidies, consumer fuel preference, and preferences for other features such as centralized heating determines heating device choice. Understanding these heating choice determinants can help the Province reveal what policies and programs will be most effective.

In addition, developing a better understanding of the decision-making process around heating devices can better cater policies to influence choice. A study conducted by Habart & Associates (2005) asked developers in Oregon about the process under which custom homebuyers choose a heating device. The study revealed heating device choice is one of the many decisions a homebuyer has to make among many other home design features and under tight time restrictions. The reality is granite counter tops and hard wood floors likely get more attention than heating equipment.

The Habart study also found the consumer choice process conducted by developers is not conducive to energy efficient choices. None of the developers in the study provided information on cost savings of efficient devices and it did not appear that the sales staff were knowledgeable about the lifecycle costs of heating equipment or had incentive to sell high efficiency equipment. Developers suggested that government/utilities should provide education and support materials to their sales force, help builders understand energy efficiency as a sales tool, and offer financial incentives to builders.

8.4.1 Effectiveness

8.4.1.1 Certainty

Ranking = Medium

Studies show variance on the cost and effectiveness of subsidies for energy efficient equipment. Using econometric analysis on the adoption of thermal insulation in residential new construction, Jaffe and Stavins found that subsides would have been three times as effective as an equivalent increase in energy prices.[87] Hassett and Metcalf (1995) found subsidies eight times more effective than equivalent increases in energy prices; they speculated that the reason for the difference is energy price increases are seen as temporary. On the other hand, Loughran and

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[87] This suggests that decisions on energy efficiency are more sensitive to upfront capital costs than long term operating costs.

Kulick's (2004) econometric analysis of 324 U.S. electric utilities who spent $15 billion on demand side management, found energy savings lower than reported by these utilities. DSM expenditures lowered mean electricity sales by between 0.6 and 1.2 percent at an average cost of $0.06-0.12/kWh, whereas utilities reported savings between 1.8 and 2.3 percent at an average cost of $0.02-0.03/kWh.

The level of uptake of a subsidy is also to some degree uncertain. Of five developers interviewed in Oregon, while all were aware of space heating efficiency incentive programs, only one developer used the subsidy and the remainder either left the cash benefits for the homeowner or ignored the program. None of the developers viewed the incentives as providing value to their businesses (Habart & Associates Consulting Inc., 2005).

In summary, the certainty of electric space heating load reductions resulting from a subsidy depend on its perceived benefit to a consumer and its level of free riding. Several questions remain before determining the effectiveness and cost of a subsidy including: What is the effect of different levels of financial incentive? What amount of free riding is associated with different types of subsidies and how does this change over time? To what degree may a subsidy shift market behaviour in the long-term?

8.4.1.2 Reduction of Annual Electricity Consumption and Peak Demand

As outlined above, electricity savings estimates for a high efficiency heating device subsidy depend on the market penetration of a subsidy, levels of free riding, and fuel choice; it is difficult to estimate these factors without choice data on consumer/developer intangible preferences, discount rates used for capital costs, response to subsidies, and perceived future natural gas and electricity prices. Further data is therefore required to provide a good estimate of energy savings from high efficiency heating device subsidies. This section presents a range of potential savings from subsidies.

If a natural gas subsidy, achieved a 100 percent substitution of forecasted electric furnace and electric baseboard heated homes, substantial electricity savings are possible (see Table 43 through Table 46 in Appendix C). These Tables present maximum avoided electricity consumption not actual energy conservation, in other words, BC Hydro experiences electricity savings but energy costs and environmental impacts continue to accrue from the natural gas use. Maximum electricity savings through fuel switching is an unrealistic goal. The Builder's Grand subsidy of $1000 for high efficiency natural gas heating had only 500 participants in 2004.

Approximately 1038 people used natural gas in 2004.[88] Terasen estimates the Builder's Grand subsidy has a free riding rate of 50 percent; at this level of free riding, approximately 250 people switched to natural gas as a result of the subsidy elevating the percentage of new construction natural gas users from 26 to 34 percent.[89] [90] Even with a significant subsidy of $1000, the level of fuel switching under Builder's Grand is far from 100 percent; in other words, while a high level of fuel switching is appealing to BC Hydro, it is unrealistic unless natural gas rates drop to levels seen in 1994-1999.[91] At the same time, even if a natural gas subsidy does not reduce electric space heating loads through fuel switching, if it moves a customer from a mid to a high efficiency furnace it has positive benefits for energy conservation and peak load reduction for Terasen Gas - these benefits are beyond the scope of this study.

The increased use of heat pumps has lower but perhaps more likely potential electricity savings when compared to fuel switching – especially to encourage consumers to switch away from electric furnaces (see Table 18 and Table 19 below). Between 2000-2005, electric furnaces were installed in eight percent of the new homes (see Figure 12 and Table 37 in Appendix B).[92] The incremental cost capital cost of an electric furnace is approximately $5,000 greater than that of electric baseboard heating (see Table 2), but provide no operating cost savings; in fact, due to the zonal nature of electric baseboards and the fact they do not use a blower motor, baseboards are more efficient than an electric furnace. Electric furnaces are also more expensive than mid-efficiency natural gas furnaces by about $1,600 (see Table 2). The presence of electric furnaces could indicate a consumer desire for central heating and consumer preference for electric heating.

If consumers continue to install electric furnaces at the rate found in the Habart and Energuide databases, a subsidy that moved all forecasted electric furnaces to heat pumps could achieve savings of 43.61 GWh in 10 years. Savings could be lower if electric furnaces would "naturally" be eliminated from the market (without the subsidy) and higher if a subsidy would move some homes from baseboard to heat pumps.[93] An advantage to offering both a natural gas and a heat pump subsidy if there are strong preferences for electricity as a heating fuel, is that there is still an option to promote high efficiency heating equipment; therefore there is a greater

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[88] This number is based on BC Hydro load forecast and Habart/Energuide database numbers.
[89] It is unknown how Terasen/BC Hydro determined the free riding rate.
[90] The Builder's Grand subsidy is available to row houses in addition to single family dwelling, therefore its influence on the market penetration of natural gas in single family dwellings may be lower than these numbers suggest.
[91] Even low rates may not be sufficient to achieve the market penetration of natural gas seen in the nineties, as significant subsidies were offered for natural gas heating at that time.
[92] The low sample size could also play a role in inflating numbers for electric furnaces.
[93] Cumulative heat pump savings for replacing all low efficiency electric heating is also an unlikely scenario (see Appendix C Table 47 and Table 48) but demonstrate significant savings.

chance electricity savings will occur. The savings are actual energy savings, not just electricity savings from the perspective of BC Hydro.[94]

Table 18 Potential Electricity Displacement From Heat Pumps Replacing Electric Furnaces (GWh)

10 Year Cumulative[95]	
HSPF 9 - replacing Electric Furnaces	43.61

Table 19 Levelized Potential Electricity Displacement From Heat Pumps Replacing Electric Furnaces (GWh)

	1 Year	5 Years	10 Years
HSPF 9 - replacing Electric Furnaces (GWh)	8.13	14.92	17.03

8.4.1.3   Market Oriented

Ranking = Yes

Economic theory sees subsidies as potentially distorting, creating inefficiencies in the economy. If market imperfections or distortions already exist, under the right conditions, there can be justification for subsidies. The use of a financial incentive is, to a degree, using the market to achieve policy ends.

8.4.1.4   Free Ridership

Ranking = Present

The greatest concern about subsidies is the potentially high level of free riding, which can result in excessive public expenditures without great reductions in electricity consumption. Free riding results in public money going to households that would have made energy efficient changes without the subsidy. A stringent requirement for efficiency of heat pumps, in order to take advantage of the financial incentive, could minimize free riding but also minimize penetration of the subsidy. Even if a subsidy caused a household to move from a heat pump with

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[94] Peak savings are not calculated as the load and coincident factors available to this study are based on average HSPF of 7.3. Using these load factors would likely underestimate potential peak savings.
[95] Ten-year perspective is taken because subsidies will likely be short lived, although their benefits will last on average 14 years (the average life of a heat pump).

an HSPF of 7.8 to 9, at least some energy reductions occur. Greater efficiency savings are incurred by requiring households to participate in a standardized heat pump installation program in order to receive the financial incentive. It is imperative free riding estimates be taken into account when assessing the costs and benefits of a program.

8.4.2   Economic/Financial Impact

Ranking = High for Utilities/the Province, Medium-high for Homeowners

For a subsidy to be most effective, it must be able to decrease the payback period of an energy efficient option to an acceptable level for a consumer. Due to low space heating loads from Vancouver Island's mild climate, when comparing high to low efficiency appliances payback periods are high. Even with a 7 percent tax incentive and a $1000 subsidy, the incremental savings required per gigajoule for a high efficiency compared to mid efficiency natural gas furnace to achieve a 15 year payback period are unrealistic (see Table 20 below).

Heat pumps only have realistic payback periods when compared to electric furnaces (see Table 21 below). One thousand dollar subsidies do little to reduce payback periods required when heat pumps are compared to electric baseboard heating. Even when the social cost of electricity at high electricity prices is taken into account (if compared to electric baseboard), payback periods are higher than the average life of the appliance (see Table 22 below).[96] In essence, heat pumps only have realistic payback periods on Vancouver Island if a consumer desires centralized heating (i.e., compares a heat pump to an electric furnace).

Still the appeal of a subsidy could realistically convince consumers on the margin to opt for a high efficiency versus a low efficiency-heating appliance. There will likely be consumers on the margin (those who desire centralized heating) who may choose a heat pump with a subsidy to offset the high purchase costs. In addition, the average space heating load is used in this analysis but larger homes may introduce economies of scale that improve high efficiency device payback times. Heat pumps and high efficiency furnaces are being installed in new construction so heterogeneous costs, a desire for centralized heating, and other forces are likely at work.

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[96] EIA electricity prices are not significantly different from current rates.

Table 20 Incremental Savings Required for a 15 year Payback Period on a High-Efficiency Natural Gas Furnace (compared to a Mid-Efficiency Furnace)

	Incremental Capital Cost	Space Heating Load (GJ)	Incremental Savings Required ($/GJ)	Annual Savings Required	Amortised Payback Period
High Efficiency Natural Gas - 94%	$4,611	40	$12.34	$464.76	15
With $1,000 Subsidy	$3,611	40	$9.66	$363.96	15

Source 18 Capital Costs TBKG Consultants Incorporated

Table 21 Payback Periods for Heat Pumps of Varying Efficiencies at Current Electricity Rates

		Incremental Capital Cost	Annual Incremental Savings	Amortized Payback Period
Heat Pump - 7.3 HSPF - 2.15 COP	Compared to Baseboard	$5,586	$360.16	40
	$1000 subsidy	$4,586		24
	Compared to Electric Furnace	$570		2
Heat Pump - 8 HSPF - 2.35 COP	Compared to Baseboard	$6,965	$386.82	40
	$1000 subsidy	$5,965		40
	Compared to Electric Furnace	$1,949		6
Heat Pump - 9 HSPF - 2.65	Compared to Baseboard	$10,146	$419.25	40
	$1000 subsidy	$9,146		40
	Compared to Electric Furnace	$5,130		20
	$1000 subsidy	$4,130		14

Source 19 Capital Costs TBKG Consultants Incorporated

Table 22 Payback Periods for Heat Pumps of Varying Efficiencies at Social Cost of Electricity

		Average Annual Incremental Savings	Amortized Payback Period
Heat Pump - 7.3 HSPF - 2.15 COP	Compared to Baseboard	$522.10	19
	$1000 subsidy		14
	Compared to Electric Furnace		2
Heat Pump - 8 HSPF - 2.35 COP	Compared to Baseboard	$560.74	25
	$1000 subsidy		19
	Compared to Electric Furnace		4
Heat Pump - 9.9 HSPF - 2.91	Compared to Baseboard	$607.76	40
	$1000 subsidy		40
	Compared to Electric Furnace		11
	$1000 subsidy		8

Source 20 Capital Costs TBKG Consultants Incorporated

As previously mentioned, the major drawback of subsidies is the potentially high levels of public expenditure. A transfer of $1,000 to consumers is a significant outlay of public funds. There is precedence on Vancouver Island for large financial incentives for high efficiency heating - the Builder's Grand subsidy provides a $1000 incentive – but policymakers need to question whether these public dollars are better spent elsewhere if there are more effective policies to conserve space heating energy at lower costs.

At the same time, studies have shown subsidies to be more effective than an equivalent decrease in capital cost (Sadler, 2003). FortisBC has found subsidy expenditures to be acceptable in their heat pump studies. They have subsidized approximately 235 heat pumps a year since

1999 with annual costs for loans at $35,000 and subsidies at $60,000.[97] FortisBC spends approximately 5¢ per kWh saved, however, the electricity savings could be more costly as it is not making any allowance for free ridership.

8.4.3 Equity

Ranking = Medium-high

This program raises the same equity issues as any subsidized demand-side management program. Not all taxpayers or ratepayers will be able to benefit from such a program but (if effective) the downward pressure on future rate increases will benefit all ratepayers – a trade-off generally considered acceptable. If the subsidy is targeted at specific developers with tendencies to build with low efficiency heating devices it will introduce equity concerns for those who are not approached. If designed "properly" targeted subsidies will not be offered the subsidy are early adopters who, in fact, "should" be rewarded for taking risks or choosing conservation measures based on an environmental ethic. As long as developers who want to take advantage of the program can, this equity issue is not of great concern.

8.4.4 Administrative Ease

Ranking = High

Incentive programs for high efficiency heating devices will likely have a low level of administrative complexity. Working with and gathering information from developers adds a layer of administrative intricacy but enables program evaluation. BC Hydro, the Provincial Government, and Terasen Gas all have considerable experience in administering subsidies.

8.4.5 Political Feasibility

Ranking = High

Subsidies are perhaps the most favoured demand side management technique due to their appeal politically. Consumers/developers favour incentives as they are rewarded for energy efficiency. Generally, the public and many politician welcome public expenditure on subsidies for activities they deem desirable.

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[97] FortisBC serves more than 98,000 customers and approximately 49,000 customers through the wholesale supply of power to municipal distributors in South Central British Columbia, including Kelowna, Osoyoos, Trail, Castlegar, Princeton and Rossland.

8.5 Mandatory Energuide for New Houses Standard

A provincial mandate that all new homes meet an Energuide for Houses (EGH) rating of 80 by 2010 would increase the diffusion of high efficiency heating equipment and reduce the space heating load from new construction. Under this policy option, all new homes must reach a minimum energy efficiency performance standard based on a national, currently voluntary, ranking system. Of all the policy options in this study, this one is unique in it does not prescribe how to achieve reduction in space heating load. Energy efficient heating equipment can be used to meet the EGH rating, but a homeowner or developer has the independence to meet the standard through energy efficiency measures that suit their needs. If electric baseboard heating is the least cost or preferred way to heat a home, there is no restriction on its use but the efficiency standard must then be met through other means; for example, increasing the thermal efficiency of the building shell or the efficiency of ventilation. Ultimately, the standard will still reduce electricity consumption and a large portion of the energy savings will be through a reduction in space heating load.

The Office of Energy Efficiency in Natural Resources, in cooperation with the Canada Mortgage and Housing Corporation, developed Energuide for Houses (EGH) program. The goal is to increase the energy efficiency of low rise housing in Canada. Energuide is currently a voluntary program that evaluates and rates the energy efficiency of homes; the program also recruits and trains a pool of qualified energy experts to provide the energy assessment services.

The program runs under the central coordination of Natural Resource Canada (NRCan) who recruits regional delivery agents to implement and deliver the EGH program based on methodology and evaluation software developed nationally. NRCan also maintains a national quality assurance program and provides support materials including workshop and technical publications. Service organizations and private contractors conduct the evaluations across Canada. Regional delivery agents coordinate and implement the EGH program at the local or regional level. They recruit and train energy advisors who conduct the EGH evaluation. To be EGH certified, energy advisors must complete training in a number of fields related to residential energy efficiency and also conduct several home evaluations under the guidance of an instructor.

Table 23 Energuide for Houses Typical Ratings for Different Housing Types

Housing Type	Typical Rating
Old house not upgraded	0 – 50
Upgraded old house	51 - 65
Energy-efficient upgraded old house or typical new house	66 - 74
Energy-efficient new house	75-79
Highly energy-efficient new house	80 – 90
House requiring little or no purchased energy	91-100

Source 21 Natural Resources Canada

The Energuide rating system rates a home's energy performance on a scale of zero to 100. The range of 65 to 100 is applicable for new houses (see Table 23 above). The rating system is fuel and technology neutral; it encourages energy efficiency improvements, but no fuel, construction material, equipment, or building technology is favoured over another. The energy efficiency rating is based on the energy performance of the building envelope and the installed mechanical equipment including heating, hot-water heating and ventilation equipment. The number of occupants or lifestyle differences is not rated. It is a Canada-wide rating system adjusted for local weather conditions. The Energuide program for new construction has certified energy advisor analyze house plans and make energy-efficient upgrade recommendations. Once the home is built, the evaluator verifies the energy upgrades, and performs a blower door test to provide/confirm the rating.

If the Energuide system were used as a mandatory efficiency standard, documentation on a home's rating would be required before connection to the electricity grid. If the rating of 80 is not achieved or the documentation cannot be provided, the developer must pay a fine. Energy advisors would still be available for advice on energy efficient upgrades but would not be required. Only the blower door test and rating calculation is required. An optional component of the mandatory EGH policy is to establish by 2010 a system of variable compliance fees for new buildings based on the EGH rated energy performance. The fees would be set at a level to promote compliance so that non-compliant buildings pay a significant fee. If implemented, this

regulation will likely apply provincially therefore has implications beyond Vancouver Island. When making recommendations, related to this policy this study is only taking the perspective of implications for Vancouver Island.

8.5.1 Effectiveness

8.5.1.1 Certainty

Ranking = High

The mandatory nature of this policy, the relative ease of monitoring, and the quality assurance mechanisms already established by NRCan impart a high certainty rating on this policy option. Fines for non-compliance could be an enforcement mechanism that increases the assurance of implementation.[98] One minor drawback is the uncertainty of impact on energy reduction and peak load.

Due to a non-prescriptive nature of the rating system and the manner in which it is calculated, there is no specific formula for the reduction in energy consumption per rating point or the device by which energy is reduced. Higher rating/efficiency gains could come from ventilation, space heating or domestic water heating; each of these appliances have different load and coincidence factors. Therefore, there is some degree of uncertainty about the level of peak electricity reductions.

8.5.1.2 Reduction of Annual Electricity Consumption and Peak Demand

Table 24 Net Cumulative Electricity Savings from Mandatory EGH 80

	10 Years	20 Years
Energy Saved (TJ)[99]	385	552
Electricity Saved (GWh)[100]	57.6	77.1

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[98] See section 8.5.4 for further discussion on monitoring and quality control.
[99] At the customer meter.
[100] With 12.9740 percent transmission losses.

Table 25 Peak Cumulative Electricity Savings from Mandatory EGH 80

	10 Years	20 Years
Peak Reduction Hydro (MW)	17.5	22.41

A cautious estimate shows significant energy savings from the mandatory energy efficiency standard (see Table 24). In total, over twenty years 552 terajoules of energy could be conserved because of this policy.[101] [102] Not all the energy savings would result in conserved electricity, as many homes are also heated with natural gas, but BC Hydro could expect approximately 77 GWh of electricity savings. In addition, not all electricity savings would result from space heating; peak reduction takes into account the fact a portion of the savings from water heating have lower load and coincident factors. Levelized savings outlined below have no energy savings in the first year as the legislation will not come into effect until 2010, although some energy savings prior to 2010 are anticipated as the building industry ramp up efforts to gain expertise in energy efficient building. It should be emphasized that these numbers are only approximations based on the best information available; numbers change significantly as baseline assumptions change.[103]

Table 26 Net Cumulative Levelized Electricity Savings from Mandatory EGH 80 at 8 percent Discount Rate

	1 Year	5 Years	10 Years	15 Years
Cumulative Levelized Energy Saved (TJ) [104]	0.0	42.4	66.9	69.2
Cumulative Levelized Electricity Gain BC Hydro (GWh) [105]	0.0	9.6	14.1	14.5

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[101] Because this number is not used for comparison, for ease of calculation, heat pumps are included and transmission losses are not.

[102] A terajoule is 10^{12} joules.

[103] For example, the baseline assumes that Vancouver Island homes have a high EGH rating and that it would improve at consistent rates overtime. If baseline efficiency were lower and savings would not naturally occur over time this policy could have a much greater impact.

[104] At the customer meter.

[105] With 12.974 percent transmission losses.

Table 27 Net Cumulative Levelized Peak Savings from Mandatory EGH 80 at 8 percent Discount Rate

	1 Year	5 Years	10 Years	15 Years
Cumulative Levelized Peak Gain BC Hydro (MW)	0.00	2.93	4.29	4.41

8.5.1.3 Market Oriented

Ranking = Yes

The EGH standard takes a compulsory approach by setting a mandatory efficiency level for new construction but the rating system allows a developer and/or homeowner to choose the least cost or preferred method of reaching the target. The policy focuses on a performance based rather than a prescriptive target. This type of policy has been referred to as, sector-specific market-based policies, which allow industry the flexibility on how to meet an efficiency or emission target thereby minimizing compliance costs. This flexibility stimulates innovation as the industry will pursue technologies and building design to meet the efficiency or emission reduction target at the lowest cost (Jaccard, 2004a:; Rivers, 2005). These targets can become more stringent over time as the industry develops new technology and learns how to meet the target more easily. Industry will also likely lower costs by building in-house for energy efficiency planning and conducting the blower door test, which would further lower costs.

8.5.1.4 Free Ridership

Ranking = None

The mandatory EGH 80 standard has no free riding problem, as no subsidy is required for policy implementation. Builders who have been using energy efficient measures will be rewarded with compliance, as they already possess the skills and the knowledge on how to build energy efficient homes.

8.5.2 Economic/Financial Impact

Ranking = Low for Utilities/the Province, High for homeowners

From a full social cost perspective, based on examples of energy efficiency bundles that are options under EGH 80, this policy has an acceptable payback periods if the marginal social cost of electricity is considered and energy prices are high (see Appendix A for details on energy

efficiency bundles).[106] From a consumer cost perspective, specific energy efficient bundles have high payback periods especially the bundle that uses a heat pump. Ultimately, consumers pay for the cost of these energy efficiency upgrades and the utility/ratepayers who benefit from lower peak capacity requirements and generation costs. This policy would be appealing from the provincial government/utility perspective but not necessarily from a consumer.

Table 28 EGH Rating Energy Efficient Bundles

	Bundle #1 - No Heat Pump	Bundle #2 - Heat Pump
Incremental Capital Cost	$3,379.00	$5,071.00
Average Electricity Savings (kWh)	4784	6216
Initial Energuide Rating	76	76
Final Energuide Rating	80	81

Source 22 (Cooper, 2004)

Private cost analysis for two bundles of energy efficient upgrades for new single family dwellings reveal high payback periods (see Table 28 above and Table 29 below). At the same time, if consumers paid the marginal cost of electricity and energy prices remain high, payback periods are reduced. Table 29 reveals that with current electricity prices homeowners face a 19 year payback for bundle #1, which does not include a heat pump, and a 30 year payback for bundle #2. These are long payback periods especially considering heat pumps have an average life of approximately 14 years. Under this policy, at least developers can choose the lowest cost bundle and reduce payback periods. Payback period also depends if a customer wants centralized heating or not. If the heat pump bundle were compared to an electric furnace, the incremental cost would be much lower.

Using the average marginal cost of electricity, with the high gas price forecast in cost analysis, the payback period drops to 12 years for bundle #1 and 16 years for bundle #2 - these are more acceptable payback periods.[107] Adding a low-end externality cost to the marginal cost of electricity for a cost more representative of the social cost of energy (and assuming electricity

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[106] High electricity price versus EIA electricity price.
[107] If gas prices drop to the levels in the EIA forecast, the payback period for the marginal cost of electricity is approximately the same.

generation uses 50 percent CCGT and 50 percent green) only decreases the payback periods by about a year.

Table 29 EGH Rating Energy Efficient Bundles Private and Marginal Cost Payback Analysis

	Annual Savings		Amortized Payback	
	Bundle #1 -	Bundle #2 -	Bundle #1	Bundle #2
Private Cost	$289.43	$376.07	19	30
High Gas Marginal Cost	$419.57	$545.16	11	15
High Gas Social Cost	$438.30	$569.49	11	13

Canada Mortgage and Housing Corporation (CMHC) offers a 10 percent refund on its mortgage loan insurance premium for homeowners for energy efficient homes. Homebuyers also have the opportunity to extend the amount of time required to repay their mortgage from 25 years to a maximum of 35 years. To qualify for this refund, the home's energy efficiency must be rated using the EnerGuide for Houses rating system or be R-2000 certified. This offer, if continued, would help homeowners to pay for the incremental cost imposed by this standard.

Enforcement, monitoring, and implementation costs to the Province will likely be minimal as many of the administrative and implementation channels are already established. BC Hydro already makes site visits to new homes to connect them to the grid. The Province already has BC Building Code enforcement staff if there are problems. Natural Resource Canada, regional delivery agents, and energy advisors are already in place, although incremental costs for increased use of the program as it becomes mandatory are likely. There could be a cost sharing agreement between the Province and BC Hydro (and Terasen Gas as they also benefit from peak load reduction from this policy) to share any monitoring and enforcement costs. In addition, fines for non-compliance could be used to offset any monitoring, enforcement, and implementation costs.

8.5.3 Equity

Ranking = Low

One drawback of this policy is the equity issues it presents. As previously mentioned, under the legislated heritage contract all BC citizens should benefit from the heritage electricity assets of the Province. It is contradictory to have new homeowners pay for energy conservation, while existing homeowners benefit from the downward pressure on rates. In addition, existing homeowners have access to subsidized home energy improvements through BC Hydro and the Energuide for houses program. New customers impose a greater incremental wires cost (through extension costs) onto the BC Hydro system; yet, a proposed extension policy will impose a significant share of these incremental wires costs onto new customers. Introducing residential rate redesign, such as regional differentiation of rates, would better reflect the marginal cost of electricity, address some of these equity concerns, and decrease the payback periods.

At the same time, an incremental cost of $3,400 and $5,100 is not large in comparison to current housing prices on Vancouver Island; the average price of a single family home in Victoria in February 2006 was $492,483. If condos and apartment buildings are excluded from these requirements, homeowners who are buying into lower end housing will not have to pay but benefit from the downward pressure on rates. The Province is also looking to upgrade commercial and industrial standards to ASHRAE 90.1 code so the costs of such policies are not borne only by the residential sector.

Finally, smaller homes, which have a lower impact on space heating load do not benefit under the EGH rating system. If a large and a small home each had equivalent energy efficiency measures in thermal insulation, the larger home would have a greater space heating load. The energy efficient rating is the ratio of the actual space and domestic water heating energy consumption to a benchmark space and domestic water heating. The benchmark is adjusted by the home's volume; as a result, the rating does not penalize larger more affluent homes that have a greater space heating load. When a regression is run on the EGH database using the rating as the dependent variable and home size as an independent variable, the relationship is positive; in other words, a larger home is more likely to have a higher EGH rating (see Appendix C for details on the regression analysis). This result could be the consequence of several factors. Owners of larger homes have more access to capital to engage in energy efficient improvements and use lower discount rates in making energy efficient decisions due to their higher income levels (Dubin, 1984:; Hausman, 1978:; Sadler, 2003), or they have greater incentive to lower heating bills

because of the higher space heating load (i.e., have shorter payback time on energy efficient improvements).

At the same time, larger homes will also have higher incremental costs to achieve an equivalent EGH rating. These added expenses would likely avoid introducing a distortion in the market that would favor larger volume homes in order to more easily obtain an Energuide rating. More study is needed to determine if larger volume homes have longer or shorter payback period to reach an Energuide rating of 80. If a shorter payback is experienced, the inequity is exacerbated as individuals who can afford a larger home also benefit from a shorter payback period.

8.5.4 Administrative Feasibility

Ranking = Medium

The administrative ease of this policy is moderate. Monitoring will likely fit well into current procedures but the legislative authority to regulate the efficiency of the built environment and the capacity of the current EGH infrastructure may present some administrative hurdles. The administrative ease is partly dependent on whether NRCan and regional deliver agents have sufficient capacity to train the number of energy advisors required provide a rating for all new single family dwellings. The industry would have almost four years to prepare for the requirement likely allowing sufficient time to train the required number of energy advisors. Industry representatives are already discussing this policy option with governments.

Monitoring and enforcement will add some administrative complexity but will likely fit into current protocols. All new homes require a site visit by BC Hydro for connection to the grid and installation of meters. If the appropriate documentation for the rating system cannot be provided at the time of connection, BC Hydro could notify municipal building inspectors who would be responsible for the enforcement of this policy under the BC Building Code.[108] Without proper public education or follow-up mechanisms, there may be problems with homeowners, rather than developers, having to pay the compliance costs. One administrative hurdle is to obtain the legislative authority to regulate a building's efficiency levels. The Provincial Government is currently looking at expanding the scope of the Provincial *Energy Efficiency Act* to allow for the regulation of the built environment at the Provincial level, which would enable them to regulate the EGH rating.

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[108] A printed label of a home's energy efficiency rating will be affixed to the home - perhaps, the electrical panel.

8.5.5 Political Feasibility

Ranking = Medium

An efficiency standard that increases costs for the residential development industry will likely receive some negative political backlash. Non-governmental organizations and the Province have been working closely with industry on this proposal potentially minimizing opposition. If equity issues are not addressed, opposition may be greater, yet regional rate differentiation is also a contentious issue.

8.6 Regulating Natural Gas and Heat Pump Efficiency

A final policy option is to increase the minimum performance standard for natural gas furnaces and heat pumps. Heat Pumps would be required to have a minimum HSPF of 7.7 for heating region IV and natural gas furnaces would be required to have an AFUE of 90 percent. As this policy option would require updating the *Energy Efficiency Standards* regulation, the regulation would be applicable elsewhere in the Province.

Past performance standards for space heating appliances have increased energy efficiency levels. In the nineties, under the authority of the *Energy Efficiency Act*, Natural Resources Canada prohibited the sale of standard efficiency natural gas furnaces, AFUE 65 to 70 percent. By 1998, standard efficiency furnaces were no longer found in the market; the average AFUE for natural gas furnaces in Canada was 85.3 percent.

Table 30 Natural Gas Furnace Sales by Efficiency Level, 1990 and 1998 in Canada

	1990	1998
Low-efficiency	63%	0%
Mid-efficiency	16%	62%
High-efficiency	22%	38%

8.6.1 Effectiveness

8.6.1.1 Certainty

Ranking = Low

Typically command and control regulation is perceived as having fairly certain policy outcomes, as long as monitoring and enforcement is practical and not too costly. The situation on Vancouver Island runs counter to common situations for standards regulations primarily because a close to perfect substitute is available. Increasing the costs of higher efficiency appliances, by restricting choice, could potentially increase market penetration of other "low efficiency" space heating equipment options such as electric baseboards and electric furnaces. Lower than average space heating loads (from mild climatic conditions), and higher than average natural gas prices, have maintained baseboard heating as a low cost option on Vancouver Island.

In addition, regulation in the United States on heat pump performance could shift the baseline to a higher standard so Canadian legislation would do little to increase heating equipment efficiency. Both British Columbia and the Pacific Northwest United States, have an average HSPF of 7.3. In September 2006, the U.S. Department of Energy will begin enforcing a new standard that require heat pumps to have a minimum of 7.7 HSPF; this regulation in the United States will likely also shift performance levels in Canada up to the same standard. Canada is an extremely small heat pump market as compared to the United States; it is doubtful that manufacturers will continue to produce lower HSPF heat pumps for such a small market.

8.6.1.2 Reduction of Annual Electricity Consumption and Peak Demand

There is potentially no electricity conservation on Vancouver Island from this policy; there is a chance for an increase in electricity consumption due to substitution away from natural gas furnaces and heat pumps and towards electric furnaces and baseboard heaters. Natural gas energy use and emissions are likely reduced by to some degree on Vancouver Island, but it is not a criterion for this policy analysis.

8.6.1.3 Market Oriented

Ranking = No

Prescriptive standards on energy efficiency rank low in terms of market efficiency in relation to the other policy options.

8.6.1.4 Free Ridership

Ranking = None

Free riding is not an issue with command and control policy.

8.6.2 Economic/Financial Impact

Ranking = Low for Utilities and the Province, High for Homeowners

Regulating high efficiency furnaces may impose costs that move consumers towards electric baseboards. Based on the private cost analysis in Section 6.1.1.2 and 8.4.2, the savings required for high versus mid efficiency furnaces are unlikely. At the same time, capital costs for 90 percent AFUE furnaces were not analysed, but rather the 94 percent AFUE furnace. It is possible that savings also could be made in a lower end high efficiency furnace. Economies of scale may also exist in larger homes or homes with higher space heating load. Because lower HSPF heat pumps will no longer be accessible due to regulation in the United States, this policy will have no impact on the heat pump baseline.

This regulation would have implications beyond new construction, as replacement furnaces would also have to be high efficiency-condensing furnaces. Potentially high private costs may be imposed on some homeowners due problems in venting condensing furnaces. In replacement applications, it is often not practical to install a plastic vent through the roof, required for condensing furnaces. Most replacement furnaces must be vented through a sidewall in the house, this can be costly and impractical depending on where a furnace is located in the house.

Economic costs for utilities and the province are low as monitoring the sale of furnaces and heat pumps already occurs. At the same time, if fuel switching away from natural gas to electric baseboard heating occurs, greater electric space heating load costs will be imposed on BC Hydro. Terasen Gas will have fewer customers to accrue rents and pay off their debt.

8.6.3 Equity

Ranking = Low-Medium

Some of the same equity concerns under the mandatory 80 EGH rating are also raised by this policy; new homeowners must pay higher costs to maintain lower rates for all citizens. Yet, differing circumstances increase the equity rating of this policy option as compared to the EGH

rating option. All homeowners at some point in time replace heating equipment, so new construction is not the only target of this policy. In addition, there are low cost substitutes that allow any homeowner to avoid the standard (electric baseboards).

8.6.4   Administrative Ease

Ranking = High

This policy option has a high level of administrative feasibility due to its low level of complexity and the existing authority to regulate. The Province not only has legislative authority to regulate but they already regulate end-use energy performance through the *Energy Efficiency Standards Regulation.*

8.6.5   Political Feasibility

Ranking = Medium-low

Natural gas furnace distributors, contractors, developers, and Terasen Gas Vancouver Island may oppose this policy option if it restricts consumer choice and potentially moves consumers away from natural gas use on the Island. Consumers may also oppose this regulation because it restricts their choice and imposes higher capital costs with long payback periods.

8.7 Summary of Policy Analysis

Table 31 Summary of Policy Criteria and Assessment

Criteria	Measured by	Heat Pump Program	Subsidy	EGH 80 Rating	Regulation
Effectiveness	**Certainty**	Low-medium	Medium	High	Low
	Electricity consumption [109]	Cumulative 1.5 GWh Levelized 0.5 GWh	Depends Cumulative 44 GWh Levelized 17 GWh	Cumulative 58 GWh Levelized 14 GWh	None to low
	Peak demand reduction	Uncertain	Depends	Cumulative 18 MW Levelized 4.3 MW	Low
	Free riding	None	Present	None	None
	Market Oriented	No	Yes	Yes	No
Economic/ Financial Impact	**Payback period**	None	14-40 yrs	19-30 yrs	High (when compared to baseboard heating)
	Cost to utilities or government	Medium	High	Low	Low
Equity		Medium-high	Medium-high	Low	Low-medium
Administrative ease		Medium-low	High	Medium	High
Political Feasibility		High	High	Medium-low	Medium-low

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[109] A ten year time horizon is used to compare policies.

Recommendations

Depending on the degree of compulsoriness and intervention required/desired, different policy options may be amenable to the provincial energy efficient strategy. The policy options analysed by this study vary in terms levels of government intervention. Possibilities exist for mixing features from different policies presented in order to enhance desired policy characteristics and offset some negative qualities. Equity considerations will affect decisions the province makes on energy efficiency, as policies vary in their cost impact on new homeowners versus existing customers.

I recommend a provincial fuel neutral policy approach to reduce electric space heating load on Vancouver Island, as this study found little evidence of market failure to support a fuel switching policy. Sufficient justification for restricting consumer fuel choice is not found based on marginal cost (unless Terasen can provide more accurate information on marginal costs) or environmental impacts. Consumers appear to be making choices based on cost. In addition, the current policy context, including the heritage contract and the Utilities Commission Act, do not support a fuel switching agenda.

A mandatory Energuide for New Houses rating of 80 is the best policy choice if the equity issues can be addressed. This policy could be considered a more assertive approach in reducing electric space heating load. The mandatory EGH rating is appealing due to its flexible nature, its potential to stimulate the industry to seek low-cost methods to reduce residential space heating load, and achieve energy and peak savings with a fair degree of certainty. One concern however is the equity issues related to the mandatory rating.

The most efficient way to deal with the equity issue would be to eliminate postage stamp rates and increase rates on Vancouver Island to reflect better the marginal cost of at least bulk transmission to the Island. The EGH policy places the cost burden of maintaining lower electricity rates on new homeowners, while existing home are eligible for a suite of energy efficiency upgrade subsidies. This potential contradiction to the legislated heritage contract may be overcome in two ways: subsidies and rate redesign. Small subsidies could be offered to each new home (for an initial period) to offset the high payback period this standard may present.

Introducing a regionally differentiated and/or a stepped residential rate would likely be a more economically efficient way of addressing the equity issues raised by this policy. New homeowners will still face higher capital costs but their payback times would be reduced due to the rate differential. However, the full implications of such a rate design have not been examined in this study.

Private cost analysis reveals a high cost to switch from baseboard to high efficiency heating. A marketing strategy around the comfort of centralized heating could increase the appeal of high efficiency heating. Heterogeneous costs, increasing desire for centralized heating, and perhaps increasing affluence in homeowners (due to high housing prices) could produce a higher market penetration of high efficiency equipment despite private cost analysis.

A less assertive approach to reducing space heating load on Vancouver Island may favour a short-term subsidy for high efficiency appliances along with a heat pump quality assurance installation program. Subsidies are politically highly feasible, but potentially high free riding costs could result in a high level of public expenditures. Careful design and further examination of choice determinants is required if subsidies are pursued.

If administrative costs can be kept low, a heat pump installation/maintenance program is an option that could prevent peak load problems due to poor heat pump performance and should be part of any space heating policy package. If air-source heat pumps continue to gain popularity, a standardized heat pump installation program may be important to limit peak performance problems even if no other space heating policy is pursued. If the EGH program is amenable, at minimum, the Province or BC Hydro should ensure that energy advisors provide information to heating contractors about problems with efficiency losses due to improper installation. Preferably, heat pump installation inspection and some form of testing should become part of the EGH assessment.

Based on this study's policy analysis, upgrading the energy efficiency standards for natural gas furnaces and heat pumps may prove to be problematic for space heating on Vancouver Island. Electric baseboards and furnaces are close to perfect substitutes for space heating on the Island; and if the capital costs for natural gas and heat pump options increase, there is a real chance for further substitution away from these options. At the same time, such regulation could prove to significantly increase efficiency and reduce emissions elsewhere in the Province. Policy makers should take into account the potential effects on Vancouver Island when assessing whether or not to pursue this policy.

Jaffe and Stavins (1994a) found that both, command and control regulations and incentive-based economic instruments, can both be used to achieve various levels and rates of change of technological diffusion. The optimal policy instrument depends on the relative importance of the causes of gradual diffusion of efficient technologies. I therefore recommend that more research focus on better understanding the determinants and the extent of their influence on heating fuel and equipment choices. Further research, undertaken with program implementation would help determine the impact of the principal-agent problem, lack of information, and consumer preferences/intangible costs. Interviews, and perhaps, stated preference surveys of developers and new homebuyers on heating appliance choice could shed more information on the best space heating policies for Vancouver Island.

This study identifies market failures and proposes policy options to address those market failures. The case must still be made that policy can effectively reduce space heating demand by addressing market failures at a reasonable cost to society. Heterogeneous costs, varying intangible preferences and other legitimate non-market "failures" prevent an identification of an optimal market penetration of fuel-efficient technologies. Government policy should still strive to generate benefits that exceed the costs. Therefore, further analysis is required to assess policy options from a full cost benefit perspective. All policy options require a more complete assessment of internal programming and administration costs for BC Hydro and the Province before making final recommendations. To some extent, the benefit-cost value of each policy option depends on costs to these entities.

Conclusion

Despite the current focus on fuel switching for Vancouver Island, I find little evidence for market failure in residential heating fuel choice. A fuel switching policy approach will impose on new homeowners capital costs that do not have realistic payback periods. A fuel neutral approach offers viable policy options to reduce the economic cost of electric space heating on Vancouver Island without imposing these costs.

The Province has a role to play in encouraging energy efficient heating appliances, especially related space heating. To date, BC Hydro's focus has been on fuel switching, and does not encourage high efficiency electric heating appliances. Heat pumps can perform well in Vancouver Island's climate but their installation requires monitoring and quality control assurance of the installation practices and skills level in the sector. The Province has policy tools at its disposal to ensure this energy efficiency niche is encouraged.

The mandatory EGH 80 standard is the policy option that will most effectively reduce the social cost of electric space heating at acceptable costs while stimulating innovation in energy efficiency for new housing - assuming the government addresses equity considerations. Subsidies have potentially limited impact due to the great cost difference between low and high efficiency heating appliances and could result in potentially high public expenditures. Regulating the efficiency of heating devices is not an optimal policy for Vancouver Island.

The most efficient way to address the EGH standard's equity issues is likely redesign residential electricity rates to reflect better the marginal costs of generation and distribution. The Province should examine the implications of regional rate differentiation. Without examining the full implications of such rates, this study does not go so far as recommending these rate changes should occur, but it appears to be one of the most effective ways to encourage increased use of energy efficiency in the residential sector.

Appendices

Appendix A –Methodological Detail

Heating Choice Determinants in New Construction

Three factors drive developers of new housing: capital cost, skills and knowledge of staff/contractors, and consumer influence. Capital cost is the main driver for developers unless energy efficiency and air quality can be used as a successful marketing strategy (Habart & Associates Consulting Inc., 2005). Unless they can make a return on investment on expensive heating equipment, there is little incentive for them to make a more capital-intensive choice. Discrete choice modelling of space and water heating fuel choice determinants in multifamily dwellings on the Lower Mainland found capital costs a significant variable (Tiedemann, 1994:; 1995). For both types of heating device, the probability of choosing natural gas over electricity increased by .02% for every incremental dollar; this finding is noteworthy, as a $1000 incentive would increase the probability of choosing natural gas by 200 percent.

Tiedmann also found that fuel savings, natural gas, and electricity price were significant variables in his model (1994:; 1995) indicating to some degree, developers are influenced by operating costs. Sensitivity to energy prices and fuel savings suggest that these developers felt they could gain a sales advantage from these devices by catering to consumer preferences.

Finally, the skills of a developer and their knowledge on building with specific heating equipment influence the installation of heating device and fuel type. Time and money are required to increase their knowledge and skills. In the case of new or more complex technologies, such as heat pumps and condensing furnaces, HVAC contractors must first gain the skills to install and maintain such systems before they will begin promoting them. [110] At the same time, once a developer has spent money to acquire a skill set within their company, there is an incentive to receive a return on this investment.

Consumers on the other hand have a greater focus on operating cost and other heat device attributes. When making buying capital intensive equipment (or choosing to delay capital expenditure), a consumer must weigh heating choice alternatives against their conjecture of future use, energy prices, potential operating savings, their access to capital, and other purchasing

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[110] Heat pumps as heating systems have been used since 1931 but could be considered new because of their recent popularity in British Columbia.

decisions. Their choice is constrained by the information they possess or choose to gather. A recent Canadian stated preference survey found the top three very important space heating attributes were reliability at 72 percent; operating costs at 57 percent (energy prices received a similar response); and comfort at close to 50 percent (Sadler, 2003).[111] Consumers, much like developers, are constrained also by knowledge, information, and time. Some consumers are conscious about what choices are available to them, the cost implications, and/or may have specific preferences; other consumers take the builders' recommendations.[112]

Marginal Economic Cost Analysis

Economic analysis is only concerned with the marginal or additional costs of individual or societal choices. Marginal cost is the cost of increasing output by one unit. Sunk costs or dollars spent in the past, even debt payments, are irrelevant from the economic perspective because they have no opportunity cost – no potential next best opportunity foregone. Economists also exclude taxes and subsidies because they are simply considered a transfer from one sector to another.

This study does not attempt to translate environmental externalities into dollar figures to generate a marginal social cost for space heating. Very little agreement exists on the social cost of different air pollutants. Impacts also vary a great deal depending on where emissions are released; therefore, the marginal cost comparison excludes environmental externalities.

Natural Gas Costs

The economic cost of natural gas space heating is calculated by adding the incremental production (or net resource value), processing and transmission, and distribution costs. The marginal cost of production (MC_P) changes with the season and time of demand. The marginal cost of transmission (MC_T) and distribution (MC_D) are driven by capacity requirements and adjusted by a residential and space heating load and coincident factors; these costs are driven by peak demand as incremental consumption requires additional storage, transmission, and distribution capacity to meet demand on peak days.

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[111] Other attributes included: purchase price, responsiveness, environment, and labelling.
[112] Personal Communication, Richard Kadulski, Canadian Home Builders' Association of British Columbia, March 7th, 2006.

$$MC_{NG} = MC_P + MC_T + MC_D$$

Load and Coincidence Factors

A space heating load factor (LF_{SH}) is the ratio of the annual energy consumption (D_A) (adjusted for the number of hours in a year) to the peak demand (D_P). Coincidence demand is the demand of a particular end-use measured at the time of total system peak. The space heating coincidence factor (CF_{SH}) is the ratio of the coincident demand (C_D) to maximum demand (D_M).

$$LF_{SH} = D_A / 8760 / D_P$$

$$CF_{SH} = C_D / D_M$$

The load and coincident factors used are from the Northwest Power and Conservation Council (see Table 32 and Table 33 below). The bulk power system extreme winter peak factors are used to represent the "worst case" scenario for space heating; when cold temperatures are experienced for long periods, due to decreased thermal load in a home, load factors are lower and coincident factors are higher, exacerbating the space heating cost on the system.

Table 32 Load Factors for Different End Uses and Peak Periods

END-USE	Bulk Power System Extreme Winter Peak	Bulk Power System Winter Peak	Bulk Power System Summer Peak	Group Diversified Peak Load Factor
Heat Pump	0.13	0.25	1.23	0.16
Forced Air Furnace	0.18	0.22	2.08	0.19
Electric Baseboard	0.18	0.27	8.93	0.24

Table 33 Coincident Factors for Different End-uses and Peak Periods

END-USE	Bulk Power System Extreme Winter Peak	Bulk Power System Winter Peak	Bulk Power System Summer Peak	End Use Diversified Peak
Heat Pump	0.66	0.36	0.07	0.56
Forced Air Furnace	0.48	0.37	0.04	0.43
Electric Baseboard	0.70	0.47	0.01	0.54

Production Costs

The economic cost of natural gas production is its opportunity cost or market value at the wellhead.[113] The net resource value used for natural gas is not only expenditures to find, develop, and produce gas - it is the price obtained on the market. Sumas natural gas price forecasts, net transmission costs, are used to represent production and processing costs. The Sumas price is the delivered price of natural gas to Huntingdon at the Canadian/U.S. border (in the Lower Mainland) including gathering, processing, transportation, and losses. Approximately $0.60 to $0.70 per gigajoule of the Sumas natural gas price is for processing. Transmission losses are approximately 2 percent. Terasen uses gas from a variety of sources and techniques such as long-term contracts and storage facilities to provide customers with the lowest commodity price possible. Without access to Terasen's pricing formula, I use the Sumas price as a reasonable proxy for gas commodity prices.

Two natural gas forecasts used in BC Hyrdo's 2006 Integrated Energy Plan (IEP) scenario analysis are used. The EIA forecast is provided by the United States Energy Information Agency from their report Annual Energy Outlook. The forecast assumes technology and exploration will have a difficulty keeping pace strong demand growth causing the cost of production to increase with cumulative consumption. It decreases to four dollars by 2012 and climbs at a steady rate (see Figure 10).

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[113] The production costs plus the net return that could have been realized in the next best alternative market.

Figure 10 Sumas Historical and Natural Gas Price Forecasts 1996-2025 (2005 $CDN)
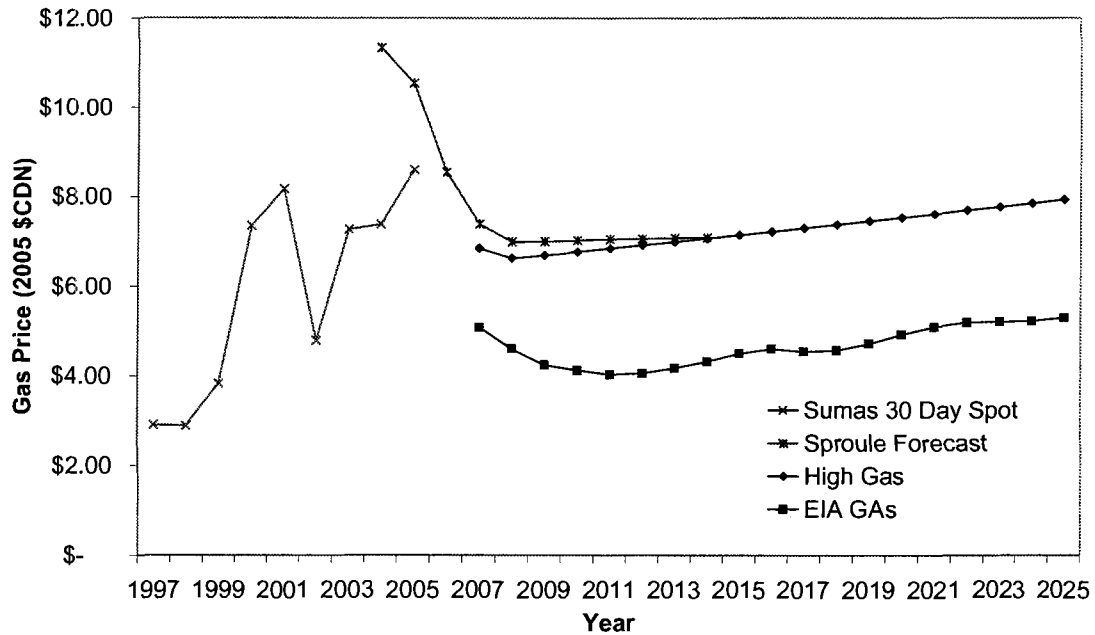
Source 23 BC Hydro and National EnergyBoard

The high gas price scenario was generated by BC Hydro on the assumption that higher gas prices persist. The price climbs from just below seven dollars to almost eight by 2025. I blended a more recent forecast from December 2005 from Sproule Associates, a worldwide petroleum-consulting firm, into the high gas forecast from 2007 to 2011 to better reflect current prices. A heating season adjustment factor is used to adjust the forecast to better represent space heating commodity costs; it is obtained by averaging the variation in Sumas natural gas prices between heating season and the yearly average for a twenty year period.

Transmission Costs

Westcoast Energy Incorporated, owned by Duke Energy, operates the integrated natural gas gathering, processing, and transmission facilities in British Columbia and adjacent regions. The system is at capacity with several expansion projects proposed for the region (Terasen Gas Incorporated, 2005).[114] Obtaining incremental cost estimates associated with these expansions was not possible and it is unclear the impact on overall cost. In an economic cost analysis of natural gas and electricity as space heating fuels, Shaffer (1991) uses Westcoast Energy's current

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[114] Pipeline capacity expansions include: TransCanada Pipeline's connector from Kingsgate to Seattle; Duke Energy's expansion from Station 2; Northwest Pipeline Corporation through the Columbia Gorge; Terasen Gas' Inland Pacific Connector; and Gas Transmission Northwest's pipeline Oregon Lateral.

cost of service for the incremental transmission cost. He postulates that higher processing and transmission costs may reduce the wellhead value of natural gas, and therefore uses current variable costs to remain consistent with the wellhead forecasts. This study uses Terasen Gas' midstream charge, which represents Westcoast Energy's transmission charge, as an estimate for transmissions costs.[115] The charge for Vancouver Island is added to the Lower Mainland storage midstream charge, the midstream charge for transportation to the Lower Mainland is already included in the Sumas gas price.

Distribution Costs

Natural gas distribution utilities have three primary cost categories: delivery related costs, demand related costs, and customer related costs (BC Gas, 2001). The latter two categories occur whenever a customer applies a load to the system. Delivery related costs are associated with the per GJ consumption of natural gas.

- **Incremental Demand Related Costs** - These are the costs for additional capacity required to meet peak demand. Demand or capacity related costs are infrastructure expenditures, such as transmission and distribution mains, pipeline looping, curtailment, and compressor and storage costs for liquid natural gas. Future incremental storage costs include the expansion of current facilities (e.g., Jackson Prairie Storage) and proposed liquid natural gas (LNG) import terminals.

- **Incremental Delivery Related Costs** - There are few delivery related costs for a natural gas distribution system. They include gas transportation, and central and administration expenses.

- **Customer Related Costs** - These costs include costs to attach a customer to the distribution system (service line, meter, and a portion of the distribution main costs), meter gas usage, and maintain an account. Every urban household will connect to the electricity grid but whether or not a resident connects to the natural gas distribution system largely depends on whether or not the household uses natural gas for space heating.

A long-term incremental cost study of natural gas distribution is not publicly available; therefore, I use 2006-2007 variable distribution charges provided by Terasen Gas as incremental distribution cost proxies. When possible, average variable costs should not be used as a substitute for marginal costs; but there is precedence for using variable distribution costs in M. Shaffer and Associate's space heating incremental cost study (1991).

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[115] The midstream charge includes the cost of storage.

To compare natural gas to electricity, levelized costs for one, five, and ten-year periods are generated. Because no incremental cost study is available, midstream and distribution costs used are static based on 2006 costs. I use an eight percent discount rate to remain consistent with BC Hydro's long-term incremental cost study. The revenue to cost ratio for residential customers is adjusted from .88 to 1 to remove the soft cap on rates. The royalty credit provided by the Provincial government is not included in the variable distribution charge nor is the amount used to pay off the revenue deficiency deferral account (the original debt load).

Midstream and distribution charges already include residential load factors but an additional load factor for space heating will be applied to these capacity related costs. No load and coincident factors for natural gas space heating is available so load factors for electric furnaces were used as proxies. As with each natural gas cost, distribution costs are then adjusted by space heating appliance efficiency of 94 percent to obtain the supply cost per output gigajoule.

Incremental Electricity Costs

Marginal electricity (MC_E) costs include generation (MC_G), transmission (MC_T), and distribution costs (MC_D).

$$MC_E = MC_G + MC_T + MC_D$$

Generation Costs

Marginal generation costs can either be measured by the incremental cost of a BC Hydro's production, or the opportunity cost of their electricity production.[116] Given BC Hydro's integration with the western electricity market, the opportunity cost of generation or the market price of electricity at the B.C.-U.S. border is used.

Electricity market price forecasts are used to estimate the future value of electricity at the Lower Mainland Canada-US border. The market price of electricity at the border is the opportunity cost or market value of a megawatt hour of additional export from the BCH system or the cost of an additional import delivered to the border. The price forecasts used are those generated by BC Hydro using the MARKETSYM Energy Services simulation software. The software takes into account the load growth and shape in the Western Electricity Coordinating Council (WECC) (including BC Hydro), estimated hydrological conditions, resource base, and

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[116] Incremental cost of generation is more inline with the provincial rate policy. If the Province conducts further work on comparing marginal costs, using the cost of production as a means to calculate the incremental cost of electricity generation would be a worthwhile comparison to the figures in this study.

natural gas price forecast. The prices are set by what is considered the most economical resource - natural gas combined cycle turbine. The electricity market prices used are based on the High Gas (integrated with the Sproule forecast) and EIA Sumas natural gas forecasts (see Figure 11 below).

The market price of electricity on Vancouver Island is adjusted by bulk inter-regional and intra-regional transmission losses. The numbers for peak inter-regional losses are obtained from the 2008/9 Bulk Transmission System Incremental Losses based on the Network Integrated Transmission Standard (NITS). [117] Because losses during peak load hours are higher than monthly average losses (that is the average over all the hours that electric heat is used), the bulk transmission peak losses are adjusted using average monthly loss factors. [118] The transmission loss factor used in this study is the average for the heating season. Deductions for intra-regional transmission and distribution losses, at 8.1 and 4 percent respectively, are also made. Adjustments are also made to the market price of electricity to reflect high prices in the heating season; these adjustments are obtained from the differences in monthly forecast prices in BC Hydro's *Long-Run Incremental Cost Update – 2005/06* .[119] Figure 11 shows the electricity prices after all transmission and heating season adjustments.

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[117] These transmission losses were also used by the 2005 IEP modelling group.

[118] These transfer loss factors were provided by BC Hydro staff but originate in the confidential report, *June 2004 Value of Electricity Report.*

[119] These are BC Hydro's 2004 draft estimates as the study was never finalized or filed publicly.

Figure 11 Electricity Price Forecasts 2006-2026 (2005 $CDN)

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$120.00

$100.00

$80.00
Z
D
C
$60.00
5
0
0
2
$40.00
                                          — High Price Adjusted
                                          —♦— High Price
$20.00                                    —■— EIA Price Adjusted
                                          —▲— EIA Price

  $-
      F2006  F2008  F2010  F2012  F2014  F2016  F2018  F2020  F2022  F2024
                                      Year
```
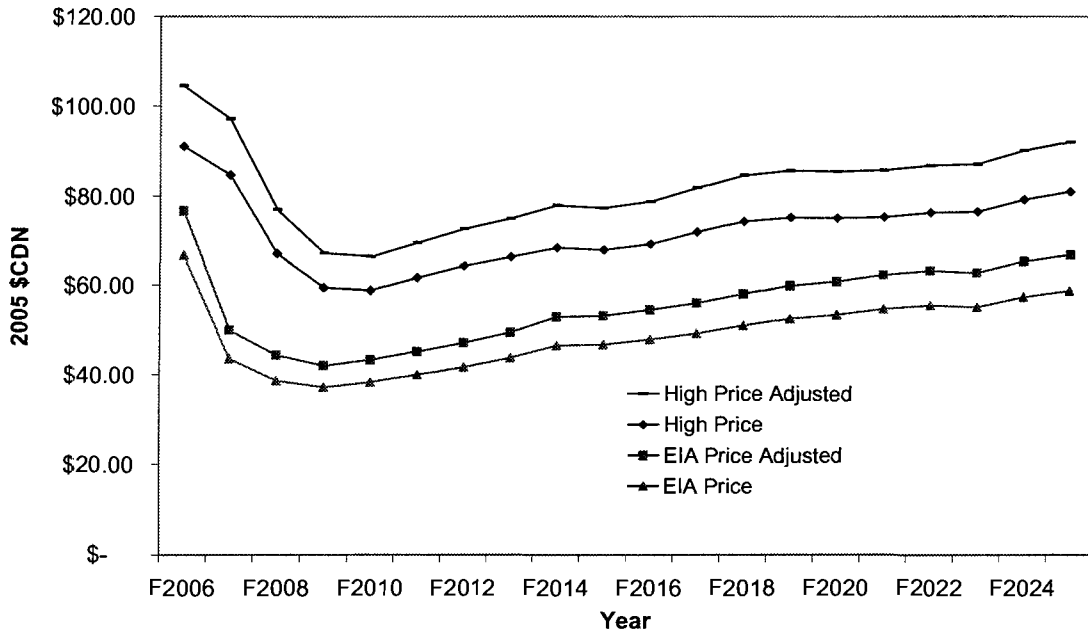
Source 24 BC Hydro

Transmission and Distribution Costs

Incremental transmission costs are made up of bulk transmission, local transmission, and stations capacity costs. Bulk transmission is inter-regional high voltage transmission transfer capability, moving electricity from generators to regions for use. Local transmission is considered to be between the lower end of bulk transmission and the lower voltage distribution systems.

The cost estimates are obtained from BC Hydro's 2004 draft estimates in their *Long-Run Incremental Cost Update 2005/06* (Horii, 2004). Transmission and distribution capacity costs ($/kW-yr) are used to obtain a cost per megawatt ($/MWh) using the formula below. Demand estimates for one, five, and ten-year increments are generated. Annual and peak demand are generated from the model I constructed outlined in Section 6.2.

$$\frac{PD * (CC * 1000)}{AD} = AIC$$

PD= Peak Demand (MW)

CC= Capacity Cost ($/kW-yr)

AD= Annual Demand (GWh)

AIC= Annual Incremental Cost

Peak Demand is determined by:

$$AD\ /\ LF_{SH}\ /\ CF_{SH} = PD$$

LF_{SH}= Electric Baseboard Space Heating Load Factor

CF_{SH}= Electric Baseboard Space Heating Coincident Factor

A demand increase beyond the BC Hydro forecast may pose greater incremental capacity costs. When compared to BC Hydro's forecast numbers, the electric space heating demand forecast by this study stays well within the limits of BC Hydro's forecast.

Explanation for Marginal Greenhouse Gases as Environmental Indicator

Marginal, as opposed to average, emissions intensity is used to compare GHGs. It is not appropriate to use average emissions intensity to assess the environmental impacts of incremental energy use or incremental conservation. While, on average, 90 percent of British Columbia's electricity is generated from hydro electricity, electrical demand in British Columbia now exceeds domestic electricity generation except in years of very high runoff. Additional demand requires that additional energy be imported or that additional domestic energy resources be built. Since it is new demand that spurs new generation production, impacts from new demand should be associated with this new generation. New conservation measures would scale back requirements for this new demand.

Due to constantly changing domestic supply, demand, and market conditions, BC Hydro's marginal source of domestic production and/or source of imported electricity can change

hourly. Yet, environmental impacts linked to British Columbian's electricity demand are assumed to be the dependable electricity production and firm energy planned to meet domestic demand. [120] BC Hydro enters into purchase contracts and constructs generation capacity based on domestic demand forecasts.

British Columbia's marginal generation sources differ in the short and long term. In the short term, resources are generally dispatched in order of least- to most-expensive marginal production cost. The marginal production cost is related to the fuel (or opportunity) cost and other variable costs as well as the dispatchability of the resource, that is, how easily the generation can be adjusted to match short-term variations in load. Many gas-fired generating plants are dispatchable resources, with fuel costs for every kWh of electricity produced; therefore, except for the spring runoff period when there is usually plentiful hydro generation in the Pacific Northwest, CCGT resources are on the margin. In the medium to long term, BC Hydro's resource expenditure and expansion decisions are determined by domestic demand; so marginal resources are those resources that would be delayed or advanced due to an increase or decrease in demand. As British Columbia's electricity demand over the next twenty years is forecasted to consistently rise and in the long-term, peak demand is strongly upward, British Columbia's annual electricity production will continue to operate at capacity. Changes in space heating demand will advance or delay the point in time resources will be required. [121]

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[120] Dependable capacity and firm energy is planned and constructed or purchased to meet BC Hydro's annual average electricity requirements. The definition of dependable capacity is that "it can reliably provide three hours in the peak load period of the weekday during two continuous weeks of cold weather". Peak demand occurs in the winter driven in particular by residential space heating load and a higher lighting load due to shorter daylight hours in the winter. High demand period is considered 6 AM to 10 PM on winter weekdays in December and January.

[121] It would require substantial demand reductions, in the order of 3000 GWh for BC Hydro to scale back resource allocation decisions, so for smaller demand-side management electricity reduction those resources would likely be sold as export displacing other electrical generation, likely gas-fired, in the integrated grid.

Summary of Regional Space Heating Loads

Table 34 Space Heating Loads Provided by BC Hydro Through Innes Hood – Typical New Construction

Typical New Construction			
Electric heat			
	MJ	EGH	KWh
Lower Mainland	52300	74	14528
Vancouver Island	40067	75	11130
North Interior	106300	71	29528
Southern Interior	61200	73	17000

Gas heat			
	MJ	EGH	KWh
Lower Mainland	73600	72	20444
Vancouver Island	50300	75	13972
North Interior	133700	71	37139
Southern Interior	61500	73	17083

Table 35 Space Heating Loads Provided by BC Hydro Through Innes Hood – Energy Efficient New Construction

Energy Efficient New Construction			
Electric heat			
	MJ	EGH	kWh
Lower Mainland	29900	78	8305.556
Vancouver Island	21700	79	6027.778
North Interior	62070	78	17241.67
Southern Interior	32400	79	9000

Gas heat			
	MJ	EGH	kWh
Lower Mainland	43200	79	12000
Vancouver Island	28500	81	7917
North Interior	69700	80	19361
Southern Interior	41300	80	11472

Heat Pump Efficiency

A bin model for Vancouver Island is created to verify that Vancouver Island heat pump performance is equivalent to DOE heating region IV. A bin model generates a seasonal coefficient of performance (COP) based on optimal heat pump operation over a particular period.[122] Comox climate data, obtained from Environment Canada, provides the forty-year average for the number of hours at each temperature that would require space heating. COPs for each temperature (COP_{temp}) are weighted by the number of heating hours (HH_{temp}) at the specific temperature (t) divided by the total number of temperatures (HH_{total}). The COP for each temperature was obtained from five different heat pump field studies (Reichmuth, 2005). The

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[122] Note: COP is defined in a previous section it is essentially the efficiency of a heat pump.

conclusion is it is appropriate to use the DOE heating region IV HSPF to determine heat pump performance.

$$COP = COP_{temp}\left(\frac{HH_{temp}}{HH_{total}}\right)$$

Mandatory Energuide for Houses Standard Energy Savings

No specific energy savings per EGH point exists therefore it is difficult to estimate the reduced energy consumption if the mandatory energy system is implemented. The rating adjusts calculated energy consumption by a baseline, which varies with fuel used, the volume of the house, regional weather, and even local water main temperature. Still an estimate for energy savings and peak load reduction is made using the BC Energuide for Houses database.

Data, from houses built between 2000-2005 that have undergone an Energuide, assessment are used to calculate an estimate for energy savings and peak load reduction. Average incremental energy savings is divided by the related incremental change in rating to obtain an average energy savings per point. Vancouver Island's average came from only 28 cases.[123]

A baseline for "natural energy savings" without policy intervention is established and deducted from the energy savings due to policy intervention. It is assumed that without the mandatory requirement, the average home rating would continue to increase; these energy savings are considered baseline. In order to obtain a large enough sample size, BC Energuide numbers for both Vancouver Island and the Lower Mainland are used. The estimated average rating for homes on Vancouver Island is 73. Average energy savings per unit is 3675 MJ and 4195 MJ.[124] [125] Of the houses assessed on Vancouver Island, the average rating for homes built between 2000 and 2005 is 74.5 (±3.2); unfortunately the sample size is only 28.[126] Between 1995-1999, the average EGH is 71.5 (±4.6) with a sample size of 70. Based on the larger Lower Mainland sample, EGH rating changes an average of 2 EGH points between these time periods or 0.4 points per year. Considering Vancouver Island's higher level of efficiency, it could be expected to grow slightly slower and therefore the baseline energy efficiency increase per year is considered to be 0.3 rating point or 204 kWh.[127] Energy savings in new homes using a heat pump

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[123] Regions with much higher sample sizes, the Lower Mainland and the Southern Interior, had greater savings per point; this is evidence that the Vancouver Island average is underrated.
[124] Based on Vancouver Island average rating between 75 and 80.
[125] MJ = Megajoule
[126] The average rating on the Lower Mainland for houses in the same time period is 70 with a sample size of 183.
[127] Lower Mainland EGH between 1995-1999 67.6 (±6.2) (N=558) and 2000-2005 70 (±5.6) (N=183).

in the baseline forecast is not included in the electricity savings. An average new home using a heat pump would likely have a rating EGH 80 or greater. When calculating the electricity savings, only the number of homes heated electrically is included in the analysis. I assume that all houses using electric space heating also use electric domestic hot water heating.

Because of limits to the information entered into the BC Energuide database, it is not possible to calculate the percentage of energy savings from space heating, only the overall energy saved. Assumptions are made on the break down of end-use savings so load and coincident factors can be used to estimate peak load savings. I assume that space heating makes up 70 percent of the energy savings and domestic hot water the remaining savings.[128] Heating and cooling are estimated to consume 41 percent of residential energy and hot water heating 16 percent.

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[128] These end-uses are the only energy conservation taken into account in the EGH rating system.

Potential Energy Efficient Measures to Achieve the Mandatory Energuide for Houses Requirement

Vancouver Island - Electricity - Single-Detached Units		
	Bundle #1 - No Heat Pump	Bundle #2 - Heat Pump

Technical

Framing	advanced	Advanced
Wall insulation	3.5	3.85
Ceiling insulation	7	7
Basement insulation	1.8	2.1
Coverage	full height	full height
Windows	lowE, argon	lowE, argon
Heating system	baseboard	ASHP
Furnace fan motor	N/A	ECM
DHW	conv.	conv.
Air tightness	3.9	3.9
Ventilation	exhaust	HRV
L/s	40.3	40.3
hr/day	24	24
Total critical air changes	0.3	0.3
Lighting	standard	standard
Electric utilities	23.7	23.7
Temperature - main floor	20	20
- basement	18	18
EnerGuide value	80	81
Electricity consumption	98,515	76,138
Electricity savings	0	22,377

Financial

Incremental capital cost	938	5,071
NPV of energy costs	2,068	5,155

Source 25(Cooper, 2004)

Appendix B

State of High Efficiency Heating - Fuel choice descriptive stats

Table 36 Single Family Dwelling New Construction Fuel Choice on Vancouver Island

SFD New Construction Fuel Choice		
Space Heating Fuel	1994-1999	2000-2005
Natural Gas	59%	34%
Electricity	38%	56%
Other Fuel /Don't Know	3%	10%
Sample size	93	193

Source 26 BC Energuide for Houses Database and Habart BC Fuel Choice Study

The market shift towards electric space heating from 1994-1999 to 2000-2005 appears captured by both baseboard and air source heat pumps (see Figure 12 below). Of the 18 percent increase in electric heating, the majority comes from baseboard heating. Baseboard heating shares shifted from 26 to 38 percent. Air source heat pumps experienced an eight percent increase in total market shares, while the share of electric furnaces decreased slightly. Sample sizes are limited so a greatly deal of precision cannot be attributed to these numbers (see Table 36 and Table 37).

Figure 12 Single Family Dwelling New Construction Fuel Choice Electric Primary Heating Equipment
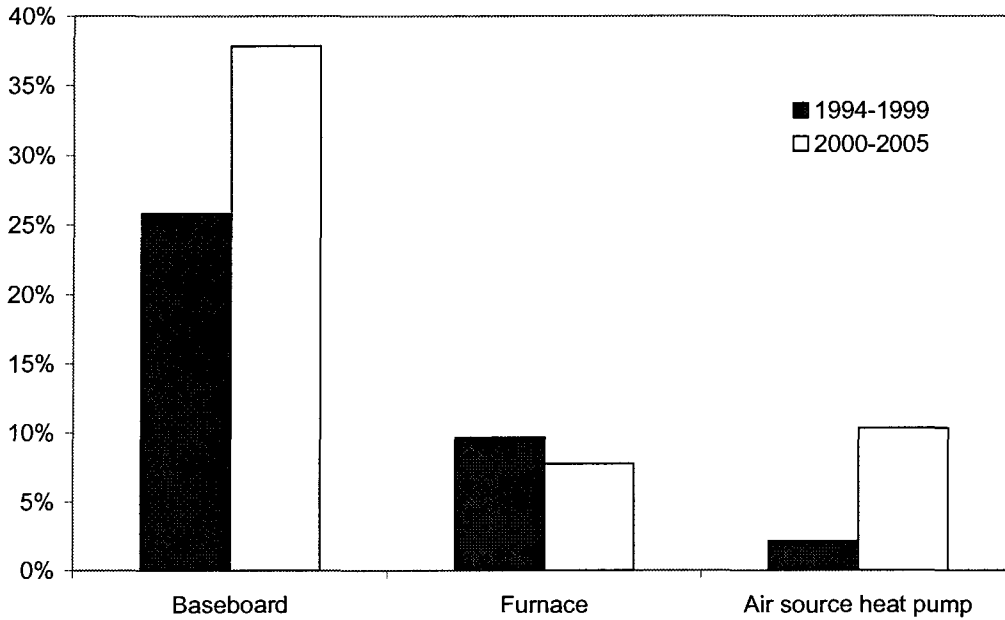
Source 27 BC Energuide for Houses Database and Habart BC Fuel Choice Study

Table 37 Single Family Dwelling New Construction Fuel Choice Electric Primary Heating Equipment

Electric Primary Heating Equipment				
Heating Equipment	1994-1999		2000-2005	
	Total Electric	Total	Total Electric	Total
Baseboard	69%	26%	68%	38%
Furnace	26%	10%	14%	8%
Air source heat pump	6%	2%	19%	10%
Total Electric	100%	38%	100%	56%

Sample size	35	108

Source 28 BC Energuide for Houses Database and Habart BC Fuel Choice Study

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Appendix C – Fuel Choice Regression Results

Fuel Choice Regression Results

Table 38 Descriptive Statistics for Fuel Choice

		Frequency	Percent
Fuel Choice	Electric	143	54
	Natural Gas	120	46
	Total	263	100

Table 39 Descriptive Statistics for Independent Variables – Natural Gas Prices and Housing Starts

	Mean	Minimum	Maximum
Natural Gas Price	$5.80	$1.94	$11.33
Housing Starts	1696	958	3353

Table 40 Unstandardized and Standardized Coefficients for Predictor Variables of the Fuel Choice Regression

	Unstandardized Coefficients	Standardized Coefficients
Natural Gas Price	-0.17**	0.84**
Housing Starts	0.00	1.00

Dependent Variable: Fuel Choice

Note: $p < .01$**

Energuide for Houses Regression Results

The forced entry method of multivariate regression was used to analyze how average space heating energy used by a household and the floor area varies with different Energuide for Houses ratings on Vancouver Island for houses built between 1995 and 2005. The model has an excellent goodness-of-fit as the adjusted R Square is .86; in other words, the predictor variables chosen explain 86 percent of the variation in the Energuide for Houses rating.[i] The Durbin Watson test result is 1.4 demonstrating that data is not systematically ordered and there is little autocorrelation. The collinearity statistics tests (Tolerance and VIF) reveal no problems with multicollinearity. The distribution of standardized residuals in a scatterplot demonstrates little sign of heteroscedasticity.

The multivariate results, using the EGH as a dependent variable in ordinary least squares regression, are summarized in Table 42. The Table contains unstandardized coefficients, which reveal the relationship between the EGH rating and each predictor variable. Also included in Table 42 are the standardized regression coefficients that provide a comparison of the relative magnitude of the effect of each independent variable. Both predictors made a significant contribution to the model with confidence greater than 99%.

Table 41 Descriptive Statistics for Outcome and Predictor Variables of the Energuide for Houses Regression

	Sample Size	Mean	Minimum	Maximum
EGH Rating	98	72	54	82
Space Heating Energy	98	64933	18801	171172
Floor Area	98	251	95	645

Table 42 Unstandardized and Standardized Coefficients for Predictor Variables of the Energuide for Houses Regression

	Unstandardized Coefficients	Standardized Coefficients
Space Heating Energy	0.00**	-23.67**
Floor Area	0.02**	11.53**

Dependent Variable: Energuide for Houses Rating

$p<.01$**

Appendix D– Maximum Electricity Savings from Eliminating Low Efficiency Electric Heating

Fuel Substitution

Table 43 Maximum Potential Electricity Displacement From Natural Gas Space Heating Use (GWh)

	10 Years	20 Years
Electric Furnace Demand (GWh)	70	111
Electric Baseboard Demand (GWh)	277	448

Table 44 Levelized Potential Electricity Displacement From Natural Gas Space Heating Use (GWh)

	1 Year	5 Years	10 Years	15 Years
Electric Furnace Demand (GWh)	13	24	27	28
Electric Baseboard Demand (GWh)	59	104	117	118

Table 45 Potential Peak Electricity Displacement From Natural Gas Space Heating Use (MW)

	10 Years	20 Years
Electric Furnace Demand (MW)	56	89
Electric Baseboard Demand (MW)	120	194

Table 46 Levelized Potential Peak Electricity Displacement From Natural Gas Space Heating Use (MW)

	1 Year	5 Years	10 Years	15 Years
Electric Furnace Demand (MW)	11	19	22	22
Electric Baseboard Demand (MW)	26	45	51	51

Heat Pumps

Table 47 Potential Electricity Displacement From Heat Pump Use (GWh)

10 Year Cumulative		
HSPF 9	Electric Furnace Demand (GWh)	43.6
	Electric Baseboard Demand (GWh)	172.3
HSPF 10	Electric Furnace Demand (GWh)	45.0
	Electric Baseboard Demand (GWh)	182.6

Table 48 Levelized Potential Electricity Displacement From Heat Pump Use (GWh)

		1 Year	5 Years	10 Years
HSPF 9	Electric Furnace Demand (GWh)	8.1	14.9	17.0
	Electric Baseboard Demand (GWh)	36.9	64.6	73.0
HSPF 10	Electric Furnace Demand (GWh)	8.6	15.8	18.0
	Electric Baseboard Demand (GWh)	39.1	68.5	77.3

Table 49 Potential Peak Electricity Displacement From Heat Pump Use (MW)

20 Year Cumulative		
HSPF 7.3	Electric Furnace Demand (MW)	36
	Electric Baseboard Demand (MW)	49

Table 50 Levelized Potential Peak Electricity Displacement From Heat Pump Use (MW)

		1 Year	5 Years	10 Years
HSPF 7.3	Electric Furnace Demand (MW)	6	10	12
	Electric Baseboard Demand (MW)	18	32	36

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[i] The ANOVA test had a significance of 0.00 increasing the confidence in the explanatory power of the model.