Energy Trust of Oregon

Natural Gas Furnace Market Assessment

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Furnace Market

The Oregon natural gas furnace market is estimated to absorb between 46,000 and 50,000 furnaces per year. Of these furnaces, about 36,000 to 40,000 occur in the NW Natural service territory.

Information from Distributors, supported by information from contractors and a bottom up estimate of market demand for furnaces indicates that, in 2004, about 44% of the furnaces went to new construction while the balance (56%) went to the replacement market.

The analysis also indicates that about 44% of the total furnaces sold in the NW Natural service territory were high efficiency. The share of high efficiency furnaces in the replacement market was estimated at 71%, but in new construction the share was only 11%. The low penetration in new construction was supported by developer interviews which indicated that the default furnace was a single stage mid efficiency unit, and while developers often offered a furnace upgrade option, the sales staff did not understand the benefits nor did they appear to try to sell the options.

Compared with other jurisdictions, Oregon has a higher penetration of efficient furnaces than British Columbia, which has a colder climate. However it has not achieved market transformation which does appear to have happened in Wisconsin.

The Oregon Department of Energy provides a significant incentive for furnaces with variable speed blower motors (VSM)[1]. Overall; about 43% of the furnaces sold in Oregon in 2004 were equipped with a VSM. This is significantly higher than the share in British Columbia (24%) and Wisconsin (20%). In high efficiency furnaces the share is 77% relative to British Columbia (53%) and Wisconsin (23%). The higher share in Oregon is likely a result of the Oregon Department of Energy's (ODOE) $ 350 incentive, as the incentive in both B.C. and Wisconsin was $ 150. In B.C., when the incentive for VSMs was removed, the share of high efficiency furnaces with VSMs in the replacement market dropped from 57% to about 43%.

Pricing Analysis

As part of this project, pricing information was collected from furnace distributors, contractors and developers to provide a basis for determining customer economics, and to better understand pricing mark-up behaviour.

In the new construction market, the incremental cost of a high efficiency furnace at the distributor level was $267. This increased to $ 854 at the contractor level,

[1] These are also referred to as electronically commutated motors (ECM).

and then to about $ 1,200 at the developer level which was the price the consumer paid. The mark-up at the contractor level is almost twice as high in new construction as in replacement. This may be a result of the lower market share of high efficiency furnaces and possibly may drop if the market share of efficient furnaces in new construction can be increased.

For the replacement furnace market, the incremental cost of the high efficiency furnace was $ 465 at the distributor level and $ 956 at the contractor or retail level.

For the VSM feature (which includes a 2-stage furnace), in the new construction market, the additional cost at the distributor level was $318, increasing to $ 908 at the contractor level, and $ 1,200 to the consumer. Again, the mark-up at the contractor level is higher that for the replacement market, and may drop if the market share for VSMs can be increased for new construction.

In the replacement market, the incremental cost of the VSM at the distributor level was $ 419, increasing to $ 875 at the contractor or retail level.

Compared with a study of mark-ups in the furnace distribution channel done by the US DOE, and changes in the incremental cost of VSMs in British Columbia, it may be possible to increase efficiency in the distribution channel in Oregon and reduce the incremental cost to consumers. This should be considered as part of program design.

Cost Effectiveness

In this study, cost effectiveness was looked at from the perspective of customer cash flow, that is, would the customers monthly costs increase or decrease as the result of purchase of a high efficiency furnace or a VSM. This is not a proxy for a Total Resource Cost Test, which was outside the scope of the project as the Energy Trust of Oregon (ETO) has done these calculations. The study also considered simple payback, the number of years required to recover the investment.

In new construction, it was assumed that the incremental cost would be included in the purchase price of the house, and hence would be part of a 30 year mortgage. For the replacement customer, it was assumed that the customer would take a ten year loan.

Three fuel price scenarios were developed. The base case scenario assumes a 15% real natural gas price increase in the first year and a 0.8% increase in subsequent years. Electricity prices are assumed to increase at half the rate of natural gas prices.

Based on this scenario, a high efficiency furnace, when purchased as part of a new home or as a replacement, provides a positive cashflow of about $30 per year to the homeowner, along with a simple payback of about 6 to 10 years. If the incentives are removed, the purchase is essentially cashflow neutral, and the payback increases to between 7 and 13 years. However homeowners may consider the additional protection from fuel price increases a significant benefit.

Cost effectiveness of the VSM feature is more complex, as the economic benefit is directly proportional to the amount the furnace blower is used for ventilation. For both new construction and the replacement market, VSMs do not provide a positive cashflow to the homeowner if the furnace blower is only used while the furnace is providing heat or cooling. However if the homeowner uses continuous ventilation, the cashflow benefit is significant, about $285 per year for new construction and about $ 275 for a replacement customer. The key to appropriate use of the technology will be to ensure that the customer has valid information to determine if a VSM is cost effective for his intended use.

The interviews with contractors provided some information on the installation of air conditioners and on the usage of continuous ventilation. In the replacement market, contractors reported installing air conditioning in 40% of the installations, while 50% of the furnaces were set up for continuous ventilation. Looking at the replacement market, if all furnaces had VSMs this usage would provide a positive cashflow of $ 85 per year on average, and a break even of slightly less than 5 years. However, contractors reported that all of the continuous ventilation installations used VSMs, so that these homeowners will achieve a significant benefit.

In new construction, the reported share of air conditioners was about 45%, but no data was provided regarding continuous ventilation. For the analysis, it was assumed that the VSMs would use the same share of continuous ventilation as in the replacement market, but as the share of VSMs is much lower in new construction, the overall level of ventilation usage is lower. Looking at the new construction market, this usage would provide a breakeven cashflow on average, and a 14 year simple payback.

Incentives

The trade allies were interviewed to determine their perspectives on the incentives provided to the high efficiency furnace and VSM market. Distributors and Contractors both felt that the incentives were key to increasing the shares of high efficiency furnaces in Oregon and provided a good business opportunity for them. However this was not true of developers who have largely ignored the incentives. While a number of developers do provide options for furnace upgrades, most leave it to the customers to apply for the incentives.

When asked about the impact of reducing or removing the incentives, both Distributors and Contractors felt that the share of efficient furnaces would erode over time, but felt that the industry had learned to sell these products. However both groups felt that the share of VSMs would fall much more dramatically and the market would revert to PSC motors.

The customer economic analysis indicates that if there were no incentives for high efficiency furnaces, new construction homeowners will still achieve a positive cashflow, while in the replacement market the cashflow would be neutral. This indicates that market share for efficient furnaces should not deteriorate significantly if the furnace incentive is removed, assuming the base price scenario occurs.

The case of VSMs is more interesting. For both new construction and the replacement market, removal of the incentives will reduce the cashflow by about $75 per year for new construction and by $40 per year for the replacement market. However it does not change the types of usage that provide a positive cashflow to the homeowner. Continuous ventilation either during the heating and / or cooling season or all year still provides a positive cashflow.

Trade Ally recommendations for the Energy Trust.

The trade allies were asked for suggestions on how to encourage consumers to install HE furnaces and VSMs. Common themes include:

- Continue the incentives as they are required to bring the payback down for consumers
- Provide more information for customers - furnace purchases are very infrequent, and customers don't know the alternatives.
- Provide training for the trade allies, specifically for the smaller contractors who compete on price and for the sales staff of new housing.
- Increase the focus on new construction.

With regards to customer information, the analysis of VSM economics emphasizes the point that they are uneconomic to the homeowner if the furnace blower is not used for some form of circulation in addition to providing heat and cooling. Experience in British Columbia indicated that Contractors did not have valid information about the energy savings of the VSM in various types of operation, or their impact on natural gas consumption. Therefore one role for the Energy Trust may be to provide valid information related to the economics of VSMs in Oregon, which can be made available to contractors, developers and directly to would-be purchasers. However homeowners may want to purchase VSMs for other benefits such as quieter operation and more even heating.

Program Opportunities

In the replacement furnace market, the ETO and ODOE programs have been very successful in changing the market to high efficiency furnaces with VSMs. Judging from Wisconsin experience, some further small increases may be possible, but the emphasis should be on market transformation, including reducing the pricing premiums and reducing or eliminating the incentives.

Two furnace replacement markets that are hard to address are low income families and rental units. The Energy Trust should consider working with the Community Action agencies regarding what can be done for low-income groups, and push the Business Energy Tax Credit for rental property owners.

Another area identified in this study that may require assistance is for small contractors who sell on price alone. The higher end manufacturers and their dealer networks have sophisticated and successful upsell strategies for higher efficiency, VSMs and enhanced filters. They believe these are better products and can sell them when they can talk with the end customer. However training for small contractors on selling these products may be beneficial.

The main market that is underserved by both the ETO efficient furnace program and the ODOE VSM tax credit is new construction. Two options to address this market in the near term are: a standalone furnace program; or a comprehensive new construction energy efficiency program, such as the new Energy Star program.

Some developers feel that the comprehensive approach gives them more ability to differentiate their product, and given the low level of interest by builders today in promoting the high efficiency furnaces, the comprehensive program may be the preferred approach. In addition, having complete new home developments with high efficiency furnaces will allow for volume bids for both the furnace and VSMs and should reduce the price premiums noted in the distribution channel. The ETO should continue to ramp up the Energy Star new home program

In addition to the new homes program, the ETO may wish to develop and provide point of purchase materials outlining the benefits and economies of high efficiency furnaces and VSMs and make this material available for use by developers who currently provide high efficiency furnace options.

In the medium term, the ETO should continue to work with ODOE to support the development of new building code standards that will encourage the more efficient use of energy, including natural gas.

Areas for Further Research

Additional information is required on how furnace blowers are used in Oregon in order to understand the economic and energy impact of VSMs. This data may be collected as part of another research project, such as a residential evaluation or an end use study. It may be possible to partner with either NW Natural and / or PG&E as both utilities will have an interest in how VSMs affect their load, if this can be a low cost addition to some research they are conducting.

1. Introduction

The Energy Trust of Oregon (ETO) is an independent non-profit organization dedicated to providing energy efficiency services and renewable energy benefits to the Oregon customers of Portland General Electric, PacifiCorp and NW Natural Gas. As part of their mandate, ETO has commissioned this study of the natural gas furnace market in their jurisdiction.

Oregon has a history of promoting energy efficiency, with the Residential Energy Tax Credit Program starting in 1979. This program has evolved and been regularly revised to encourage current technologies and practices. In 2001 furnaces were added to the program and currently provide a $ 350 incentive for a furnace with an AFUE of 90% or better and a permanent magnet variable speed DC blower motor. These blower motors will be referred to as variable speed motors or VSMs in this report.

In addition, since 1995, North West Natural Gas (NW Natural) has provided an additional incentive of $200 for a furnace with a 90%+ AFUE rating. This program is now operated by the Energy Trust of Oregon (ETO). NW Natural also operates a contractor referral program to link customers with qualified contractors.

1.1 Objectives

The specific objectives of the study are to:

- Develop a market model showing the shares of mid and high efficiency furnaces sold in the new construction and replacement markets.
- Estimate furnace pricing or incremental pricing of efficiency upgrades.
- Determine economics to the customer.
- Determine trends and barriers affecting the markets for efficient furnaces.
- Highlight program opportunities and recommendations.

1.2 Organization of Report

The report is organized in six sections with detailed supporting information included as Appendices.

- Section 2 outlines the methodology used in the project.
- Section 3 provides an overview of furnace technology to provide background for readers who are not familiar with natural gas furnaces.
- Section 4 provides a summary of the primary market research conducted with furnace distributors, contractors and residential new home developers.
- Section 5 presents the secondary research done to support the project, and then provides the analysis of efficiency opportunities.
- Section 6 provides the recommendations.

2. Methodology

Data collection for this project consists of a mix of primary and secondary research. Primary research was used to determine furnace market information and pricing that is specific to the Energy Trust of Oregon (ETO) territory. Secondary research was used to obtain technical information on the furnace market and heating system usage in Oregon, and on performance of both furnaces and blowers.

The primary research was undertaken by Mr. Dave Hewitt of Hewitt Consulting. Mr. Hewitt has a long experience in energy efficiency in both Oregon and Wisconsin and is experienced in this type of data collection. The interviews were undertaken primarily in March 2005, and were based on an interview protocol jointly developed by Habart & Associates Consulting and Mr. Hewitt, and reviewed by the Energy Trust prior to implementation.

Interviews were undertaken with furnace distributors, major heating contractors and developers. This included:

- Seven distributors who account for over 80% of western Oregon furnace sales.
- Nine heating contractors who account for between 10 and 15% of the furnace installations in the NW Natural Gas service territory.
- Five developers who cover a range of mid and large developments in Western Oregon.

Data pertaining to the market has been weighted by the reported or estimated market share of each respondent. In some cases the largest respondent is responsible for about forty times the volume of the smallest respondent in that group and data weighting better reflects their impact on the market.

However, it should be remembered that, while those interviewed account for a high proportion of the furnaces sold, the data was collected by interview, and hence reflects their understanding of the market rather than a detailed analysis of hard sales data.

A wide range of secondary data sources and contacts were used to obtain information about the furnace market and furnace operations in western Oregon. These include:

- American Council for an Energy-Efficient Economy (ACEEE)
- BC Hydro (Vancouver, Canada)
- Ecotope
- Energy Center of Wisconsin
- Gas Appliance Manufacturers Association (GAMA)
- Natural Resources Canada (Canada)
- Northwest Energy Efficiency Alliance
- Northwest Power and Conservation Council
- Northwest Natural Gas
- Stellar Processes
- Terasen Gas (Vancouver, Canada)

The author would like to thank the above groups and individuals for the willing support provided by all those contacted in regards to this project. This is an indication of the strong support for energy efficiency in the Pacific Northwest and high regard and support for the Energy Trust of Oregon.

3. Technology Analysis

This section provides a brief overview of the major elements of furnace design that affect efficiency. Appendix A contains a more detailed overview of furnace technologies.

Natural gas furnaces consist of five basic components:

1. a gas valve to control the flow of natural gas and respond to the call for heat from the thermostat,
2. a combustion assembly to control the mixture of natural gas and oxygen and create the heat,
3. a heat exchanger to extract the heat from combustion while keeping the exhaust fumes out of the dwelling,
4. a blower to force air over the heat exchanger and then circulate the air throughout the house[2], and
5. controls to co-ordinate the operation of the components within the furnace.

There are three basic categories of furnace efficiency which have evolved and include: standard efficiency; mid efficiency; and high efficiency. The different efficiencies are achieved through variations in the design of the five basic components.

As interest in energy efficiency grew in the 1970's, a standard for measuring the efficiency of furnaces was developed and provides the ratings used today. This is called AFUE (annual fuel utilization efficiency), and represents the annual efficiency of a furnace as measured under set test conditions. This provides a better representation of energy consumption than the "steady state" efficiency of a furnace while it is in operation. It includes the impact of a pilot light (if any) which consumes natural gas when the furnace is not operating; the lower level of efficiency as the furnace is coming up to temperature; and etc.

The original furnace design, which continued to be shipped into Oregon until 1996, is referred to as a standard efficiency furnace, and has an equivalent AFUE of about 65 to 70%. However, as many of the standard efficiency furnaces that are now being replaced did not have an AFUE rating when new, the actual rating is subject to discussion[3]. Typically these furnaces used a standing pilot light to ignite the gas when heat was called for (and consumed in the order of 75 – 95 therms of natural gas per year), a permanent split capacitor (PSC) motor with an efficiency between 34 – 39% in low speed mode and 55 - 67% in high speed mode[4] and an electricity demand (at least in Canada) of in the range of 350

[2] The furnace blower runs longer than the burner to circulate the residual heat in the heat exchanger. Hence blower hours exceed heating hours.

[3] In Canada, it was commonly thought that these furnaces had an AFUE efficiency of 60 – 65%. However billing analysis done for Terasen Gas in British Columbia by the author determined an AFUE equivalent efficiency of about 70%.

[4] Sachs, HM et al, "Residential HVAC Fans and Motors are Bigger than Refrigerators, ACEEE, 2002

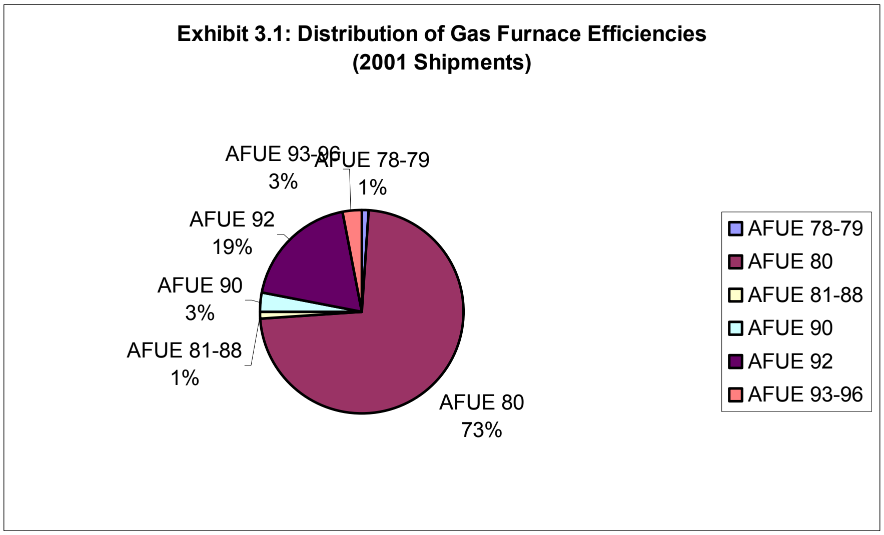
watts[5]. Venting for these furnaces is typically a metal B-vent which exhausts through the roof of the dwelling.

The next step in increased efficiency is the mid efficiency furnace which typically has an AFUE rating of between 78% and 80%. The major design change was to replace the pilot light with electronic ignition. Other changes were also made to the combustion and heat exchanger design and most mid efficiency furnaces use a flue damper and a small draft inducer fan to ensure adequate combustion air. These draft inducer fans draw in the range of 50 to 90 watts. As the efficiency of the furnace increases, the temperature of the air crossing the heat exchanger drops, and the volume of air required to deliver the same amount of heat to the dwelling increases. As a result of this, and increasing incidence of air conditioning, or furnaces being set up to be "air conditioning ready", the size of the blower motors has gradually increased over the years. While the efficiency of the PSC motor has increased, furnace blower draws of 500 – 600 watts are now common. Venting of exhaust gasses is still through the B-vent in the roof of the dwelling.

The highest level of furnace efficiency came with the advent of the condensing or high efficiency furnace in the early 1980's. The major design change was the addition of a second or a two-stage heat exchanger to extract more heat from the flue gases and condense the water vapour in the exhaust gas. This condensing design results in a condensate which is mildly acidic and must be drained[6]. As well, the exhaust fumes are also acidic and will corrode a standard B-vent. The common vent for a condensing furnace is PVC pipe. In replacement applications it is not practical to install a plastic vent through the roof and most replacements are vented through the sidewall of the dwelling. For new construction, they may be vented through either the sidewall or the roof, but sidewall venting is typical. The AFUE rating of these furnaces is typically between 90 and 94%, and is improving over time. In addition, some of these furnaces are designed to draw combustion air from outside the house rather than drawing heated air. These are referred to as 2-pipe systems, and are likely more efficient when the furnace is installed in conditioned space, although this will not be reflected in the AFUE rating.

Exhibit 3.1[7] shows the share of furnace efficiencies in the US for 2001.

[5] Phillips, 1995
[6] The lack of an appropriate drain location can be a limiting factor when replacing a furnace in an existing dwelling. Condensate pumps are available, but add to the expense and complexity of installation.
[7] GAMA 2002



In addition to the evolution of the standard efficiency furnace, two other changes in furnace design are relevant to energy efficiency; the 2-stage furnace and the VSM blower motor.

The 2-stage furnace[8] is an evolution of the mid and high efficiency furnace, and allows operation at either full rated output, or in a "low-fire" mode which is typically about 65% of the rated capacity. This design is intended to provide more comfort to the home owner by providing lower temperature air for a longer period of time than if the furnace was operating in "high-fire" mode. Field tests[9] indicate that these furnaces operate in low-fire mode about 80% of the time (the major exception being recovery from temperature set-back) which means that the furnace blower operates about 40% more hours per year, but at a lower speed and with a lower power draw. A 2-stage furnace design requires that both the draft inducer fan and the furnace blower fan also operate at two speeds.

There is no clear data to indicate if there is a difference in efficiency when the furnace is operating in low-fire mode. Furnaces operate at a lower efficiency after a call for heat from the thermostat as they come up to full operating temperature. The longer firing cycle of a two-stage furnace will reduce the number of furnace cycles over a given time period, and hence should result in the furnace operating in its efficient range more of the time. However it is not clear if the heat exchanger functions as efficiently in low-fire mode. There is also some thought that the lower air speed in the ducts during low-fire mode may increase the heat losses through the ducts[10] as there is more heat transfer through the duct material. However differences in efficiency due to these issues are likely to be small.

[8] In addition to the 2-stage furnace design, there is a modulating furnace design which allows a range of firing levels, perhaps from 40% to 100%. However these are not common in the market, and hence not specifically discussed.
[9] Pigg,s, "Electricity Use by New Furnaces", Wisconsin Division of Energy, 2003
[10] The Canadian Government Combustion Lab is currently investigating this issue.

A range of alternative technologies to the PSC motor exists, which provide higher efficiency and variable speed control, including electronically commutated motors, switched reluctance motors, and PSC motors with variable speed controllers. Of the emerging technologies, the electronically commutated motors, primarily GE's ECM motor (VSM), have made the greatest penetration into the furnace fan market. The VSM motors have significant efficiency advantages over PSC motors at low speeds, although this advantage decreases as motor speed and load increases. In low speed mode the efficiency may be about 70%, increasing to 74 – 78% in high speed mode.[11]

The heat loss of the blower motor contributes useful heat to the house during heating mode. The energy savings resulting from the motor efficiency are partially offset by increases in natural gas consumption[12]. In cooling mode there is also likely some additional savings due to the reduced heat output from the motor.

Currently furnaces are available in mid efficiency and high efficiency, with an option of 2-stage operation, and VSMs. The VSMs are typically available only on the 2-stage furnaces. The full range of furnaces is available in the replacement market, and while the same range is available for new construction, the bulk of the new construction market is populated with stripped down versions of the single stage furnace, in either a mid efficiency or high efficiency unit.

The new construction market functions somewhat differently than the replacement market in that the replacement market is served primarily by contractors who sell the furnaces "one on one" with the home-owner who will pay the cost of the furnace and installation, but who will also get the benefit of lower operating costs and comfort features. This provides an opportunity for a knowledgeable contractor to "upsell" the homeowner on the benefits of high efficiency and VSMs.

However in the new construction market, developers have contractors who will bid on the installation of furnaces for a number of dwellings at once. This changes the dynamic in a number of ways. The homeowner is typically not involved in the choice (but more of this later), and the developer does not accrue the benefit of lower operating costs or increased comfort. Hence the focus in on first costs and multiple unit sales, with price a critical success factor for the contractor (and the manufacturer). This results in strong price competition and the development of "builder's special" versions of basic furnaces along with reduced costs.

Differences between the basic replacement furnace and the "builder's special" vary by manufacturer, and may include:

- Lower quality heat exchanger

[11] Sachs, 2002

[12] Gustdorf, J "Final report on the Project to Measure the Effects of DCPM Furnace Motors on Gas Use at the CCHT Research Facility", Natural Resources Canada, 2003

- Shorter warrantee periods
- Single speed PSC motor
- Less or no cabinet insulation
- Different igniters

However, one distributor in the interviews commented that the reduced features of these furnaces were more to justify the lower cost than to provide the source of the lower cost. The manufacturers were responding to market pressures, and perhaps obtaining some economies due to volume sales, rather than achieving the price reduction through lower manufacturing costs.

The builder's special furnaces are not available to the replacement market as the lower cost likely requires volume sales. At least some distributors require an agreement from contractors that they will not sell these furnaces into the replacement market.

4. Market Research Summary

The distribution channel for furnaces in Oregon is typical of practices in North America. Manufacturers sell furnaces to distributors (who may be aligned with only one manufacturer or who may carry multiple lines of equipment), who in turn sell the furnaces directly to contractors. The contractors both sell and install the furnaces, directly to customers in the case of replacements of equipment in existing houses, or to developers in the case of new construction.

4.1 Distributor Interviews

Interviews were undertaken with five furnace distributors and two manufacturer's representatives. This group accounts for the sale of between 40,000 and 45,000 furnaces per year, which is thought to be most of the annual sales in Oregon.

Furnace sales in Oregon fall into three categories, new construction, conversion from another fuel (typically oil) to natural gas, and replacements where an older natural gas furnace is replaced with a new model. While Northwest Natural splits their results by these three categories, distributors and contractors could only provide data by new construction or replacement, so only these two categories are used in most analysis. Conversion and replacement sales are combined as replacements.

Exhibit 4.1.1 shows the estimated market share of high efficiency furnaces in the new construction and replacement markets for the past three years. It shows that efficient furnaces have a much higher share in the replacement market than in new construction, and that the share has been growing in both markets. However the rate of growth may be declining in the replacement market as it matures.

Exhibit 4.1.1: Share of Efficient Furnace Sales - Distributors[13]

	2002 (%)	2003 (%)	2004 (%)
New Construction	5	7	12
Replacement	46	62	72

Exhibit 4.1.2 shows the split of sales between the new and retrofit market, the mid efficiency vs. high efficiency sales and the PSC vs. VSM blower motor sales. The shares shown in the table represent the share of the overall furnace market.

[13] Shares in this Exhibit differ from subsequent tables due to differing numbers of distributors providing information.

Exhibit 4.1.2: Natural Gas Furnace Market Model - Distributors

		High Efficiency			Mid Efficiency		
	Share	Units	1-stage	VSM	Units	1-stage	VSM
New	44%	5%	2%	3%	39%	37%	2%
Replacement	56%	39%	9%	30%	16%	9%	7%
Total	100%	44%	11%	34%	56%	47%	9%

The Exhibit shows that about 44% of furnace sales are to new construction and likely reflect the current high level of new construction in Oregon at this time. As the building rate subsides, the share of sales to the replacement market will likely increase.

Replacement sales in Oregon are driven by a combination of replacements of natural gas furnaces and conversions from other fuels to natural gas. Based on information from NW Natural, it is thought that between 5,000 and 6,000 conversions per year are taking place. Replacements of existing natural gas furnaces are primarily driven by failure or expected failure of the existing furnace. Evaluations of Terasen Gas' programs suggest an average age of replaced furnaces of about 25 years, and also indicate that the "time limited" incentive program can advance the decision to replace the furnace by 1 – 2 years[14].

Exhibit 4.1.3 shows the market share data for new construction. It shows that only about 11% of the furnaces in new construction are high efficiency, but that about two thirds of these HE furnaces are 2-stage with VSMs which likely indicates owner involvement in the decision. About 89% of the furnaces are mid efficiency, and about 95% of these are the most basic single stage units, the "builder's special" stripped down units. The new construction market is discussed more fully in Sections 4.3.

Exhibit 4.1.3: New Construction Market - Distributors

	High Efficiency			Mid Efficiency		
	Units	1-stage	VSM	Units	1-stage	VSM
New	11%	34%	66%	89%	95%	5%

Exhibit 4.1.4 shows the market shares for replacement furnaces. It shows that about 70% of the furnaces sold in the replacement market are high efficiency, and that over three quarters of the HE furnaces are 2-stage with VSMs. It is interesting that virtually no 2-stage furnaces with PSC motors are sold in this market, a change that the distributors attribute to the tax incentive. The remaining 30% of the replacement furnaces are mid efficiency, and over 40% of these appear to have VSMs (largely due to one brand), which is higher than the share seen in other markets. It is thought that there will always be a share of the replacement market that will not go

[14] Habart, "2002 Residential Heating System Upgrade Program Evaluation", Terasen Gas, 2003

to high efficiency due to:

- Smaller dwellings where the additional cost of the HE furnace will not be recovered in fuel savings;
- Rental properties where the landlord / owner pays the cost of the furnace, but not the operating cost;
- Low income and other groups with limited funds who cannot afford the higher cost of the high efficiency furnace;
- Dwellings where it is difficult to install the side venting for the furnace or the condensate drain; and
- People who plan to move in the near future and will not see a benefit from the lower fuel costs.

Exhibit 4.1.4: Replacement Market - Distributors

	High Efficiency			Mid Efficiency		
	Units	1-stage	VSM	Units	1-stage	VSM
Replacement	71%	23%	77%	29%	57%	41%

Exhibit 4.1.5 shows the reported cost[15] at the distributor level for natural gas furnaces; however, reporting for some categories was sparse, so the information should be used with caution. The price difference between the basic furnace and the VSM equipped models includes both the cost increase between a single stage furnace and a 2-stage PSC furnace, and the cost from the PSC blower to the VSM blower. In a separate question, the incremental cost of the VSM feature was reported to be $ 333. For replacements the quoted prices for the high efficiency furnaces then indicate about $150 increase for the 2-stage feature and about $300 for the VSM motor, which is in line with prices noted in British Columbia.

Exhibit 4.1.5: Natural Gas Furnace Costs – Distributor

	Mid Efficiency	High Efficiency		Cost Increase	
	1-stage	1-stage	VSM	Mid to HE	HE to VSM
New	$373 (n=4)	$621 (n=3)	$1,1261 (n=3)	$267 (n=3)	$318 (n=2)
Replacement	$461 (n=5)	$925 (n=6)	$1,343 (n=6)	$465 (n=5)	$419 (n=5)

When asked about trends in the incremental cost of VSMs over the past two years, 30% responded that prices had not changed, 40% noted they had dropped, and 30% said they had increased by about 10%. When asked about

[15] Care must be taken when using this cost data. While the distributors represent a high proportion of the furnaces available for sale, there are significant product and cost differences between manufacturers that make setting an average cost difficult and potentially misleading. Numbers presented represent weighted averages to reflect differing levels of sales. The (n=X) indicates the number of responses used to calculate each weighted average. The price difference is based only on respondents who provided prices on both models, as calculating the difference based on weighted averages introduced distortion into the price comparison.

expectations for pricing, 30% expected prices to increase, 30% expected a price decrease and 40% expected no change. This indicates no clear direction either in the past few years or the next few years although there may be pricing adjustments within the product lines of various manufacturers.

When asked if there were any disadvantages to the VSMs, the two issues that arise are that the VSM equipped furnaces are more complex, likely due to the controls for the VSM, and that a replacement motor, should it be required, is expensive, more expensive than the cost of the upgrade according to one respondent.

Awareness of the programs for high efficiency furnaces and VSMs is universal among the respondents. The distributors believed that their contractors took advantage of the offers, and that their business benefited from the promotions. Typically they viewed the promotions as helping them to sell higher end equipment, but were split as to whether there was a higher margin associated with the higher end units. However, even with the same margin, sale of a more expensive unit results in an increased profit per sale.

The distributors viewed the incentives as being very important in driving the market towards high efficiency and VSM equipped furnaces. However, responses were mixed when the distributors were asked about the impact on the level of high efficiency furnace sales if the incentives were dropped. Some felt that there would be a gradual drop in the share of HE furnaces as contractors had developed the habit of selling these units while others felt there would be a more significant drop. However when asked about the impact on VSM motors, they were unanimous that there would be a dramatic reversion to PSC motors.

One distributor noted that 5 years ago the standard furnace sold in the retrofit market was a mid efficiency 2-stage unit. The standard now is the high efficiency 2-stage with VSM, a change which he attributes to the incentive programs.

When asked for suggestions to encourage the installation of high efficiency furnaces with VSM, the major comments were:

- Provide more information / education for consumers. They make a furnace purchase decision very infrequently and need information.
- Continue the incentives; otherwise the ROI is too long for the consumers.
- Focus on new construction

4.2 Contractor Interviews

Interviews were undertaken with nine furnace contractors in Western Oregon and 1 in Washington. The Oregon distributors represent sales of about 6,500 furnaces in 2004, or about 15% of the furnace sales in the NW Natural territory. Sales per contractor ranged from about 100 per year up to about 1,800, so these represent a range of firm sizes. About 84% of their furnace sales are natural gas, slightly higher than the number reported by distributors. This may reflect that the respondents are located in the larger urban areas, and hence sell a lower proportion of oil or propane.

These contractors reported that about 30% of their sales were to new construction while 70% are replacement. This represents a lower share to new construction than reported by distributors and likely reflects that a proportion of new construction is handled by specialized firms who do not do replacements. These firms do not advertise to the general public, and hence were not found for this study. For new construction, they reported that about 34% of their work was for custom homes while the remaining 66% was for "tract" housing.

Exhibit 4.2.1 shows the estimated market share of high efficiency furnaces in the new construction and replacement markets for the past 3 years. It shows much the same rate of growth as does the estimates from the distributors, but does show a greater share of high efficiency furnaces. In the new construction market, this share is almost twice as high as the average, and may indicate that these contractors do a disproportionate share of the custom homes where the owner is involved in the heating decisions and chooses higher end furnaces. The share of high efficiency is also greater in the replacement market, which may indicate that these larger firms are better able to sell the advantages of high efficient furnaces. Some of these contractors commented that smaller firms tended to focus on lower price to close sales rather than selling the features. The data from both distributors and contractors show an increasing rate of growth for new construction and a levelling off for the replacement market

While lowest first cost is the primary driver in the new construction market, the two exceptions to this are for developers participating in the Energy Star home program and contractors who can talk directly with the future owner to sell efficiency and air quality as a differentiating marketing strategy.

The contractors interviewed all supported high efficiency natural gas furnaces and VSMs. Some believe that VSMs offer the homeowners more benefits (comfort, efficiency, improved indoor air quality, reduced noise) than do high efficiency, and noted that indoor air quality and comfort are big selling points.

Exhibit 4.2.1: Share of Efficient Furnace Sales - Contractors[16]

	2002 (%)	2003 (%)	2004 (%)
New Construction	11	14	24
Replacement	65	79	81

Exhibit 4.2.2 shows the split of sales between the new and retrofit market, the mid efficiency vs. high efficiency sales and the PSC vs. VSM blower motor sales. The shares shown in the table represent the share of the overall furnace market.

[16] Shares in this Exhibit differ from subsequent tables due to differing number of contractors providing information.

Exhibit 4.2.2: Natural Gas Furnace Market Model - Contractors

		High Efficiency			Mid Efficiency		
	Share	Units	1-stage	VSM	Units	1-stage	VSM
New	29%	6%	4%	3%	23%	23%	0%
Replacement	71%	56%	8%	49%	15%	10%	5%
Total	100%	63%	11%	51%	37%	33%	5%

Exhibit 4.2.3 shows that in the new construction market, virtually all the mid efficiency furnaces are single stage while over 40% of the high efficiency furnaces are 2-stage with VSMs.

Exhibit 4.2.3: New Construction Market – Contractors

	High Efficiency			Mid Efficiency		
	Units	1-stage	VSM	Units	1-stage	VSM
New	21%	58%	42%	79%	99%	1%

In the replacement market, as shown in Exhibit 4.2.4, almost 80% of the furnaces are high efficiency, and of these about 85% are 2-stage with VSMs. Again, the bulk of the mid efficiency furnaces (69%) are the basic single stage units, likely reflecting the same issues as noted in Section 4.1.

Exhibit 4.2.4: Replacement Market - Contractors

	High Efficiency			Mid Efficiency		
	Units	1-stage	VSM	Units	1-stage	VSM
Replacement	79%	14%	86%	21%	69%	31%

Exhibit 4.2.5 shows the reported prices for furnaces, and represents the cost of the furnace and installation, and hence is not directly comparable with the distributor prices. Again there was a significant variation in the prices reported by various contractors, so that this data should be used with caution.

The pricing data for new construction was sparse, with only four contractors providing any prices for the new construction market. In new construction, the price increase to move from a single stage HE furnace to a VSM appears to be in the range of $ 700 to $ 1,000 from contractors who could provide both prices. This is larger than the furnace cost increment from the distributors, but also includes the change from a b-vent to side venting, which some contractors noted was about $ 50 - $ 100 more expensive.

The pricing data was better for the replacement market, where most contractors could provide pricing for the single stage mid efficiency furnace and the two classes of high efficiency furnaces. Based on data from contractors who provided data for all three categories, the incremental cost to move from a single stage mid efficiency furnace to a single stage HE unit is $ 956 (range of $ 300 to $2,000) while the cost to move from a single stage high efficiency furnace to a

2-stage furnace with VSM is an additional $ 857 (range $700 to $ 1,700).

Exhibit 4.2.5: Natural Gas Furnace Costs

	Mid Efficiency	High Efficiency		Cost Increase	
	1-stage	1-stage	VSM	Mid to HE	HE to VSM
New	$2,021 (n=3)	$2,845 (n=2)	$3,918 (n=3)	$854 (n-2)	$ 908 (n=2)
Replacement	$2,212 (n=9)	$3,083 (n=8)	$4,044 (n=9)	$956 (n=8)	$ 875 (n=8)

There appears to be significant interest in adding air conditioning and improving air quality in Western Oregon. Contractors reported that 45% of their new installations include central air conditioning while 35% reported the installation of a better than standard air filter.

For the replacement market, contractors reported that in about 50% of the installations the blowers were set up for continuous operation, and that virtually all these installations used VSMs. The contractors were unanimous that the installation of VSMs was correlated with the use of continuous ventilation. As 50% reported continuous ventilation and 54% of the furnaces have VSMs, this appears reasonable. These contractors were also unanimous that VSMs were the best choice for their customers, and hence they recommend them. About 41% of the installations included air conditioning while 49% included an upgraded filter which may indicate interest in indoor air quality (IAQ).

For the new construction market, most contractors could not provide information on furnace blower usage, but did indicate that 44% of the installations included air conditioning while 34% had some form of upgraded furnace filter.

The only negative issue with VSMs noted by the contractors was the high cost of replace a VSM motor.

Contractors strongly supported high efficiency furnaces as the best choice for their customers with the exception of smaller houses and rental units. The only difficulties noted for high efficiency furnaces was that sometimes they are difficult to vent, and it is difficult to drain the condensate.

All the contractors were aware of the promotions, promoted them to their customers, and took advantage of the promotions. They felt the programs provided a range of benefits for their businesses, including:

- Increasing sales
- Allowing for the sale of higher end equipment
- Providing credibility with the customers for the use of high efficiency furnaces and VSMs.

The contractors all believe that the incentives are very important to both the high efficiency furnace and the VSM market. They think that without the incentives the sale of high efficiency furnaces would drop, perhaps a bit or even by half. However impact on the sale of VSMs would be even greater, with shares dropping to half or lower.

The contractors offered some suggestions on how to increase the penetration of efficient furnaces and VSMs. These include:

- Provide sales training to contractors for these features. This is likely more applicable to the smaller contractors who are selling on price rather than the larger firms.
- The ETO should take a holistic look at the house and provide information about the environment and other energy opportunities in the home, such as windows and duct sealing.
- The ETO should provide linkages to quality contractors.
- Provide a (higher) incentive only for the VSM equipped furnaces.
- Provide incentives and education to the builders.
- Provide more customer education.

4.3 Developer Interviews

Five developers in Western Oregon were interviewed to determine furnace selection practices for new housing. These five developers were responsible for over 1,200 units in 2004, and represent the spectrum of large and small developers with 2004 completions ranging from 15 units to over 500 units. About 44% of these developments were townhomes while the rest were single family dwellings.

All of the developers contacted specify a basic "builders special" single stage mid efficiency furnace as the standard offering in their developments. From the developers' perspective, the main criteria for selecting a furnace are: brand; price; warrantee; and reliability. The latter two criteria likely reflect a desire not to have "call backs" on the house due to the heating system.

However many of these developers did provide furnace upgrade options along with the cabinet, tile and other options which appears to be typical of most developers in this area. Based on these developers, it would appear that about 9% of the customers select high efficiency furnaces, which is comparable the 11% suggested by distributor information presented in Exhibit 4.1.2[17]. However most developers did not consider the furnace upgrades to be good value relative to options such as granite countertops, and they did not know the benefits of VSMs.

The process used to select options in these developments is likely not conducive to encouraging the sale of efficient furnaces. One respondent described it as follows. "Our customers have 10 minutes or less to decide if they want to upgrade the furnace. All the customer choices regarding the home are made in about four hours, moving through the stations at our design centre". It is

[17] However, some more research may be required as the HE furnace shares reported by the developers ranged from 1% to 15%, and in this small sample, one developer accounted for over 85% of the HE furnaces.

apparent that there is no information available on efficiency or the impact of reducing electricity or natural gas costs on home ownership. Further, the sales staff does not appear to be knowledgeable about energy issues nor are they incented to sell the more efficient equipment. Hence the customer is faced with trading off the increased capital cost of a high efficiency furnace and / or a VSM with upgraded granite counter tops, upgraded cabinets and carpets.

Prices noted for these upgrades were about $ 1,200 to go from the mid efficiency to a basic single stage high efficiency furnace (which are also available in "builder special" models), and another $ 1,000 to $ 1,200 to go to a 2-stage furnace with VSM. The upgrade costs are expected to be higher than in the retrofit market as the base price of the "builders" special is a lower cost unit than the single stage furnace sold in the retrofit market and there is one more step in the distribution chain (the developer) with an associated mark-up on the furnace. As the contracting business for new construction is very competitive (more so than the retrofit market) with multiple furnaces in each bid, which reduces margins, the upgrade packages are likely viewed as a way to recapture some of the margin as the additional cost (and margin) is borne by the purchaser, not the developer.

There does appear to be significant interest in mechanical system features. Interviewed developers reported that over 40% of the new dwellings included central air conditioning, while virtually all installations were designed for it, and 8% of the installations had some form of advanced air filtration. However, furnace efficiency is largely invisible to the consumer during the purchase process.

From the developer's perspective, participation in the "Earth Advantage" program costs about $ 2,500, while the Energy Star program costs an additional $ 1,000. These programs attract more customer interest and provide a greater ability for the developer to differentiate his product on the market than does the furnace option.

Awareness of the promotional programs was high, with all respondents being aware. However, only one of the developers participates directly in the incentives, the remainder either leave it to the home purchaser or ignore them. None of the developers viewed the programs as providing value to their businesses.

The developers provided a number of suggestions on how to encourage the installation of high efficiency furnaces and VSMs. These include:

- Provide education (and support material) for the sales force.
- Help builders understand how to use energy efficiency as a sales tool.
- Offer an incentive to the builder.

4.4 Manufactured Housing

The Oregon Department of Energy (ODOE) tracks data on manufactured housing. According to the ODOE, in 2004 approximately 2100 new manufactured homes were sold in Oregon (about 10% of the total new home construction), and approximately 15% to 18% of those homes had natural gas furnaces, with the remainder using heat pumps or electric resistance heating. The share of manufactured homes that have gas heat has been growing, as more homes are being located in places served by natural gas, and electricity prices have been increasing. The retrofit market is thought to be quite small at this point due to the modes market share of gas 15 to 25 years ago.

Only three of 18 manufacturers promote a high efficiency furnace option, and the market share of high efficiency furnaces in Oregon is estimated at 1% of the gas heat market. Typically, high efficiency furnaces have been put into two story manufactured homes sold to housing authorities in Washington, but these types of sales have not occurred in Oregon. The incremental cost to the consumer of the high efficiency furnace option is $412 and the predominant manufacturer is Intertherm. The VSM is not an option with these furnaces, they are single stage units. They qualify for the $200 grant, but not for the tax credit.

5. Analysis

5.1 Natural Gas Furnace Sales

5.1.1 Furnace Shipments

Exhibit 5.1.1 shows data for natural gas furnace shipments by efficiency level to Oregon for the period from 1995 to 2002. The AFUE column shows that Standard efficiency furnaces (AFUE <80) were shipped to Oregon until 1997. It also shows that furnace shipments have fluctuated between 55,000 and 60,000 units per year while the share of HE furnaces has increased from just over 14% and then fluctuated between 21% and 22% through this period. Industry experts have suggested that the number of furnaces shipped in 2004 may have dropped to about 51,000 units.

The data in Exhibit 5.1.1 is from the Gas Appliance Manufacturers Association (GAMA) and represents the state to which the furnace was shipped from the factory. However shipments to Oregon may not match sales in Oregon. There is likely "leakage" to neighboring regions, such as distributors in Portland supplying contractors in Vancouver, Washington, which can distort the data.

Exhibit 5.1.1: Natural Gas Furnace Shipments to Oregon

AFUE	1995	1996	1997	1998	1999	2000
<80	11,377	13,670	15,696			
80 – 88	37,067	35,177	35771	41,823	47,417	43,209
> 88	8,141	12,033[18]	13,738	11,919	12,690	11,401
Total	56,585	60,880	65,205	53,742	60,107	54,610
HE Share	14.4%	19.8%	21.1%	22.2%	21.1%	20.9%

As part of the Distributor interviews, some information was gathered on furnace sales and inferences were made from other sources. This analysis suggests natural gas furnace sales of about 46,000 to 50,000 per year in Oregon. Appendix C contains a "bottom up" estimate of furnace demand in Oregon, and suggests that total sales in the Northwest Natural service territory may be in the range of 36,000 to 40,000 in 2004.

5.1.2 High Efficiency Furnace and VSM Market Shares

The market model was developed from the distributor interviews, and the contractor interviews basically substantiated the product shares in the model.

The market model is reproduced below for convenience.

[18] NW Natural's furnace incentive program launched in October 1995, and program records indicated that incentives were provided for 2,200 furnaces in 1996.

Exhibit 4.1.2: Natural Gas Furnace Market Model – Oregon

		High Efficiency			Mid Efficiency		
	Share	Units	1-stage	VSM	Units	1-stage	VSM
New	44%	5%	2%	3%	39%	37%	2%
Replacement	56%	39%	9%	30%	16%	9%	7%
Total	100%	44%	11%	34%	56%	47%	9%

Exhibit 4.1.3: New Construction Market - Oregon

	High Efficiency			Mid Efficiency		
	Units	1-stage	VSM	Units	1-stage	VSM
New	11%	34%	66%	89%	95%	5%

Exhibit 4.1.4: Replacement Market - Oregon

	High Efficiency			Mid Efficiency		
	Units	1-stage	VSM	Units	1-stage	VSM
Replacement	71%	23%	77%	29%	57%	41%

Exhibit 4.1.2 shows the overall market share of HE furnaces at 44%. This appears quite high relative to the 21% share shown in the GAMA data. However the respondents also provided estimates of how the share of efficient furnaces has grown over the past 3 years. Exhibit 5.1.2 "backcasts" the market model data based on a sales split of 44% to new construction and 56% to replacements and total sales of 45,000. It shows that in 2002 the share of efficient furnaces would have been about 28%. Given that the tax credit programs started in 2001, an increase from 21% to 28% over a two year period appears reasonable.

However it should be noted that some industry observers thought that the reported share of high efficiency furnaces in 2004 was high, perhaps by 10%.

Exhibit 5.1.2: Estimated HE Furnace Shares

	2002	2003	2004[19]
New – Total Sales	19,800	19,800	19,800
New – HE Share	5%	7%	12%
New – HE Sales	990	1,386	2,376
Repl. – Total Sales	25,200	25,200	25,200
Repl. – HE Share	46%	62%	72%
Repl. – HE Sales	11,592	15,624	18,144
Total - Sales	45,000	45,000	45,000
Total - HE Sales	12,582	17,010	20,520
Total - HE Share	28%	38%	46%

It is also useful to compare the shares of efficient furnaces and VSMs with other

[19] Slight differences from Exhibit 4.1.2 are due to rounding

jurisdictions. A market assessment was done in British Columbia in early 2004, and summary results are shown in Exhibit 5.1.3 below. It should be noted that the VSM results reflect the effects of a HE furnace program which provided a $300 incentive for the furnace and an additional $150 for the VSM motor. The program was available from September to December, a period during which about 50% of the annual furnace sales take place. In 2004 the VSM incentive was dropped, and the share of VSM motor sales during the program dropped from 57% to about 43%.

Exhibit 5.1.3 shows the market model for British Columbia (B.C.) in 2003, developed using a comparable methodology. The share of new and replacement markets are different than Oregon, with a lower share of furnaces going to the replacement market. In B.C. there is essentially no conversion "off-oil" market as this was addressed by government programs in the 1970s and 1980s which, in addition to differences in construction rates' likely explains the different shares.

Exhibit 5.1.3: Natural Gas Furnace Market Model – B.C.

		High Efficiency Furnaces				Mid Efficiency Furnaces			
	Total Units	Total HE	Single Stage	2-stg PSC	2-stg VSM	Total ME	Single Stage	2-stg PSC	2-stg VSM
New	49%	10%	6%	0%	4%	40%	35%	4%	1%
Replace	51%	26%	9%	2%	15%	25%	11%	10%	4%
Total	100%	36%	15%	2%	19%	65%	46%	14%	5%

Exhibit 5.1.4: New Construction Market - BC

	High Efficiency			Mid Efficiency		
	Units	PSC	VSM	Units	PSC	VSM
New	20%	60%	40%	80%	97%	3%

Exhibit 5.1.5: Replacement Market - BC

	High Efficiency			Mid Efficiency		
	Units	PSC	VSM	Units	PSC	VSM
Replacement	51%	43%	57%	49%	84%	16%

Exhibit 5.1.4 summarizes the shares of HE furnaces and VSMs in these markets. Within the new construction market, the share of high efficiency furnaces is 11% in Oregon versus 20% in B.C.. Within the high efficiency market, about 66% of the units in Oregon have VSMs while in B.C. the share is lower at 40%. For mid efficiency furnaces, the VSM share in Oregon is about 5% while in B.C. it is about 3%.

While the higher VSM shares in Oregon are likely a reflection of the $ 350 tax credit it is interesting that the share of VSMs on mid efficiency furnaces in the replacement market is over twice as high as in B.C. as the price of these furnaces approach the price of a high efficiency furnace. Anecdotally, this may be an unintended outcome of NWN's desire to retain natural gas hot water load. The retrofit of a high efficiency furnace in a house using a masonry chimney would require the use of a liner in the chimney if only the natural gas water heater is vented, which may push the contractors to recommend mid efficiency units and avoid this cost.

Within the replacement market, the share of HE furnaces in Oregon is about 70% vs about 51% in B.C. The higher share in Oregon may be due to Oregon's program being available throughout the year while BC's is typically only available between September and December, when about 50% of the furnaces are installed. Within the HE replacement market, the share of VSMs is about 77% vs 57% in B.C. The share of VSMs in the mid efficiency replacement market is also much higher in Oregon than in B.C.

Some data was also available for Wisconsin for 2003 which shows the overall penetration of HE furnaces and VSMs, but without a breakdown between new construction and retrofit. This is shown in Exhibit 5.1.4. In Wisconsin there is no incentive for HE furnaces, with the market having been transformed to HE in the mid 1990s. However this is a $150 incentive for furnaces with VSM motors.

Looking at the overall furnace market, Wisconsin has the highest penetration of HE furnaces at 85%, and is likely the leading state in the US. However Oregon with a 44% share leads BC with 36% even though heating load in Oregon is lower than Vancouver. In terms of VSMs, Oregon has the highest share at 43%, almost double that of the other two markets.

Exhibit 5.1.4: Comparison of HE furnace and VSM Shares

	Relative Weather (degree Days)	HE Furnace Share	HE Furnace w/ VSM Share	Mid Furnace w/ VSM Share	Total VSM Share
Oregon	4366	44%	77%	16%	43%
B.C.	5400	36%	53%	8%	24%
Wisconsin	7976	85%	23%	6%	20%

5.2 Pricing Analysis

This section looks at the pricing structure for furnaces through the distribution chain in Oregon. Again the caution noted in previous sections regarding the pricing variance in furnaces means that these weighted averages should be used with caution.

The price difference between the Distributor and the Contractor includes the cost to transport and install the furnace as well as Contractor's mark-up on the furnace.

Exhibit 5.2.1 New Construction Market Pricing

				Price Increase			
	Mid Efficiency	High Efficiency	HE with VSM	Mid to High Efficiency		High Efficiency to + VSM	
				Price	%	Price	%
Distributor	$ 373	$ 621	$ 1,261	$ 267		$ 318	
Contractor	$2,021	$2,854	$3,918	$ 854	220	$ 908	185
Developer				$ 1,200	40	$ 1,200	32

Exhibit 5.2.1 shows that the contractor is marking up the incremental cost of the HE furnace and the VSM feature by about 200%. This mark-up appears high, but may reflect the low share of HE furnaces and VSM sales in new construction. A study done for the DOE[20] to support furnace rule making suggested that the normal retailer mark-up of the distributor furnace cost was between 28% and 53%. The developer mark-up of these options is between 30% and 40%, a number also mentioned by one of the contractors.

Exhibit 5.2.2 shows similar pricing data for the replacement market. It shows that the distributors' price of the "builders' special" furnaces are lower than the models provided for the replacement market, but that the price of the VSM equipped furnace is similar.

Exhibit 5.2.2 Replacement Market Pricing

				Price Increase			
	Mid Efficiency	High Efficiency	HE with VSM	Mid to High Efficiency		High Efficiency + VSM	
				Price	%	Price	%
Distributor	$ 461	$ 925	$ 1,343	$ 465		$ 419	
Contractor	$2,212	$3,083	$4,044	$ 956	105	$ 875	108

While no information was obtained from the contractors on their pricing strategies, the data is consistent with a strategy of a 100% mark-up on the furnace cost, which leaves a residual of between $1,300 and $1,600 for the transportation and installation costs. However, when looking at just the incremental costs, this pricing appears to almost triple the distributor cost increase for the mid to high furnace, and VSM options.

As part of this project, one Washington based contractor was also interviewed. He provided pricing information for the replacement market. Compared with Oregon, the Washington prices were slightly higher.

However, compared with the BC market, the incremental cost to add the 2-stage feature plus VSM is higher in Oregon. Further, there appears to have been a

[20] "Furnaces and Boilers Standards Rulemaking – Engineering Analysis – Draft", Building Technology Program, Office of Energy Efficiency and Renewable Energy, US Department of Energy, September 19, 2002.

significant drop in incremental price between 2003 and 2004 in B.C. that does not appear to have occurred in Oregon.

Appendix E contains an extract on a short market assessment done in British Columbia in Spring 2005. It presents VSM prices recording during Terasen Gas' incentive program in 2003 and 2004. The price increase for the VSM feature in 2003 was $C 953 but for 2004 it had dropped to $C 558. Converted to US dollars, this represents a drop from about $760 to $ 450. Appendix E also contains an estimate of the "normal" mark-ups in the distribution chain done by the DOE to support rule making. It indicates a normal mark-up at the contractor level of between 28 and 53%. This experience may indicate some room for price decreases in Oregon.

5.3 Customer Economics

This section reviews the economics of the HE furnaces and VSMs from the customer's perspective, based on the economics of fuel savings. However it should be remembered that VSMs provide other benefits to clients including reduced drafts, increased comfort and possibly improved indoor air quality.

The approach taken for customer economics is to look at the impact of the efficiency investment on their cashflow and the simple payback for the investment. For new construction, the approach is to compare the increased monthly mortgage payment to cover the cost of the upgraded furnace or blower motor, based on a 30 year mortgage and a 6% interest rate. For replacement furnaces, the approach is similar, but assumes a 10 year loan and a 6% interest rate.

Fuel price changes are a significant factor in the payback on the investment. Three scenarios of natural gas prices were developed to consider a 25 year period and then the average of these prices was used in the scenarios. The electricity price increase was driven off the natural gas price increase on the basis that a 1% increase in natural gas price will coincide with a 0.5% increase in the price of electricity.

The analysis of the customer economics of the HE furnace choice are quite straight forward, as the energy savings is principally a function of the change in furnace efficiency. However, for VSMs, the analysis is more complex, as the savings depend on how the furnace blower is used, (for example, is it used just when providing heat; for ventilation part of the year; or for continuous ventilation) and whether the house has air conditioning..

The input data to the analysis is summarized in Exhibits 5.3.1 to 5.3.4.

Exhibit 5.3.1: Financial Assumptions

	Rate	Term
Mortgage	6%	30 years
Loan	6%	10 years

Exhibit 5.3.2 summarizes the incentives available to purchasers of HE furnaces and VSMs.

Exhibit 5.3.2 Incentives

	HE Furnace	HE + VSM
Tax Credit	-	$ 350
ETO / NW Natural Gas	$ 200	-
	$ 200	$ 350

Exhibit 5.3.3 shows the costs of the furnace upgrades with and without the incentives. The "package" price includes the upgrade costs of both the furnace and the VSM, and is used to evaluate the net impact for a customer who purchases the whole package.

Exhibit 5.3.3 Furnace and VSM Upgrade Costs

	No Incentive			With Incentive		
	HE furnace	VSM	Package	HE furnace	VSM	Package
New	$1,200	$1,200	$2,400	$ 1000	$ 850	$1,850
Replacement	$ 956	$ 875	$1,831	$ 756	$ 525	$ 1,281

Three fuel cost scenarios were considered for the analysis. The "Low" scenario is based on constant real fuel prices; the "Base" scenario consists of a 15% price increase in the first year, and then a 0.8% real increase in each of the subsequent years. The "High" scenario assumes that natural gas prices will double over the next five years, and then increase by 0.8% per year after that.

Exhibit 5.3.4 Fuel Costs

	Low	Base	High
Electricity	$ 0.0876 kWh	$ 0.0990 kWh	$ 0.1272 kWh
Natural Gas	$ 1.1078 Therm	$ 1.4100 Therm	$ 2.2973 Therm

5.3.1 High Efficiency Furnace Payback

Exhibit 5.3.5 shows the impact to the consumer when moving from a mid efficiency furnace to an HE furnace, and includes the impact of the available incentives. For both new construction and replacements, the choice of a HE furnace provides a positive cashflow to the homeowner. The payback ranges from 5.8 to 10.6 years. From a social investment perspective, this is reasonable. However if the homeowner moves within the payback period, and if the housing resale market does not provide a premium for the efficient equipment, then the homeowner will not totally recover the investment. Further, it should be noted that the incentive does not appear to be widely used for new construction.

Exhibit 5.3.5 HE Furnace Upgrade Economics - Incentives

	Annual Payment	Annual Savings	Simple Payback
New	$ 73	$ 94	10.6 years
Replacement	$103	$ 130	5.8 years

Exhibit 5.3.6 shows the economics of the same choices, but without including the incentive. The decision to purchase an HE furnace for new construction still provides a positive cashflow, However the simple payback period stretches out and the new home buyer would have to stay in the home for about 13 years to recover the investment, assuming that the housing resale market does not provide a price premium for the HE furnace and the lower utility bill. In the replacement market the choice is cashflow neutral without the incentive.

Exhibit 5.3.6 HE Furnace Upgrade Economics – No Incentives

	Annual Payment	Annual Savings	Simple Payback
New	$ 87	$ 94	12.7 years
Retrofit	$130	$ 130	7.4 years

Fuel Price Sensitivity

Exhibits 5.3.7 and 5.3.8 show the cost savings and simple payback with the alternate fuel prices.

With the existing incentives and the "low price scenario" (constant real prices) the upgrade to a high efficiency furnace provides essentially a neutral cashflow. However, when the incentives are removed, cashflow is negative. However with the "high price scenario", the cashflow is positive in all cases and provides between $ 67 and $ 107 back to the homeowner.

Exhibit 5.3.7 Fuel Price Sensitivity – Incentives

		Low Scenario		High Secnario	
	Annual Payment	Annual Savings	Simple Payback	Annual Savings	Simple Payback
New	$ 73	$ 74	13.5 years	$154	6.5 years
Retrofit	$103	$ 102	7.4 years	$211	3.6 years

Exhibit 5.3.8 Fuel Price Sensitivity – No Incentives

		Low Scenario		High Secnario	
	Annual Payment	Annual Savings	Simple Payback	Annual Savings	Simple Payback
New	$ 87	$ 74	16.2 years	$154	7.8 years
Retrofit	$130	$ 102	9.4 years	$211	4.5 years

5.3.2 Variable Speed Blower Motors

The analysis of the energy impact of the VSMs is more complex, as it is a function of how the home owner uses the heating system. The use of the heating system affects both the relative efficiency of the VSM vs. PSC motor as well as the hours of operation.

VSM Energy Savings

Exhibit 5.3.7 shows the relative efficiencies of the PSC and VSM motors. A complete discussion of the derivation of these numbers is included in Appendix B. The table shows that the VSMs efficiency benefit increases under light load. The overall benefit to the customer will depend on the amount of time the furnace blower is operated in each mode.

Exhibit 5.3.7 VSM Capacity Reduction

Mode	VSM	PSC	Reduction
Heating mode	156 W	474 W	67%
Air conditioning mode	428 W	582 W	26%
Circulation mode	90 W	484 W	81%

Furnace Blower Usage

No studies were found with Oregon specific information on furnace blower usage. Therefore the approach used will be to look at the most common patterns of furnace blower usage, based on studies conducted by Terasen Gas in British Columbia and develop the economics of High Efficiency furnaces and VSMs from the perspective of each of these types of usage. Finally, some estimates of the potential overall impact based on data provided by the contractor interviews is provided.

The Terasen Gas market research identified different modes of furnace blower operation. These are:

- Intermittent – the blower operates only when the furnace or air conditioning is operating for
    - Heating
    - Heating and Cooling
- Continuous – the blower operates at low speed through the year, and at higher speeds when delivering heat or cooling.
- Seasonal Continuous – the blower operates continuously during the heating or cooling period, which is assumed to be 4 months for heating and 3 months for cooling.
    - Heating
    - Heating and Cooling
- + ventilation refers to intermittent usage for circulation for part of the year. Respondents who indicated usage for ventilation indicated that the blower was used in this mode for approximately 6 months of the year.

Exhibit 5.3.8 below shows the hours of use for the furnace blower under various types of operation for existing housing stock. The data for heating (burner) hours cooling hours was obtained from Ecotope[21], and apply to the existing building stock. A study by the Energy Center of Wisconsin[22] determined that the 2-stage furnace operates 20% of the time in high-fire mode and 80% in low-fire mode[23] and this was used to estimate the hours for a 2-stage furnace. The same study indicated that the blower for a single stage furnace operated about 15% longer than the burner, while 2-stage furnace runs about 7% longer, and also determined that a VSM equipped furnace had a stand-by consumption that was about 30 kWh / year higher than a PSC furnace as the blower motor is always energized. Finally, the study noted that the reduced heat loss from the VSM motor will reduce air conditioning load during cooling operation. Appendix F contains the detailed derivation of these estimates.

Exhibit 5.3.8: Hours of Use for Furnace Blower – Existing Stock

	Burner hrs/yr		Blower hrs/yr	
	1-stage	2-stage	1-stage	2-stage
Heating hours	720	1008	828	1,079
Cooling hours	270	270	270	270
+ Ventilation (6 months / yr)			2,920	2,640
Continuous			8,760	8,760

The following Exhibit combines the data on hours of use for the furnace and the energy consumption of the blower motor to determine the savings resulting from moving from a single stage furnace with PSC motor to a 2-stage furnace with VSM. Using the rate for electricity from the base scenario, the annual level of savings is shown for each type of furnace usage.

Exhibit 5.3.9: Energy and Cost Reduction – Existing Stock

	Energy Reduction (kWh)	Cost Reduction (per yr)[24]
Intermittent		
- heating	194	$ 19.23
- heating & cooling	250	$ 24.73
Seasonal Continuous		
- heating	1,041	$103.06
- heating & cooling	1,853	$183.45
Continuous	3,342	$330.86
+ Ventilation (6 mos)	1,616	$160.01

Exhibit 5.3.10 and 5.3.11 shows the same information, but for new building stock

[21] Baylon, David, Ecotope, Personal communication
[22] Wisconsin, 2003
[23] Wisconsin, 2003
[24] The financial savings for electricity are estimated at the current residential rate of $ 0.0876.

where the hours of furnace and blower operation are reduced due to more energy efficient construction.

Exhibit 5.3.10: Hours of Use for Furnace Blower – New Construction

	Burner hrs/yr		Blower hrs/yr[25]	
	1-stage	2-stage	1-stage	2-stage
Heating hours	550	770	633	824
Cooling hours	220	220	220	220
+ Ventilation (6 months / yr)			2,920	2,640
Continuous			8,760	8,760

Exhibit 5.3.11: Energy and Cost Reduction – New Construction

	Energy Reduction (kWh)	Cost Reduction (per yr)[26]
Intermittent		
- heating	141	$ 13.99
- heating & cooling	287	$ 18.53
Seasonal Continuous		
- heating	1,060	$104.92
- heating & cooling	1,882	$186.30
Continuous	3,361	$332.71
+ Ventilation (6 mos)	1,635	$161.87

Furnace plus VSM Payback - Incentive

Exhibit 5.3.12 shows the impact to the replacement customer of purchasing an HE furnace and VSM, including the benefit of the incentive. It also includes the cost of the increased natural gas usage required to offset the reduced heat loss from the VSM motor. Comparing the monthly payment to monthly savings, the table illustrates that the package does not provide a positive cash flow if the blower is used only for heating and cooling. However increased usage provides a positive cashflow, with paybacks ranging from 3 to 6 years.

[25] Wisconsin, 2003

[26] The financial savings for electricity are estimated at the current residential rate of $ 0.0876.

Exhibit 5.3.12: Customer Payback – Replacement - Incentives

	Annual	Annual Savings			Simple
	Payment	Elec.	N.Gas	Net	Payback
Intermittent					
- heating	$174	$ 19	$120	$140	9.2 years
- heating & cooling	$174	$ 25	$120	$145	8.8 years
Seasonal Continuous					
- heating	$174	$103	$120	$223	5.7 years
- heating & cooling	$174	$183	$120	$304	4.2 years
Continuous	$174	$331	$120	$451	2.8 years
+ Ventilation (6 mos)	$174	$160	$120	$280	4.6 years

Exhibit 5.3.13 shows the same data for new construction. In this case also there is a negative cashflow if the furnace blower is only used for heating and air conditioning. For other uses the cashflow becomes positive. The payback is longer than in the replacement case because the furnace cost is higher. However the payment is lower due to the assumption that, in new construction, the cost is included in a 30 year mortgage while in the replacement market it is a 10-year loan.

Exhibit 5.3.13: Customer Payback – New Construction – Incentives

	Annual	Annual Savings			Simple
	Payment	Elec.	N.Gas	Net	Payback
Intermittent					
- heating	$134	$14	$88	$102	18.2 years
- heating & cooling	$134	$19	$88	$106	17.4 years
Seasonal Continuous					
- heating	$134	$105	$88	$193	9.6 years
- heating & cooling	$134	$186	$88	$274	6.8 years
Continuous	$134	$333	$88	$420	4.4 years
+ Ventilation (6 mos)	$134	$162	$88	$250	7.4 years

Furnace plus VSM Payback – No Incentive

Exhibit 5.3.14 shows the same data, but without the incentives. In this case the package does not provide a positive cashflow to the homeowner unless the furnace blower is used for more than five months of the year.

Exhibit 5.3.14: Customer Payback – Replacement - No Incentives

	Annual	Annual Savings			Simple
	Payment	Elec.	N.Gas	Net	Payback
Intermittent					
- heating	$249	$ 19	$120	$140	13.1 years
- heating & cooling	$249	$ 25	$120	$145	12.6 years
Seasonal Continuous					
- heating	$249	$103	$120	$223	8.2 years
- heating & cooling	$249	$183	$120	$304	6.0 years
Continuous	$249	$331	$120	$451	4.1 years
+ Ventilation (6 mos)	$249	$160	$120	$280	6.5 years

Exhibit 5.3.15 shows the same data for new construction. It shows that unless the furnace blower is used for more than heating or heating and air conditioning, it is not cashflow positive. However if the blower is used longer, it is cashflow positive.

Exhibit 5.3.15: Customer Payback – New Construction – No Incentives

	Annual	Annual Savings			Simple
	Payment	Elec.	N.Gas	Net	Payback
Intermittent					
- heating	$174	$14	$88	$102	23.6 years
- heating & cooling	$174	$19	$88	$106	22.6 years
Seasonal Continuous					
- heating	$174	$105	$88	$193	12.5 years
- heating & cooling	$174	$186	$88	$274	8.8 years
Continuous	$174	$233	$88	$420	5.7 years
+ Ventilation (6 mos)	$174	$162	$88	$250	9.6 years

Fuel Price Sensitivity

Exhibit 5.3.16 shows the cost savings and simple payback with the alternate fuel prices. As with the base case prices, the low price scenario does not provide a positive cashflow until some level of extended blower operation is used. However, in the high price scenario, a positive cashflow is generated even for intermittent usage. If the incentives are removed, the Annual Payment increases from $ 174 to $ 259, and then intermittent usage again does not provide a positive cashflow.

Exhibit 5.3.16: Fuel Price Sensitivity – Replacement - Incentives

		Low Scenario		High Scenario	
	Annual Payment	Annual Savings	Simple Payback	Annual Savings	Simple Payback
Intermittent					
- heating	$174	$112	11.5 years	$221	5.8 years
- heating & cooling	$174	$116	11.0 years	$228	5.6 years
Seasonal Continuous					
- heating	$174	$186	6.9 years	$329	3.9 years
- heating & cooling	$174	$257	5.0 years	$432	3.0 years
Continuous	$174	$387	3.3 years	$621	2.1 years
+ Ventilation (6 mos)	$174	$236	5.4 years	$402	3.2 years

Exhibit 5.3.17 shows the same information for New Construction. The pattern is the same as for the replacement market. With the low price scenario, at least some form of continuous operation is required to provide a positive cashflow. However with the higher price scenario, a positive cashflow is obtained in all usage. If the incentives are removed, the Annual Payment increases from $ 134 to $ 174, and again intermittent usage does not provide a positive cashflow.

Exhibit 5.3.17: Fuel Price Sensitivity – New Construction - Incentives

		Low Scenario		High Scenario	
	Annual Payment	Annual Savings	Simple Payback	Annual Savings	Simple Payback
Intermittent					
- heating	$134	$81	22.8 years	$161	11.5 years
- heating & cooling	$134	$85	21.7 years	$167	11.1 years
Seasonal Continuous					
- heating	$134	$162	11.4 years	$278	6.7 years
- heating & cooling	$134	$234	7.9 years	$382	4.8 years
Continuous	$134	$363	5.1 years	$570	3.2 years
+ Ventilation (6 mos)	$134	$212	8.7 years	$351	5.3 years

5.4 Potential Market impact of HE Furnace and VSM

As shown in the previous section, the economic benefit of the VSM blower is dependent on the level of usage of the blower. Survey data on the level of use in Oregon could not be found. However the contractor interviews did provide some information.

In the replacement market, contractors reported that 41% of the installations included air conditioning while 50% have the blower set for continuous operation. Exhibit 5.4.1 shows the overall impact of these assumptions, assuming an even spilt of continuous operation between heating and heating / cooling. It shows that if the overall market had converted to VSMs, on average consumers would experience a slightly negative cashflow.

Exhibit 5.4.1: Replacement market - Incentives

	Annual	Annual Savings			Simple
	Payment	Elec.	N. Gas	Net	Payback
Replacement	$174	$140	$120	$261	4.9 years

In new construction, where the contractor data was more sparse, about 45% of the installations included air conditioning. No information was provided on blower setting, but if the same ratio of continuous operation to VSMs as in the replacement market (56% VSM, 50% continuous operation, or 89%), then about 10% of new construction uses continuous ventilation. In this case, if the overall market adopted VSMs, the cash flow is essentially neutral.

Exhibit 5.4.2: New Construction Market - Incentives

	Annual	Annual Savings			Simple
	Payment	Elec.	N. Gas	Net	Payback
New Construction	$134	$48	$88	$136	13.6 years

The above analysis indicates that, given the data about air conditioning and blower operation, high efficiency furnaces and VSMs provide a neutral or positive overall benefit to homeowners.

However this analysis does not address the question of whether the promotion of furnaces with VSMs leads to an increase in the use of continuous ventilation and hence an increase in electricity use rather than a decrease.

No Oregon based data was found on which an analysis could be based. However work done in British Columbia by Terasen Gas and BC Hydro provided data on furnace blower usage by 200 homeowners who replaced an existing furnace. Half of these participated in an incentive program for high efficiency furnaces while the other half were non participants to installed a mix of mid and high efficiency furnaces.

Market drivers for more continuous ventilation include increasing concerns about indoor air quality (between 30 – 50% of new furnaces in Oregon have upgraded air filters), increased comfort (more constant temperature, better heating of rooms furthest from the furnace), and quieter operation. However on the other side of the discussion, contractors strongly feel that they are selling the VSM rather than the customer demanding it (this is supported by 34% of consumers in BC not being aware of VSMs prior to purchase, and the contractor / salesperson as the primary source of information about VSMs). It seems likely that the use of continuous ventilation is increasing both due to market drivers such as IAQ and that contractors are selling more ventilation. The issue then becomes how big are these changes, and is the overall market more or less energy efficient as a result of VSMs?

Exhibit 5.4.3 shows the change in blower usage between those who purchased furnaces with PSC motors and those who chose VSMs. It shows that, for people who chose PSC furnaces, intermittent usage increased slightly from 74% to 75% while seasonal continuous usage decreased from 17% to 13%, continuous usage increased from 8% to 9% and +ventilation increased from 1% to 3%. For people who chose a VSM furnace, intermittent usage dropped from 70% to 55%, seasonal continuous usage increased from 10% to 17%, continuous increased from 12% to 18% and +ventilation increased from 7% to 9%. This comparison indicates clearly that people who chose VSMs make greater use of ventilation than those who chose PSC blowers. It also shows that people who ultimately chose VSMs used more blower circulation on their old furnaces. However, it also shows that those who chose VSMs made greater use of circulation that those who did not, so that VSMs are finding the right market.

Exhibit 5.4.3: British Columbia Furnace Blower Usage

	PSC		VSM		Average	
	Before	After	Before	After	Before	After
Intermittent						
- heating	61%	48%	57%	36%	58%	41%
- heating & cooling	13%	27%	13%	19%	13%	23%
Seasonal Continuous						
- heating	11%	4%	6%	6%	9%	5%
- heating & cooling	6%	9%	4%	11%	4%	10%
Continuous	8%	9%	12%	18%	10%	13%
+ Ventilation (6 mos)	1%	3%	7%	9%	6%	7%
PSC (kWh/yr)	975	1061	1135	1556	1075	1305
VSM (kWh/yr)		343		425		383
Reduction (kWh/yr)		718		1131		922

The lower part of Exhibit 5.4.3 shows the change in electrical consumption that would be experienced by customers in Oregon if they had the same furnace blower usage mix as those in B.C.. The table shows that, based in the reported changes in ventilation usage, there is still an average reduction in consumption of 922 kWh per customer if the whole market had converted to VSMs with the "average" blower usage. If the blower usage had increased as a result of sale of the VSM, then average consumption (from the "VSM – Average" Column) would be 425 kWh which is still lower than the pre-furnace replacement consumption with PSC motors of 975 kWh.

The analysis does not answer the question of whether promoting VSMs is increasing the use of higher levels of ventilation, but it does say that, based on the experience in B.C., the overall level of electricity consumption by furnace blowers is reduced in a market where VSMs were being promoted.

6. Recommendations

6.1 Trade Ally recommendations for the Energy Trust.

The trade allies were asked for suggestions on how to encourage consumers to install HE furnaces and VSMs. Common themes include:

- Continue the incentives as they are required to bring the payback down for consumers
- Provide more information for customers - furnace purchases are very infrequent, and customers don't know the alternatives.
- Provide training for the trade allies, specifically for the smaller contractors who compete on price and for the sales staff of new housing.
- Increase the focus on new construction.

With regards to customer information, the analysis of VSM economics emphasizes the point that they are uneconomic to the homeowner if the furnace blower is not used for some form of circulation in addition to providing heat and cooling. Experience in British Columbia indicated that Contractors did not have valid information about the energy savings of the VSM in various types of operation, or their impact on natural gas consumption. Therefore one role for the Energy Trust may be to provide valid information related to the economics of VSMs in Oregon, which can be made available both to contractors and directly to would-be purchasers. However homeowners may want to purchase VSMs for other benefits such as quieter operation and more even heating.

6.2 Program Opportunities

In the replacement furnace market, the ETO and ODOE programs have been very successful in changing the market to high efficiency furnaces with VSMs. Judging from Wisconsin experience, some further increases may be possible, but the emphasis should be on market transformation and reducing or eliminating the incentives.

Two furnace replacement markets that are hard to address are low income families and rental units. The Energy Trust should consider working with the Community Action agencies regarding what can be done for low-income groups, and push the Business Energy Tax Credit for rental property owners.

Another area identified in this study that may require assistance is for small contractors who sell on price alone. The higher end manufacturers and their dealer networks have sophisticated and successful upsell strategies for higher efficiency, VSMs and enhanced filters. They believe these are better products and can sell them when they can talk with the end customer. However training for small contractors on selling these products may be beneficial.

The main market that is underserved by both the ETO efficient furnace program and the ODOE VSM tax credit is new construction. Two options to address this market in the near term are: a standalone furnace program; or a comprehensive new construction energy efficiency program, such as Energy Star.

Some developers feel that the comprehensive approach gives them more ability to differentiate their product, and given the low level of interest by developers today in promoting the high efficiency furnaces, the comprehensive program may be the preferred approach. In addition, having complete developments with high efficiency furnaces will allow for volume bids for efficient furnaces and VSMs, and should reduce the price premiums noted in the distribution channel. The ETO should continue to ramp up the Energy Star New Home Program.

In addition to the new homes program, the ETO may wish to develop and provide POP material outlining the benefits and economics of high efficiency furnaces and VSMs for use by developers who currently provide these options.

In the medium term, the ETO should continue to work with ODOE to support the development of new building code standards that will encourage the more efficient use of energy, including natural gas.

6.3 Areas for Further Research

Additional information is required on how furnace blowers are used in Oregon in order to understand the economic and energy impact of VSMs. This data may be collected as part of another research project, such as a residential evaluation or an end use study. It may be possible to partner with either NW Natural and / or PG&E as both utilities will have an interest in how VSMs affect their load, if this can be a low cost addition to some research they are conducting.

7. Appendix A – Furnace Technologies

Furnace Technology

Fuel-burning furnaces (typically natural gas, oil or propane) provide heat by passing combustion products past a heat exchanger. Furnaces pass household air over the outside of the heat exchanger, transferring the heat from the fuel to the air. Fuel-burning furnaces exhaust the products of combustion to the atmosphere through the flue passage connected to the heat exchanger. In electric furnaces, since no products of combustion are formed, air passes directly over the electrically heated elements. Furnaces use a fan or blower to propel the air over the heat exchanger and circulate the air through the distribution system to the house.

Types of Furnaces

A range of technologies and configurations exist for furnaces. A brief overview of different furnace options is presented below.

Interior versus Exterior Installations

Weatherized furnaces are generally installed outdoors (often on rooftops), and non-weatherized furnaces are installed indoors. The primary difference between a weatherized furnace and a non-weatherized furnace is that the weatherized furnace is insulated and has a weather-resistant external case. The heat loss through the jacket in a weatherized furnace is dissipated outside, resulting in a lower efficiency compared to an equivalent non-weatherized furnace installed indoors.

Thermal Efficiency

Furnaces can be either non-condensing or condensing. When the flue temperature is substantially higher than the water dew point and the latent heat (the heat from condensation of water vapor in the combustion products) is lost in the flue, the furnace is classified as non-condensing. The annual fuel utilization efficiency (AFUE) of such furnaces is generally below 83 percent AFUE. These appliances are generally vented through the roof, using a B vent pipe

Condensing gas furnaces recover more heat from the combustion products by condensing the water vapor (typically with the addition of a secondary corrosion-resistant heat exchanger). The condensate contains dilute sulfuric acid. The annual fuel utilization efficiency (AFUE) of such furnaces is generally over 90 percent. A condensing furnace requires some extra equipment, such as an additional stainless steel heat exchanger and a condensate drain device. Condensing furnaces also require a different venting system, since the buoyancy of the flue gases is not sufficient to draw the gases up a regular chimney. Plastic through-the-wall venting systems are typically used in conjunction with condensing furnaces. Many condensing units can be configured as 1 pipe or 2 pipe systems. In the 1 pipe system, combustion air is taken from the dwelling space, whereas, 2 pipe systems draw air from the exterior. Early configurations of one pipe systems suffered from premature failure due to corrosive chemicals found indoors such as chlorine bleach rusting out the heat exchanger. These early failures have largely been eliminated.

Most of the non-condensing (and non-weatherized) gas furnaces on the market have an efficiency of 80 percent AFUE. This level is generally considered safe by manufacturers, because vent and heat-exchanger corrosion resulting from excessive condensation is not common with units at 80 percent AFUE or below. A few 78 percent models are still on the market to address situations in which venting condensation might become a particular concern (e.g., exterior masonry chimneys) and a higher flue temperature is desired.

Condensing models range mostly between 90 percent and 94 percent AFUE. Roughly one-quarter of current sales in the USA are condensing models. There are no gas furnaces in the 83–89 percent AFUE range. In this range, condensate problems begin to occur, but the temperature of the flue is still too high to allow the use of poly vinyl-chloride (PVC) for the venting system. Proper venting of such a furnace requires a special venting system.

The National Appliance Energy Conservation Act (NAECA) legislation of 1987 established efficiency standards for residential furnaces and boilers. The effective date for these minimum-efficiency standards was January 1, 1992, with the exception of the standard for mobile home furnaces, for which the effective date was September 1, 1990. Currently, the minimum AFUE for a furnace is 78%. Previous to the implementation of that act, standard efficiency furnaces were installed with an efficiency of 65% to 70% and use of a standing pilot light. In addition to mandating minimum efficiency of furnaces, the US Department of Energy support market transformation to condensing furnaces through labeling and the Energystar program, applicable to units with an AFUE greater than 90%.

Single Stage and Two Stage Furnaces

An emerging trend in the market is 2 stage furnaces. Two-stage furnaces can operate in one of two heating stages: high-fire (100 percent of rated output), or low-fire, which is generally about 65 percent of full output. The benefit of these units is that when running in low fire mode, the units tend to be quieter due to lower blower speeds, and the low-fire mode helps to offset the typical furnace oversizing . Discussions with manufacturers' representatives suggest there is no difference in the thermal efficiency of two stage furnaces when running in high and low speed.

Design Configurations

Four different design configurations of residential furnaces are in common use, including:

1) horizontal;
2) upflow;
3) multiple-direction, and
4) downflow or counterflow.

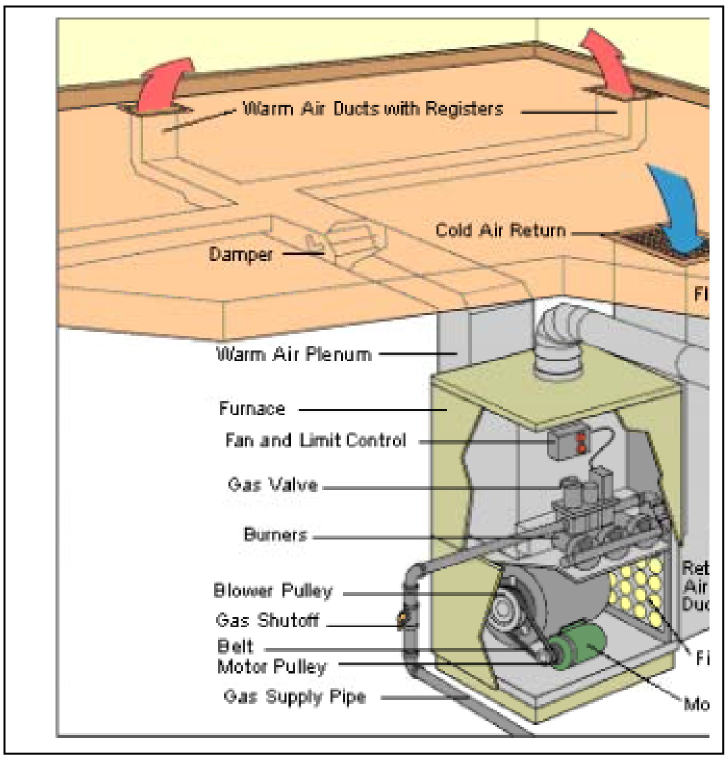
Each design configuration requires a different arrangement of its basic components.

- The horizontal furnace is used in attic spaces or crawl spaces and other locations where the height of the furnace is the constraining dimension. Air enters at one end of the unit through the fan compartment, is forced horizontally over the heat exchanger, and then exits at the opposite end.

- The up-flow design is used in basements or first-floor equipment rooms, where floor space is at a premium. The fan is located below the heat exchanger. Air enters at the bottom or lower side of the unit and leaves at the top through a warm-air outlet (plenum).

- The down-flow, or counter-flow, design is used in houses that have an under-the-floor type of heat distribution system. The fan is located above the heat exchanger. The return-air plenum is connected to the top of the unit.

- The multiple-direction design allows for up-flow and down-flow installations. Demand is growing for these products, since they allow more flexible installation. Some manufacturers noted that multiple-direction appliances are more expensive to manufacture, since they need extensive testing and more complicated controls.



Furnace Components

A typical forced air furnace is illustrated in Figure 1. These units consist of the following basic components:

- A heat exchanger;
- A combustion system including burners and controls;
- An air handler; and
- Controls

Heat Exchanger.

The heat exchanger is the part of the furnace where the heat is transferred from the combustion gases to the circulating air. The heat exchanger is usually made of cold-rolled, low-carbon steel with welded or crimped seams. There are two types of heat exchangers: individual-section and cylindrical.

Many heat exchangers—in both gas and oil units—have primary and secondary stages. The primary stage is in contact with or in direct sight of the flame and is located where the greatest heat occurs. The secondary heat exchanger follows the primary stage in the path between the burner and the flue. This is used to extract as much heat as possible from the flue gases, particularly for condensing furnaces, before the products of combustion exit through the flue to the chimney. The secondary heat exchangers are made of corrosion resistant material such as stainless steel.

Combustion Assembly.
A gas burner assembly consists of four major parts or sections including: a gas valve, an ignition device, a manifold and orifice, and gas burners and adjustments. The gas-valve section consists of a number of parts—a hand shutoff valve, a pressure-reducing valve, safety shutoff equipment, and an operator-controlled automatic gas valve—each performing a different function. On older units, these operations were entirely separate. In modern units, these parts are all contained in a combination gas valve (CGV).

On older furnaces, ignition was accomplished through the use of a standing pilot. The majority of today's furnaces use hot-surface ignition, which is perceived to be more reliable and yields higher efficiency (no gas is consumed during standby mode). The igniter is an electrically heated resistance element that ignites the gas. The flame detector circuit uses flame rectification for monitoring the gas flame.

The manifold connects the supply of gas from the gas valve to the burners, and delivers gas equally to all of the burners. The orifices permit a fast stream of raw gas to enter the burner, and meter the gas flow. They are typically small brass fittings with carefully sized holes drilled in them. Small changes in furnace capacity rating can be made by changing orifices.

Gas-burning devices require air (oxygen) to be supplied in the right amount. Primary air (air that is pre-mixed with the gas prior to combustion) is nearly one-half of the total air required for combustion. Secondary air, which is supplied to the flame at the time of combustion, should be more than about 50 percent of the total supply, to prevent the formation of carbon monoxide. To obtain complete combustion, it is essential to maintain the proper ratio between primary and secondary air. In gas furnaces, the fuel enters the burner through a venturi tube that creates a high gas velocity. In turn, the high velocity creates a sucking action that causes the primary air to enter the tube and mix with the raw gas. In gas furnaces, the burners are typically single-port (or inshot), meaning that one long flame is directed into the heat exchanger section after ignition.

In condensing and draft induced furnaces, a draft inducer fan is installed to ensure adequate combustion air. These fans are typically in the 75–90 watt size. Variable-speed and two-speed draft inducer motors are also available for 2-stage furnaces.

Air Handler.
The air handler includes a blower, the furnace casing and the duct work and plenum for distributing the tempered air. Most residential furnaces use a centrifugal fan-impeller with a shaft-mounted motor. The assembly with the fan shroud is mounted in an enclosure at the base of an upflow furnace or the

return-air end of a horizontal unit. This plenum box may have an integral air-filter rack. The output of the fan goes directly to the air side of the furnace heat exchanger, and then through the indoor (evaporator) coil of the air conditioner if one is present. The air blower and the indoor coil are housed in a factory or field-fabricated plenum called an air handler. The air is distributed throughout the house using ducts. Air blowers in residential furnaces generally use multi-speed induction motors, typically permanent split capacitor (PSC) designs. Premium furnaces may offer electronically commutated (brushless permanent magnet) motors, which have a higher efficiency and other features, such as modulating capacity controlled by the thermostat.

The electricity consumed by the blower is a function of the air-flow rate and the efficiency of the blower assembly. The most important determining factors for the airflow are the capacity of the air conditioner associated with the furnace (if any) and the capacity of the furnace itself. The capacity of the air conditioner associated with the furnace strongly influences the air-blower size selection, because of the high air-flow requirements—except in very cold climate situations, where the air conditioner may require a lower air-flow rate than the furnace.
Therefore, warmer climates require a more powerful air blower to satisfy the requirements of larger air conditioners (leading to higher electricity consumption).

Controls.
Controls operate the heating system in response to variable conditions, by turning the components on and off. The automatic controls are capable of switching the house conditioning system from heating to cooling mode. These devices operate in response to a controller, usually a thermostat that senses the room temperature, and activates the equipment to maintain the desired conditions.

PSC motors are typically wired for a range of speeds to allow the contractor to set the blower speed to match the needs of the house. Some low cost units, typically for new construction, use single speed PSC motors. However the motor has taps which the contractor adjusts, and hence only operates at one speed. This presents problems if the fan is also used for ventilation, as the speed is often too high for comfort. A separate relay and switch can be added to provide lower speed ventilation, but this increases the cost of installation. Variable speed motors are gaining popularity in the market. They have a range of benefits, including more efficient operation at low speeds compared to PSC motors, and the ability to operate over a range of speeds to accommodate heating cooling and ventilation air flows.

Energy Use of Furnaces

Electricity Consumption
Electricity consumption for gas furnaces is provided by the manufacturers and listed in the Gas Appliance Manufacturers Association (GAMA) publications. A

review of the GAMA[27] database shows substantial variation in electricity consumption for furnace fan motors installed in furnaces of the same capacity. For example:

- For one manufacturer, their various 75,000 Btu/h furnace models have electricity consumption ranges from 578 KWh/yr to 1,106 kWh/yr, corresponding to a 190% variation.
- While there is a general increase in the furnace fan electricity consumption with furnace capacity, there is also significant variation. For example one manufacturer has a 54,000 Btu/h furnace with a fan motor that consumes 1,034 KWH/yr. The same manufacturer has an 80,000 Btu/h furnace with a fan motor that uses 660 KWh/hr. [28]

An evaluation of the impact of VSM on electrical and gas energy use was recently completed by Gustdorf [2003]. A comparison of PSC and VSM motors is summarised in **Table 1**. As can be seen, it is estimated the VSM will reduce fan energy by 40% when operating in heating mode and 78% when operating in ventilation mode.

Table 1: Comparison of PSC and VSM Electricity Consumption [Watts]

Fan	PSC	VSM	% Reduction
Space Heat Mode	505	303[29]	41%
Circulation Mode	350 to 500	75 to 125	78%

The above energy consumption comparison is based on a series of test runs completed on two identical homes, one equipped with a typical PSC motor and the second equipped with an VSM motor. The results of these tests were modelled using HOT2000[30] and extended for an entire heating season and for four climates in Canada. It was found that installation of variable speed motors reduced electricity consumption and an increase in gas consumption due to lower internal gains. However, due to the price difference between gas and electricity, home-owners achieved an overall cost reduction.

The Wisconsin Department of Energy [2003] recently completed an analysis of electricity use from furnaces. Results of monitoring 31 homes show significant energy savings from VSM. For example, the median variable speed furnace

[27] www.gamanet.org/consumer/certification/certdir.html
[28] Fan motor electricity consumption data is provided by furnace manufacturers based on a standard US Department of Energy test procedures. However, no specific information was obtained on the test procedure.
[29] This estimate provides an average for single and multi-stage furnaces. In multi-stage furnaces, the motor will operate over a range of speeds. These estimates are consistent with results of the analysis by the Wisconsin Department of Energy [2003].
[30] HOT 2000 is an energy simulation software analysis package developed by NRCan.

motor in the study used about 5 kWh per GJ[31] of gas in heating mode, which is about half that of the median non-variable speed furnace fan home. This suggests heating-mode savings of about 400 kWh per year for a typical older home with annual gas consumption of 80 GJ. Similar savings were found when the furnaces were used in continuous ventilation mode. Based on their analysis, it was found that variable speed furnace fan motors draw less than 200 Watts of continuous-fan power, with 100 Watts as the average value. In contrast, the multi-speed and single speed furnaces motors drew between 400 and 800 Watts, with 500 being the average value.

Furnace Manufacturers

Five manufacturers account for about 85–90 percent of sales of gas furnaces. A summary of manufacturer by market share is presented in **Table 2** for the USA.

Table 2: Manufacturer Market Shares for Gas Furnaces (%) Manufacturer 1995 1998 2000[32]

<table>
<tr><th></th><th>1995</th><th>1998</th><th>2000</th></tr>
<tr><td>Carrier/ITC</td><td>21</td><td>23</td><td rowspan="2">31</td></tr>
<tr><td>International Comfort Products</td><td>10</td><td>10</td></tr>
<tr><td>Goodman</td><td>14</td><td rowspan="2">17</td><td rowspan="2">17</td></tr>
<tr><td>Amana</td><td>3</td></tr>
<tr><td>Lennox</td><td>11</td><td rowspan="2">12</td><td rowspan="2">15</td></tr>
<tr><td>Ducane</td><td>2</td></tr>
<tr><td>American Standard (Trane)</td><td>10</td><td>10</td><td>12</td></tr>
<tr><td>Rheem</td><td>3</td><td>13</td><td>12</td></tr>
<tr><td>York</td><td>10</td><td>7</td><td>5</td></tr>
<tr><td>Nordyne</td><td>4</td><td>4</td><td>4</td></tr>
<tr><td>Others</td><td>3</td><td>4</td><td>4</td></tr>
</table>

[31] Assuming a typical BC house uses 70GJ of natural gas for space heating, results in a furnace fan consumption of 331 KWh/yr for a variable speed motor and 660 KWh per year for a non-variable speed motor. These results are consistent with the savings predicted in **Table 1**.

[32] Ref: Source: Appliance Magazine, September 2001

8. Appendix B – VSM Efficiency Improvements

Two sources were referenced to provide information on the consumption of PSC and VSM motors in actual operation.

- John Gusdorf of Natural Resources Canada undertook a study[33] of the impact of ECM furnace motors on both electricity and natural gas using the Canadian Centre for Housing Technology (CCHT) in Ottawa which consists of two identical houses which were used to compare the impacts of the two types of motors.
- Scott Pigg, of the Energy Center of Wisconsin conducted a field study[34] of 31 furnaces, both PSC and VSM, *in situ*, over the winter of 2002 – 2003.

Data from these two studies was reviewed and used to develop the economic analysis for this report.

The concept of the Gusdorf study was to take two identical furnaces and replace the PSC blower motor of one furnace with a VSM motor (and GE ECM motor) so that the effect of the motor could be isolated from any other impacts, such as the effects of different brands of furnaces and the difference between a single stage furnace and a 2-stage furnace.

Exhibit 8.2.1: Impact of ECM – Gusdorf

Mode	VSM	PSC	Reduction
Heating mode	246 W	423 W	42%
Circulation mode	22 W	316 W	93%
Equal circulation	146 W	316 W	54%

It should be noted that there will be additional savings in air conditioning mode from the VSM motor as the compressor will have less heat gain from the blower motor to overcome. However this is estimated to be in the range of 20 – 25 kWh per year and has not been quantified in this report.

The concept of the Pigg study was to look at the actual performance of a range of furnaces as they were installed by various contractors in a range of houses and operated by different occupants. It specifically includes both single stage and 2-stage furnaces. The data in Exhibit 8.2.2 was summarized from the appendix of the study and represents the measured consumption of these 31 furnaces. The study included 13 ECM equipped furnaces and 18 PSC furnaces. The PSC furnaces were primarily single stage, although there was one 2-stage furnace with PSC which was removed from the sample so that the comparison could be made between single stage PSC furnaces and 2-stage VSM furnaces. The VSM furnaces were 2-stage with the exception of two fully modulating

[33] Gusdorf, J, *et al*, 2002, "The impact of ECM furnace motors on natural gas use and overall energy use during the heating season of CCHT research facility", Gas Technology Institute, Orlando, Florida, Sept 29 – Oct 2, 2002

[34] Pigg, S, 2003, "Electricity Use by New Furnaces – A Wisconsin Field Study", Energy Center of Wisconsin, 2003

furnaces. The fully modulating furnaces were left in the sample as they were thought not to unduly affect the blower energy results.

The Pigg study also indicated that 2-stage furnaces operated in low-fire mode for over 80% of the time. This ratio of high fire to low fire mode was used to determine the average power consumption.

Exhibit 8.2.2 summarized the electricity draw from PSC and VSM motors in the Pigg study. Appendix A contains the detailed information on the individual furnaces.

Exhibit 8.2.2: Impact of ECM - Pigg

Mode	VSM	PSC	Reduction
High-fire mode	399 W	474 W	16%
Low-fire mode	95 W	474 W	80%
Avg-fire mode	156 W	474 W	67%
Air conditioning	428 W	582 W	26%
Circulation (total sample)	182 W	504 W	64%
Circulation (outliers removed)	90 W	484 W	81%

Comparing the ratio of VSM and PSC wattage between the two studies shows that the Wisconsin field test has lower savings that the more controlled NR Can test. Part is this may be explained by errors in furnace blower set-up by the installing contractors and "real world" differences in operation.

The larger reduction for the VSM motors for heating mode in the Wisconsin study is likely a result of the 2-stage operation of the furnaces, as blower energy consumption increases as the square of air volume and the 2-stage furnace operating in low-fire mode 80% of the time will reduce the consumption by the blower. However this is partly offset by the increased hours of operation for a 2-stage furnace.

The lower level of savings for air conditioning in the Wisconsin study is more interesting, as the field study indicated a lower level of savings for VSMs when operating a high load levels than the Gusdorf study would indicate.

The savings in circulation mode are also less in the field study than in the Gustdorf study. This may be attributed to improper set-up of some of the furnaces such that they were delivering a much higher volume of air than required for ventilation. Three of the furnaces in the study (1 PSC and 2 VSM) consumed more electricity in circulation mode than in high fire heating mode (ie: they were delivering too much air). When these three "outliers" are omitted, the efficiency improvement in circulation mode increased from 64% to 81%, and is closer to the 91% noted by Gusdorf. This adjusted data has been used for the economic analysis.

In addition, some of the difference in efficiency improvement may be attributed to duct design in the field houses (relative to the CCHT), as the study commented on the relatively high static duct pressure in these houses relative to AFUE test standards.

As the purpose for this update is to provide guidance to ETO for program design, it was determined to use the adjusted energy savings from the Wisconsin study as they are more conservative and more likely to represent “real world” results.

9. Appendix C – Oregon Furnace Sales

A number of sources of information were reviewed to determine the level of furnace sales in Oregon, and how these sales are distributed to the new construction, conversion and replacement markets. The detailed calculations are included on the following page.

Two "top-down" approaches were used.

1. As part of the market research for this project, distributors were asked for their sales or market share. Summing this data resulted in an estimate of 46,000 furnaces per year sold to contractors.
2. GAMA shipment data was obtained for the period from 1995 to 2000 and then reviewed with an industry source to develop a current estimate of furnace shipments to Oregon. This resulted in an estimate of 51,000 furnaces shipped to Oregon in 2004. However it is recognized that some furnaces shipped to Oregon will be installed outside of the state, such as in Vancouver Washington. If it is assumed that 5,000 furnaces are installed out of state, this estimate is consistent with the distributors' estimates.
3. NorthWest Natural's service territory represents about 79% of the natural gas customers in Oregon. Using this share for furnace installations, then about 36,500 furnaces would be installed in NWN's service territory. This estimate may be low if NWN has a disproportionate share of either new construction or conversions.

Two "bottom-up" approaches were used.

1. A market model was constructed based on
    a. New home construction in 2004
        i. Oregon construction starts
        ii. NWN's share of new construction
        iii. SFD and Row Houses
        iv. Natural fuel shares
    b. Conversions from other fuels (primarily oil)
    c. Replacements
        i. based on a 25 year furnace life
        ii. 4% of the installed stock of natural gas furnaces in 1980
        iii. the number of furnaces installed in 1980
2. A utility sales estimate was developed in conversation with NWN marketing staff.
3. The market model provided an estimate of 40,000 furnaces being required to meet the estimated demand for new furnaces, while the utility sales estimate was for 36,400 furnaces.

Considering both the top-down and bottom-up estimates for new furnaces, it appears that the 2004 sales in NWN's service territory will range between 36,500 and 40,000 furnaces.

Oregon - Furnace Sales (2004)

	Estimate	Source or Reference	
1 Top Down	**Estimate**	**Source or Reference**	
Gama Estimate	51,000	GAMA data (Table 5.1.1) & knowledgable industry source	
Net outflow	5,000	(Guestimate)	Dave thinks at least 3,000 to Vancouver Wa.
New new furnaces	46,000		
Distributor Estimate of Oregon Sales	46,000	From survey of Distributors	
NW Natural Share of Oregon Market			
NW Natural Residential Customers	490,000		
Avista Res. Customers	80,000	Kerry @ Avista	82% NG Furnaces
Cascade Res. Customers	47,000	Press relase on Cascade Program	
Total N Gas served customers	617,000		
NW Natural Share	79%	(Guestimate was 80%)	
NW Natural # Furnaces	**36,532**		
2 Bottom Up			
		From NW Natural Tracking	
Market Demand Model			
New Construction (Oregon)			
SFD	20,877	NWPCC 5 Year plan	
Row House	5,220	(Guestimate - No US stats for RH, only for multi - BC RH share)	
SFD NG Share	89%	Phil @ NW Natural	
RH NG Share	48%	(Guestimate - BC RH But Phil's number was 50 - 70%)	
SFD Furnace Demand	18,581		
RH Furnace Demand	2,506		
Total Furnace Demand	21,086		
NW Natural Share (79%)	16,746	15,000 in Draft 2004 NWN IRP	
Conversions	5,000	6,000 in Draft 2004 NWN IRP	
Replacements*			
1980 Res. Customers	210,000	From Draft 2004 NWN IRP	
Replacements (4%)	8,400	NW Natural seems to assume about 20,000 BCH was 2.7% or about 13,250	
1980 Load addition	10,000	Bottom up is 4% of 1980 cust base (200k)+1980 growth (about 10K)	
Total Replacements	18,400		
Total Furnace Demand	**40,146**	About 20% low.	

* Concept is that: if a furnace lasts 25 years demand in current year will consist of 4% of the households in existence 25 years ago plus the number of new additions in that year.

3 Estimate from Phil at NWN		Conversation with Phil C
Total NWN SFD adt	11,683	
Total Multifamily adt.	3,354	
Remove Wash. Adt.	-2,651	
Net New Construction	12,386	
Conversions	6,000	
Replacements	18,000	
NWN Demand	36,386	

10. Appendix D – Other Furnace Considerations

Load impact of furnace replacement.

Note that the electrical consumption will increase when a 25 year old furnace is replaced with a new furnace as the blower motors have increased in size. Indications are that a typical motor in an old furnace drew about 350 W (add footnote), while a typical PSC motor today draws about 500W.

Power Factor

Also add a note about power factor. This is lower with VSM motors than PSC motors and affects the load on the system (ie: the savings will be a bit smaller). Data from Wisconsin study.

Operating Mode	VSM	PSC
Heating – Low fire	0.72	
Heating – High fire	0.68	0.88
Cooling	0.63	0.81
Continuous fan	0.69	0.87
Standby	0.62	0.40

If a system problem, power factor could be dealt with using a capacitor.

Market Pressures

GE has recently sold the motors division that manufacturers ECM motors. Some observers think that the new owners may market the technology more aggressively, which could contribute to lower prices.

Impending SEER ratings in the US may force some manufacturers to adopt ECMs motors to meet the new standards, which will also tend to expand the market.

2-stage furnaces

Skip Hayden of the Canadian Gov't Combustion Lab has raised two issues with 2-stage furnaces (presentation to Terasen Gas – January 2005).

- The lower fan speed of a 2-stage furnace in low fire may allow more of the heat to be lost through the ducts, which may reduce efficiency gains if the ducts are not in conditioned space. (Comment - I don't if this would be the same problem with the flexible ducts used in Oregon. Also the lower fan speed (and pressure) may actually reduce the losses through duct leaks.)
- In low fire mode there may be potential for corrosion in the primary heat exchanger due to condensing taking place in this stage. (Comment – worth checking with industry, but 2-stage furnaces have been in the market for some time, so would expect the trade would be aware of it if there is an issue).

11. Appendix E - VSM Pricing – British Columbia Experience

This section is reprinted with permission from the update to the "Market Assessment of High Efficiency Furnace Blower Motors" for BC Hydro, Power Smart, as noted in the references.

VSM Pricing

At the time of the Market Baseline Assessment in early 2004, the incremental cost for a VSM was estimated at about $700 - $1,000. VSMs are typically available on two-stage furnaces only, so this cost increment includes the cost of both the 2-stage feature and the variable speed blower motor. However at the time of the previous study, there appeared to be some price breaking in the market, with some dealers / contractors quoting incremental costs in the range of $ 650.

The estimate of average incremental VSM cost in the 2004 study, based on interviews with Contractors was $ 769, excluding the cost of the 2-stage furnace feature of $ 250, for a total cost of $1,019.

Exhibit 3.1 shows the incremental installed cost of furnaces from Terasen Gas' 2003 and 2004 Furnace Upgrade Programs. These data represent the reported installed costs of high efficiency furnaces rebated under the program and hence represent sales to the high efficiency retrofit market. They show that the incremental cost of a VSM (assumed to be a 2-stage furnace in each case) has dropped from about $ 950 to about $ 560. Further, it appears that the incremental cost of a 2-stage furnace over a single stage furnace has remained relatively constant at about $ 250. This indicates that the price of the VSM has dropped to about $310, or by about 50% in the past year.

Exhibit 3.1: Installed Cost of Heating System

	2003		2004	
	VSM	Non-VSM	VSM	Non-VSM
Weighted Average	$4,063	$3,110	$4,061	$3,503
Incremental Cost	$953		$558	

During the 2004 project, it was estimated that the cost at the manufacturer's level for a VSM was about $100. A study done for the US Department of Energy[35], which documented average manufacturer, wholesaler and contractor mark-ups to determine consumer prices for furnaces and boilers which could be applied to factory costs, was used to estimate potential incremental consumer costs for VSMs. To be conservative, the $100 was assumed to be the incremental

[35] "Furnaces and Boilers Standards Rulemaking – Engineering Analysis - Draft", Building Technology Program, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, September 19, 2002

cost over a standard motor to the furnace manufacturer.

Exhibit 3.2 shows the estimated range of costs to the consumer for the VSM motor, assuming "normal" mark-ups in the distribution channel. The range shown in the column "DOE Estimate" reflects the average and marginal mark-ups from the DOE study. The estimated Price column shows the "best guess" prices in BC based on the interviews conducted during the 2004 project while the BC mark-up shows the approximate mark-up at each level of the distribution channel based on the "best guess" prices. This exhibit shows that, as the market for VSMs mature, the incremental price of the VSM can be expected to drop, perhaps to the $ 180 - $ 260 range.

Exhibit 3.2: Estimated potential price of VSM motor upgrade

	Estimated BC Price	Estimated BC Mark-up	DOE Estimated Mark-up	Potential price
Motor OEM	$ 100			$ 100
Furnace mfgr.	$ 200 (est.)	100%	25%	$ 125
Distributor	$ 370	85%	11 – 36%	$ 140 – $ 170
Retailer	$ 769	108%	28 – 53%	$ 180 - $ 260

It should be noted that higher mark-ups through the distribution chain are not unusual during the early stages of a new technology. As well as representing an opportunity for higher profits, they reflect a range of costs associated with "early adopter" technologies including engineering costs that must be recovered, technology risk such as higher warrantee costs, lower product turnover rates and design / production efficiencies that will be realized with higher market shares of the new technology.

12. Appendix F – VSM Energy Savings

The analysis of the energy impact of the VSMs is more complex than the analysis of the high efficiency furnace, as it is a function of how the home owner uses the heating system. The use of the heating system affects both the relative efficiency of the VSM vs. PSC motor as well as the hours of operation.

Exhibit 12.1 shows the relative efficiencies of the PSC and VSM motors. A complete discussion of the derivation of these numbers is included in Appendix B. The table shows that the VSMs efficiency benefit increases under light load. The overall benefit to the customer will depend on the amount of time the furnace blower is operated in each mode.

Exhibit 12.1 VSM Capacity Reduction

Mode	VSM	PSC	Reduction
Heating mode	156 W	474 W	67%
Air conditioning mode	428 W	582 W	26%
Circulation mode	90 W	484 W	81%

Furnace Blower Usage

No studies were found with Oregon specific information on furnace blower usage. Therefore the approach used will be to look at the most common patterns of furnace blower usage, based on studies conducted by Terasen Gas in British Columbia and develop the economics of High Efficiency furnaces and VSMs from the perspective of each of these types of usage. Finally, some estimates of the potential overall impact based on data provided by the contractor interviews is provided.

The Terasen Gas market research identified different modes of furnace blower operation. These are:

- Intermittent – the blower operates only when the furnace or air conditioning is operating for
  - Heating
  - Heating and Cooling
- Continuous – the blower operates at low speed through the year, and at higher speeds when delivering heat or cooling.
- Seasonal Continuous – the blower operates continuously during the heating or cooling period, which is assumed to be 4 months for heating and 3 months for cooling.
  - Heating
  - Heating and Cooling
- + ventilation refers to intermittent usage for circulation for part of the year. Respondents who indicated usage for ventilation indicated that the blower was used in this mode for approximately 6 months of the year.

Exhibit 12.2 below shows the hours of use for the furnace blower under various types of operation for existing housing stock. The data for heating (burner) hours cooling hours was obtained from Ecotope[36], and apply to the existing building stock. A study by the Energy Center of Wisconsin[37] determined that the 2-stage furnace operates 20% of the time in high-fire mode and 80% in low-fire mode[38] and this was used to estimate the hours for a 2-stage furnace. The same study indicated that the blower for a single stage furnace operated about 15% longer than the burner, while 2-stage furnace runs about 7% longer, and also determined that a VSM equipped furnace had a stand-by consumption that was about 30 kWh / year higher than a PSC furnace as the blower motor is always energized. Finally, the study noted that the reduced heat loss from the VSM motor will reduce air conditioning load during cooling operation.

Exhibit 12.2: Hours of Use for Furnace Blower – Existing Stock

	Burner hrs/yr		Blower hrs/yr	
	1-stage	2-stage	1-stage	2-stage
Heating hours	720	1008	828	1,079
Cooling hours	270	270	270	270
+ Ventilation (6 months / yr)			2,920	2,640
Continuous			8,760	8,760

The following Exhibits combine the data on hours of use for the furnace and the energy consumption of the blower motor to determine the savings resulting from moving from a single stage furnace with PSC motor to a 2-stage furnace with VSM. Using the current marginal rate for electricity, the annual level of savings is shown for each type of furnace usage.

Exhibit 12.3: 1-stage PSC Energy Use – Existing Stock

	Heating (hrs)	Cooling (hrs)	Circulation (hrs)	Total (hrs)	Consumption (kWh/yr)
Intermittent					
- heating	828		0	828	392
- heating & cooling	828	270	0	1,098	550
Seasonal Continuous					
- heating	828		2,092	2,920	1,405
- heating & cooling	828	270	4,012	5,110	2,491
Continuous	828		7,932	8,760	4,232
+ Ventilation (6 mos)	828		3,552	4,380	2,112

[36] Baylon, David, Ecotope, Personal communication
[37] Wisconsin, 2003
[38] Wisconsin, 2003

Exhibit 12.4: 2-stage VSM Energy Use – Existing Stock

	Heating (hrs)	Cooling (hrs)	Circulation (hrs)	Total (hrs)	Consumption (kWh/yr)
Intermittent					
- heating	1,079		0	1,079	198
- heating & cooling	1,079	270	0	1,349	300
Seasonal Continuous					
- heating	1,079		1,841	2,920	364
- heating & cooling	1,079	270	3,761	5,110	638
Continuous	1,079		7,681	8,760	890
+ Ventilation (6 mos)	1,079		3,301	4,380	495

Exhibit 12.5: Energy and Cost Reduction – Existing Stock

	Energy Reduction (kWh)	Cost Reduction (per yr)[39]
Intermittent		
- heating	194	$ 19.23
- heating & cooling	250	$ 24.73
Seasonal Continuous		
- heating	1,041	$103.06
- heating & cooling	1,853	$183.45
Continuous	3,342	$330.86
+ Ventilation (6 mos)	1,616	$160.01

Exhibit 12.6 through 12.9 shows the same information, but for new building stock where the hours of furnace and blower operation are reduced due to more energy efficient construction.

Exhibit 12.6: Hours of Use for Furnace Blower – New Construction

	Burner hrs/yr		Blower hrs/yr[40]	
	1-stage	2-stage	1-stage	2-stage
Heating hours	550	770	633	824
Cooling hours	220	220	220	220
+ Ventilation (6 months / yr)			2,920	2,640
Continuous			8,760	8,760

The following Exhibits combine the data on hours of use for the furnace and the energy consumption of the blower motor to determine the savings of moving from a single stage furnace with PSC motor to a 2-stage furnace with VSM. Using

[39] The financial savings for electricity are estimated at the current residential rate of $ 0.0876.

[40] Wisconsin, 2003

the current marginal rate for electricity, the annual level of savings is shown for each type of blower usage.

Exhibit 12.7: 1-stage PSC Energy Use – New Construction

	Heating (hrs)	Cooling (hrs)	Circulation (hrs)	Total (hrs)	Consumption (kWh/yr)
Intermittent					
- heating	633		0	633	300
- heating & cooling	633	220	0	853	428
Seasonal Continuous					
- heating	633		2,288	2,920	1,407
- heating & cooling	633	220	4,258	5,110	2,498
Continuous	633		8,128	8,760	4,234
+ Ventilation (6 mos)	633		3,748	4,380	2,114

Exhibit 12.8: 2-stage VSM Energy Use – New Construction

	Heating (hrs)	Cooling (hrs)	Circulation (hrs)	Total (hrs)	Consumption (kWh/yr)
Intermittent					
- heating	824		0	824	159
- heating & cooling	824	220	0	1,044	241
Seasonal Continuous					
- heating	824		2,096	2,920	347
- heating & cooling	824	220	4,066	5,110	607
Continuous	824		7,936	8,760	873
+ Ventilation (6 mos)	824		3,556	4,380	479

Exhibit 12.9: Energy and Cost Reduction – New Construction

	Energy Reduction (kWh)	Cost Reduction (per yr)[41]
Intermittent		
- heating	141	$ 13.99
- heating & cooling	287	$ 18.53
Seasonal Continuous		
- heating	1,060	$104.92
- heating & cooling	1,882	$186.30
Continuous	3,361	$332.71
+ Ventilation (6 mos)	1,635	$161.87

[41] The financial savings for electricity are estimated at the current residential rate of $ 0.0876.

13. Appendix G – References

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