The Sheltair Group

HIGH EFFICIENCY FURNACE BLOWER MOTORS

MARKET BASELINE ASSESSMENT

Final Report

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1 SUMMARY

1.1 Background
Interest in improving the efficiency of air handling equipment has been a long standing technical issue that has recently become of broader interest. A CEA paper in 1995 reported annual electricity consumption in furnace fans ranged from 250 kWh/yr to 1,000 kWh/yr, and could be considerably more than the consumption of a new refrigerator. At the same time newer, more efficient direct current permanent magnet (DCPM) motors were coming on the market, and an ACEEE article in 2002 suggested that these motors could reduce overall consumption by up to 500 kWh/yr.

Further, a number of trends are occurring in the furnace market that result in longer hours of operation for furnace fan motors. These trends include:

- The rapid growth in popularity of two-stage furnaces that operate up to 90% of the time in low firing mode, which will increase the number of fan hours during the heating season by 40 - 50%.
- The use of the furnace blower as part of the strategy to meet ventilation requirements, which can result in an additional 8 hours per day of operation.
- An increase in continuous fan operation both to improve indoor air quality when used with advanced filters, and to improve perceived home comfort where the continuous fan operation reduces temperature variations within the house.

To further understand the issues surrounding the furnace market and the more efficient DCPM motors, BC Hydro partnered with Terasen Gas to offer an incentive program for energy efficient furnace fan motors in high efficiency furnaces for the retrofit market. That program operated between September and December 2003, and appears to have been successful with over 50% of the furnaces installed through the program equipped with a DCPM motor.

Project Objectives
This report provides an assessment of furnace motor technologies, documents the trends in fan usage noted above, and provide an assessment of the opportunities for improving the energy efficiency of furnace fan motors in B.C.

1.2 Technology Description
At this time, two blower motor technologies dominate the furnace market. They are permanent split capacitor (PSC) motors and direct current permanent magnet motors (DCPM). When used in heating mode, DCPM motors consume about 40% less electricity that PSC motors, and this increases to 78% less when the furnace fans are used in circulation mode. The increase in efficiency is
significant enough that it results in a measurable increase in natural gas usage in furnaces equipped with the technology.

**1.3 Market Analysis**

New furnaces are sold into two distinct markets, as heating systems for new construction and to replace old furnaces in existing homes. It is estimated that currently about 11,000 furnaces per year are sold into the new construction market and about 12,000 are sold into the retrofit market. While the share of sales between these markets will vary from year to year, the market is assumed to be constant for this analysis.

The new construction market has two segments, the custom segment where the home owner is involved in the heating system decisions, and where it appears high efficiency furnaces with variable speed motors dominate. The larger segment is the “spec” market where developers make the decisions regarding the heating system, and low cost and reliability are the primary decision factors. In that segment, the basic mid efficiency furnace with PSC motor dominates.

The retrofit market also appears to have two segments. About half of the market purchases high efficiency furnaces and only about 1/3 of these are the basic model. However over 20% of the retrofit market purchasers appear to be price sensitive and buy the least expensive model available. That group likely includes landlords who do not pay the operating costs, people planning to sell their houses, and groups on limited budgets who want the least expensive option to heat their house.

Furnace distributors were contacted to obtain information about the make-up of the furnace market in B.C. Currently about 51% of the retrofit market consists of high efficiency furnaces, and over 55% of these furnaces are equipped with DCPM motors. However only 20% of the new construction market installs high efficiency furnaces and about 40% of these are equipped with DCPM motors. In the mid efficiency market, the variable speed motors have only about an 8% market share. In terms of the overall market, DCPMs have about a 24% market share, which appears to be higher than their share in the USA. These shares are represented graphically in the following chart.
Information was collected from residential developers and contractors, as well as secondary sources, to understand the use of furnace fans in B.C. In the installed base of customers, about 80% use the furnace fan intermittently. 15% use the fan continuously, however when the existing furnace is replaced, it appears that about 30% of these fans are used continuously. In the new construction market, the share of fans operating continuously is also about 30%, but in addition, about 45% of the remaining furnace fans operate for 8 hours per day as part of the strategy to meet the ventilation codes. This represents a significant load increase for BC Hydro.

**Market Penetration of DCPM Motors**

Furnace distributors and contractors were asked for their views on the changing market shares for DCPM motors. They suggested that DCPM motors will increase from their current 24% share to about 36% in two years and to 58% in five years. An analysis of the major furnace decision issues was undertaken for both the new and retrofit markets, and it was felt that these estimates were unlikely to be met unless there was a major change, such as an aggressive program to market this technology. However, these numbers were used as the basis of this analysis as it was felt they would provide a conservative, or low, estimate of the potential in this market.

Based on this data, the technical potential for DCPM motors was estimated as shown in the Table S1. The fan uses with the highest technical potential by 2014 are: ventilation for new construction; continuous fan usage for new construction; and continuous fan usage after furnaces are retrofitted.
Table S1:  Savings Potential of DCPM Motors

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>10</td>
<td>5</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>2009</td>
<td>47</td>
<td>20</td>
<td>67</td>
<td>4</td>
</tr>
<tr>
<td>2015</td>
<td>66</td>
<td>18</td>
<td>84</td>
<td>5</td>
</tr>
</tbody>
</table>

Program Development Analysis

Estimating a market potential is outside the scope of this project. However it must be noted that DCPM are not cost effective in all applications. The current market price of the variable speed motor is about $ 750, and it is usually only available on a 2-stage furnace which adds an additional $ 200 to the price. It is estimated that, when the increase in natural gas usage in included, the annual customer savings are:

- Heating only $ 16
- Heating and cooling only $ 30
- Ventilation (8 hrs / day) $ 46
- Continuous $188

In order to determine where the DCPM motors are cost effective, an analysis was done to consider the incremental cost to the homeowner relative to the savings on the utility bill. For a new home, it was assumed the incremental cost would be included in a 25 year mortgage, while for a retrofit customer the cost estimate was based on a 10-year loan. The following table shows the fan uses which are cost effective at various incremental costs for the variable speed motor.

Table S2:  Furnace Blower Usage – Customer Payback

<table>
<thead>
<tr>
<th>Savings</th>
<th>$1000</th>
<th>$750</th>
<th>$500</th>
<th>$250</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>New</td>
<td>Retro</td>
<td>New</td>
<td>Retro</td>
</tr>
<tr>
<td>Payment</td>
<td>$59</td>
<td>$119</td>
<td>$45</td>
<td>$89</td>
</tr>
<tr>
<td>Heat</td>
<td>$16</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AC</td>
<td>$30</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vent.</td>
<td>$46</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cont.</td>
<td>$188</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

While the estimated average cost of the variable speed motor and 2-stage furnace is about $ 950, the range in prices is significant, and it is possible to purchase the combination today for about $ 750. Therefore, it is economic to address continuous ventilation in all markets and the ventilation use in new construction.
A review of mark-up through the existing distribution chain from DCPM manufacturer to the final consumer suggest that these products are attracting a “premium” mark-up. Based on a US study done by the Department of Energy, if “normal” mark-ups (ie: the same mark-up as a basic furnace) were applied to the DCPM products, the incremental cost would be in the range of $ 180 - $ 260 rather than the current $ 750.

**Program Development Strategy**

Strategies have been suggested to address the new and retrofit markets. For the new construction market, while it would be preferable to persuade the developer to install DCPM motors on all furnaces in a development, the incremental cost is significant and developers were unanimous that they would not be able to recover this additional cost from customers. Therefore, an alternate strategy has been suggested which involves creating heating system upgrade packages with the developer and the sales agent which can be marketed to the prospective buyer at the time of sale and included in the mortgage. This approach is often used with appliance packages in new developments. One manufacturer has undertaken some market research in Ontario which supports the idea that purchasers would be interested in furnace options.

For the retrofit market, the current joint approach with Terasen Gas appears effective in addressing the growing high efficiency segment although the potential level of free ridership is an issue that must be considered. However, addressing the mid efficiency segment may require developing an additional offering through distributors and heating contractors to increase the penetration of variable speed motors.

In both markets, the programs should be supported with a strong educational component for consumers.

**1.4 Standards Enhancement Analysis**

A range of activities is ongoing related to updating the energy efficiency of furnace fan motors. The Canadian Electricity Association (CEA) is currently drafting an update to standard 832-XX dealing with domestic furnace blowers. In addition, the CSA is currently updating the standard on test methods for measuring the AFUE of residential furnaces and boilers. Finally, the BC Ministry of Energy Mines is currently reviewing its standards. It is recommended that BC Hydro work within these ongoing initiatives to provide a regulatory backstop as part of a larger market transformation strategy.
2 INTRODUCTION

This report provides an assessment of opportunities for improving the energy efficiency of furnace fan motors in the BC Hydro service territory.

2.1 Project Objectives

The objectives of this assignment are:

1. To understand the current market penetration of high efficiency furnace blower motors in new gas-fired and electric forced air furnace installations (either as complete furnace replacements in existing homes or as new furnace installations in new homes) in residential dwellings; and

2. To determine how the consumer decision process can be influenced in favour of high efficiency furnace blower motors.

2.2 Project Scope

The scope of this analysis is to identify opportunities for energy efficiency related to direct current permanent magnet (DCPM) motors in residential furnace fans in the BC Hydro service territory. The analysis includes gas-fired and electric forced air furnaces. The focus of the analysis is on new furnaces installed in new and existing homes. Installation of DCPM motors into existing furnaces is an ongoing research topic, and not examined in detail in the current analysis.¹

2.3 Approach

The approach employed to complete the current assignment includes a range of primary research, secondary research and a survey of industry representatives.

A series of questionnaires were developed to obtain information from industry groups through a structured telephone interview. Specific groups targeted in the survey included:

1. Motor and appliance manufacturers,
2. Furnace distributors,
3. Heating contractors, and
4. Developers and homebuilders.

2.4 Description of Technologies Used For Furnace Blower Motors

2.4.1 Furnace Description

A typical forced air furnace consists of the following basic components:

- a cabinet or casing;
- heat exchangers;

¹ Personal Communication, John Gustdorf, Natural Resources Canada.
• a combustion system including burners and controls;
• a forced-draft fan and motor;
• a circulating air blower and motor; and
• an air filter and other accessories such as a humidifier, an electronic air cleaner, an air-conditioning coil, or a combination of these elements.

The current analysis is focused on the motor used to drive the blower.

2.4.2 **Furnace Motor Description**

A range of technologies exist for furnace fan motors, including:

- Shaded pole,
- Capacitor start,
- Permanent split capacitor (PSC), and
- Direct current permanent magnet (DCPM).

Typical fan motor efficiencies are summarised in Table 1. As can be seen, older shaded pole motors have efficiencies as low as 10 to 25%, while newer split capacitor motors have efficiencies of 55% to 67% in high-speed mode. It should be noted that when PSC furnace fans are used for ventilation only, their speed drops, and as noted in the table below, their efficiencies in low speed are typically 34% to 39%.

**Table 1: Motor Efficiency of Typical Air Handling Equipment**

<table>
<thead>
<tr>
<th>Motor Type</th>
<th>Efficiency</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shaded Pole</td>
<td>10% - 25%</td>
<td>Allen, 1993</td>
</tr>
<tr>
<td>Capacitor Start</td>
<td>35% - 50%</td>
<td>Allen, 1993</td>
</tr>
<tr>
<td>Permanent Split Capacitor</td>
<td>Low Speed Mode 34–39%</td>
<td>Sachs, 2002</td>
</tr>
<tr>
<td></td>
<td>High Speed Mode 55–67%</td>
<td></td>
</tr>
<tr>
<td>Direct Current Permanent Magnet</td>
<td>Low Speed Mode &gt;70%</td>
<td>Sachs, 2002</td>
</tr>
<tr>
<td></td>
<td>High Speed Mode 74–78%</td>
<td></td>
</tr>
</tbody>
</table>

Phillips [1995] notes that there has been a 13% to 19% increase in the efficiency of furnace fans motors between 1960 and 1994 due to a switch from shaded pole motors to permanent split capacitor motors, improvements in the design of permanent split capacitor motors, as well as improvements to fan design. However, this has not translated into a decrease in blower energy use, as typical power requirements have increased from 350 watts to 500 watts, due principally to higher air flow rates. Phillips also notes a trend towards increased furnace motor power, based on the results of a manufacturer survey. The reason for this shift is to ensure a product that is “air conditioning ready”, to permit increased furnace efficiency and to increase life of the heat exchanger through lower

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2 Anecdotal information from HVAC contractors suggests that when used for ventilation, PSC motors, are often operated at heating speed. This is due to an additional relay being needed to operate at a lower speed.
operating temperatures. While these trends have generally improved the efficiency of furnaces from the perspective of a space-heating appliance, they have resulted in increased fan electric energy use.

As noted by Sachs, “manufacturers often offer very similar furnaces with different furnace fans. For example, one manufacturer offers alternative 90,000 Btu/h condensing furnaces with variable speed blowers. Moderate climate units for installations requiring a 3-ton air conditioner need about 1,200 cfm (400 cfm/ton) and require 670 kWh/year. Hot climate versions support 5 ton air conditioning systems that need about 2,000 cfm, requiring 1,070 kWh/yr.” As over sizing of furnaces and furnace fans is typical, this leads to increased energy consumption.

The market for furnaces is currently dominated by permanent split capacitor (PSC) motors. Sachs [2002] estimates that 95% of furnaces sold in the United States are PSC Motors. While older units were single speed motors, newer models are generally multi-speed units. In BC, single speed motors are still provided for “builder’s special” furnaces for new construction, but furnaces intended for retrofits have 3 or 4 speed motors. Interestingly, our research indicates that DCPM motors accounted for over 20% of furnace sales in BC in 2003, which is significantly higher than estimates of sales in the US. The current rebate offered by BC Hydro for DCPM motors likely contributes to this high penetration rate.

A range of alternative technologies to PSC motors exist, which provide higher efficiency and variable speed control, including electronically commutated motors, switched reluctance [US DOE, 1999] motors, and PSC motors with variable speed controllers (presumably inefficient at lower speeds). Of the emerging technologies for furnace fan motors, DCPM motors have made the most significant penetration into the furnace fan market.

DCPM motors are significantly more efficient than the Permanent Split Capacitor (PSC) motors used in most residential air handling equipment sold today\(^3\). As shown in Table 1, DCPM motors can operate at efficiencies of 74 to 78% compared to 35 to 45% for PSC motors.

General Electric is the primary manufacturer of DCPM motors (their trade name for these type of motors is ECM motors) for furnaces, having more than 90% of the market share for that product. Since production started in 1992, they have sold over 3,000,000 units, and expect the number of units installed to double within the next three years.

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\(^3\) Motor market share is discussed in Chapter 4.
2.5 Outline of the Report

The remainder of this report is divided into the following sections:

- Section 3 presents a market analysis of residential furnaces and air handlers;
- Section 4 provides a program development analysis including costs, market barriers, potential program options and program partners;
- Section 5 provides an overview of furnace motor technology;
- Section 6 provides standards enhancement analysis; and
- Section 7 provides recommendations.
3 MARKET ANALYSIS

This section summarizes the relevant trends in the furnace market in British Columbia to provide a baseline upon which decisions about DSM programming may be based. In order to develop this information, a combination interview / survey was undertaken with the major distributors of furnaces in BC, with a cross section of new housing developers, and with a cross section of heating contractors. In addition, secondary data was included as available.

3.1 Demand for Furnaces

The demand for furnaces is driven by two distinct markets; heating systems for new construction and the replacement of old furnaces in existing houses.

3.1.1 New Construction

The new construction market consists of three segments when it comes to decision making for furnaces. These are:

- **Custom home market.** These homes are built for the owner, who is involved with many of the decisions about the home, including the choice of heating system. In the major urban centres, these homes tend to be focused in the mid or upper price range, as the lower price market is served by “spec” housing. However this may not be true in smaller centres outside of the lower mainland where there is not a supply of spec housing.

  It was not possible to quantify the size of the custom market, but anecdotally it was thought that this was the largest market for upper end heating systems. While radiant heating systems are popular, this is also a market for high efficiency furnaces and DCPM motors.

- **Semi-custom home market.** This is a term used to describe a project where the developer pre-sells units and allows customers to make choices about the units prior to construction. In the current “hot” real estate market in the Lower Mainland, choices tend to be limited to selecting from a range of interior finishing and appliance packages such as stainless steel trim. However, in less busy periods, and in the Interior region, choices may also include heating system options such as furnace efficiency, air conditioning and types of furnace filters.

- **“Spec” home market.** This term describes a dwelling or a number of adjacent units that are built by a developer and then offered for sale. The salient difference between the spec market and the semi-custom market is the homeowner’s inability to influence choices in the home.

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4 I.e. housing built for the speculative housing market.
In those segments of the new construction market where the homeowner does not make the choice of furnace, the decision is typically made jointly between the property developer and the heating contractor, except in larger projects where a mechanical design firm may also be involved and provide specification for the equipment. However the sales agent for the property appears to have a significant influence over the developer’s choices.

From the developer’s perspective the furnace selection criteria, in order of importance, are:

1. Reliability or lack of call-backs on the heating system;
2. Cost of the furnace; and
3. Perceived customer demands.

BC regulations now require the developer to be responsible for the heating system for the first two years, and this has resulted in some change among furnace suppliers as a result of call back issues. As the cost of a service call can be quite high in relation to the cost of a “builders special” furnace, this was the first criterion for over 40% of the respondents. Capital cost was the second most important criteria. Perceived customer demand was third, but typically reflects the views of the sales agent for the project rather than direct input from the customer for the semi-custom and spec markets.

Custom homes are a separate market, as the ultimate occupant is directly involved in many decisions about the home, including the heating system. In many ways, this sector is more like the retrofit market. In urban centres it is expected that the custom homes will be in the mid to high end of the spectrum, where high-end heating systems are a part of the package. While radiant heating is a popular choice, there may be a trend towards more forced air systems (including heat pumps) driven by the desire for air conditioning and improved indoor air quality and continuous ventilation. In smaller centres, where there is little or no spec housing to choose from, lower end heating systems may predominate.

### 3.1.2 Retrofit Market

The retrofit market is driven primarily by the age and life expectancy of the existing furnace. Data collection as part of Terasen’s 2002 Residential Heating System Upgrade Program included collecting the age of the furnace being replaced by the heating contractor as well as from the homeowner, with numbers ranging from 24 to 26 years. As noted in Appendix 9.1, this results in a replacement rate of between 2.5 and 2.9% per year. This number is lower than the 4% rate that may be expected from the 25 year average furnace life, but reflects the growing housing stock in BC, with few of the furnaces installed in the past 20 years being replaced.
The volume of sales in the retrofit market is primarily driven by the life expectancy and age of the furnace, but replacement timing is influenced by exogenous factors such as expected fuel prices and marketing programs.

The furnace mix in the retrofit market has been influenced by Terasen marketing programs over the past three years which have provided incentives for the installation of high efficiency furnaces. In 2003, Power Smart augmented this program with a $150 incentive towards the purchase of high efficiency furnaces equipped with DCPM motors.

3.1.3 Demand for Furnaces in BC
A number of sources of data were referenced in determining the “best estimate” of furnace sales in British Columbia. Sources include:

- HRAI statistics on furnace shipments into BC,
- data from furnace distributors,
- data from heating contractors, and
- estimates based on a market model of the retrofit and new construction demand for furnaces.

These estimates are summarized in Table 2 below. Appendix 9.1 includes a more detailed discussion of this estimate.

### Table 2: Estimated Furnace Sales in BC (2003)

<table>
<thead>
<tr>
<th></th>
<th>Mid Efficiency</th>
<th>High Efficiency</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Construction</td>
<td>8,900</td>
<td>1,950</td>
<td>10,850</td>
</tr>
<tr>
<td>Retrofit</td>
<td>5,825</td>
<td>5,825</td>
<td>11,650</td>
</tr>
<tr>
<td>Total</td>
<td>14,725</td>
<td>7,775</td>
<td>22,500</td>
</tr>
</tbody>
</table>

3.1.4 Furnace Blower Usage Trends
Historically furnace blowers were used to deliver heat when the furnace was operating, to deliver cooling for those customers with air conditioning, and to provide cooling / air circulation during hot weather for a small proportion of the population. However, a number of trends are increasing the usage of furnace blowers:

- Ventilation codes that may be met or augmented through use of the furnace blower.
- A desire on the part of homeowners to increase comfort levels through a combination of two stage furnaces and continuous fan operation.
- A desire to improve indoor air quality through the use of advanced air filtration such as electrostatic and ultraviolet air filters and continuous ventilation. A number of distributors commented that these advanced filters are the “hot” item in their business.
Data from a number of sources was collected to better understand the furnace fan usage in BC. In addition to reviewing Canadian and USA information, data was collected from BC Hydro market research, Terasen market research, and developer and contractor interviews. This provides data on how furnace blowers are set up in new construction, how they are set up in retrofit situations, and the general usage patterns for installed furnaces. Appendix 9.2 contains a detailed review of the research and the analysis. Table 3 shows our assessment of the available data.

Table 3: Usage Patterns of Furnace Fans for Existing Stock

<table>
<thead>
<tr>
<th>Usage of Furnace Fan – Existing Stock</th>
<th>Share of households</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intermittent – heating season</td>
<td>76%</td>
</tr>
<tr>
<td>Intermittent – heating and cooling season</td>
<td>4%</td>
</tr>
<tr>
<td>Continuous – heating season</td>
<td>3%</td>
</tr>
<tr>
<td>Continuous – heating and cooling</td>
<td>2%</td>
</tr>
<tr>
<td>Continuous - ventilation</td>
<td>15%</td>
</tr>
</tbody>
</table>

In new furnace installations, the amount of fan usage is significantly higher. Developers and contractors indicate that 20 to 25% of the fans in new construction operate in continuous mode while another 45% operate 8 hours per day as part of the ventilation strategy. These results are summarised in Table 4.

Table 4: Usage Patterns of Furnace Fans for New Stock

<table>
<thead>
<tr>
<th>Usage of Furnace Fan – New Construction</th>
<th>Share of households</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intermittent</td>
<td>25 - 30%</td>
</tr>
<tr>
<td>Ventilation – 4 to 8 hours / day</td>
<td>45%</td>
</tr>
<tr>
<td>Continuous ventilation</td>
<td>25 - 30%</td>
</tr>
</tbody>
</table>

Data from Terasen’s Furnace evaluation is summarised in Table 5. This usage pattern is based on current (2004) practices. The analysis shows that continuous fan usage after retrofit is likely twice the current level in the base stock. It is expected that the share of continuous ventilation will continue to increase due to concerns over indoor air quality (IAQ) and the desire for increased comfort from continuous ventilation.

Table 5: Terasen Gas Furnace For Replacement Market

<table>
<thead>
<tr>
<th>Usage of Furnace Fan – Retrofits</th>
<th>Share of households</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intermittent</td>
<td>70%</td>
</tr>
<tr>
<td>Continuous ventilation</td>
<td>30%</td>
</tr>
</tbody>
</table>
3.1.5 Furnace Distribution Channels

Furnaces are provided through distributors in B.C. The 10 major distributors handle 15 brands of furnaces out of the approximately 30 brands available, and likely account for more than 90% of the total furnace sales in B.C. Some distributors, such as Lennox and Carrier have one branch which serves all of British Columbia, while others have regional branches in geographic areas such as the Lower Mainland, Vancouver Island and various locations in the Interior region. Further, North East BC and the West Kootneys may be supplied from Alberta, and one distributor serves the Okanagan from Calgary. Some distributors are dedicated to furnaces only while others supply furnaces or heating systems along with a wide range of other products.

Distributors sell through three major channels: dealers; heating contractors (who are sometimes also plumbing contractors); and licensed gas fitters. Dealers are essentially heating contractors who are affiliated with a specific manufacturer and who have to meet certain standards to qualify as dealers. It appears that dealers receive more product training and therefore are better able to sell the higher end products such as DCPM motors.

Based on distributor interviews, about 73% of sales are through dealers, 24% are through independent heating contractors, 1% are through gas fitters, and remaining 1% through other channels.

3.1.6 Energy Use Ratio of Popular Furnaces

It was not possible to develop a profile of furnace sales by model number and manufacturer. However, a review of the work by the State of Wisconsin [2003] illustrates the trend that furnaces equipped with a DCPM motor use approximately 4.7 kWh of electricity per gigajoule of gas consumption, compared to non-DCPM equipped furnaces which consume approximately 9.5 kWh of electricity per gigajoule of natural gas.

Sachs [2003] has proposed to use the GAMA database to quantify the motor efficiency, by using the ratio of the annual average auxiliary electricity use, Eae (measured in kWh/yr) to the average annual fuel use consumption, Ef (measured in million Btu/h). Sachs argues that equipment with a ratio of Eae/Ef that is less than 6 represents an energy efficient motor.

3.2 Market Penetration

Table 6 shows the market share information for furnaces and blower motors as collected from the major furnace distributors. It should be noted that DCPM motors are not available on single stage furnaces. The table is structured to show the market shares for new construction and retrofit separately, and then shows the breakdown of each market by mid and high efficiency furnaces and by single stage, 2-stage with PSC motor and 2-stage with DCPM motors. The percentage number in each cell of the table represents the share of total furnace
sales. For example, the share of DCPM motors in Retrofit is 15% of total furnace sales.

### Table 6: Estimate of Furnace and Blower Motor Market Shares (2003)

<table>
<thead>
<tr>
<th></th>
<th>High Efficiency Furnaces</th>
<th>Mid Efficiency Furnaces</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total Units</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
</tr>
<tr>
<td>New</td>
<td>49%</td>
<td>10%</td>
</tr>
<tr>
<td>Retro</td>
<td>51%</td>
<td>26%</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>36%</td>
</tr>
</tbody>
</table>

This table shows that, while DCPM motors are available on mid efficiency furnaces, they have a relatively small share, accounting for about 16% of mid efficiency furnaces in the retrofit market and less than 3% in the new construction market. DCPM motors account for over 50% of the blower motors for high efficiency furnaces in the retrofit market, although this number is influenced by the current Power Smart incentive program. DCPM motors have a lower penetration in the price sensitive new construction market.

Figure 1 illustrates the relative market shares of PSC and DCPM motors in the overall market and show that, in 2003, PSC motors had about 76% of the overall market while DCPM motors had about 24%. However, the market shares are significantly different between the new construction market, where DCPM motors have only 10% of the new construction market, and the retrofit market where they have about 37% of the market.

**Figure 1: Market Share of Motors (2003 Sales)**

Figure 2 shows a further breakdown of sales of DCPM and PSC motors in the new construction market. It shows that DCPM motors are specified for only
about 2% of the mid efficiency 2-stage furnaces. However, for high efficiency furnaces there appear to be two markets. The single stage high efficiency market likely represents developers who are specifying high efficiency due to difficulties with installing a b-vent (flue), while the 2-stage market, which is exclusively DCPM, may represent the custom market where the owner / occupier wants a high end forced air furnace.

**Figure 2: New Construction Market (2003 Sales)**

![Bar Chart](chart.png)

Figure 3 shows the same breakdown of the retrofit market. In this case DCPM motors have about 16% of the mid efficiency market, but over 50% of the high efficiency market. The higher share of two stage furnaces in the mid efficiency market, which may be considered the most price conscious of the retrofit markets, indicate that customers are willing to pay a premium for the perceived benefits of the 2-stage furnace, but are not yet convinced that the benefits of DCPM motors are warranted. However, in the high efficiency retrofit market, 2-stage furnaces with DCPM motors dominate. The share for 2003 will be influenced by the BC Hydro incentive program; however, estimated shares of DCPM motors in previous years support the notion that this segment of the market is willing the pay the price premium for this product.
The DCPM market appears to be growing quite rapidly. Table 7 shows the estimated market share of DCPM motors for the past three years, based on distributor data.

Table 7: DCPM Market Share in B.C.

<table>
<thead>
<tr>
<th></th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
</tr>
</thead>
<tbody>
<tr>
<td>DCPM Share</td>
<td>9%</td>
<td>13%</td>
<td>24%</td>
</tr>
</tbody>
</table>

This trend is corroborated by the contractor’s survey which indicated shares of 10%, 18% and 27% respectively and results of Terasen’s program files which also show a rapid growth of DCPM motor penetration. While the Terasen data only reflects sales of high efficiency furnaces in the retrofit market during the September to December period in each year, the penetration of DCPM motors has increased from about 25% in 2001 to 36% in 2002 and over 50% in 2003.

The increasing penetration of DCPM motors appears to be driven by two factors:
- The desire for comfort and improved indoor air quality.
- The expectation of cost savings on the electricity bill. A number of contractors and distributors have quoted savings in the order of $100 - $200
This suggests that contractors may be over-selling the benefits of DCMP motors

3.3 Market Potential

The ultimate market potential for DCMP motors will depend on a combination of drivers for the product, and barriers or limitations that will prevent adoption.

3.3.1 Barriers:

- **Initial Cost.** The major barrier for DCMP motors at this time is initial cost. Interviews were conducted at all levels of the distribution chain. While it is difficult to obtain detailed pricing information in a competitive market, the following prices are thought to be representative.

<table>
<thead>
<tr>
<th>Estimated Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>OEM from manufacturer</td>
</tr>
<tr>
<td>Distributor</td>
</tr>
<tr>
<td>Retail</td>
</tr>
</tbody>
</table>

DCPM motors are typically only available on the premium models of 2-stage mid and high efficiency furnaces. Table 9 shows the approximate prices for furnaces in B.C. The new construction furnace prices were estimated from interviews with manufacturers and distributors. The retrofit furnace price information was extrapolated from the Terasen furnace evaluation and represents an average over all furnace models (1-stage, 2-stage, 2-stage DCPM). The incremental price for a 2-stage furnace is about $ 200.

<table>
<thead>
<tr>
<th>New – mid efficiency</th>
<th>&lt; $ 750</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td>New – high efficiency</td>
<td>&lt; $ 1,000</td>
<td>NA</td>
</tr>
<tr>
<td>Retrofit - mid Efficiency</td>
<td>$ 1,070</td>
<td>$ 2,200 - $ 2,400</td>
</tr>
<tr>
<td>Retrofit - high Efficiency</td>
<td>$ 1,600</td>
<td>$ 3,100 - $ 3,600</td>
</tr>
</tbody>
</table>

5 Potential savings are presented in Section 4.1.

6 A review of the mark-up through the existing distribution chain from DCPM manufacturer to the final consumer suggests that these products are obtaining a “premium” mark-up. Based on a US study done by the Department of Energy, if a “normal” mark-up (ie: the same mark-up as the basic furnace) were applied to the product, the incremental cost of the DCMP motor would be in the range of $ 180 to $ 260. (DOE, 2002)
This data shows that the addition of a DCPM represents a significant increase to the cost of the furnace, especially in the builder’s market.

- **Customer awareness and preferences.** As noted previously, there are a number of drivers that are encouraging increased usage of the furnace blower (improved comfort, and IAQ). However there appears to be little awareness of the relative inefficiency of the current PSC technology and the electricity and cost savings that result from the use of DCPM in situations where the fan is used for more that just heating.

- **Reliability.** A related price concern is the replacement cost of DCPM motors when they fail, which appears to be 3 or 4 times the cost of a PSC motor. While there has not been any significant failure of DCPM motors outside of the warrantee period, this concern was raised by a number of distributors and contractors.

- **Technical issues.** While the basic technology of DCPM motors has been around for over 10 years, there are still some technical issues relating to use but these appear to be relatively minor. Issues include:
  
  - **Duct Sizing.** There is a reported problem with the use of DCPM motors in some older homes with small duct systems. Reportedly, in this environment DCPM motors will create excessive noise and / or vibration in the ductwork. PSC motors can be set to work in these situations. Use of DCPM motors could require replacement of ductwork which is expensive and in the case of slab on grade houses where the ducts are in the slab, virtually impossible. However this appears to be a small number of cases.
  
  - **System Complexity.** Some concerns have been raised about DCPM motors increasing the complexity of furnaces and making them more difficult to service. For at least some brands of furnaces a diagnostic tool is required which plugs into the furnace board to obtain diagnostics. This tool costs about $1,000. It is expected that this will be a short-term barrier, but may be hardest to overcome with independent heating contractors and gas fitters.

### 3.3.2 Drivers

A range of drivers are pushing the DCPM market. These are described below.

- **Cost savings** due to the increased efficiency of the DCPM motor relative to the PSC motor. As discussed in Section 6, the DCPM will use about 41% less electricity when operating in space heating mode and 78% when
operating in circulation mode. However with the current motor pricing, these motors are not cost effective when used just in heating mode.

- **Superior comfort** when the furnace fan is used for continuous ventilation. As noted previously, there are three main drivers for this trend.
  - Increased occupant comfort though a combination of 2 stage furnaces and DCPM motors where the fan is used continuously to circulate air on a low setting, and then ramps up as the furnace fires.
  - Improved indoor air quality. Distributors have identified advanced air filters, which provide improved IAQ when used with continuous ventilation, as a significant trend. It should be noted, however, that contractors may be overselling these benefits, as the benefits of filtration to improve IAQ are not well documented.

- **Ventilation codes** where the furnace fan is used as part of the house ventilation to meet code requirements. In this situation fresh air make-up is ducted into the return plenum to provide continuous fresh air. Based on our survey of property developers and contractors use of the furnace fan as the principle exhaust could be as high as 45%.

- **Improved performance** has been noted for DCPM motors because in some cases they can compensate for problems with ductwork, especially by improving comfort in under-heated rooms at the end of long duct runs. A number of parties indicated customer satisfaction with better heating in some rooms after the installation of a furnace with a DCPM.

- **Product quality**. Except for the potential failure issue noted in Section 5.2, DCPM motors are regarded as a superior quality product both relative to the PSC motors and in terms of the impact on quality of heat delivered to the occupants.

- **Profit**. At this time DCPM motors provide a higher level of profit for both distributors and contractors, and hence they both have an incentive to promote this technology.

### 3.3.3 Market – Medium Term

The medium term potential is based on the assumptions that furnace technology will remain relatively stable, and while the price of DCPM motors may decline, they will remain at a significant premium to PSC motors. It is assumed that Terasen’s program will continue.

In the new construction market, it is likely that DCPM motors will continue to capture more of the custom market where the occupant can select the furnace. However, for DCPM motors to gain market share in the spec built homes it will likely be necessary to have both strong customer demand and either a lower priced “builder special” furnace which includes a DCPM (which is assumed will
not happen in this timeframe), or a change in market operation to allow customers to influence the choice of a furnace for the new construction segment.

In the retrofit market, it is likely that the share of high efficiency furnaces will increase as the Terasen program continues, and that the 2-stage furnace will draw some of the market from single stage to 2-stage. However, the share of DCPM motors may decline if the Power Smarts DCPM program is not operating.

The shift from mid efficiency to high efficiency furnaces will be limited by two factors:

• First it is not economical in all cases to replace existing standard or mid efficiency furnaces with high efficiency furnaces due to difficulties with installing the sidewall exhaust ducting, and due to the lack of a drain for condensate. Responding to Terasen research, contractors indicated that this could be a problem in up to 24% of the installations although this is thought to be high. There may also be similar venting problems with new construction in row housing and narrow lot-line projects. One developer noted problems with steam build-up between buildings when they are close together while others noted problems with venting to the front or rear of the building.

• Second, there is a cost conscious segment of the market that will look for the lowest priced furnace, for any of a number of reasons including lack of cash when the replacement is needed or landlords looking for a low capital cost as they don’t pay the operating cost.

For these reasons, we have assumed the penetration of mid efficiency furnaces in the retrofit market are unlikely to drop below 20% in the medium term. In the mid efficiency furnace retrofit market, it is likely that DCPM motors will continue to grow in the 2-stage market.

The distributors have estimated that the share of DCPM motors will increase from the current 24% of the market to about 36% in two years and 58% in five years. Interestingly, the contractor estimate was also about 36% in two years although they were unable to provide an estimate for 5 years. Based on these estimates and the market logic above, the following estimates for market shares for DCPM motors could increase as shown in Table 10. These estimates are based on sales projections from the distributors. There is no clear mechanism which would cause this growth without an external force such as a program.
Table 10: Estimate Potential Furnace and Motor Shares – 2 years

<table>
<thead>
<tr>
<th></th>
<th>Total Units</th>
<th>High Efficiency</th>
<th></th>
<th>Mid Efficiency</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total HE</td>
<td>Single Stage</td>
<td>2-stg PSC</td>
<td>2-stg DCPM</td>
</tr>
<tr>
<td>New</td>
<td>49%</td>
<td>10%</td>
<td>6%</td>
<td>0%</td>
<td>4%</td>
</tr>
<tr>
<td>Retro</td>
<td>51%</td>
<td>31%</td>
<td>5%</td>
<td>6%</td>
<td>20%</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>40%</td>
<td>11%</td>
<td>6%</td>
<td>24%</td>
</tr>
</tbody>
</table>

Compared with Table 6, this estimate shows the same split between new construction and retrofit, and the same split between high efficiency and mid efficiency in the new construction market. The high efficiency shares remain unchanged; the custom market remains the same size and chooses the high end product; and the same share of developers are forced to high efficiency due to flue related problems. In the mid efficiency segment, it is assumed the share of single stage “builder’s specials” remains the same, while the share of DCPM furnaces increases from 1% to 3%.

In the retrofit market the high efficiency furnace share increases from 26% to 31%, presumably through Terasen’s program or market momentum. The share of DCPM motors increase from 15% to 20% (or 65% of high efficiency retrofit furnaces). In the mid-efficiency market, the overall share of single stage furnaces remains essentially constant representing the cost conscious segment of the market, while the DCPM share doubles from 4% to 8%.

Table 11 shows how the market shares would likely have to change in order for DCPM motors to achieve a 57% market share.

Table 11: Estimate Potential Furnace and Motor Shares – 5 years

<table>
<thead>
<tr>
<th></th>
<th>Total Units</th>
<th>High Efficiency</th>
<th></th>
<th>Mid Efficiency</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total HE</td>
<td>Single Stage</td>
<td>2-stg PSC</td>
<td>2-stg DCPM</td>
</tr>
<tr>
<td>New</td>
<td>49%</td>
<td>10%</td>
<td>6%</td>
<td>0%</td>
<td>4%</td>
</tr>
<tr>
<td>Retro</td>
<td>51%</td>
<td>35%</td>
<td>0%</td>
<td>0%</td>
<td>35%</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>45%</td>
<td>6%</td>
<td>0%</td>
<td>39%</td>
</tr>
</tbody>
</table>

In this scenario, it is assumed that the new construction market shares remain fairly static between mid and high efficiency furnaces, but that more of the mid efficiency market moves towards 2-stage furnaces, and they are exclusively DCPM.

In the retrofit market, it is assumed that high efficiency furnaces continue to gain share, albeit at a slower rate, limited by the price conscious element of the

---

7 This corresponds to the 39% market share of high efficiency plus 18% of mid efficiency market share.
retrofit market. Further it assumes that all two stage furnaces are now DCPM motors. Again this scenario appears overly optimistic in terms of the market shares of DCPM motors given the significant price of this product, and the assumption that there is not an external force such as a program to change the market.

3.3.4 Market Analysis – Long Term.

In the longer term, it may be assumed that furnace technology will change and that the significant price premium for DCPM motors will decline or disappear.

There is a common perception with some manufacturers and distributors that DCPM motors will come to dominate the market and push out PSC motors just as PSCs supplanted the earlier technologies. However, as noted in the previous section, until the cost structure of DCPM motors changes, there will continue to be a role for lower cost motors in the price sensitive segment of the market.

None of the industry representatives had a clear vision of how or when the market would evolve, other than indicating it would likely result from new players in the DCPM market combined with a continued demand from consumers for continuous ventilation. However, the general sense is that this change will occur during the next 10 years. The scenario suggested for the market in 5 years may be more representative of the potential in the long term rather than the medium term.

3.3.5 Market Analysis – DCPM Technical Potential.

The following technical potential has been developed, based on the scenario analysis suggested above, with the DCPM market share growing to 36% in two years (2006) and 58% in five years (2009).

For the purpose of the analysis, which is contained with more detail in Appendix 9.2, it was assumed that DCMP market shares would expand and that the technical potential is the remaining furnaces which would be installed with PSC motors. Estimation of the achievable savings potential is outside the scope of analysis, as it requires additional information on potential program design, proposed incentives, information and regulatory components of a high efficiency motor program.

The savings potential in BC was estimated as summarised in Table 12. In the retrofit market the technical potential drops between 2009 and 2015 reflecting the “baseline” increase of DCPM furnaces as discussed above.
Table 12: Savings Potential - DCPM

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>10</td>
<td>5</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>2009</td>
<td>47</td>
<td>20</td>
<td>67</td>
<td>4</td>
</tr>
<tr>
<td>2015</td>
<td>66</td>
<td>18</td>
<td>84</td>
<td>5</td>
</tr>
</tbody>
</table>

Demand savings based on the technical savings potential are summarised in Table 12. These results are based on the assumption that 30% of the space heating load occurs during the winter peak [BC Hydro, Pg 97, 2003]. As noted in Table 12, peak load reduction is forecast to be 1 MW in 2004, increasing to 5 MW in 2015.

3.4 Consumer Analysis

This study did not include market research directly with consumers. However contractors were asked about the primary concerns that they hear being expressed by customers. The consistent answer was: furnace cost, fuel cost and comfort. There appears to be a growing belief that continuous ventilation combined with the quiet, low speed operation of a DCPM leads to a more comfortable house. One contractor noted that these furnaces are now being installed in upper end houses.

Furnace fan motors were not included in the customers preconceived requirements for furnaces, but rather these are being sold by the contractors along with continuous ventilation and advanced air filters as a high quality heating system.

In the new construction market, one manufacturer has undertaken some market research in Ontario that suggests customers would like to have options on heating systems for new construction. Part of the rationale is that the incremental cost of a higher quality heating system is very small relative to the cost of the dwelling, and the impact on monthly mortgage payments relative to savings on the utility bill may reduce costs.

3.5 Potential Partners, Allies & Opponents

A number of stakeholders exist whose objectives to promote DCPM motors overlap with Power Smart.

3.5.1 Utilities

Reducing electricity consumption is primarily BC Hydro’s interest. However, Terasen Gas the major natural gas utility in B.C. has an overlapping interest in the furnace market.
Terasen has operated successful programs promoting high efficiency furnaces in the retrofit market for the past three years. As noted earlier, DCPM motors have the highest penetration in the high efficiency furnace retrofit market where customers are looking for a high end heating solution and where the proportional increase in cost for a DCPM is less. This is a natural market in which to promote DCPM motors. Power Smart has already undertaken a joint promotion with Terasen in 2003, which appears to have been successful as DCPM motors were specified in over 50% of the furnaces installed.

The other markets for forced air furnaces include natural gas territories outside of Terasen’s service territory; electric furnaces; and propane furnaces. Discussions could be held with Pacific Northern Gas (PNG), but they are relatively small (about 37,000 residential customers) and currently not active in residential programs. Discussions could be held with the propane distributors, but this market is small and fragmented, and it is likely more effective to work with the furnace distributors and heating contractors if this market is of interest. Similarly, the electric furnace market is likely best addressed through the furnace distributors and heating contractors.

Programs held in other jurisdictions will help to develop awareness and momentum for DCPM motors. For example, Enbridge in Ontario has already conducted programs for DCPM motors.

### 3.5.2 Natural Resources Canada

Natural Resources Canada (NRCan) has a mission to improve energy efficiency in all sectors, including residential buildings. They have provided funding to help offset the cost of incentives for both Power Smart and Terasen programs. However, in addition to the financial support, NRCan also operates programs and provides information to the residential sector. NRCan can be encouraged to provide more public education on the benefits of DCPM motors, and may be encouraged to include a specific component on blower motors in the EnerGuide for Houses program which provides a detailed analysis of energy efficient upgrade opportunities for interested homeowners.

### 3.5.3 HVAC Distributors and Trades

As noted earlier, the heating industry is very competitive, and profit margins on basic furnaces appear to be small. The higher end 2-stage and variable speed options appear to allow higher profits and possibly higher margins. Therefore there is a natural motivation for both distributors and trades to support DCPM motors.

In the 2003 Terasen program, the manufacturer’s incentives included extended warrantees, programmable thermostats and price reductions. Value of the

---

8 It is not clear if the profit margins are also higher, but this is thought to be the case
coupons ranged from $150 to $600. Both distributors and the trade noted that the extended warrantee was effective in closing furnace purchases with DCPM motors, which may indicate some reservations with reliability of the technology on the part of consumers.

The trades are also potential allies, although perhaps more so in the retrofit market than in the new construction market. For retrofits, if the trade understand the benefits of DCPM motors, they can introduce them to the customers and educate them on the benefits.

Distributors noted that some contractors, even though they were selling high efficiency furnaces, were not taking advantage of the incentives. This may indicate a need for more education for the Trades, or possibly indicates that they find too much overhead in participating in the program.

In new construction, the business model is more to provide bids on heating systems, and both the developers and the trades have noted that low price is the main criteria, assuming the reliability is acceptable. In a bidding process, where there is no ability to adjust the offer, contractors are unlikely to offer a higher price furnace and risk losing the whole job.

3.5.4 Manufacturers
Most of the major manufacturing of residential heating and venting equipment is located in the United States, having moved out of Canada as part of the consolidation that took place after NAFTA. Manufacturers representatives have indicated that component manufacturing is already moving out of the US to Asia, and anticipate that furnace manufacturing will also move.

In this environment, products are developed to meet the broadest range of needs, and essentially precludes development of special models for British Columbia, or even the Canadian market. Therefore the manufacturers’ role is likely going to be around the development and adoption of lower cost versions of DCPM in existing products in response to market forces rather than any specific role of developing specific models to increase the penetration of DCPM motors.

3.5.5 Standards Writing Organizations
Discussion of standards and standards writing organisations is presented in Section 6.1.
4 PROGRAM DEVELOPMENT ANALYSIS AND BUSINESS PLAN

This section provides an overview of a program development plan, including:
1. Program development analysis
2. Program development strategy

4.1 Program Development Analysis
The two key issues for program development analysis are:
- What are the priority markets to be addressed, and
- What are the economics of addressing these opportunities

Table 13 shows the largest potential savings for new construction are for ventilation usage, followed by continuous ventilation.

Table 13: New Construction Technical Potential

<table>
<thead>
<tr>
<th></th>
<th>2004 (GWh)</th>
<th>2009 (GWh)</th>
<th>2014 (GWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intermittent</td>
<td>0.72</td>
<td>4.34</td>
<td>7.96</td>
</tr>
<tr>
<td>Ventilation</td>
<td>3.91</td>
<td>23.48</td>
<td>43.04</td>
</tr>
<tr>
<td>Continuous</td>
<td>5.13</td>
<td>18.89</td>
<td>15.23</td>
</tr>
<tr>
<td>Total</td>
<td>9.76</td>
<td>46.71</td>
<td>66.23</td>
</tr>
</tbody>
</table>

Table 14 shows that the largest potential saving market for retrofit is for continuous ventilation.

Table 14: Retrofit Market Technical Potential

<table>
<thead>
<tr>
<th></th>
<th>2004 (GWh)</th>
<th>2009 (GWh)</th>
<th>2014 (GWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intermittent</td>
<td>1.4</td>
<td>6.3</td>
<td>8.7</td>
</tr>
<tr>
<td>Continuous</td>
<td>5.2</td>
<td>15.3</td>
<td>10.1</td>
</tr>
<tr>
<td>Total</td>
<td>5.5</td>
<td>19.8</td>
<td>18.4</td>
</tr>
</tbody>
</table>

These estimates should be considered as conservative, as they are based on the industry forecast of DCPM motor penetrations of 36% in two years and 58% in five years, which is thought to be optimistic without external pressures such as a program. In addition, this estimate does not allow for increasing use of continuous ventilation.

A number of factors have been determined which affect the economics of DCPM motors. They include:
- Single stage or 2-stage furnace, which affects the number of hours of fan usage, as the fan is assumed to run 40% longer due to the lower firing
rate and hence the longer time required to deliver the same quantity of heat. This number is based on the typical low firing rate of about 2/3 of the maximum, and the furnace operating at this rate about 80% of the time.

- Usage of the furnace blower, which has been categorized as:
  - Intermittent – heating season
  - Intermittent – heating and cooling for customers with air conditioning
  - Ventilation – 8 hours per day as part of the ventilation strategy for new construction
  - Continuous ventilation

Table 15 summarizes these uses and the associated electricity savings.

**Table 15: Furnace Blower Usage - Technical**

<table>
<thead>
<tr>
<th></th>
<th>1-stage Hrs/yr</th>
<th>2-stage Hrs/yr</th>
<th>1-stage kWh/yr</th>
<th>2-stage kWh/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intermittent - heating</td>
<td>1,200</td>
<td>1,680</td>
<td>242</td>
<td>339</td>
</tr>
<tr>
<td>Intermittent – heating &amp; cooling</td>
<td>1,800</td>
<td>2,280</td>
<td>364</td>
<td>461</td>
</tr>
<tr>
<td>Ventilation (8 hrs/day)</td>
<td>2,920</td>
<td>2,640</td>
<td>801</td>
<td>742</td>
</tr>
<tr>
<td>Continuous</td>
<td>8,760</td>
<td>8,760</td>
<td>2,699</td>
<td>2,640</td>
</tr>
</tbody>
</table>

The perspective taken for this analysis is to review the economics from the perspective of a homeowner who is making the decision to buy the additional upgrade from a basic single stage furnace to a 2-stage furnace with variable speed blower. For new construction, the assumption is that the additional cost is added to the mortgage and is paid over 25 years. For retrofit, the assumption is that the additional costs are repaid from a 10-year loan. Then the economics of each application is a function whether the annual cost exceeds the annual savings.

Table 16 shows the results of the economic analysis for each of the market segments, based on the 2-stage furnace hours of operation. It includes a range of incremental prices for the DCPM furnaces, and shows how the cost effective uses of these technologies changes. Those applications where the repayment cost is less than the savings are marked with a check (✔).

The table shows that with the current incremental cost estimate of $1,000 ($800 for the DCPM and $200 for the 2-stage furnace), the technology is only cost effective for continuous ventilation. However some contractors currently sell the package for less today (and it may be argued that the 2-stage furnace cost should not be included as this technology seems to be widely adopted when the homeowner has the choice – i.e.: in the retrofit market). When the price drops to $750, DCPM motors pass for new construction where the furnace fan is used as part of the ventilation strategy. However, it is not until the incremental price
drops to $250 that DCPM motors become cost effective for normal heating operation. Given that the OEM price increase is about $ 80 – 120, and the distributor price increase is about $ 370, this is not necessarily out of reach, but would require significant market development to obtain this much of a price reduction.

### Table 16: Furnace Blower Usage – Customer Payback

<table>
<thead>
<tr>
<th>Sav- ings</th>
<th>$1000</th>
<th>$750</th>
<th>$500</th>
<th>$250</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>New</td>
<td>Retro</td>
<td>New</td>
<td>Retro</td>
</tr>
<tr>
<td>Payment</td>
<td>$59</td>
<td>$119</td>
<td>$45</td>
<td>$89</td>
</tr>
<tr>
<td>Heat</td>
<td>$16</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AC</td>
<td>$30</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vent.</td>
<td>$46</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cont.</td>
<td>$188</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
</tbody>
</table>

In summary, the primary opportunities for electricity savings are for ventilation in the new construction market and for continuous ventilation for both new construction and for retrofits. The customer based financial analysis indicates that the continuous ventilation applications are cost effective with current prices, and ventilation is cost effective if the incremental cost of a DCPM is $750 or less.

### 4.2 Program Development Strategy

As noted in Section 3, the two major barriers to the adoption are:
- Initial cost
- Customer awareness and preference.

While the developer and contractor community seem to be doing a good job of selling the 2-stage furnaces and the benefits of ventilation, they are having less impact with DCPM equipped furnaces. When asking distributors and contractors for their advice on how to further develop the market, the two recommendations were:
- More advertising and promotion from Power Smart on the benefits of the variable speed technology; and
- Retain the incentive programs both to help the economics and to provide a “reason to act”.

Developers also noted that they would only respond to consumer demand if the incentives were enough to cover the total incremental cost.

#### 4.2.1 Retrofit market

The high efficiency market can be effectively addressed in conjunction with Terasen’s High Efficiency Furnace Program, and provides a number of advantages including reduced administration costs with Terasen providing the logistics; the incentive via their customer billing system; shared promotion
costs; simplified paperwork on the part of the contractor / homeowner, and the combination of incentives to provide more “bang” for the homeowner. However the disadvantage is that Terasen is primarily interested in addressing the high efficiency market.

While the high efficiency furnaces are gaining market share in the retrofit market, mid-efficiency still accounts for almost 50% of this market. Further, the share of DCPM motors in the mid efficiency market is only about one quarter that of the high efficiency market. Therefore Power Smart may also want to address this market.

It would be most cost effective to set the program up as part of the existing program with Terasen, as this would build on the existing infrastructure, and would be simplest from the perspective of the trade allies, as it would appear as one integrated program. However Terasen may feel that this weakens their message to move to high efficiency furnaces, and may not be interested in participating. If this is the case, a separate program will need to be set up, using both the distributors and the contractors as allies to deliver the program.

It is likely that an incentive program will not capture all of this market as the mid-efficiency market has a price sensitive segment. This group would include landlords (who don’t pay the energy costs), homeowners planning to sell and groups on restricted budgets who cannot afford the higher front end investment. The incentive model is unlikely to address this market as the customer must still make a significant additional cash outlay. In theory, financing could be offered on the BC Hydro electricity bill, which would remove the up-front cost barrier and hold monthly payments constant. However the payback periods, given current DCPM prices are sufficiently long as to likely make this impractical. A reduced price premium for DCPM motors will be necessary to fully capture this market.

In parallel with these incentive programs, Power Smart needs to include an education element in their outreach programs to inform customers about the various ventilation uses of furnace fans and where DCPM motors make economic sense. Power Smart also needs to include an educational package in the distributor / contractor material to provide objective information on the economics of these products. Some of the anecdotal information on appropriate usage of the technology and associated economics is significantly inaccurate for BC.

4.2.2 New Construction Market
Strategically, there are two options for addressing the new construction market:
- Work directly with developers to have DCPM furnaces installed as the standard offering in new developments; or
- Provide optional heating packages which include DCPM equipped furnaces.
Conceptually, working directly with developers, as done traditionally with the Power Smart New Home Program would be the best vehicle to increase penetration. However, conversations with a number of developers indicated this will have limited success unless Power Smart can underwrite essentially the total incremental cost of the DCPM, as developers do not believe that they can pass this additional cost on to the consumer. They would only standardize on this more expensive product if they believed that customers were demanding it, and they would lose sales if it was not provided. This is not the case today.

The alternative is to work with developers and the sales agents to provide an option package for new construction. This approach is currently used for interior finishing, and kitchen appliances. This approach could be extended to include heating system options. To some extent this is already done in the Interior region of the Province with air conditioning options in some developments. This approach addresses the primary barrier from the perspective of the developer, a way to recover the additional costs involved. It is expected that the public would be interested, and one manufacturer cited market research they had undertaken in Ontario that found customers would have appreciated having the option at the time of buying, and would have been interested as the incremental cost on the mortgage would be offset by lower energy bills.

Power Smart would have to work with both developers and the sales agents to put these packages together. The developers appear to rely heavily on the sales agents when determining what features to offer, and the addition of options at the construction phase (especially if high efficiency furnaces are included) will add another complexity to the construction. The sales agents are primarily motivated to close the sale, and therefore must view the option as another way to close the sale, rather than as a barrier to the sale. Some of the heating contractors may also be allies for this program. Pricing on the cost of heating systems for new construction is very competitive, and higher end furnaces may provide more margins for this group.

There may also be an opportunity in the custom home market, but research is needed on the size of the market and the types of heating systems installed to determine if there is additional potential in this market that is worth pursuing.

As with the retrofit market, there will be a need to support the direct program with advertising and promotion to build consumer awareness of the alternatives,

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9 The current $150 offer has a very low level of awareness among developers and distributors. However when asked about this offer, most said it would not motivate them to install DCPM equipped furnaces.

10 Note: this concept could easily be expanded to include Power Smart appliances, which have a relatively low penetration in new construction relative to retail. It could also include high efficiency furnaces, which would be attractive to furnace manufacturers, Terasen, and NRCan.
and to support the developers and sales agents in their efforts. Power Smart has been very effective with this type of activity in the past.
5 TECHNOLOGY ANALYSIS

This section provides an overview of the technologies employed in furnace fan motors. Detailed information is presented on:

1. Energy and capacity (demand) requirements and savings potential,
2. Physical reliability,
3. Power quality,
4. Health and safety,
5. Environmental impact, and
6. Functional impact of energy efficient technologies.

5.1 Energy and Capacity (Demand) Requirements and Savings Potential

5.1.1 Literature Review

Reducing the capacity of the air handler equipment is an ongoing topic in the literature. On one hand, higher airflows have enabled manufactures to increase the efficiency of their heating equipment, resulting in a significant reduction in natural gas consumption. On the other hand, these higher flow rates have generally been designed for hot and mixed climates rather than cold climates. This results in higher flow rates for a given unit of heat output than is generally required in cold climates. Theoretical blower power requirements are proportional to the cube of the airflow. Therefore, small reductions in airflow can have a substantial impact on reducing fan power requirements. A review of the GAMA\textsuperscript{11} 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.\textsuperscript{12}

An evaluation of the impact of DCPM on electrical and gas energy use was recently completed by Gustdorf [2003]. A comparison of PSC and DCPM motors is summarised in Table 17. As can be seen, it is estimated the DCPM will reduce fan energy by 40\% when operating in heating mode and 78\% when operating in ventilation mode.

\textsuperscript{11} www.gamanet.org/consumer/certification/certdir.html

\textsuperscript{12} 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.
Table 17: Comparison of PSC and DCPM Electricity Consumption [Watts]

<table>
<thead>
<tr>
<th>Fan Mode</th>
<th>PSC</th>
<th>DCPM</th>
<th>% Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space Heat</td>
<td>505</td>
<td>303</td>
<td>41%</td>
</tr>
<tr>
<td>Circulation</td>
<td>350 to 500</td>
<td>75 to 125</td>
<td>78%</td>
</tr>
</tbody>
</table>

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 DCPM motor. The results of these tests were modelled using HOT2000 and extended for an entire heating season and for four climates in Canada.

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 DCPM. For example, the median variable speed furnace motor in the study used about 5 kWh per GJ 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.

Data comparing electricity consumption of two stage furnaces operating in low firing versus high firing mode is limited. Additional analysis is recommended on this issue.

5.2 Physical Reliability

A review of the warranty provided for furnaces equipped with variable speed and PSC motors shows no difference in warranty, suggesting the DCPM may be expected to be as reliable as PSC motors. However, results of the interviews suggest there was a problem with some DCPM motors failing prematurely. The distributors confirmed these problems were usually dealt with under warranty, and reliability issues appear to have been resolved. Sachs [2002] notes that

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13 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].

14 HOT 2000 is an energy simulation software analysis package developed by NRCan.

15 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 17.
DCPM should run at lower bearing temperatures, resulting in prolonged motor life. This comment was also made by a motor manufacturer, although, no specific data was provided. It was also noted that power factor controllers in the motor contribute to lower current in the AC supply from which enhanced reliability can be achieved.\textsuperscript{16}

No quantitative results of reliability were obtained from the motor manufactures. Discussion with the manufacturer revealed that since there is a computer attached to the motor there may be more opportunity for field issues. However, this is partially offset in typical installations using DCPM because they are often done by better contractors with better equipment.

5.3 Power Quality
Measurements of power factor were completed for 31 furnaces tested in Wisconsin [Wisconsin State Department of Energy, October, 2003]. The results are summarized in Table 18. As can be seen, results of the survey show that the DCPM had somewhat lower power factors compared to multi-speed motors, except in standby mode.

Table 18: Median Measured Power Factor, by Operating Mode.

<table>
<thead>
<tr>
<th>Operating Mode</th>
<th>Furnaces With DCPM</th>
<th>Furnaces Without DCPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating</td>
<td>0.72 (low-fire)</td>
<td>0.88</td>
</tr>
<tr>
<td></td>
<td>0.68 (high-fire)</td>
<td></td>
</tr>
<tr>
<td>Cooling</td>
<td>0.63</td>
<td>0.81\textsuperscript{17}</td>
</tr>
<tr>
<td>Continuous Fan</td>
<td>0.69</td>
<td>0.87</td>
</tr>
<tr>
<td>Standby\textsuperscript{18}</td>
<td>0.62</td>
<td>0.40</td>
</tr>
</tbody>
</table>

5.4 Impact on Manufacturing Industry
No negative impacts are expected on the furnace manufacturing industry as a result of programs to support DCPM motor equipped furnaces. In fact, these programs would likely support the move to high efficiency furnaces which the industry is encouraging.

In terms of motor manufacturers, it was noted previously that General Electric is the primary manufacturer of these motors, with well over 90% of market share. However, Emerson Motors and EO smith are currently developing DCPM.

\textsuperscript{16} Personal Communication, Armin Hauer, ebm-papst
\textsuperscript{17} It is expected the power factor should be higher in cooling mode than heating mode due to the higher operating speed. No explanation was provided for this discrepancy.
\textsuperscript{18} Based on the review by the State of Wisconsin [2003], standby power ranged from 4 to 13 Watts, with a median of 8 Watts. DCPM furnaces dominate the higher end of the distribution, possibly due to large and more complicated control circuitry. On average, the DCPM furnaces consumed 4 Watts of standby power above that consumed by the non-DCPM furnaces in the study. This translates into additional electricity consumption of about 30 kWh per year for furnaces equipped with DCPM motors and running in heat only mode.
motors for application in furnaces. Therefore, it is expected that increased competition resulting in decreased prices will result for wider adoption of this technology.

5.5 Health and Safety

5.5.1 Health and Safety Issues
Discussions with the manufacturer confirmed that there are no health and safety issues associated with the production of DCPM.

5.5.2 Human Health Considerations
Recent analysis on the cost effectiveness of energy efficiency upgrades in new residential buildings [SAR, 2004] included an analysis of opportunities for improved ventilation systems. Current ventilation requirements in the BC Building code [BCBC, 1998] requires installation of a principle exhaust fan running for 2-four hour cycles daily. Based on typical air tightness characteristics of new homes, it was estimated that ventilation rates during shoulder seasons was below the recommended levels defined in CSA F326. Installation of continuous ventilation using a furnace fan was found to result in ventilation rates meeting the requirements of CSA F326, and appear to be adopted in some new developments. It should be noted that under some circumstances, moving from a principle exhaust fan to continuous ventilation might result in increased electricity consumption. Additional analysis is required to understand potential load growth implications.

5.6 Environmental Impact

5.6.1 Disposal and Recycling of Motors
Discussion with the manufacturer suggest that DCPM have no incremental impact compared to PSC motors.

5.6.2 Greenhouse Gas Impacts
Based on the energy savings summarised in Table 12, and assuming a GHG emissions factor of 360 tonnes/GWh\(^{19}\), the impact of DCPM in terms of greenhouse gas emissions is summarised in Table 19. Emissions are therefore forecast to reduce by about 9,800 tonnes per year in 2005, increasing to almost 83,000 tonnes per year in 2020.

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\(^{19}\) Source: BC Hydro estimate based on year 2000 Integrated Electricity Plan.
Table 19: Greenhouse Gas Impact of DCPM

<table>
<thead>
<tr>
<th>Year</th>
<th>GHG Emissions Reduction [Tonnes CO2e]</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>5,400</td>
</tr>
<tr>
<td>2009</td>
<td>24,120</td>
</tr>
<tr>
<td>2015</td>
<td>30,240</td>
</tr>
</tbody>
</table>

5.7 Functional Impact of Energy Efficient Technologies

As discussed in Section 4, there appears to be a strong trend towards continuous ventilation for increased comfort; for improved indoor air quality when combined with advanced air filters and to meet ventilation codes. In the interviews conducted for this project, many actors associated DCPM motors with continuous ventilation. However, this does not imply a cause and effect relationship. Rather, continuous ventilation appears to be driven by the underlying trends, and more knowledgeable decision-making is leading to variable speed technologies both for comfort and cost savings.
6 STANDARDS ENHANCEMENT ANALYSIS AND BUSINESS PLAN

This section provides information efforts related to improving the energy efficiency standards of furnace fan motors. Discussion is presented on:

1. Analysis of standards enhancement,
2. A standards development strategy,
3. Funding and scheduling to complete standards development, and
4. Risk

6.1 Standards Enhancement Analysis

6.1.1 CSA823-XX Domestic Furnace Blowers

The Canadian Electricity Association (CEA) is currently drafting an update to standard 832-XX dealing with domestic furnace blowers. A draft is currently being reviewed by the CEA. In addition, the CEA is currently investigating an update of Technology profiles in this area. It is noted that opportunities may exist to update the C747 small motor standard and incorporate reference to Energy Consumption in the appropriate gas program standard.

6.1.2 CGA P.2-1991 (Testing Method for Measuring AFUE of Residential Furnaces and Boilers)

The CSA is currently updating the standard on test methods for measuring the AFUE of residential furnaces and boilers. Work on this commenced in November 2003 with revisions to the standard scheduled for completion in November 2005. It proposes that the test methods of P.2 and P.8 include the measurement and reporting of the total electricity consumption of the unit, as well as the total electricity consumption of the blower’s or pump’s motor. NRCan is active in chairing this work and is seeking information on the electricity consumption of gas furnaces and boilers. While this work is ongoing in Canada, GAMA recently voted down inclusion of Watts in the AFUE calculation, which could have benefited DCPM.

6.2 Standards Development Strategy

Harvey Sachs [2002, 2003, personal communication] has been actively supporting the concept of incorporating the electricity use in furnaces into the AFUE test methods. Sachs is currently working to develop a metric for electricity consumption for furnace fan motors called the Electricity Use Ratio, EUR. EUR is the ratio of the annual electricity use, EA, divided by the furnace capacity, in thousands of Btu/h. For example, a furnace with EA = 500 kWh/yr, and 50,000 Btu/h capacity, EUR = 500/50 = 10. Sachs found that few models listed on the GAMA web site operate with an EUR of 6 or less, but significant numbers have an EUR greater than 6. He notes that the larger fan sizes are

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20 Personal Communication, Brian Killins, Natural Resources Canada
21 Personal Communication Hantz Prosper, Natural Resources Canada.
generally designed to accommodate the cooling loads for southern US climates. Therefore, developing a furnace fan motor sizing program based on EUR requirements provides an opportunity for substantial reduction in air handler flow rates and electricity consumption. Consistent with this approach, the US Department of Energy, the American Council for an Energy Efficient Economy, the Consortium for Energy Efficiency and the CSA are reviewing the test methods for furnace energy use in order to provide a means to compare the performance of different units.

6.3 Funding and Schedule to Complete Standards Development
As noted above, an update is underway to the CGA P.2-1991 standard that will likely incorporate reporting of the total electricity consumption of the unit, as well as the total electricity consumption of the blower’s or pump’s motor. This work has recently commenced and is scheduled for completion in November 2005.

6.4 Risk
There are a number of risk factors associated with promoting DCPM

- **Lack of Competition.** General Electric manufactures approximately 90% of the DCPM motors installed in furnaces. From a utility perspective, promoting products with a single manufacturer may create competitiveness concerns among other motor manufacturers that could impact other BC Hydro programs. This is likely a short-term issue that will diminish as DCPM increases market share.

- **Installation Quality.** As noted by the motor manufacturer, “We have good equipment being sold and poorly installed, which robs the consumer, the utility and our environment”. Installation quality concerns have been described elsewhere [Phillips, 1995, Wisconsin, 2003] and confirm the need for continued trades training to optimize the quality of installations to improve savings and reliability.

- **Increased Gas Sales.** While installation of DCPM will result in lower electricity bills, they will also result in increased use of space heating fuels. While gas is relatively cheap, the overall costs of operating a furnace will decrease. However, if gas costs continue to rise, the overall cost savings may disappear, resulting in customer concerns. Based on the analysis by Gusdorf, the increase in gas consumption is expected to be less than 5%.

- **Free Riders.** DCPM are widely available in condensing furnaces that are eligible for incentives through Terasen rebates. Customers who choose to purchase a condensing furnace may be willing to purchase a unit with a variable speed motor, in the absence of incentives from BC Hydro. Identification of the free rider potential may be a significant program risk and should be addressed as part of the evaluation of the
program with Terasen.

- **Market Share of HE furnaces.** As noted above, high efficiency furnaces currently represent the largest share of DCPM motors. Conversations with the heating contractors indicate that the market share of high versus mid efficiency furnaces is quite unstable and depends upon the availability of incentive programs and the perception of future natural gas prices. If either of these change, the current share of high efficiency furnaces and DCPM motors could drop.

- **Load Growth.** While the focus of a variable speed motor program is to reduce load growth, if customers switch from using a PSC motor in heating mode to a variable speed motor in continuous mode, overall electricity consumption will increase. Therefore, managing load growth also requires informing contractors about preferred installation set-up that may include an assessment of a house’s existing ventilation rate.

- **Changes to the Building Code.** The BC Building code is currently under revision. As the BCBC strives for harmonization with the national building code, there will be a push towards balanced ventilation systems using heat recovery ventilation (HRV) in new housing. This implies that separate strategies may be required for existing and new houses. In particular, use of DCPM in furnaces in a house equipped with an HRV is not likely a cost effective opportunity. If the code is implemented and heat recovery ventilators are mandated, then this use would not be recommended as a target market for programming purposes. However, should these changes occur, it does suggest that targeting HRVs may be appropriate.
7  RECOMMENDATIONS

7.1  Market Analysis
There is a growing trend towards installation of furnaces equipped with DCPM motors. Market share is currently estimated at 24%. In the next two years, the industry expects the market share for DCPM motors to increase to 36% and over the next five years market share to reach 58%. However, the market analysis of these estimates make them appear unlikely without an external influence such as an incentive program. Based on the industry estimate of growth in the DCPM market, electricity savings of 84 GWh per year is projected for 2015. To the extent that the industry estimate is high, the potential is understated.

7.2  Program Development
Furnace fan operation varies for new and existing buildings. In new housing, 45% of installations run furnace fans as the principle ventilation fan. A further 25% to 30% of homes run the furnace fans continuously. For new construction the largest potential savings are for DCPM motors that include ventilation usage, followed by those used for continuous ventilation. To capture the market for DCPM motors in the new market, it is recommended that BC Hydro encourage builders to provide optional heating packages which include DCPM equipped furnaces.

In the retrofit market, it is estimated that furnaces are being set to run continuously in 30% of the installations. For the retrofit market, the most significant savings opportunities for DCPM motors are for continuous ventilation. To capture the market for DCPM motors in the retrofit market, it is recommended that BC Hydro continue to work with Terasen Gas through its incentive program to the extent it is cost effective.

Due to the incremental cost of DCPM motors, the cost-effectiveness of installing the units depends on how the furnaces are being run. With current incremental costs approaching $1,000 (for a 2 stage furnace equipped with a DCPM motor), the installation of a DCPM motor is cost effective only when the fan is being run continuously. If the incremental cost drops to $750, then it is cost effective to address the use of furnace fans used as the principle ventilation fan in new construction.

7.3  Standards Enhancement Analysis;
A range of activities is ongoing related to updating the energy efficiency of furnace fan motors. The Canadian Electricity Association (CEA) is currently drafting an update to standard 832-XX dealing with domestic furnace blowers. In addition, the CSA is currently updating the standard on test methods for measuring the AFUE of residential furnaces and boilers. Finally, the BC
Ministry of Energy Mines is currently reviewing its standards. It is recommended that BC Hydro work within these ongoing initiatives to provide a regulatory backstop as part of a larger market transformation strategy.
8 REFERENCES

8.1 Canadian Standards


8.2 Other References

Allen Associates, Efficient and Effective Residential Air Handling Devices, CMHC, 1993

BC Hydro, Conservation Potential Review, BC Hydro, 2003

BC Hydro, Residential End Use Survey, BC Hydro, 2003


Gusdorf, John, “Final Report on the Project to Measure the Effects of DCPM Furnace Motors on Gas Use at the CCHT Research Facility” Natural Resources Canada, January, 2003

HRAI, Residential Mechanical Ventilation, Heating Refrigerating and Air Conditioning Institute of Canada, 1996


NRCan, Trends in energy Characteristics of Homes in Canada, 1997


Terasen Gas, *Residential End Use Survey Results*, December 2003


State of Wisconsin Department of Administration Division of Energy Residential Programs, *Electricity Use by New Furnaces*, October 2003
9 APPENDICES
9.1  Sales of furnaces in BC

A number of sources of data were referenced in determining the “best estimate” of furnace sales in British Columbia. Sources include: HRAI statistics on furnace shipments into BC, data from furnace distributors, data from heating contractors, and estimates based on a model of the retrofit and new construction demand for furnaces.

9.1.1  HRAI Furnace Shipment Data

HRAI data of furnace sales is summarised in Table 20 in terms of units sold.

Table 20: HRAI Furnace Shipments in B.C. [Number of Units]

<table>
<thead>
<tr>
<th>Year</th>
<th>Mid Effic. Gas</th>
<th>High Effic Gas</th>
<th>Oil</th>
<th>Electric</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>14,151</td>
<td>5,534</td>
<td>885</td>
<td>651</td>
<td>21,221</td>
</tr>
<tr>
<td>2003</td>
<td>13,821</td>
<td>4,950</td>
<td>880</td>
<td>900</td>
<td>20,551</td>
</tr>
</tbody>
</table>

In general, “shipment to BC data” tends to understate BC sales as they record the location of the initial shipment from the manufacturer and hence do not pick up shipments from the manufacturer to the distributor who then ships into BC. In addition sales in the East Kootnehs and north eastern BC where supply are often obtained from Alberta based wholesalers are not included. Further the HRAI statistics do not totally reflect sales in a given year, as some inventory is carried over from one year to the next.

9.1.2  Market Model for Furnaces

Table 21 shows the housing completion data for BC, based on both CHMC housing completion statistics and forecasts from BC Central Credit Union for 2003 and 2004.

Table 21: Housing Completions / Forecast for BC. (CMHC)

<table>
<thead>
<tr>
<th>Year</th>
<th>SFD</th>
<th>Duplex</th>
<th>Row</th>
<th>Apartment</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>7,976</td>
<td>789</td>
<td>1,690</td>
<td>3,825</td>
<td>14,280</td>
</tr>
<tr>
<td>2002</td>
<td>9,468</td>
<td>1,102</td>
<td>1,947</td>
<td>7,591</td>
<td>20,108</td>
</tr>
<tr>
<td>2003*</td>
<td>12,336</td>
<td>1,436</td>
<td>2,537</td>
<td>9,891</td>
<td>26,200</td>
</tr>
<tr>
<td>2004*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>28,800</td>
</tr>
</tbody>
</table>

* Forecast: Source BC Central Credit Union – BC Hydro Load Forecast

In order to determine the number of furnaces required for new construction and retrofits, we need the incidence of furnaces. Table 22 summarises the type of heating systems found in Canadian homes. As can be seen, hot air furnaces make up the largest portion of the stock of heating systems at 69% of existing homes. In addition, these systems are gaining in popularity, as they are being
installed in 71% of new homes\textsuperscript{22}. These estimates are consistent with a query completed on BC Hydro’s Residential End Use Survey, which suggests that 67% of existing single-family homes in BC have furnaces.

Table 22: Percentages of Heating Systems for Existing Housing Stock by Heating Appliance [SHEU, 2000]

<table>
<thead>
<tr>
<th>Heating Appliance</th>
<th>Hot Air Furnace</th>
<th>Hot Water Boiler</th>
<th>Wood Stove</th>
<th>Electric Baseboard</th>
<th>Heat Pump and Other</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>69%</td>
<td>4.50%</td>
<td>5.50%</td>
<td>14%</td>
<td>7.20%</td>
</tr>
</tbody>
</table>


Table 23: Housing Stock for BC Hydro Service Territory (2001)

<table>
<thead>
<tr>
<th>Housing Type</th>
<th>SFD / Duplex</th>
<th>Row</th>
<th>Mobile</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stock</td>
<td>804,032</td>
<td>104,351</td>
<td>102,269</td>
<td>1,010,652</td>
</tr>
<tr>
<td>Hot air furnace - %</td>
<td>67%</td>
<td>64%</td>
<td>72%</td>
<td></td>
</tr>
<tr>
<td>Hot air furnace - #</td>
<td>538,701</td>
<td>66,785</td>
<td>73,634</td>
<td>679,120</td>
</tr>
</tbody>
</table>

Estimates of turnover rates for furnaces were developed using a number of sources.

- The Survey of Home Retrofits [NRCan, 2000] estimates a replacement rate of 2.9% for existing homes. This indicates a demand for furnaces in BC is about 19,694 per year. While the housing stock estimate is based on 2001 data, the furnace demand for replacements is expected to be more consistent between years than for new construction.

- The Terasen program evaluation looked at the age of furnaces replaced during the program. The average age was 26 years. If the housing stock was constant, this would imply a turn-over rate of just under 4%. However there is a growing stock of new houses, and very few replacements will take place during the first 20 years. 2.5% of the current stock is very close to 4% of the 1980 stock of houses in B.C.

Based on this data, an estimated turnover rate of 2.5% has been used.

9.1.3 Furnace Distributor Estimates of Furnace Sales in 2003

As part of this project, a combination interview / survey was conducted with the 10 major furnace distributors in BC, who wholesale 15 brands of furnaces.

\textsuperscript{22} NRCan, Survey of Household Energy Use, Pg. 69.
While there are about 30 brands of furnaces available in BC, the market appears to be quite concentrated, with the two major brands likely accounting for over 50% of sales. This is supported by review of furnace data from Terasen’s 2002 program which indicated that, for high efficiency furnaces sold during their promotion, the top 10 brands accounted for over 90% of the sales. Based on this information, we have assumed that the dealers covered will account for at least 90% of the furnace sales in B.C.

Table 24 summarize the data on estimated total sales of mid and high efficiency furnaces to both new and retrofit applications. These estimates do not include out of province adjustments.

Table 24: Distributor Estimated Sales of Furnaces for New and Retrofit Installations (2003 Sales)

<table>
<thead>
<tr>
<th></th>
<th>Mid Efficiency</th>
<th>High Efficiency</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Construction</td>
<td>8,776</td>
<td>1,975</td>
<td>10,498</td>
</tr>
<tr>
<td>Retrofit</td>
<td>5,485</td>
<td>5,704</td>
<td>11,442</td>
</tr>
<tr>
<td>Total</td>
<td>14,261</td>
<td>7,679</td>
<td>21,940</td>
</tr>
</tbody>
</table>

9.1.4 BC Furnace Sales Market

Based on this analysis, Table 25 shows the estimates furnace sales in BC for 2003.

Table 25: Estimated Furnace Sales in BC (2003 Sales)

<table>
<thead>
<tr>
<th></th>
<th>Mid Efficiency</th>
<th>High Efficiency</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Construction</td>
<td>8,900</td>
<td>1,950</td>
<td>10,850</td>
</tr>
<tr>
<td>Retrofit</td>
<td>5,825</td>
<td>5,825</td>
<td>11,650</td>
</tr>
<tr>
<td>Total</td>
<td>14,725</td>
<td>7,775</td>
<td>22,500</td>
</tr>
</tbody>
</table>

9.2 Operation of Furnace Blowers in B.C.

A number of data sources were consulted to understand the use of furnace fans in British Columbia. Terasen [2002] asked questions of both the heating contractors and customers about their usage of furnace blowers, the results of which are shown in Table 26. When the numbers are adjusted to remove the DK / NR (don’t know/no response) bias, it appears that the percentage of furnaces where the fan runs continuously drops from about 21% before the furnace change out to about 16% after the change out. The percentage that runs intermittently increases from 79% to 84%.
Table 26: Customer Reported Blower Usage

<table>
<thead>
<tr>
<th></th>
<th>Prior to furnace change</th>
<th>After furnace change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ran intermittently</td>
<td>74.3%</td>
<td>80.7%</td>
</tr>
<tr>
<td>Ran continuously</td>
<td>19.3%</td>
<td>14.9%</td>
</tr>
<tr>
<td>DK / NR</td>
<td>6.4%</td>
<td>4.5%</td>
</tr>
</tbody>
</table>

In the same evaluation, contractors were asked about the share of installations where the furnace fan ran continuously, by level of furnace efficiency. Terasen’s 2002 REUS study indicated the following furnace penetrations: standard efficiency – 34.5%; mid efficiency – 16.6%; and high efficiency 9.4%. Using these weighting factors provides an estimate of 23% of furnace fans running continuously, consistent with the estimate of 21% from customers. These results are shown in Table 24.

Table 27: Contractor Reported Share of Installations Where Fan Runs Continuously

<table>
<thead>
<tr>
<th></th>
<th>Standard efficiency</th>
<th>Mid efficiency</th>
<th>High efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>19.8%</td>
<td>24.5%</td>
<td>32.4%</td>
</tr>
</tbody>
</table>

BC Hydro’s 2003 REUS study also asked respondents how often their furnace fan operated.

Table 28: BC Hydro – Furnace Fan Operation

<table>
<thead>
<tr>
<th></th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intermittent</td>
<td>65%</td>
</tr>
<tr>
<td>Continuous during heating season</td>
<td>4%</td>
</tr>
<tr>
<td>Continuous year round</td>
<td>9%</td>
</tr>
<tr>
<td>Don’t know / refused</td>
<td>22%</td>
</tr>
</tbody>
</table>

When these numbers are adjusted to remove the DK/NR bias, it appears that about 83% of the fans run intermittently, which is interpreted to mean only when heating and air conditioning are required. Further, about 12% reported that they run their fan continuously all year round. This is smaller than the number provided by the Terasen survey, and provides a range of 12 to 20%. We have assumed 15%, which is similar to the percentage reported by Terasen customers after the furnace replacement.

The last piece of information is the incidence of air conditioning in BC Hydro’s REUS report identifies this at 6%, and further determined that they were used for an average of four months per year.
In order to estimate the current share of households, both the Hydro and Terasen surveys suggest that about 80% of the households run the fan intermittently for heating and cooling. A further 15% are assumed to operate their fans continuously. This leaves about 5% of the customers who operate their fan continuously, but only during the heating or cooling season. This has been arbitrarily split between heating, and heating and cooling, with more on cooling as some literature indicates that continuous operation is more prevalent during cooling.

Table 29: Estimated Current Fan Usage in B.C.

<table>
<thead>
<tr>
<th>Share of households</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intermittent – heating season</td>
</tr>
<tr>
<td>Intermittent – cooling season</td>
</tr>
<tr>
<td>Continuous – heating season</td>
</tr>
<tr>
<td>Continuous – heating and cooling</td>
</tr>
<tr>
<td>Continuous - ventilation</td>
</tr>
</tbody>
</table>

9.2.1 New Construction

Information was collected from developers and contractors to understand the fan usage practices for new construction. Interviews with developers, suggest that in about 25% of new installations the fan runs continuously, while in another 45% of cases the fan runs between 4 and 8 hours per day as part of the ventilation system. This high incidence of usage is supported by interviews with contractors who undertake installations in new construction.

When looking at new installations, the heating contractors responding to the Terasen study reported that 25% of mid efficiency furnaces and 32% of high efficiency furnaces are being set up for continuous operation. Mid efficiency furnaces are currently 65% of the sales mix while high efficiency furnaces are about 35%. This would indicate that about 27% of new furnaces are set for continuous ventilation. This corresponds quite well with the developer surveys which found that about 25% of new installations have fans that run continuously, while another 45% have fans tied to ventilation and run more than just during heating and cooling. This supports the trend to more fan operation over time, and indicates this trend could be in the range of 25 to 30%.

Interviews with contractors indicated that of the furnaces installed in new construction, and running continuously, about 63% of the motors will be PSC. Given that about 5% of the new installations have DCPM motors and if all the DCPM motors were used for continuous ventilation, then about 20 – 25% of the installations in new construction will have continuous ventilation with PSC motors. Table 30 shows a summary of estimated fan usage in new construction.
Table 30: Estimated Fan Usage in New Construction.

<table>
<thead>
<tr>
<th>Share of households</th>
<th>Share with PSC motors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intermittent</td>
<td>25 - 30%</td>
</tr>
<tr>
<td>V. 4 – 8 hrs/day</td>
<td>45%</td>
</tr>
<tr>
<td>C. ventilation</td>
<td>25 - 30%</td>
</tr>
</tbody>
</table>

9.2.2 Retrofit Installations

For furnace retrofits to existing houses, interviews with the contractors indicate that about 34% of the installations have continuous ventilation, although it is not certain how many of these may be turned down by home owners after the installation. This number is somewhat higher than the Terasen finding of about 25% of mid efficiency and 32% of high efficiency furnaces, or about 27% of total new furnaces are installed with continuous ventilation. This provides a range of between 27% and 34% with continuous ventilation.

Table 31: Estimated Fan Usage in Retrofits.

<table>
<thead>
<tr>
<th>Share of households</th>
<th>Share with PSC motors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intermittent</td>
<td>70%</td>
</tr>
<tr>
<td>C. ventilation</td>
<td>30%</td>
</tr>
</tbody>
</table>
