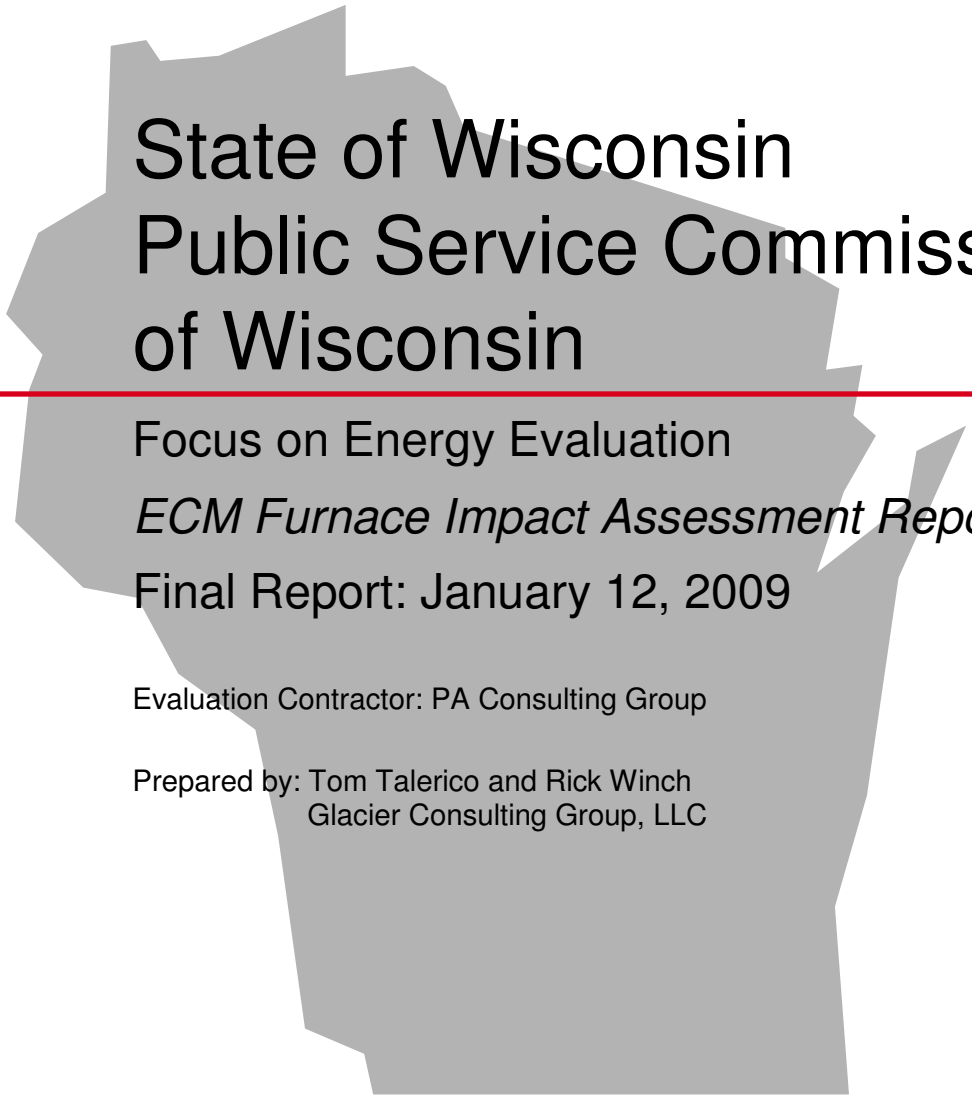
PA Consulting Group



# State of Wisconsin Public Service Commission of Wisconsin

## Focus on Energy Evaluation

## *ECM Furnace Impact Assessment Report*

Final Report: January 12, 2009

Evaluation Contractor: PA Consulting Group

Prepared by: Tom Talerico and Rick Winch
Glacier Consulting Group, LLC

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## *ECM Furnace Impact Assessment Report*

## Final Report: January 12, 2009



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## TABLE OF CONTENTS



## Appendices

## 1. EXECUTIVE SUMMARY

This study was designed to update a previous impact analysis report for furnaces with electronically commutated motors (ECMs).[1] Because the way in which people operate their furnace fans has significant ramifications on ECM furnace impacts, the purpose of this study is to examine the behavioral aspects of ECM furnace fan operation and apply these behavioral results to previously established technology-based savings estimates; thereby providing an update of the savings that derive from installing ECM furnaces in Wisconsin homes. This study assesses not only furnace fan operation behavior both before and after the installation of the furnace but also the reasons why changes in behavior occurred.

This assessment is important for two reasons. First, Focus on Energy (Focus) has continued its emphasis on and promotion of ECM furnaces as part of its Efficient Heating and Cooling (EHC) program. Second, the size of ECM furnace impacts, which relative to other Focus-qualifying measures is large, is highly dependent on customer operational behavior and little, if any, independent research is available documenting the prevalence of various types of furnace fan operational behavior among Wisconsin homeowners.

As part of the study, we conducted a total of 232 interviews between two groups of homeowners:[2]

1. *EHC Participants with ECMs*. We conducted 150 interviews with owners of existing homes who purchased an ECM furnace through EHC. The results from this group are used to estimate savings for ECM furnaces installed in existing homes.

2. *Nonparticipant Furnace Replacers*. We conducted 82 interviews with owners of existing homes who recently purchased a new furnace outside of EHC. The sample for this group was identified through calling a sample of single-family homeowners and screening for households that replaced a furnace during the last two years. As the control group for participants with ECMs, the results from this group also contribute to estimating savings for ECM furnaces installed in existing homes.

The focus of the interviews was to assess how homeowners operate their furnace fans throughout the year and understand the reasons why operation practices have changed among those homeowners who modified their practices subsequent to the installation of the new furnace. The interviews also addressed HVAC contractor advice on furnace fan operation practices, furnace filter maintenance, housing characteristics, and household demographics.

We also completed interviews with 46 HVAC contractors who sold ECM furnaces through Focus during 2007. The goal of the HVAC contractor interviews was to provide a better

[1] Tom Talerico and Rick Winch, Glacier Consulting Group, critical review by Ralph Prahl, Prahl and Associates, *State of Wisconsin Department of Administration, Division of Energy. Focus on Energy Public Benefits Evaluation: Home Performance with ENERGY STAR® and Wisconsin ENERGY STAR® Homes ECM Furnace Impact Assessment Report*, June 28, 2004.

[2] Because ECM furnaces installed in existing homes comprise the vast majority (97 percent) of the impacts derived from ECM furnace program activity, the research focused solely on ECM furnaces installed in existing homes.

assessment of the reasons for changes in furnace fan operation behavior among purchasers of ECM furnaces.

## 1.1 KEY FINDINGS AND CONCLUSIONS

This study shows that a considerable number of homeowners who purchase ECM furnaces significantly increase the frequency with which they operate their furnace fan subsequent to the installation of the ECM furnace. In particular, these homeowners switched their fan operation behavior from never running their furnace fan independent of the operation of the furnace or CAC (setting the fan switch on their thermostat to "auto") to running their furnace fans 24 hours per day, every day depending on the time of the year (setting the fan switch on their thermostats to "on").

The root cause for switching fan operation behavior has substantial ramifications on ECM furnace savings estimates. At one extreme, if switching is due entirely to installation of the ECM furnace (technology-induced), then the savings from the installation of the ECM furnace are entirely negated and energy use actually increases. This is because the increase in operating hours from switching more than offsets the increase in efficiency of the ECM furnace over the non-ECM furnace. At the other extreme, if switching is due entirely to the installation of new furnaces in general and independent of the installation of an ECM furnace (naturally occurring), then savings from the installation of the ECM furnace increase. This is because these homeowners would have switched behavior even if they had installed a non-ECM furnace. Therefore, the degree to which switching fan operation behavior is technology-induced or naturally occurring is crucial for determining ECM furnace savings estimates.

Based on the information we have, namely the practices of participants before and after installation and the practices of a control group before and after installation, we considered using three different baseline scenarios from which to calculate ECM savings for participants who switched fan operation behavior subsequent to the ECM furnace. The first is to use practices of participants before the installation as the baseline. This assumes that all switching is technology-induced. The second is to use the practices of participants after the installation as the baseline. This assumes that all switching is naturally occurring. The third is to use changes in practices among a control group to understand naturally occurring changes in practices. This assumes that the incidence of changes in practices among the control group is representative of changes in practices that are naturally occurring due to the installation of new furnaces in general.

We recommend using the savings estimates based on the control group baseline assumption. This results in a savings estimate of 733 kWh for existing homes (Table 1–1).

**Table 1–1. Alternate Baseline Assumptions**

| Savings Estimates by Baseline Assumptions | | |
|---|---|---|
| **Before Installation (All Switching Technology-induced)** | **Control Group** | **After Installation (All Switching Naturally Occurring)** |
| 626 | 733 | 1,216 |

For existing homes, the use of the control group results in a much higher prevalence of technology-induced versus naturally occurring switching. For example, the 733 kWh estimate is much closer to the 626 kWh estimate, which assumes that all changes were technology-induced, than the 1,216 kWh estimate, which assumes that all changes are naturally occurring. In other words, the use of the control group tells us that homeowners who install ECM furnaces are increasing their furnace fan operation more considerably than would be expected (via the switching behavior of the control group) had they installed a non-ECM furnace.

We assert that the predominance of technology-induced over naturally occurring switching is entirely reasonable. One of the key findings from this study is that advice from HVAC contractors plays a pivotal role in homeowner's decision to change from auto to continuous mode subsequent to the installation of the ECM furnace. In particular, HVAC contractors tell participants about a wide array of benefits (saving energy/money, air circulation, not costing much to operate the fan, even temperature, air filtration, increased comfort), with much of their advice related to running the ECM furnace fan continuously to fully take advantage of these benefits. These findings, which are from the perspective of the homeowner, are corroborated by findings from interviews we conducted with HVAC contractors actively involved with EHC. The HVAC contractor interview results show that the type of furnace fan operation advice given by contractors varies significantly by whether or not customers have installed an ECM furnace. Almost 70 percent of HVAC contractors always recommend continuous fan operation to ECM furnace purchasers who were previously operating their fan in auto mode and none never do. On the other hand, only 20 percent of HVAC contractors reported that they always recommend continuous fan operation to non-ECM furnace purchasers previously operating in auto mode and over half said that they never do. The stark contrast between these results shows that HVAC contractor recommendations to switch fan operation behavior from auto to continuous mode are driven in large part by the installation of the ECM furnace itself. These results support this study's finding on the prevalence of technology-induced switching behavior from auto to continuous mode and is consistent with the results from the previous study.

Another key study finding is that almost two thirds of interviewed HVAC contractors tell ECM purchasers that switching from auto to continuous operation will save money or cost the same as remaining in auto mode with the ECM. This trend was also documented in the previous analysis. This study demonstrates that the increase in operating hours caused by switching from auto to continuous mode will offset the electricity savings from the ECM furnace, unless continuous fan operation reduces furnace/CAC runs times sufficiently to counter the increase in fan electrical consumption as a result of switching from auto to continuous mode. This study did not formally address the effects of furnace fan operation methods on the run times of furnaces and CACs, but many interviewed HVAC contractors believe that running the fan continuously increases comfort and/or provides more even temperatures in the house and that these improved conditions in turn decrease furnace and CAC run times, either by inducing homeowners to decrease (increase) their thermostat setting during the heating (cooling) season or by causing the thermostat to be satisfied during a longer period of time throughout the day reducing the need to call for heating/cooling. We recommend that future technical ECM research investigate these issues to more fully understand the effects of fan operation practices on furnace and CAC electrical use.

The two central limitations to the study are related to the control group.[3] First, the control group is based on a relatively small sample size of nonparticipant replacers. This study, however, more than doubled the sample size from the previous study (82 versus 36 interviews, respectively). Unfortunately, the budget allocated for this evaluation research was not sufficient to fund the extra cost to identify additional nonparticipant replacers. That said, the results from this research are consistent with those from the previous study. Second, self-selection issues are inherent in any research that employs a control group. In this study, for example, we cannot say with certainty that participants are not comprised of those who are predisposed to switching furnace fan behavior. While future research can attempt to address self-selection issues, the efforts will be hindered by the fact that the data required from the respondent is based, in part, on responses to hypothetical scenarios and self-reported actions in the absence of information to which they have already been exposed. In other words, the purchase decision process they experienced as a result of the ECM furnace installation has the potential to bias their responses to hypothetical questions about what they would have done in the absence of going through the purchase process in the first place.

The major issue is the extent to which the control group is an adequate representation of naturally occurring changes in switching behavior subsequent to the installation of a new furnace. Despite the study's limitations, the findings clearly demonstrate that (1) a considerable number of homeowners who purchase ECM furnaces increase the frequency with which they operate their furnace fan continuously subsequent to the installation of the ECM furnace, (2) advice from HVAC contractors plays a pivotal role in homeowner's decision to increase fan operation, and (3) HVAC contractors are more likely to tell homeowners to increase their fan operation if they install an ECM furnace versus a non-ECM furnace. When taken together, these three findings are indicative of technology-induced switching behavior, which is entirely consistent with the representation of the control group. Therefore, we conclude that the control group provides the best possible benchmark currently available for determining the extent to which switching fan operation behavior subsequent to the installation of the ECM furnace is technology-induced versus naturally occurring.

[3] Study limitations are discussed more thoroughly in Chapter 6 of this report.

## 2. BACKGROUND

This study was designed to update a previous impact analysis report for furnaces with electronically commutated motors (ECMs).[4] Because the way in which people operate their furnace fans has significant ramifications on ECM furnace impacts, the purpose of this study is to examine the behavioral aspects of ECM furnace fan operation and apply these behavioral results to previously established technology-based savings estimates; thereby providing an update of the savings that derive from installing ECM furnaces in Wisconsin homes. This study assesses not only furnace fan operation behavior both before and after the installation of the furnace but also the reasons why changes in behavior occurred.

This assessment is important for two reasons. First, Focus on Energy (Focus) has continued its emphasis on and promotion of ECM furnaces as part of its Efficient Heating and Cooling (EHC) program. Second, the size of ECM furnace impacts, which relative to other Focus-qualifying measures is large, is highly dependent on customer operational behavior and little independent research is available documenting the prevalence of various types of furnace fan operational behavior among homeowners in Wisconsin.

In this study, we assess furnace fan operation practices during three periods (heating season, cooling season, and shoulder periods).

1. *Heating season* is the time of the year when temperatures are cold enough that homeowners need to run their furnaces to heat their homes.

2. *Cooling season* is the time of the year when temperatures are warm enough that homeowners decide to run their central air conditioners (CACs) to cool their homes.

3. *Shoulder periods* are the times of the year, particularly spring and fall, when homeowners are not running their furnaces to heat their homes and ***not*** running their CACs to cool their homes.

For each of these periods, we classify furnace fan operation into three categories (auto, continuous, sporadic).

1. *Auto mode operation* is when the furnace fan operates only when the furnace or CAC is operating. From the perspective of thermostat operation, this entails leaving the fan switch set to “auto” all of the time during the period in question.

2. *Continuous operation* is when the furnace fan is always operating during the period in question, regardless of whether or not the furnace or CAC is operating. From the perspective of thermostat operation, this entails leaving the fan switch set to “on” all of the time during the period in question.

3. *Sporadic operation* is when the furnace fan is operated independent of furnace and CAC operation at various times during the period in question, but not all of the time during the period in question. From the perspective of thermostat operation, this entails

[4] Tom Talerico and Rick Winch, Glacier Consulting Group, critical review by Ralph Prahl, Prahl and Associates, *State of Wisconsin Department of Administration, Division of Energy. Focus on Energy Public Benefits Evaluation: Home Performance with ENERGY STAR® and Wisconsin ENERGY STAR® Homes ECM Furnace Impact Assessment Report*, June 28, 2004.

setting the fan switch to “auto” some of the time and to “on” some of the time during the period in question.

The way in which people operate their furnace fans has significant ramifications on ECM furnace impacts. Of the three categories, *auto mode operation* yields the lowest ECM furnace impacts and *continuous operation* yields the highest impacts. This assumes, however, that furnace fan operating characteristics subsequent to the installation of an ECM furnace are the same as they would have been had an ECM furnace not been installed. The extent to which this is not the case has potential ramifications on ECM furnace impacts. For example, the incidence of homeowners changing their behavior from *auto mode operation* to *continuous operation* solely as a result of the ECM technology would result in lower savings potential.

The body of this report is organized as follows.

- Chapter 3 outlines the study approach. Here we discuss the study objectives, the interview approach, and the types of interviews we conducted (EHC participants, nonparticipant furnace replacers, and participating HVAC contractors).
- Chapter 4 presents the derivation of ECM impacts for existing homes. We discuss EHC participant and nonparticipant furnace replacer interview results pertaining to furnace fan operation behavior both before and after the installation of the furnace and present a very detailed step-by-step explanation of the impact estimation process. We also include comparisons to results from the previous analysis.
- Chapter 5 presents the key results from the EHC participant and nonparticipant furnace replacer interviews and the HVAC contractor interviews. The focus of the discussion is on the reasons why changes in furnace fan operation behavior occurred.
- Chapter 6 presents our recommendations for which ECM impact estimate to apply to existing homes. We also discuss the key issues for consideration and identify the limitations inherent in this research, including suggestions for future research efforts to address these limitations.

Five appendices are included at the end of the report.

- Appendix A presents the key inputs, from the previously conducted ECM field study, for deriving technology-related impacts for ECM furnaces.
- Appendix B presents other findings from the interviews with participant and nonparticipant furnace replacers.
- Appendix C contains the guide used for the EHC participant interviews.
- Appendix D contains the guide used for the nonparticipant furnace replacer interviews.
- Appendix E contains the interview guide used for the HVAC contractor interviews.

# 3. STUDY APPROACH

## 3.1 OVERVIEW OF STUDY OBJECTIVES

This study was designed to update a previous impact analysis report for furnaces with electronically commutated motors (ECMs).[5] Because the way in which people operate their furnace fans has significant ramifications on ECM furnace impacts, the purpose of this study is to examine the behavioral aspects of ECM furnace fan operation and apply these behavioral results to previously established technology-based savings estimates; thereby providing an update of the savings that derive from installing ECM furnaces in Wisconsin homes. This study assesses not only furnace fan operation behavior both before and after the installation of the furnace but also the reasons why changes in behavior occurred.

## 3.2 CUSTOMER INTERVIEW APPROACH

The focus of the interviews was to assess how homeowners operate their furnace fans throughout the year and understand the reasons why operation practices have changed among those homeowners who modified their practices subsequent to the installation of the new furnace. The interviews also addressed HVAC contractor advice on furnace fan operation practices, furnace filter maintenance, housing characteristics, and household demographics.

Figure 3–1 provides an example of the protocol (in matrix form) that we used to assess furnace fan operation practices among homeowners. The interviews were conducted by Tom Talerico and Rick Winch of Glacier Consulting Group during the period of January–March 2008. The detailed interview guides are presented in Appendices C–D.

Starting with the heating season, we asked respondents about the furnace fan operation method they use on their new furnace and recorded one of the following three categories (auto, continuous, or sporadic). Because the interviews were conducted during the heating season, we asked respondents to go to their thermostat and tell us whether the fan switch was set to “on” or “auto” in order to confirm the method they reported. For those operating their new furnace in continuous or sporadic mode, we asked for the reasons why they operate the new furnace this way. We also asked respondents about the furnace fan operation method they used during the heating season on their old furnace and recorded one of the three categories (auto, continuous, or sporadic). If the operation method on the old furnace differed from that on the new furnace, we asked respondents about the reasons for the change. We then proceeded to follow the same process for the cooling season and shoulder periods.

[5] Tom Talerico and Rick Winch, Glacier Consulting Group, critical review by Ralph Prahl, Prahl and Associates, *State of Wisconsin Department of Administration, Division of Energy. Focus on Energy Public Benefits Evaluation: Home Performance with ENERGY STAR® and Wisconsin ENERGY STAR® Homes ECM Furnace Impact Assessment Report*, June 28, 2004.

**Figure 3–1. Example of Furnace Fan Operation Protocol (in matrix form)**

| Question | | | Heating Season | Cooling Season | Shoulder Periods |
|---|---|---|---|---|---|
| New Furnace | **Method** | | Auto Continuous Sporadic | Auto Continuous Sporadic | Auto Continuous Sporadic |
| | **Continuous/Sporadic** | Reasons | | | |
| | **Sporadic** | Situations | | | |
| | | Days Per Month | | | |
| | | Hours Per Typical Day | | | |
| Old Furnace | **Method** | | Auto Continuous Sporadic | Auto Continuous Sporadic | Auto Continuous Sporadic |
| | **Old Method ≠ New Method** | Reasons for change | | | |

## 3.3 CUSTOMER GROUPS INTERVIEWED

As part of the study, we conducted a total of 232 interviews between two groups of homeowners (Table 3–1):[6] Each of these groups is discussed below.

**Table 3–1. Interviews by Homeowner Group**

| Homeowner Group | Number of Interviews | Response Rate | Precision Level[1] |
|---|---|---|---|
| EHC Participants with ECM Furnaces | 150 | 65% | ± 8% |
| Nonparticipant Furnace Replacers[2] (*Control Group*) | 82 | 81% | ± 11% |
| **Total** | **232** | | |

[1] At 95% confidence level.
[2] 2,044 of the 8,000 nonparticipant homeowners canvassed were spoken to directly. Of these 2,044 homeowners, 101 replaced their furnace in the last two years. We completed 82 interviews with this group of 101 nonparticipant furnace replacers.

*EHC Participants with ECMs*. We conducted 150 interviews with owners of existing homes who purchased an ECM furnace through EHC. The results from this group are used to estimate savings for ECM furnaces installed in existing homes.

*Nonparticipant Furnace Replacers*. We conducted 82 interviews with owners of existing homes who recently purchased a new furnace outside of EHC. The sample for this group was identified through calling a sample of single-family homeowners and screening for households that replaced a furnace during the last two years. To eliminate participants with an ECM, we screened the homeowner list against the historical list of program participants by phone number and eliminated any potential participants. As the control group for participants with ECMs, the results from this group also contribute to estimating savings for ECM furnaces installed in existing homes.

## 3.4 HVAC CONTRACTOR INTERVIEWS

We also completed interviews with 46 HVAC contractors who sold a total of 3,530 ECM furnaces through Focus during 2007, representing over a third of ECM furnaces rewarded through Focus during 2007. The contractors we interviewed covered a range of sales volumes through the program. The interviews were conducted via telephone by Tom Talerico and Rick Winch of Glacier Consulting Group during March-May of 2008. The goal of the HVAC contractor interviews was to provide a better assessment on the reasons for changes in furnace fan operation behavior among purchasers of ECM furnaces. The HVAC contractor interview guide is presented in Appendix E.

[6] Because ECM furnaces installed in existing homes comprise the vast majority (97 percent) of the impacts derived from ECM furnace program activity, the research focused solely on ECM furnaces installed in existing homes.

# 4. ECM FURNACE IMPACT ESTIMATES

This chapter presents the derivation of ECM impacts for existing homes. We discuss customer interview results pertaining to furnace fan operation behavior both before and after the installation of the furnace and present a very detailed step-by-step explanation of the impact estimation process. We also include comparisons to results from the previous analysis.[7] In Chapter 5, we discuss the reasons why changes in furnace fan operation behavior occurred.

## 4.1 STEP 1: CALCULATE DISTRIBUTION OF OPERATION PRACTICES

To assess ECM impacts in existing homes, we analyzed interview data from EHC participants who purchased a new ECM furnace and a control group of nonparticipant furnace replacers. The first step in the estimation process is to calculate the distribution of respondents from these two groups across the three operation categories (auto, continuous, sporadic) for each of the three seasons (heating, cooling, and shoulder) both before and after the installation of the new furnace. Table 4–1 presents the distribution for these two groups.

**Table 4–1. Operation Practices**

| Season | Fan Operation Practice | Participants with ECM Furnace (n=150) | | Nonparticipant Furnace Replacers (n=82) | |
|---|---|---|---|---|---|
| | | Before | After | Before | After |
| Heating Season | Auto | 90.7% | 73.3% | 91.5% | 90.2% |
| | Continuous | 9.3% | 25.3% | 6.1% | 7.3% |
| | Sporadic | 0.0% | 1.3% | 2.4% | 2.4% |
| Cooling Season | Auto | 81.3% | 65.3% | 85.4% | 82.9% |
| | Continuous | 14.7% | 30.7% | 7.3% | 9.8% |
| | Sporadic | 4.0% | 4.0% | 7.3% | 7.3% |
| Shoulder Periods | Auto | 86.7% | 81.3% | 91.5% | 87.8% |
| | Continuous | 7.3% | 13.3% | 2.4% | 6.1% |
| | Sporadic | 6.0% | 5.3% | 6.1% | 6.1% |

There are two key findings. First, there is significant movement from auto to continuous operation in each of the three seasons among participants subsequent to the installation of the ECM furnace. For example during the heating season, 90.7 percent of participants operated their furnace fan in auto mode and 9.3 percent operated continuously before the installation of the new furnace; whereas after the installation of the new furnace, 73.3 percent of participants operated their furnace fan in auto mode, 25.3 percent operated continuously, and 1.3 percent operated sporadically. Second, participants were more likely than

[7] *State of Wisconsin Department of Administration, Division of Energy. Focus on Energy Public Benefits Evaluation: Home Performance with ENERGY STAR® and Wisconsin ENERGY STAR® Homes ECM Furnace Impact Assessment Report*, issued by Tom Talerico and Rick Winch, Glacier Consulting Group, critical review by Ralph Prahl, Prahl and Associates, June 28, 2004.

nonparticipant replacers to operate their furnace fans continuously in each of the three seasons before the installation of the new furnace. For example during the cooling season, 14.7 percent of participants operated their furnace fan continuously before the installation of the new furnace compared to 7.3 percent of nonparticipant replacers. These trends are similar to those found in the previous analysis.

## 4.2 STEP 2: DOCUMENT CHANGES IN PRACTICES

The next step is to document the specific changes in practices among participants and the control group before and after the installation of the new furnace. This is important because, as discussed in the next section, each of these behavioral changes has ramifications on the savings potential from installing an ECM furnace.

**Table 4–2. Changes in Practices**

| Season | Fan Operation Practice | | Participants with ECM Furnace (n=150) | Nonparticipant Furnace Replacers (n=82) |
|---|---|---|---|---|
| | Before | After | | |
| **Heating Season** | Auto | | 72.0% | 89.0% |
| | Continuous | | 7.3% | 4.9% |
| | Auto | Continuous | 18.0% | 2.4% |
| | Sporadic | | 0.0% | 2.4% |
| | Auto | Sporadic | 0.7% | 0.0% |
| | Other[1] | | 2.0% | 1.2% |
| **Cooling Season** | Auto | | 64.0% | 82.9% |
| | Continuous | | 13.3% | 7.3% |
| | Auto | Continuous | 17.3% | 2.4% |
| | Sporadic | | 4.0% | 7.3% |
| | Auto | Sporadic | 0.0% | 0.0% |
| | Other[1] | | 1.3% | 0.0% |
| **Shoulder Periods** | Auto | | 80.0% | 87.8% |
| | Continuous | | 6.7% | 2.4% |
| | Auto | Continuous | 6.7% | 3.7% |
| | Sporadic | | 5.3% | 6.1% |
| | Auto | Sporadic | 0.0% | 0.0% |
| | Other[1] | | 1.4% | 0.0% |

[1] The "other" category includes changes from sporadic to continuous, sporadic to auto, continuous to sporadic, and continuous to auto.

Table 4–2 presents the changes in practices for these two groups. For example, during the heating season, 72.0 percent of participants operated their furnace in auto mode both before

and after the installation of the ECM furnace; 7.3 percent operated continuously both before and after, and 18.0 percent operated in auto mode before and continuously after.

The key finding is that the incidence of switching from auto to continuous fan operation subsequent to the installation of the new furnace (highlighted in Table 4–2) is significantly higher among participants compared to the control group in each of the three seasons. During the heating season, 18.0 percent of participants versus only 2.4 percent of the control group switched from auto to continuous operation subsequent to the installation of the new furnace. The same general trend in switching from auto to continuous operation subsequent to the installation of the new furnace holds for the cooling season (17.3 percent of participants versus only 2.4 percent of the control group) and the shoulder periods (6.7 percent of participants versus 3.7 percent of the control group). These trends are similar to those found in the previous analysis.

## 4.3 STEP 3: ESTIMATE SAVINGS FOR PRACTICES

The next step is to determine savings estimates for each practice within each of the three seasons. The savings estimates are based on a previous field study funded by the residential program administrator, Wisconsin Energy Conservation Corporation (WECC). The field study addressed the operational characteristics of new ECM and non-ECM furnaces to derive technology-based savings estimates for ECM furnaces.[8] The key inputs for deriving these savings estimates are presented in Appendix A.

Table 4–3 presents the savings estimates for each practice within each of the three seasons and annually. It is important to note that savings in the cooling season depend on whether or not a homeowner has a CAC. Therefore, we present the savings estimates for those without CAC in brackets to differentiate the cooling season and annual estimates. Using the cooling season as an example, furnace fan operation in auto mode both before and after the installation of the ECM furnace yields savings of 65 kWh with a CAC and -10 kWh without a CAC;[9] operation continuously both before and after yields savings of 910 kWh with a CAC and 960 kWh without a CAC; and operation in auto mode before and continuously after yields savings of -119 kWh with a CAC and -221 kWh without a CAC. Annual savings (illustrated at the bottom of Table 4–3) are simply the sum of savings from the heating season, cooling season, and shoulder periods.

There are two key findings. First, annual savings are significantly higher for those who operated continuously both before and after installation of the new furnace (3,470 with a CAC and 3,520 without a CAC). Second, those who operated in auto mode before the installation and continuously after the installation actually increase their energy use (-216 with a CAC and -318 without a CAC). This is because the increase in operating hours more than offsets the increase in efficiency of the ECM furnace over the non-ECM furnace.

[8] Wisconsin Department of Administration (DOA). 2003. *Electricity Use by New Furnaces: A Wisconsin Field Study*. Technical Report 230-1. Madison, Wisconsin: Wisconsin Department of Administration. The key inputs from this research that are incorporated in this study are presented in Appendix A.

[9] ECM furnaces use slightly more electricity than non-ECM furnaces do in *standby* mode. In the absence of a CAC, *standby* is the only operation mode during the entire cooling season, causing negative savings for ECM furnaces. This is explained in more detail in Appendix A.

**Table 4–3. Savings Estimates for Practices**

| Season | Fan Operation Practice | | Savings Estimate for Type of Practice[1] |
|---|---|---|---|
| | Before | After | |
| Heating Season | Auto | | 386 |
| | Continuous | | 1,800 |
| | Auto | Continuous | 78 |
| | Sporadic | | 786 |
| | Auto | Sporadic | 353 |
| | Other[2] | | 611 |
| Cooling Season | Auto | | 65 [-10] |
| | Continuous | | 910 [960] |
| | Auto | Continuous | -119 [-221] |
| | Sporadic | | 172 [97] |
| | Auto | Sporadic | -14 [-88] |
| | Other[2] | | 167 [101] |
| Shoulder Periods | Auto | | -8 |
| | Continuous | | 760 |
| | Auto | Continuous | -175 |
| | Sporadic | | 171 |
| | Auto | Sporadic | -37 |
| | Other[2] | | -163 |
| Annual | Auto | | 443 [368] |
| | Continuous | | 3,470 [3,520] |
| | Auto | Continuous | -216 [-318] |
| | Sporadic | | 1,129 [1,054] |
| | Auto | Sporadic | 302 [228] |
| | Other[2] | | 615 [549] |

[1] We present the savings estimates for those without CAC in brackets for the cooling season and annual estimates because savings in the cooling season depend on whether or not a homeowner has a CAC.
[2] The "other" category includes changes from sporadic to continuous, sporadic to auto, continuous to sporadic, and continuous to auto.

## 4.4 STEP 4: DERIVE ESTIMATES FOR BASELINE SCENARIOS

The next step is to determine the most appropriate baseline from which to calculate ECM savings for participants who changed practices based on the information we have, namely the practices of participants before and after installation and the practices of nonparticipant replacers before and after installation. We considered three scenarios. The first is to use

practices of participants before the installation as the baseline. This assumes that all changes in practices are due entirely to installation of the ECM furnace (technology-induced). The second is to use the practices of participants after the installation as the baseline. This assumes that all changes in practices are not technology-induced, but rather entirely due to the installation of new furnaces in general and independent of the installation of an ECM furnace installation (naturally occurring). The third is to use changes in practices among the nonparticipant replacer control group to understand naturally occurring changes in practices. This assumes that the incidence of changes in practices among the control group is representative of changes in practices that are naturally occurring due to the installation of new furnaces in general. The results from each of these three scenarios are discussed below.

### 4.4.1 Scenario 1: Practices before Installation as Baseline

Table 4–4 presents savings estimates for each of the three seasons and annually using practices of participants before the installation as the baseline. The general approach involves bringing together the behavioral data from Table 4–2 and the savings information from Table 4–3. Specifically, for each of the practices within each of the seasons, we multiply the savings estimate for each practice (from Table 4–3) by the percent of participants who use that practice in the season (from Table 4–2) to calculate the relative impact that each practice has on overall savings in a season. We then sum the relative impacts across each of the practices within each season to determine the overall impact in the season. The annual savings are simply the sum of the savings across the three seasons. For example during the heating season, the impact of operating in auto mode both before and after the installation of the furnace (386 kWh) is multiplied by the percent of participants who operated in auto mode both before and after the installation (72.0 percent) yielding the relative contribution of this practice (278 kWh) to heating season savings. This algorithm is followed for each of the other five practices in the heating season (continuous before and after, auto before and continuous after, sporadic before and after, auto before and sporadic after, and other). Then, the 438 kWh estimate is derived by adding the relative contribution across all six practices. The same process is followed for the cooling season and shoulder periods. The end result of using practices before the installation of the ECM furnace as the baseline is annual savings of 629 kWh for households with a CAC and 566 kWh for households without a CAC. Again, the key assumption for this scenario is that all changes in practices are due entirely to installation of the ECM furnace (technology-induced).

**Table 4–4. Practices before Installation as Baseline**

| Season | Fan Operation Practice | | Participants with ECM Furnace (n=150) | Savings Estimate for Type of Practice[1] | Savings from Listed Practices[1] | Total Savings[1] |
|---|---|---|---|---|---|---|
| | Before | After | | | | |
| Heating Season | Auto | | 72.0% | 386 | 278 | 438 |
| | Continuous | | 7.3% | 1,800 | 131 | |
| | Auto | Continuous | 18.0% | 78 | 14 | |
| | Sporadic | | 0.0% | 786 | 0 | |
| | Auto | Sporadic | 0.7% | 353 | 2 | |
| | Other[2] | | 2.0% | 611 | 12 | |
| Cooling Season | Auto | | 64.0% | 65 [-10] | 42 [-6] | 151 [88] |
| | Continuous | | 13.3% | 910 [960] | 121 [128] | |
| | Auto | Continuous | 17.3% | -119 [-221] | -21 [-38] | |
| | Sporadic | | 4.0% | 172 [97] | 7 [4] | |
| | Auto | Sporadic | 0.0% | -14 [-88] | 0 [0] | |
| | Other[2] | | 1.3% | 167 [101] | 2 [1] | |
| Shoulder Periods | Auto | | 80.0% | -8 | -6 | 40 |
| | Continuous | | 6.7% | 760 | 51 | |
| | Auto | Continuous | 6.7% | -175 | -12 | |
| | Sporadic | | 5.3% | 171 | 9 | |
| | Auto | Sporadic | 0.0% | -37 | 0 | |
| | Other[2] | | 1.4% | -163 | -2 | |
| Annual | Auto | | | 443 [368] | 313 [265] | **629 [566]** |
| | Continuous | | | 3,470 [3,520] | 303 [310] | |
| | Auto | Continuous | | -216 [-318] | -18 [-36] | |
| | Sporadic | | | 1,129 [1,054] | 16 [13] | |
| | Auto | Sporadic | | 302 [228] | 2 [2] | |
| | Other[2] | | | 615 [549] | 12 [11] | |

[1] We present the savings estimates for those without CAC in brackets for the cooling season and annual estimates because savings in the cooling season depend on whether or not a homeowner has a CAC.
[2] The "other" category includes changes from sporadic to continuous, sporadic to auto, continuous to sporadic, and continuous to auto.

### 4.4.2 Scenario 2: Practices after Installation as Baseline

Table 4–5 presents savings estimates for each of the three seasons and annually using practices of participants after the installation as the baseline. Impacts for this scenario are estimated in the same manner as that in the previous scenario. Given that we are using

behavior after the installation as the baseline, however, affects the savings estimates that are used for practices in which behavior changed from before to after. For example, during the heating season, the savings estimate for auto before and continuous after is 1,800 kWh. This is identical to the savings estimate for those who were continuous before and after, namely because this scenario assumes that all of those who changed from auto to continuous would have done so anyway, regardless of the type of furnace installed. The end result of using practices after the installation of the ECM furnace as the baseline is annual savings of 1,218 kWh for households with a CAC and 1,182 kWh for households without a CAC. Again, the key assumption for this scenario is that all changes in practices are not technology-induced, but rather entirely due to the installation of new furnaces in general and independent of the installation of an ECM furnace installation (naturally occurring).

**Table 4–5. Practices after Installation as Baseline**

| Season | Fan Operation Practice | | Participants with ECM Furnace (n=150) | Savings Estimate for Type of Practice[1] | Savings from Listed Practices[1] | Total Savings[1] |
|---|---|---|---|---|---|---|
| | Before | After | | | | |
| Heating Season | Auto | | 72.0% | 386 | 278 | 766 |
| | Continuous | | 7.3% | 1,800 | 131 | |
| | Auto | Continuous | 18.0% | 1,800 | 324 | |
| | Sporadic | | 0.0% | 786 | 0 | |
| | Auto | Sporadic | 0.7% | 538 | 4 | |
| | Other[2] | | 2.0% | 1,447 | 29 | |
| Cooling Season | Auto | | 64.0% | 65 [-10] | 42 [-6] | 337 [301] |
| | Continuous | | 13.3% | 910 [960] | 121 [128] | |
| | Auto | Continuous | 17.3% | 910 [960] | 157 [166] | |
| | Sporadic | | 4.0% | 172 [97] | 7 [4] | |
| | Auto | Sporadic | 0.0% | 427 [352] | 0 [0] | |
| | Other[2] | | 1.3% | 741 [766] | 10 [10] | |
| Shoulder Periods | Auto | | 80.0% | -8 | -6 | 115 |
| | Continuous | | 6.7% | 760 | 51 | |
| | Auto | Continuous | 6.7% | 760 | 51 | |
| | Sporadic | | 5.3% | 171 | 9 | |
| | Auto | Sporadic | 0.0% | 129 | 0 | |
| | Other[2] | | 1.4% | 760 | 11 | |
| Annual | Auto | | | 443 [368] | 313 [265] | **1,218 [1,182]** |
| | Continuous | | | 3,470 [3,520] | 303 [310] | |
| | Auto | Continuous | | 3,470 [3,520] | 532 [541] | |
| | Sporadic | | | 1,129 [1,054] | 16 [13] | |
| | Auto | Sporadic | | 1,094 [1,019] | 4 [4] | |
| | Other[2] | | | 2,948 [2,973] | 49 [50] | |

[1] We present the savings estimates for those without CAC in brackets for the cooling season and annual estimates because savings in the cooling season depend on whether or not a homeowner has a CAC.
[2] The "other" category includes changes from sporadic to continuous, sporadic to auto, continuous to sporadic, and continuous to auto.

### 4.4.3 Scenario 3: Control Group as Baseline

Table 4–6 presents savings estimates for each of the three seasons and annually using the control group as the baseline. Impacts for this scenario are estimated in the same manner as that used in the previous two scenarios. This method, however, uses the control group to

estimate the naturally occurring rate of switching behavior from auto to continuous in each of the three seasons after the purchase of a new furnace. Using the heating season as an example, this rate is estimated by taking the percent of the control group that switched from auto to continuous (2.4 percent) divided by the percent of the control group that operated in auto mode before the installation (91.4 percent). The result is a naturally occurring rate of 2.6 percent. This rate is then applied to the percent of participants that operated in auto mode before the installation (90.7 percent) to yield 2.4 percent as the naturally occurring percent of participants that would have switched from auto to continuous. An impact estimate of 1,800 kWh is applied to this estimate, while the lower estimate of 78 kWh is applied to the remaining portion of those switching from auto to continuous (15.6 percent). The same was done for the cooling season and shoulder periods. The end result of using the control group as the baseline is annual savings of 736 kWh for households with a CAC and 678 kWh for households without a CAC. Again, the key assumption for this scenario is that the incidence of changes in practices among the control group is representative of changes in practices that are naturally occurring due to the installation of new furnaces in general.

**Table 4–6. Control Group as Baseline**

| Season | Fan Operation Practice | | Participants with ECM Furnace (n=150) | Savings Estimate for Type of Practice[1] | Savings from Listed Practices[1] | Total Savings[1] |
|---|---|---|---|---|---|---|
| | Before | After | | | | |
| Heating Season | Auto | | 72.0% | 386 | 278 | 481 |
| | Continuous | | 7.3% | 1,800 | 131 | |
| | Auto | Continuous | 2.4% | 1,800 | 43 | |
| | Auto | Continuous | 15.6% | 78 | 12 | |
| | Sporadic | | 0.0% | 786 | 0 | |
| | Auto | Sporadic | 0.7% | 353 | 2 | |
| | Other[2] | | 2.0% | 703 | 14 | |
| Cooling Season | Auto | | 64.0% | 65 [-10] | 42 [-6] | 178 [120] |
| | Continuous | | 13.3% | 910 [960] | 121 [128] | |
| | Auto | Continuous | 2.4% | 910 [960] | 22 [23] | |
| | Auto | Continuous | 14.9% | -119 [-221] | -18 [-33] | |
| | Sporadic | | 4.0% | 172 [97] | 7 [4] | |
| | Auto | Sporadic | 0.0% | -14 [-88] | 0 [0] | |
| | Other[2] | | 1.3% | 330 [341] | 4 [4] | |
| Shoulder Periods | Auto | | 80.0% | -8 | -6 | 77 |
| | Continuous | | 6.7% | 760 | 51 | |
| | Auto | Continuous | 3.7% | 760 | 28 | |
| | Auto | Continuous | 3.0% | -175 | -5 | |
| | Sporadic | | 5.3% | 171 | 9 | |
| | Auto | Sporadic | 0.0% | -37 | 0 | |
| | Other[2] | | 1.4% | 31 | 0 | |
| Annual | Auto | | | 443 [368] | 313 [265] | **736 [678]** |
| | Continuous | | | 3,470 [3,520] | 303 [310] | |
| | Auto | Continuous | | 3,470 [3,520] | 93 [94] | |
| | Auto | Continuous | | -216 [-318] | -11 [-26] | |
| | Sporadic | | | 1,129 [1,054] | 16 [13] | |
| | Auto | Sporadic | | 302 [228] | 2 [2] | |
| | Other[2] | | | 1,064 [1,075] | 19 [19] | |

[1] We present the savings estimates for those without CAC in brackets for the cooling season and annual estimates because savings in the cooling season depend on whether or not a homeowner has a CAC.
[2] The "other" category includes changes from sporadic to continuous, sporadic to auto, continuous to sporadic, and continuous to auto.

## 4.5 STEP 5: DETERMINE OVERALL IMPACT ESTIMATES

Because the estimates vary depending on CAC ownership, the final step is to weight CAC and non-CAC estimates by the proportion of CACs among participants to determine the

overall impact estimate for ECM furnaces in existing homes. Table 4–7 presents the results for each of the three baseline scenarios.

**Table 4–7. Overall Impact Estimates for Existing Homes by Baseline Scenario**

| CAC Ownership | Percent of Participants (n=150) | Savings Estimate | | |
|---|---|---|---|---|
| | | Scenario 1: Practices Before as Baseline | Scenario 2: Practices After as Baseline | Scenario 3: Control Group as Baseline |
| CAC | 95.3% | 629 | 1,218 | 736 |
| No CAC | 4.7% | 566 | 1,182 | 678 |
| **Savings Weighted by CAC Ownership** | | **626** | **1,216** | **733** |

The end result is a savings estimate of 626 kWh using practices before the installation as the baseline, 1,216 kWh using practices after the installation as the baseline, and 733 kWh using the control group as the baseline. These results are slightly lower but in the general range of the results from the previous study and the modified savings estimate that was updated in May 2008.[10]

[10] As discussed in Appendix A, ECW completed a CAC field study that provided updated information on annual hours of cooling operation, which resulted in lower annual cooling hours than those used in the previous analysis. In May 2008, we modified the ECM savings estimates using the updated results from the ECW study, which resulted in a savings estimate of 759 kWh, which is lower than the 774 kWh estimate (control group as baseline) from the previous analysis.

# 5. KEY CUSTOMER AND HVAC CONTRACTOR INTERVIEW RESULTS

This chapter presents key results from the customer and HVAC contractor interviews. Results pertaining to furnace fan operation behavior both before and after the installation of the furnace were discussed in Chapter 4. In this chapter, we discuss the reasons why changes in furnace fan operation behavior occurred. The areas addressed are as follows:

- Reasons for using continuous/sporadic operation
- Reasons for changes in operation method subsequent to installation of ECM furnace
- Furnace fan operation advice given by HVAC contractor (from both the perspective of the homeowner and the HVAC contractor)

The findings for each of the above areas are compared across the two homeowner groups (EHC participants and nonparticipant furnace replacers). We also include comparisons to results from the previous analysis.[11]

## 5.1 REASONS FOR USING CONTINUOUS/SPORADIC OPERATION

We asked participants and nonparticipant replacers who operate their furnace fan continuously/sporadically both before and after the installation of the ECM furnace for the reasons why they operate this way. Tables 5–1 through 5–3 present the reasons given by for each of the three periods. As the tables illustrate, air circulation, even temperature, air filtration, and comfort are the more commonly mentioned reasons, with air circulation cited most prevalently. These results are comparable to the previous analysis.

**Table 5–1. Reasons for Using Continuous/Sporadic Operation–Heating Season***

| Reason | Participants with ECM Furnace (n=11)[1] | Nonparticipant Furnace Replacers (n=6)[2] |
|---|---|---|
| Air circulation | 54.5% | 66.7% |
| Even temperature | 45.5% | 0.0% |
| Air filtration | 18.2% | 16.7% |
| More comfortable | 9.1% | 0.0% |
| Advice from family/friends | 9.1% | 0.0% |
| Not cost much | 9.1% | 0.0% |
| No specific reason | 9.1% | 16.7% |

* The shaded cells highlight the most prevalent responses within each of the homeowner groups.
[1] A total of 17 responses were given by the 11 respondents.
[2] A total of 6 responses were given by the 6 respondents.

[11] Tom Talerico and Rick Winch, Glacier Consulting Group, critical review by Ralph Prahl, Prahl and Associates, *State of Wisconsin Department of Administration, Division of Energy. Focus on Energy Public Benefits Evaluation: Home Performance with ENERGY STAR® and Wisconsin ENERGY STAR® Homes ECM Furnace Impact Assessment Report*, June 28, 2004.

**Table 5–2. Reasons for Using Continuous/Sporadic Operation–Cooling Season***

| Reason | Participants with ECM Furnace (n=26)[1] | Nonparticipant Furnace Replacers (n=12)[2] |
|---|---|---|
| Air circulation | 65.4% | 83.3% |
| Even temperature | 26.9% | 0.0% |
| Air filtration | 11.5% | 8.3% |
| More comfortable | 11.5% | 25.0% |
| Moisture control | 3.8% | 0.0% |
| Advice from family/friends | 3.8% | 0.0% |
| Not cost much | 3.8% | 0.0% |
| No specific reason | 7.7% | 8.3% |

* The shaded cells highlight the most prevalent responses within each of the homeowner groups.
[1] A total of 35 responses were given by the 11 respondents.
[2] A total of 15 responses were given by the 6 respondents.

**Table 5–3. Reasons for Using Continuous/Sporadic Operation–Shoulder Periods***

| Reason | Participants with ECM Furnace (n=18)[1] | Nonparticipant Furnace Replacers (n=7)[2] |
|---|---|---|
| Air circulation | 66.7% | 57.1% |
| Even temperature | 16.7% | 0.0% |
| Air filtration | 11.1% | 14.3% |
| More comfortable | 5.6% | 28.6% |
| Moisture control | 5.6% | 0.0% |
| Not cost much | 5.6% | 0.0% |
| No specific reason | 11.1% | 14.3% |

* The shaded cells highlight the most prevalent responses within each of the homeowner groups.
[1] A total of 22 responses were given by the 18 respondents.
[2] A total of 8 responses were given by the 7 respondents.

## 5.2 REASONS FOR CHANGES FROM AUTO TO CONTINUOUS/SPORADIC OPERATION SUBSEQUENT TO INSTALLATION OF ECM FURNACE

We asked participants who changed their furnace fan operation method from auto mode before to continuous/sporadic mode after the installation of the ECM furnace for the reasons why they changed. Table 5–4 presents the reasons given by participants for each of the three periods. As the tables illustrate, air circulation is the most commonly cited reason. For example, 25.0 percent of participants mention air circulation as a reason for changing from auto to continuous during the heating season. This is comprised of 19.9 percent who explicitly mentioned air circulation based on advice from the HVAC contractor and 7.1 percent who generally cited air circulation with no reference to contractor advice. Air circulation was also

the most commonly mentioned reason in the previous analysis. Finally, advice from HVAC contractors plays a pivotal role in the decision to change from auto to continuous/sporadic mode subsequent to the installation of the ECM furnace. During the heating season, for example, 71 percent of participants mentioned a reason related to contractor advice, and out of all the responses given, 68 percent pertained to contractor advice. This is higher than the previous analysis where 56 percent of participants mentioned a reason related to contractor advice, and out of all the responses given, 51 percent pertained to contractor advice. In the table, responses relating to contractor advice are *italicized* and preceded by a √.

**Table 5–4. Reasons for Changing from Auto to Continuous/Sporadic Operation**

| Reason | Participants Who Changed Behavior | | |
|---|---|---|---|
| | Heating Season (n=28)[1] | Cooling Season (n=26)[2] | Shoulder Periods (n=10)[3] |
| Air circulation | 7.1% | 11.5% | 20.0% |
| √ *Contractor advice: Air circulation* | *17.9%* | *34.6%* | *20.0%* |
| √ *Contractor advice: Save energy/money* | *21.4%* | *23.1%* | *10.0%* |
| Even temperature | 3.6% | 3.8% | 10.0% |
| √ *Contractor advice: Even temperature* | *14.3%* | *19.2%* | *10.0%* |
| Increase comfort | 3.6% | 7.7% | 10.0% |
| √ *Contractor advice: Increase comfort* | *7.1%* | *11.5%* | *10.0%* |
| Old furnace issues | 10.7% | 0.0% | 10.0% |
| Air filtration | 0.0% | 3.8% | 0.0% |
| √ *Contractor advice: Air filtration* | *7.1%* | *3.8%* | *10.0%* |
| Moisture control | 7.1% | 3.8% | 10.0% |
| √ *Contractor advice: Moisture control* | *0.0%* | *3.8%* | *10.0%* |
| More efficient motor | 7.1% | 7.7% | 20.0% |
| √ *Contractor advice: More efficient motor* | *0.0%* | *3.8%* | *10.0%* |
| √ *Contractor advice: Less wear and tear* | *3.6%* | *3.8%* | *0.0%* |
| √ *Contractor advice: Not cost much* | *3.6%* | *11.5%* | *20.0%* |
| Family/friend advice | 3.6% | 0.0% | 0.0% |
| No specific reason | 0.0% | 3.8% | 0.0% |
| √ *Contractor advice: No specific reason* | *17.9%* | *3.8%* | *0.0%* |
| Percent of *Respondents* Giving Reasons Relating to Contractor Advice | 71% | 73% | 50% |
| Percent of *Responses* Relating to Contractor Advice | 68% | 74% | 56% |

[1] A total of 38 responses were given by the 28 respondents.
[2] A total of 42 responses were given by the 26 respondents.
[3] A total of 18 responses were given by the 10 respondents.

## 5.3 FURNACE FAN OPERATION ADVICE GIVEN BY HVAC CONTRACTOR– HOMEOWNER PERSPECTIVE

We asked participants and nonparticipant replacers if their HVAC contractor told them anything about the amount of electricity used by the fan motor of the new furnace or about how to operate the fan on the new furnace. The results are presented in Table 5–5. As the table illustrates, participants were more likely to receive furnace fan operation advice than their counterparts in the nonparticipant furnace replacer control group (49.3 percent vs. 20.7 percent). The previous analysis yielded the same trend, however, the percent of participants and nonparticipant furnace replacers who received advice was higher (60.7 percent and 25.0 percent, respectively).

**Table 5–5. Received Furnace Fan Operation Advice from HVAC Contractor***

| Received Advice | Participants with ECM Furnace (n=150) | Nonparticipant Furnace Replacers (n=82) |
|---|---|---|
| Yes | 49.3% | 20.7% |
| No | 34.7% | 67.1% |
| Don't Know | 16.0% | 12.2% |

* The shaded cells highlight the most prevalent responses within each of the homeowner groups.

Among those who received advice, we asked about what the HVAC contractor told them about the amount of electricity used by the fan motor of the new furnace or about how to operate the fan on the new furnace. The results are presented in Table 5–6. As the table illustrates, HVAC contractors tell participants about a wide array of benefits (saving energy/money, air circulation, not costing much to operate the fan, even temperature, air filtration, increased comfort), with much of their advice related to running the ECM furnace fan continuously to fully take advantage of these benefits. For example, 43.2 percent of participants mention that their HVAC contractor talked to them about the saving energy/money from the ECM furnace, with 13.5 percent saying that their HVAC contractor told them to run their furnace fan continuously because this practice would save energy/money. Further, 55 percent of participants mentioned a reason related to continuous fan operation advice, and out of all the responses given, 61 percent pertain to continuous fan operation. This is much higher than the rates among nonparticipant furnace replacers (12 percent). These trends are similar to the trends from the previous analysis. In the table, responses relating to continuous fan operation are *italicized* and preceded by a √.

**Table 5–6. Type of Advice Received from HVAC Contractor***

| Reason | Participants with ECM Furnace (n=74)[1] | Nonparticipant Furnace Replacers (n=17)[2] |
|---|---|---|
| Save energy/money | 29.7% | 52.9% |
| √ *Run fan continuously: Save energy/money* | *13.5%* | *0.0%* |
| √ *Run fan continuously: Air circulation* | *14.9%* | *0.0%* |
| √ *Run fan continuously: Not cost much* | *12.2%* | *5.9%* |
| DC motor/variable speed | 9.5% | 17.6%[3] |
| √ *Run fan continuously: DC motor /variable speed* | *2.7%* | *0.0%* |
| √ *Run fan continuously: Even temperature* | *9.5%* | *0.0%* |
| √ *Run fan continuously: Air filtration* | *5.4%* | *0.0%* |
| √ *Run fan continuously: Increase comfort* | *4.1%* | *0.0%* |
| How to operate | 4.1% | 0.0% |
| √ *Run fan continuously: Moisture control* | *2.7%* | *0.0%* |
| √ *Run fan continuously: Quiet fan/less noise* | *1.4%* | *0.0%* |
| √ *Run fan continuously: Less wear and tear* | *1.4%* | *0.0%* |
| √ *Run fan continuously: No specific reason* | *12.2%* | *5.9%* |
| Not recall specifics | 8.1% | 17.6% |
| √ *Run fan continuously: Not recall specifics* | *1.4%* | *0.0%* |
| Percent of *Respondents* Giving Reasons Relating to Continuous Fan Operation | 55% | 12% |
| Percent of *Responses* Relating to Continuous Fan Operation | 61% | 12% |

* The shaded cells highlight the most prevalent responses within each of the homeowner groups.

[1] A total of 98 responses were given by the 74 respondents.

[2] A total of 17 responses were given by the 17 respondents.

[3] Three nonparticipant furnace replacers said that their contractor told them that their furnace had a variable speed fan. This does not necessarily mean that these three customers installed an ECM furnace, as it could signify that these customers installed a two-stage furnace without an ECM motor. These three customers do not impact the results from the analysis, however, because none of them switched their fan operation from auto to continuous.

## 5.4 FURNACE FAN OPERATION ADVICE GIVEN BY HVAC CONTRACTOR–CONTRACTOR PERSPECTIVE

The above results are from the perspective of the homeowner. To provide a better assessment on the reasons for changes in furnace fan operation behavior, we also interviewed HVAC contractors to provide their perspective. We found that the contractor perspective corroborates the perspective of the homeowner. In the remainder of this chapter, we present the HVAC contractor interview results pertaining to furnace fan operation behavior.

We asked HVAC contractors how often they recommend continuous fan operation to customers who install ECM furnaces. Results are presented below in Table 5-7. Almost three-

quarters of 46 interviewed contractors reported that they always recommend continuous fan operation to customers who install ECM furnaces, 24 percent mentioned that they occasionally recommend continuous fan operation or that it depends on the situation, and only one interviewed contractor (two percent) said that he never recommends continuous fan operation. In the previous study, we found that 60 percent of HVAC contractors always recommended continuous fan operation to customers who install ECM furnaces.

**Table 5–7. HVAC Contractor Recommendation of Continuous Fan Operation to ECM Furnace Purchasers**

| Recommend Continuous Fan Operation | # of Contractors | Percent of Contractors |
|---|---|---|
| Always | 34 | 74% |
| Depends/Occasionally | 11 | 24% |
| Never | 1 | 2% |

When asked about the reasons why they recommend continuous fan operation to customers who install ECM furnaces, air filtration (67 percent), comfort (56 percent), and even temperatures (56 percent) were the three most commonly mentioned reasons among the 45 contractors who recommend continuous fan operation. Other frequently cited reasons included air circulation (22 percent), humidity/moisture control (22 percent), and saving energy/money (22 percent). Results are presented below in Table 5-8. The same trends were found in the previous analysis.

**Table 5–8 Reasons for Recommending Continuous Fan Operation to ECM Furnace Purchasers***

| Reasons for Recommending Continuous Fan Operation | # of Contractors | Percent of Contractors |
|---|---|---|
| Air filtration | 30 | 67% |
| Comfort | 25 | 56% |
| Even temperatures | 25 | 56% |
| Air circulation | 10 | 22% |
| Humidity/moisture control | 10 | 22% |
| Save energy/money | 10 | 22% |
| Not cost much | 4 | 9% |
| Less wear and tear | 4 | 9% |
| Quiet operation | 4 | 9% |
| Less use of space heaters | 1 | 2% |
| No reason | 1 | 2% |

* This question was not asked to the one contractor who never recommends continuous fan operation. A total of 124 responses were given by the 45 respondents.

We also asked the 45 HVAC contractors who recommend continuous fan operation if they recommend continuous fan operation to ECM furnace purchasers who were previously operating their fan in auto mode with their old furnace. Results are presented below in Table 5-9. The results confirm that these contractors make this recommendation even if the customer was operating in auto mode previously to installing the ECM furnace. This result is consistent with results from the previous analysis.

**Table 5–9. HVAC Contractor Recommendation of Continuous Fan Operation to ECM Furnace Purchasers Previously Operating in Auto Mode***

| Recommend Continuous Fan Operation | # of Contractors | Percent of Contractors |
|---|---|---|
| Always | 31 | 69% |
| Depends/Occasionally | 14 | 31% |
| Never | 0 | 0% |

* This question was not asked to the one contractor who never recommends continuous fan operation.

We then asked the 45 contractors who recommend continuous fan operation to ECM purchasers who previously were operating in auto mode if they tell these customers that they will save money by changing from auto to continuous fan operation. Results are presented below in Table 5-10. Almost two thirds (65 percent) tell ECM purchasers that switching from auto to continuous operation will save money (56 percent) or cost the same (9 percent) as remaining in auto mode with the ECM. As demonstrated in Chapter 4, however, the increase in operating hours caused by switching from auto to continuous mode offsets the electricity savings from the ECM furnace and results in an increase in electricity use if operated continuously year-round. Unless continuous fan operation reduces furnace/CAC runs times sufficiently to counter the increase in fan electrical consumption as a result of switching from auto to continuous mode, the HVAC contractors who promise energy savings or the same cost to customers if they switch from auto to continuous mode are providing inaccurate advice which is actually contributing to an increase in electricity use. This trend was also documented in the previous analysis.

**Table 5–10. What Contractors Tell ECM Purchasers about Costs of Switching Behavior from Auto to Continuous Operation***

| Costs of Switching Behavior | # of Contractors | Percent of Contractors |
|---|---|---|
| Saves money | 25 | 56% |
| Costs the same | 4 | 9% |
| Costs more money | 10 | 22% |
| Not sure about the costs | 6 | 13% |

* This question was not asked to the one contractor who never recommends continuous fan operation.

Next, we asked these 45 contractors if they recommend continuous fan operation to non-ECM furnace purchasers who were previously operating their fan in auto mode with their old furnace. Results are presented below in Table 5-11. Only 20 percent of these contractors reported that they always recommend continuous fan operation to non-ECM furnace purchasers previously operating in auto mode and over half said that they never do. As shown previously (Table 5-9), almost 70 percent of these 45 contractors always recommend continuous fan operation to ECM furnace purchasers who were previously operating their fan in auto mode and none never do. The stark contrast between these results shows that HVAC contractor recommendations to switch fan operation behavior from auto to continuous mode are driven in large part by the installation of the ECM furnace itself. This finding is consistent with the findings from the previous study.

**Table 5–11. HVAC Contractor Recommendation of Continuous Fan Operation to non-ECM Furnace Purchasers Previously Operating in Auto Mode***

| Recommend Continuous Fan Operation | # of Contractors | Percent of Contractors |
|---|---|---|
| Always | 9 | 20% |
| Depends/Occasionally | 12 | 27% |
| Never | 24 | 53% |

* This question was not asked to the one contractor who never recommends continuous fan operation.

Finally, we asked the 21 contractors who recommend continuous fan operation to non-ECM purchasers who previously were operating in auto mode if they tell these customers that they will save money by changing from auto to continuous fan operation. Results are presented below in Table 5-12. Only 14 percent tell non-ECM purchasers that switching from auto to continuous operation will save money and 76 percent tell customers that it will cost more money. Again, these results are in stark contrast to the previous results shown in Table 5-10.

**Table 5–12. What Contractors Tell non-ECM Purchasers about Costs of Switching Behavior from Auto to Continuous Operation***

| Costs of Switching Behavior | # of Contractors | Percent of Contractors |
|---|---|---|
| Saves money | 3 | 14% |
| Costs the same | 0 | 0% |
| Costs more money | 16 | 76% |
| Not sure about the costs | 2 | 10% |

* This question was not asked to the one contractor who never recommends continuous fan operation and the 24 contractors who never recommend continuous fan operation to non-ECM furnace purchasers previously operating in auto mode.

# 6. RECOMMENDATIONS AND KEY ISSUES

In this chapter, we present our recommendations on which ECM impacts estimates to apply to existing homes. We also discuss the key issues for consideration and identify the limitations inherent in this research, including suggestions for future research efforts to address these limitations. Our suggestions, however, do not imply that we think the study is weak or lacking in substance. To the contrary, we think that the study is strong and the findings are robust, and make suggestions solely to further strengthen the results. Further, we must point out that Focus evaluation funds have been limited, making implementation of these suggestions not feasible for this evaluation effort.

## 6.1 RECOMMENDATIONS

We recommend using the savings estimates based on the control group baseline assumption. This results in savings estimates of 773 kWh for existing homes (Table 6–1). As the table illustrates, savings estimates vary widely depending on the baseline assumptions used–from 626 to 1,216 kWh.

**Table 6–1. Alternate Baseline Assumptions**

| Savings Estimates by Baseline Assumptions | | |
|---|---|---|
| **Before Installation (All Switching Technology-induced)** | **Control Group** | **After Installation (All Switching Naturally Occurring)** |
| 626 | 733 | 1,216 |

The major issue is the extent to which the control group is an adequate representation of naturally occurring changes in furnace fan operation from auto to continuous mode subsequent to the installation of a new furnace. While there are limitations to the use of the control group, which are thoroughly discussed next in the *Key Issues and Limitations* section, we are confident that the control group provides the best possible benchmark available for determining the extent to which changes in operation from auto to continuous mode among participating homeowners subsequent to the installation of the ECM furnace were technology-induced versus naturally occurring.

For existing homes, the use of the control group results in a much higher prevalence of technology-induced versus naturally occurring switching. For example, the 733 kWh estimate is much closer to the 626 kWh estimate, which assumes that all changes were technology-induced, than the 1,216 kWh estimate, which assumes that all changes are naturally occurring. We assert that the predominance of technology-induced over naturally occurring switching is entirely reasonable given that (1) the advice from HVAC contractors is pivotal in the decision of participating homeowners to switch from auto to continuous mode subsequent to the installation of the ECM furnace and (2) HVAC contractors are much more likely to give continuous fan operation advice to those who buy ECM furnaces than to those who buy non-ECM furnaces. These two findings are discussed in more detail below in the *Key Issues and Limitations* section.

## 6.2 KEY ISSUES AND LIMITATIONS

### 6.2.1 Corroboration with HVAC Contractor Results

One of the key findings from this study is that advice from HVAC contractors plays a pivotal role in homeowner's decision to change from auto to continuous mode subsequent to the installation of the ECM furnace. In particular, HVAC contractors tell participants about a wide array of benefits (saving energy/money, air circulation, not costing much to operate the fan, even temperature, air filtration, increased comfort), with much of their advice related to running the ECM furnace fan continuously to fully take advantage of these benefits.

These findings, which are from the perspective of the homeowner, are corroborated by findings from interviews we conducted with HVAC contractors actively involved with EHC. Three findings from the HVAC contractor interviews that bear upon the results from this study are briefly discussed below.

- First, the type of furnace fan operation advice given by interviewed contractors varies significantly by whether or not customers have installed an ECM furnace. Almost 70 percent of HVAC contractors always recommend continuous fan operation to ECM furnace purchasers who were previously operating their fan in auto mode and none never do. On the other hand, only 20 percent of HVAC contractors reported that they always recommend continuous fan operation to non-ECM furnace purchasers previously operating in auto mode and over half said that they never do. The stark contrast between these results shows that HVAC contractor recommendations to switch fan operation behavior from auto to continuous mode are driven in large part by the installation of the ECM furnace itself. These results support this study's finding on the prevalence of technology-induced switching behavior from auto to continuous mode and is consistent with the results from the previous study.
- Second, almost two thirds (65 percent) tell ECM purchasers that switching from auto to continuous operation will save money (56 percent) or cost the same (9 percent) as remaining in auto mode with the ECM. As demonstrated in Chapter 4, however, the increase in operating hours caused by switching from auto to continuous mode offsets the electricity savings from the ECM furnace and results in an increase in electricity use if operated continuously year-round. Unless continuous fan operation reduces furnace/CAC runs times sufficiently to counter the increase in fan electrical consumption as a result of switching from auto to continuous mode, the HVAC contractors who promise energy savings or the same cost to customers if they switch from auto to continuous mode are providing inaccurate advice which is actually contributing to an increase in electricity use. This trend was also documented in the previous analysis. The issue of continuous fan use effects on furnace/CAC use is discussed later in this section.
- Finally, air filtration, comfort, and even temperatures were the most commonly cited reasons that interviewed HVAC contractors gave for recommending continuous fan operation to ECM furnace purchasers. These reasons are entirely consistent with what homeowner's reported in this study and are consistent with results from the previous study.

### 6.2.2 Control Group Issues

The study's use of nonparticipant furnace replacers as the control group for EHC participants who installed ECM furnaces is based on the following two key assumptions.

1. Nonparticipant furnace replacers did not install an ECM furnace

2. Nonparticipant furnace replacers and participants who operated their furnace in auto mode prior to the installation of the ECM furnace have the same predisposition to switching their operation from auto to continuous mode subsequent to the installation

We discuss each of these two assumptions below.

*A. NONPARTICIPANT ECM FURNACE INSTALLATIONS*

Regarding the first assumption, we acknowledge that not receiving a rebate for an ECM furnace through EHC does not preclude the installation of an ECM furnace by nonparticipant furnace replacers and that it is possible that a subset of this group indeed installed an ECM furnace. If ECM purchasers were in the control group, then the control group would be over-estimating the incidence of naturally occurring auto-to-continuous fan switching behavior, which would mean that use of the control group savings value of 733 kWh would over-estimate actual savings. We discuss below two scenarios regarding this important issue and the implications for the analysis.

Based on an analysis of FACTs and program data the evaluation team conducted to measure net-to-gross adjustments for ECM furnaces, we estimate that roughly 10 percent of the furnaces purchased outside EHC are ECM furnaces.[12] If this estimate is correct, then we would expect about 8 of the 82 replacers in the control group to have installed an ECM furnace. For the heating season, we know that 18 percent of participants who installed an ECM switched operation from auto to continuous. Applying this rate to the eight nonparticipant replacers whom we would have expected to install an ECM yields 1-2 nonparticipants whom we would have expected to have switched from auto to continuous. The actual number of nonparticipants we identified as switching from auto to continuous was two. A possible interpretation of the actual number being within the range of the expected number is that the control group simply represents technology-induced switching behavior and not naturally occurring switching behavior. Application of this interpretation would mean that use of the control group savings value of 733 kWh would over-estimate actual savings.

On the other hand, 20 percent of interviewed HVAC contractors reported that they always recommend continuous fan operation to non-ECM furnace purchasers previously operating in auto mode. While this result is much lower than the 70 percent of contractors who always recommend continuous fan operation to ECM furnace purchasers who were previously operating their fan in auto mode, 20 percent is a non-trivial percentage. If this estimate is

[12] Tom Talerico and Rick Winch, Glacier Consulting Group, critical review by Ralph Prahl, Prahl and Associates *State of Wisconsin, Public Service Commission of Wisconsin, Focus on Energy Evaluation. Net-to-Gross Savings Adjustments for ECM Furnaces*, September 30, 2008. The analysis (see Table 3) shows 17,798 ECMs sold in WI during 2007. Of these, 10,300 were through EHC, leaving 7,498 purchased by nonparticipants. The analysis estimates the overall market size at 82,382 FAFs. Subtracting the 10,300 ECMs purchased through EHC leaves 72,082 FAFs sold to nonparticipants. This means that roughly 10 percent (7,498 / 72,082) of nonparticipant FAF purchases were ECMs.

correct, then we would expect that 20 percent of auto-mode operating nonparticipants who installed a non-ECM furnace to have received HVAC contractor recommendations to switch fan operation behavior from auto to continuous mode. From the analysis in the previous paragraph, we would expect about eight of the 82 replacers in the control group to have installed an ECM furnace, which means that the remaining 74 would be expected to have installed a non-ECM furnace. For the heating season, we know that about 92 percent of nonparticipants operated in auto mode prior to the furnace replacement, which means 68 nonparticipants (92 percent x 74) both installed a non-ECM furnace and operated their fan in auto mode prior to the installation. Applying the 20 percent contractor switching advice estimate to these 68 nonparticipants yields 13–14 nonparticipants who both installed a non-ECM furnace and who received advice from their HVAC contractor to switch fan operation behavior from auto to continuous. Not all customers, however, will follow the recommendations from their HVAC contractor. To estimate the percent that we would expect to follow advice, we look at participants who installed ECM furnaces. We know that 70 percent of contractors always recommend continuous fan operation to ECM furnace purchasers who were previously operating their fan in auto mode. We also know that 18 percent of participants switched their operation from auto to continuous during the heating season. We use these two results to generate a proxy for nonparticipants and estimate that roughly 25 percent of nonparticipants would have followed the switching advice of their contractor. Applying this estimate to the 13–14 nonparticipants who received switching advice means that we could have expected 3–4 nonparticipants who installed a non-ECM furnace to have changed from auto to continuous fan operation. Again, the actual number of nonparticipants we identified as switching from auto to continuous was two.[13] A possible interpretation of the actual number being less than expected number is that the control group under-estimates naturally occurring switching behavior. Application of this interpretation would mean that use of the control group savings value of 733 kWh would under-estimate actual savings.

Unfortunately, we cannot determine which of the above two plausible scenarios, and associated possible interpretations, best represents reality. Until more definitive information can be brought to bear on this issue, we recommend continued use of the control group to establish ECM furnace impacts, which was the precedent established in the previous analysis.

One way for future research efforts to verify whether or not a nonparticipating customer has an ECM furnace is through collecting make and model number information from the customer, either on the phone or through an on-site visit, and then checking this information in Gas Appliance Manufacturers Association (GAMA) manuals to determine if it is an ECM furnace. The challenges to this approach are: (1) the collection of this information may cause a decrease in the survey response rate (though as footnote 13 reveals, extraordinarily cooperative respondents do exist) and (2) it is expensive to gather and look-up this information. Another option is to design a series of questions to identify whether or not the customer has an ECM furnace. The challenges to this approach are: (1) ECM furnaces are

[13] We did definitively identify one nonparticipant who switched from auto to continuous and who installed an ECM furnace. We eliminated this respondent from the analysis. During the nonparticipant replacement identification process, replacing respondents who agreed to do an interview with us were scheduled a day or two in advance of our calling. The respondent whom we excluded from the analysis independently prepared for the interview in advance and provided to us, unprompted, the make and model number of the furnace he installed. We investigated this information and found that he had installed an ECM furnace.

not typically identified as such to the end-user by contractors and through the product literature which may make them hard to identify through use of consistent terminology (this has been and continues to be an issue for respondent self-reports of even a simpler, more commonly known technology like a CFL)[14] and (2) there are also two-stage furnaces without ECMs available that have both a high and low fan motor speed latter and these could easily be a misidentified as ECM furnaces.

*B. PREDISPOSITION TO SWITCHING*

Regarding the second assumption, we acknowledge that self-selection issues are inherent in any research that employs a control group. In this study, we cannot say with certainty that participants are not comprised of those who are predisposed to changing from auto to continuous mode. In order to be classified as naturally occurring switchers, respondents would have to meet two conditions. First, they would need to have been either: (1) aware of their ability to run continuously, but not aware of the benefits; (2) not aware of their ability to run continuously and not aware of the benefits; or (3) not aware of their ability to run continuously, but aware of the benefits. Second, they would need to have still run continuously even if they had installed a non-ECM furnace. While research can attempt to address this issue, the efforts will be hindered by the fact that the data required from the respondent is based, in part, on responses to hypothetical scenarios and self-reported actions in the absence of information to which they have already been exposed. In other words, the purchase decision process they experienced as a result of the ECM furnace installation has the potential to bias their responses to hypothetical questions about what they would have done in the absence of going through the purchase process in the first place.

### 6.2.3 Sample Sizes

A limitation of the study was the small sample size of nonparticipant replacers. This study, however, more than doubled the sample size from the previous study (82 versus 36 interviews, respectively). Unfortunately, the budget allocated for this evaluation research was not sufficient to fund the extra cost to identify additional nonparticipant replacers. That said, the results from this research are consistent with those from the previous study.

### 6.2.4 Effect of Fan Operation on Furnace and CAC Use

This study did not formally address the effects of furnace fan operation methods on the run times of furnaces and CACs; however, as discussed earlier in this chapter, we know that many HVAC contractors that were interviewed believe that switching operation from auto mode to continuous mode will still decrease energy use and think that running the fan continuously increases comfort by providing more even temperatures in the house. This

[14] Perhaps the most comprehensive CFL installation study to date (involving telephone survey self-reports followed by site-visits) found that consumers had difficultly accurately self-reporting whether or not they even had CFLs in their home: “There had been a hypothesis that consumers might be accurate in at least knowing when they do not have any CFLs. In other words, that a telephone survey report of ‘zero CFLs installed’ would be accurate. This could then be used to limit necessary site visits to just those that reported having CFLs. Yet, we found that of those that reported having no CFLs, only half were accurate. The other half of these respondents did have CFLs.” (Source: Appendix B, page B-1, Evaluation of Massachusetts ENERGY STAR® Residential Lighting Program PY2004, Volume 2 Revised April 8, 2005, Submitted by Megdal & Associates and Opinion Dynamics Corporation).

finding raises two issues regarding the effect of furnace fan operation on furnace and CAC use.

- First, to what extent does running the furnace fan continuously increase the comfort of homeowners, and if comfort is increased, does the improved comfort have any effects on how homeowners set their thermostats? In order for there to be less furnace and CAC use (i.e., a positive effect on savings), continuous fan operation would need to increase comfort and this increased comfort, in turn, would need to induce homeowners to decrease their thermostat setting during the heating season and/or increase their thermostat setting during the cooling season.
- Second, to what extent does running the furnace fan continuously provide more even temperature throughout the house, and if the temperature is more even, how does the more even temperature affect the frequency with which the thermostat calls for heating/cooling? In order for there to be less furnace and CAC use (i.e., positive effect on savings), continuous fan operation would need to provide more even temperature and this more even temperature, in turn, would need to cause the thermostat to be satisfied during a longer period of time throughout the day reducing the need to call for heating/cooling.

We, therefore, recommend that any future technical ECM research address these issues to more fully understand the effects of fan operation practices on furnace and CAC use.

### 6.2.5 Non-Energy Benefits

The study identified a number of potential non-energy benefits from continuous fan operation. These include increased air circulation (comfort-related), more even temperature (comfort-related), and air filtration (health-related). The study, however, did not formally assess the extent to which these benefits accrued to homeowners. The budget allocated for this evaluation research, however, was not sufficient to fund the extra cost to fully quantify these benefits.

### 6.2.6 New ECM Furnaces Replacing Old ECM Furnaces

We did not collect information on the type of furnace replaced as part of this study, therefore, we do not know for certain if the ECM furnaces installed by participants were replacing non-ECM furnaces or ECM furnaces. We think, however, that the prevalence of ECMs replacing ECMs would be uncommon, but acknowledge that ECMs have been around for long enough now that a few of them could have failed prematurely. This issue will be more relevant in the future as more and more ECM furnaces bought in the past are replaced with ECM furnaces. From an attribution perspective, the effects of ECM-to-ECM replacements, like CFL-to-CFL replacements, would be accounted for in the net-to-gross analysis, assuming methods similar to the current market-based approaches are being applied.[15] From a behavioral perspective, a key issue will be the magnitude of technology-induced auto-to-continuous switching behavior at the time of the initial ECM purchase among customers who also installed an ECM on the subsequent purchase and the extent to which subsequent ECM purchasers who switched from auto to continuous on the initial purchase due to technology-related reasons

[15] Tom Talerico and Rick Winch, Glacier Consulting Group, critical review by Ralph Prahl, Prahl and Associates, *State of Wisconsin, Public Service Commission of Wisconsin, Focus on Energy Evaluation. Analysis of Delta Watts Values for CFLs Rewarded through the Residential Lighting Program during FY07,* March 6, 2008.

would have reverted back to auto operation if they had not installed an ECM on their subsequent purchase. Similar to addressing the self-selection bias issue (see previous discussion in 6.2.2.B), research can attempt to address the behavioral issues of ECM-to-ECM replacements, but the efforts will be hindered by the fact that the data required from the respondent is based, in part, on responses to hypothetical scenarios, self-reported actions, and initial decisions that were made, most likely, many years prior when they initially installed an ECM furnace. Moreover, research addressing the behavioral aspects of ECM-to-ECM replacements will be faced with challenges to verify whether or not the furnace replaced was indeed an ECM furnace (see previous discussion at the conclusion of 6.2.2.A).

## *APPENDIX A: IMPACT ESTIMATE ASSUMPTIONS*

This study was designed to update a previous impact analysis report for furnaces with electronically commutated motors (ECMs).[16] One of the key inputs to the previous analysis was a field study funded by the residential program administrator, Wisconsin Energy Conservation Corporation (WECC). The field study addressed the operational characteristics of new furnaces with and without electronically commutated motors (ECMs) to derive technology-based savings estimates for ECM furnaces.[17] Because the way in which people operate their furnace fans has significant ramifications on ECM furnace impacts, the purpose of this study is to examine the behavioral aspects of ECM furnace fan operation and apply these behavioral results to previously established technology-based savings estimates; thereby providing an update of the savings that derive from installing ECM furnaces in Wisconsin homes.

Appendix A presents the key inputs from the previous analysis and the field study that are incorporated in this study to derive technology-based impacts, independent of behavioral effects, for ECM furnaces.

### A.1 TECHNOLOGY-BASED ESTIMATES

#### A.1.1 Hours of Fan Operation

The field study estimated hours of furnace fan operation by three periods within the year.

1. *Heating season* is the time of the year when temperatures are cold enough that homeowners need to run their furnaces to heat their homes.

2. *Cooling season* is the time of the year when temperatures are warm enough that homeowners decide to run their central air conditioners (CACs) to cool their homes.

3. *Shoulder periods* are the times of the year, particularly spring and fall, when homeowners are not running their furnaces to heat their homes and not running their CACs to cool their homes.

Within each of the above three periods, the field study further differentiated hours by four furnace operation types.

1. The *furnace* operation type is when the fan is running when the furnace is running. This occurs only during the heating season.

2. The *CAC* operation type is when the fan is running when the CAC is running. This occurs only during the cooling season.

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[16] Tom Talerico and Rick Winch, Glacier Consulting Group, critical review by Ralph Prahl, Prahl and Associates, *State of Wisconsin Department of Administration, Division of Energy. Focus on Energy Public Benefits Evaluation: Home Performance with ENERGY STAR® and Wisconsin ENERGY STAR® Homes ECM Furnace Impact Assessment Report*, June 28, 2004.

[17] Wisconsin Department of Administration (DOA). 2003. *Electricity Use by New Furnaces: A Wisconsin Field Study*. Technical Report 230-1. Madison, Wisconsin: Wisconsin Department of Administration.

3. *Standby* is when the fan is not running at all. From the perspective of thermostat operation, this occurs when the fan switch is set to "auto" and the furnace/CAC is not running.

4. *Fan only* is when the fan is running independent of the furnace or CAC running. From the perspective of thermostat operation, this occurs when the fan switch is set to "on" and the furnace/CAC is not running

In the previous analysis and this study, we classify furnace fan operation into three categories.

1. *Auto mode operation* is when the furnace fan operates only when the furnace or CAC is operating. From the perspective of thermostat operation, this entails leaving the fan switch set to "auto" all of the time during the period in question.

2. *Continuous operation* is when the furnace fan is always operating during the period in question, regardless of whether or not the furnace or CAC is operating. From the perspective of thermostat operation, this entails leaving the fan switch set to "on" all of the time during the period in question.

3. *Sporadic operation* is when the furnace fan is operated independent of furnace and CAC operation at various times during the period in question, but not all of the time during the period in question. From the perspective of thermostat operation, this entails setting the fan switch to "auto" some of the time and to "on" some of the time during the period in question.

Each of the above three categories used in this study relates directly to the four furnace operation types defined in the field study. Specifically, *auto mode operation* during an entire period results in 0 *fan only* hours and, depending on the period and the presence of a CAC, a significant number of *standby* hours during that period. *Continuous mode operation* during an entire period, on the other hand, results in 0 *standby* hours and, depending on the period and the presence of a CAC, a significant number of *fan only* hours during that period.

Table A–1 presents the field study estimates of fan operation hours for *auto* and *continuous* modes of operation within each of the three periods across each of the four furnace operation types. As the table illustrates, the field study assumed that the heating season has a total of 4,500 hours, the cooling season has 2,400 hours, and the shoulder periods have 1,900 hours. The allocation of these hours is discussed below.

- The field study assumed that the 4,500 hours within the heating season are allocated for *auto mode operation* as 1,000 *furnace* hours, 0 *CAC* hours, 3,500 *standby* hours, and 0 *fan only* hours and for *continuous mode operation* as 1,000 *furnace* hours, 0 *CAC* hours, 0 *standby* hours, and 3,500 *fan only* hours, regardless of the presence of a CAC.

- The field study assumed that the 2,400 hours within the cooling season are allocated for *auto mode operation* as 0 *furnace* hours, 400 *CAC* hours (or 0 *CAC* hours if no CAC), 2,000 *standby* hours (or 2,400 *standby* hours if no CAC), and 0 *fan only* hours and for *continuous mode operation* as 0 *furnace* hours, 400 *CAC* hours (or 0 *CAC* hours if no CAC), 0 *standby* hours, and 2,000 *fan only* hours (or 2,400 *fan only* hours if no CAC). In 2008, ECW completed a CAC field study that provided updated

information on annual hours of cooling operation.[18] The study estimated 310 annual hours of cooling information, and we use this updated estimate, not the 400 hours estimate from the previous research, in this study.

- The field study assumes that the 1,900 hours within the shoulder periods are allocated for *auto mode operation* as 0 *furnace* hours, 0 *CAC* hours, 1,900 *standby* hours, and 0 *fan only* hours and for *continuous mode operation* as 0 *furnace* hours, 0 *CAC* hours, 0 *standby* hours, and 1,900 *fan only* hours, regardless of the presence of a CAC.

**Table A–1. Hours of Fan Operation**

| Season | Type of Operation | Total Hours | Auto Mode Operation | | Continuous Mode Operation | |
|---|---|---|---|---|---|---|
| | | | CAC | No CAC | CAC | No CAC |
| Heating Season | Furnace | 4,500 | 1,000 | | 1,000 | |
| | CAC | | 0 | | 0 | |
| | Standby | | 3,500 | | 0 | |
| | Fan Only | | 0 | | 3,500 | |
| Cooling Season | Furnace | 2,400 | 0 | | 0 | |
| | CAC | | 310 | 0 | 310 | 0 |
| | Standby | | 2,090 | 2,400 | 0 | |
| | Fan Only | | 0 | | 2,090 | 2,400 |
| Shoulder Periods | Furnace | 1,900 | 0 | | 0 | |
| | CAC | | 0 | | 0 | |
| | Standby | | 1,900 | | 0 | |
| | Fan Only | | 0 | | 1,900 | |

### A.1.2 Energy Savings

The field study estimated the energy consumption of the typical non-ECM and ECM furnace fan for the *furnace* and *CAC* operation types, and based on these estimates, calculated energy savings for these two types of furnace fan operation (Table A–2). Over the course of the average heating season, the field study found that the typical non-ECM and ECM furnace fan consumes about 800 and 400 kWh of electricity, respectively, resulting in savings of 400 kWh for the *furnace* operation type. Over the course of the average cooling season, the field study found that the typical non-ECM and ECM furnace fan consumes about 250 and 155 kWh of electricity, respectively, resulting in savings of 95 kWh for the *CAC* operation type. Updating these estimates using 310, rather than 400, annual hours of cooling operation yields consumption of 193 and 120 kWh for the typical non-ECM and ECM furnace fan, respectively, resulting in savings of 73 kWh for the *CAC* operation type

[18] Scott Pigg, Energy Center of Wisconsin, *Central Air Conditioning in Wisconsin – A Compilation of Recent Field Research*, 2008.

**Table A–2. Energy Savings for *Furnace* and *CAC* Operation Types**

| Type of Operation | Type of Furnace | | kWh Savings |
|---|---|---|---|
| | Non-ECM | ECM | |
| Furnace | 800 | 400 | 400 |
| CAC | 193 | 120 | 73 |

The savings estimates for the *furnace* and *CAC* operation types are independent of the homeowner's furnace fan operation behavior. Savings for the *standby* and *fan only* types of operation, on the other hand, depend entirely on how the homeowner operates the fan. Therefore, to estimate kWh savings for the *standby* and *fan only* types of operation, we need to apply the hours of operation, which are dependent upon homeowner furnace fan practices, to the associated connected load for each type.

The field study estimated the connected loads of the typical non-ECM and ECM furnace fan for the *standby* and *fan only* operation types (Table A–3). As the table illustrates, the field study found that the typical non-ECM and ECM furnace fan draws about 8 and 12 W of electricity, respectively, resulting in savings of -4 W for the *standby* operation type. For the *fan only* operation type, the field study found that the typical non-ECM and ECM furnace fan draws about 500 and 100W of electricity, respectively, resulting in savings of 400 W.

**Table A–3. *Standby* and *Fan Only* Connected Loads (in Watts)**

| Type of Operation | Type of Furnace | | Difference |
|---|---|---|---|
| | Non-ECM | ECM | |
| Standby | 8 | 12 | -4 |
| Fan Only | 500 | 100 | 400 |

## A.2 BEHAVIORAL-BASED IMPACTS

The impact estimates used in this study are the result of incorporating the technology-based results from Tables A–1 through A–3 to derive behavioral-based savings estimates. Tables A–4 through A–6 show results for three types of behavior: (1) auto mode operation both before and after the installation of the ECM furnace, (2) continuous mode operation both before and after the installation of the ECM furnace, and (3) auto mode operation before the installation of the ECM furnace and continuous mode operation after the installation.

### A.2.1 Auto Mode–Before and After

As Table A–4 illustrates, auto mode operation both before and after the installation of the ECM furnace results in overall savings of 443 kWh with a CAC and 368 kWh without a CAC. The overall savings are the result of adding the savings across the heating season (386 kWh, regardless of CAC), the cooling season (65 kWh with a CAC and -10 kWh without a CAC) and the shoulder periods (-8 kWh, regardless of CAC). Savings for each of the three periods, in turn, are the result of adding the savings across the four furnace fan operation types. Finally, savings for each of the four furnace fan operation types within each season are the result of incorporating the technology-based results from Tables A–1 through A–3. The estimates for the *furnace* operation type within the heating season and the *CAC* operation type within the cooling season are those presented in Table A–2. The *standby* and *fan only*

estimates are derived by applying the hours of operation from Table A–1 to the associated connected load from Table A–3. During the heating season, for example, the *standby* energy consumption of a non-ECM and ECM furnace fan is 28 kWh (3,500 hours x 8 W) and 42 kWh (3,500 hours x 12 W), respectively, resulting in energy savings of -14 kWh (28 kWh - 42 kWh). The *fan only* energy consumption of a non-ECM and ECM furnace fan is 0 kWh (0 hours x 500 W) and 0 kWh (0 hours x 100 W), respectively, resulting in energy savings of 0 kWh.

**Table A–4. Savings–Auto Mode Before and After**

| Season | Type of Operation | CAC | | | No CAC | | |
|---|---|---|---|---|---|---|---|
| | | Non-ECM | ECM | Savings | Non-ECM | ECM | Savings |
| Heating Season | Furnace | 800 | 400 | 400 | 800 | 400 | 400 |
| | CAC | 0 | 0 | 0 | 0 | 0 | 0 |
| | Standby | 28 | 42 | -14 | 28 | 42 | -14 |
| | Fan Only | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 828 | 443 | 386 | 828 | 443 | 386 |
| Cooling Season | Furnace | 0 | 0 | 0 | 0 | 0 | 0 |
| | CAC | 174 | 120 | 73 | 0 | 0 | 0 |
| | Standby | 17 | 25 | -8 | 19 | 29 | -10 |
| | Fan Only | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 210 | 145 | 65 | 19 | 29 | -10 |
| Shoulder Periods | Furnace | 0 | 0 | 0 | 0 | 0 | 0 |
| | CAC | 0 | 0 | 0 | 0 | 0 | 0 |
| | Standby | 15 | 23 | -8 | 15 | 23 | -8 |
| | Fan Only | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 15 | 23 | -8 | 15 | 23 | -8 |
| **Total** | | **1,053** | **611** | **443** | **863** | **495** | **368** |

### A.2.2 Continuous Mode–Before and After

As Table A–5 illustrates, continuous mode operation both before and after the installation of the ECM furnace results in overall savings of 3,470 kWh with a CAC and 3,520 kWh without a CAC. The overall savings are the result of adding the savings across the heating season (1,800 kWh, regardless of CAC), the cooling season (910 kWh with a CAC and 960 kWh without a CAC) and the shoulder periods (760 kWh, regardless of CAC). Savings for each of the three periods, in turn, are the result of adding the savings across the four furnace fan operation types. Finally, savings for each of the four furnace fan operation types within each season are the result of incorporating the technology-based results from Tables A–1 through A–3. The estimates for the *furnace* operation type within the heating season and the *CAC*

operation type within the cooling season are those presented in Table A–2. The *standby* and *fan only* estimates are derived by applying the hours of operation from Table A–1 to the associated connected load from Table A–3. During the heating season, for example, the *standby* energy consumption of a non-ECM and ECM furnace fan is 0 kWh (0 hours x 8 W) and 0 kWh (0 hours x 12 W), respectively, resulting in energy savings of 0 kWh. The *fan only* energy consumption of a non-ECM and ECM furnace fan is 1,750 kWh (3,500 hours x 500 W) and 350 kWh (3,500 hours x 100 W), respectively, resulting in energy savings of 1,400 kWh (1,750 kWh - 350 kWh).

**Table A–5. Savings–Continuous Mode Operation Before and After**

| Season | Type of Operation | CAC | | | No CAC | | |
|---|---|---|---|---|---|---|---|
| | | Non-ECM | ECM | Savings | Non-ECM | ECM | Savings |
| Heating Season | Furnace | 800 | 400 | 400 | 800 | 400 | 400 |
| | CAC | 0 | 0 | 0 | 0 | 0 | 0 |
| | Standby | 0 | 0 | 0 | 0 | 0 | 0 |
| | Fan Only | 1,750 | 350 | 1,400 | 1,750 | 350 | 1,400 |
| | Total | 2,550 | 750 | 1,800 | 2,550 | 750 | 1,800 |
| Cooling Season | Furnace | 0 | 0 | 0 | 0 | 0 | 0 |
| | CAC | 193 | 120 | 73 | 0 | 0 | 0 |
| | Standby | 0 | 0 | 0 | 0 | 0 | 0 |
| | Fan Only | 1,045 | 209 | 836 | 1,200 | 240 | 960 |
| | Total | 1,239 | 329 | 910 | 1,200 | 240 | 960 |
| Shoulder Periods | Furnace | 0 | 0 | 0 | 0 | 0 | 0 |
| | CAC | 0 | 0 | 0 | 0 | 0 | 0 |
| | Standby | 0 | 0 | 0 | 0 | 0 | 0 |
| | Fan Only | 950 | 190 | 760 | 950 | 190 | 760 |
| | Total | 950 | 190 | 760 | 950 | 190 | 760 |
| **Total** | | **4,739** | **1,269** | **3,470** | **4,700** | **1,180** | **3,520** |

### A.2.3 Auto Mode Before and Continuous Mode After

As Table A–6 illustrates, auto mode operation before the installation of the ECM furnace and continuous mode operation after the installation results in overall savings of -216 kWh with a CAC and -317 kWh without a CAC. The overall savings are the result of adding the savings across the heating season (78 kWh, regardless of CAC), the cooling season (-119 kWh with a CAC and -221 kWh without a CAC) and the shoulder periods (-175 kWh, regardless of CAC). Savings for each of the three periods, in turn, are the result of adding the savings across the four furnace fan operation types. Finally, savings for each of the four furnace fan operation types within each season are the result of incorporating the technology-based results from

Tables A–1 through A–3. The estimates for the *furnace* operation type within the heating season and the *CAC* operation type within the cooling season are those presented in Table A–2. The *standby* and *fan only* estimates are derived by applying the hours of operation from Table A–1 to the associated connected load from Table A–3. During the heating season, for example, the *standby* energy consumption of a non-ECM and ECM furnace fan is 28 kWh (3,500 hours x 8 W) and 0 kWh (0 hours x 12 W), respectively, resulting in energy savings of -28 kWh (28 kWh - 0 kWh). The *fan only* energy consumption of a non-ECM and ECM furnace fan is 0 kWh (0 hours x 500 W) and 350 kWh (3,500 hours x 100 W), respectively, resulting in energy savings of -350 kWh (0 kWh - 350 kWh).

**Table A–6. Savings–Auto Mode Before and Continuous Mode After**

| Season | Type of Operation | CAC | | | No CAC | | |
|---|---|---|---|---|---|---|---|
| | | Non-ECM | ECM | Savings | Non-ECM | ECM | Savings |
| Heating Season | Furnace | 800 | 400 | 400 | 800 | 400 | 400 |
| | CAC | 0 | 0 | 0 | 0 | 0 | 0 |
| | Standby | 28 | 0 | 28 | 28 | 0 | 28 |
| | Fan Only | 0 | 350 | -350 | 0 | 350 | -350 |
| | Total | 828 | 750 | 78 | 828 | 750 | 78 |
| Cooling Season | Furnace | 0 | 0 | 0 | 0 | 0 | 0 |
| | CAC | 174 | 120 | 73 | 0 | 0 | 0 |
| | Standby | 17 | 0 | 17 | 19 | 0 | 19 |
| | Fan Only | 0 | 209 | -209 | 0 | 240 | -240 |
| | Total | 210 | 329 | -119 | 19 | 240 | -221 |
| Shoulder Periods | Furnace | 0 | 0 | 0 | 0 | 0 | 0 |
| | CAC | 0 | 0 | 0 | 0 | 0 | 0 |
| | Standby | 15 | 0 | 15 | 15 | 0 | 15 |
| | Fan Only | 0 | 190 | -190 | 0 | 190 | -190 |
| | Total | 15 | 190 | -175 | 15 | 190 | -175 |
| **Total** | | **1,053** | **1,269** | **-216** | **862** | **1,180** | **-318** |

## *APPENDIX B: OTHER CUSTOMER INTERVIEW RESULTS*

This appendix presents other customer interview findings that were not presented in Chapters 4 and 5. Appendices C and D present the interview guides for the customer interviews. We do not include an analogous appendix for HVAC contractor interview results because all contractor results relevant to the impact analysis were reported in Chapter 5. Please see Appendix E for the HVAC contractor interview guide.

Appendix B presents customer interview results addressing the following four areas:

- Furnace filter maintenance
- CAC ownership
- Household characteristics
- Demographics

The findings for each of the above four areas are compared across the two homeowner groups (EHC participants and nonparticipant furnace replacers). We also include comparisons to results from the previous analysis.[19]

### B.1 FURNACE FILTER MAINTENANCE

We asked participants and nonparticipant furnace replacers about how often the filter is changed on their furnace. Results are presented in Table B–1. As the table illustrates, the frequency with which participants change their furnace filters is less than the frequency with which nonparticipant furnace replacers change their furnace filters. This may be due, in part, to the fact that participants are more likely to have had a high performance filter installed with their new furnace, and these filters do not need to be changed as frequently as standard filters. This trend is the same as in the previous analysis, except the percent of participants and nonparticipant furnace replacers who changed their filter annually was lower (33.3 percent and 5.6 percent, respectively).

**Table B–1. Furnace Filter Maintenance***

| Received Advice | Participants with ECM Furnace (n=150) | Nonparticipant Furnace Replacers (n=82) |
|---|---|---|
| Annually | 44.7% | 23.2% |
| Twice per year | 15.3% | 13.4% |
| 3–6 times per year | 19.3% | 36.6% |
| Monthly | 12.7% | 22.0% |
| Every years | 0.7% | 1.2% |

[19] Tom Talerico and Rick Winch, Glacier Consulting Group, critical review by Ralph Prahl, Prahl and Associates, *State of Wisconsin Department of Administration, Division of Energy. Focus on Energy Public Benefits Evaluation: Home Performance with ENERGY STAR® and Wisconsin ENERGY STAR® Homes ECM Furnace Impact Assessment Report*, June 28, 2004.

| Received Advice | Participants with ECM Furnace (n=150) | Nonparticipant Furnace Replacers (n=82) |
|---|---|---|
| Cleans filter | 5.3% | 3.7% |
| Don't know | 2.0% | 0.0% |

* The shaded cells highlight the most prevalent responses within each of the homeowner groups.

## B.2 CAC OWNERSHIP

Table B–2 compares CAC ownership before and after the installation of the new furnace. As the table illustrates, participants are more likely to have a CAC both before and after the installation than their counterparts in the nonparticipant replacer control group (88.0%/95.3% vs. 61.0%/80.5%). The percent of participants with a CAC after the installation of the ECM furnace is higher compared to the previous analysis (92 percent). Another key finding is that homeowners without a CAC are deciding to add a CAC as part of the furnace replacement. This is occurring across both groups and is more prevalent among participants. For example, about 61 percent participants who did not own a CAC before the furnace replacement added a CAC as part of the replacement. This is slightly lower than the previous result for participants (66.7 percent).

**Table B-2. CAC Ownership–Before and After Installation of New Furnace**

| CAC Ownership | Participants with ECM Furnace (n=150) | Nonparticipant Furnace Replacers (n=82) |
|---|---|---|
| % Having CAC Before Installation | 88.0% | 61.0% |
| % Having CAC After Installation | 95.3% | 80.5% |
| % of Those Not Having CAC Before Installation Who Have CAC After Installation[1] | 60.8% | 50.0% |

[1] The formula for this calculation is as follows:
(% Having CAC After Installation - % Having CAC Before Installation) ÷
(1 - % Having CAC Before Installation)

## B.3 HOUSEHOLD CHARACTERISTICS

In this subsection, we compare the following household characteristics among the five groups of homeowners:

- Type of residence
- Size of residence
- Number of levels
- Year home built

Table B–3 compares the residence type among the two groups. As the table illustrates, residence type is comparable (98.7 percent vs. 98.8 percent). The prevalence of single family homes among nonparticipant furnace replacers was lower in the previous analysis (91.7 percent).

**Table B–3. Type of Residence***

| Type of Residence | Participants with ECM Furnace (n=150) | Nonparticipant Furnace Replacers (n=82) |
|---|---|---|
| Single Family Home | 98.7% | 98.8% |
| Duplex or Triplex | 0.7% | 0.0% |
| Row or Townhouse | 0.7% | 1.2% |

* The shaded cells highlight the most prevalent responses within each of the homeowner groups.

Table B–4 compares the residence size among the two groups. As the table illustrates, participants are more likely to have larger homes than their counterparts in the nonparticipant replacer control group (2,028 vs. 1,750). This trend is the same as the previous analysis, however, both groups reported smaller homes (1,948 vs. 1,661).

**Table B–4. Size of Residence**

| Size of Residence | Participants with ECM Furnace (n=150) | Nonparticipant Furnace Replacers (n=82) |
|---|---|---|
| Average Square Feet | 2,028 | 1,750 |
| Average Number of Bedrooms | 3.3 | 3.1 |

Table B–5 compares the number of home levels for the two groups. As the table illustrates, the participants are more likely to have two story homes (49.3 percent vs. 41.5 percent), and nonparticipant furnace replacers are more likely to have one story homes (51.2 percent vs. 39.3 percent). The higher prevalence of two story homes among participants is a possible explanation for their higher rate of continuous fan operation before the installation of the ECM furnace given that those with more than one story are more likely to have air circulation issues that can be rectified by continuous fan operation. In the previous analysis, the number of home levels among participants and their counterparts in the nonparticipant replacer control group was comparable, and the prevalence of two story homes among both participants and nonparticipant furnace replacers was higher (56.7 percent vs. 58.3 percent, respectively).

**Table B–5. Number of Levels***

| Number of Levels | Participants with ECM Furnace (n=150) | Nonparticipant Furnace Replacers (n=82) |
|---|---|---|
| One Story | 39.3% | 51.2% |
| Bi-Level | 4.7% | 6.1% |
| Two Story | 49.3% | 41.5% |
| Tri-Level | 4.0% | 0.0% |
| Three Story | 2.0% | 1.2% |
| Refused | 0.7% | 0.0% |

* The shaded cells highlight the most prevalent responses within each of the homeowner groups.

Table B–6 compares the year of home construction among the two groups. As the table illustrates, the average year of home construction for participants is more recent than that of their counterparts in the nonparticipant replacer control group (1966 vs. 1957). The same trend was found in the previous analysis, except that the homes the average year of home construction was of older vintage for both participants and nonparticipant furnace replacers (1956 vs. 1945, respectively).

**Table B–6. Year Home Built**

| Year Home Built | Participants with ECM Furnace (n=150) | Nonparticipant Furnace Replacers (n=82) |
|---|---|---|
| Average Year Home Built | 1966 | 1957 |

## B.4 DEMOGRAPHICS

In this subsection, we compare the following demographics among the five groups of homeowners:

- Home ownership
- Number of years in home
- Household size
- Education
- Income
- Gender

Table B–7 compares the prevalence of home ownership among the two groups. As the table illustrates, home ownership rates are the same, both at 100 percent. In the previous analysis,

participants were more likely to own their home than their counterparts in the nonparticipant replacer control group (100.0 percent vs. 94.4 percent).

**Table B–7. Own or Rent**

| Own or Rent | Participants with ECM Furnace (n=150) | Nonparticipant Furnace Replacers (n=82) |
|---|---|---|
| Own | 100.0% | 100.0% |
| Rent | 0.0% | 0.0% |
| Refused | 0.0% | 0.0% |

Table B–8 compares the number of years residing in the current home. As the table illustrates, the average length of residence for participants is lower than that of nonparticipant furnace replacers (17 vs. 20). In the previous analysis, the average length of residence for participants was higher than that of their counterparts in the nonparticipant replacer control group (17.5 vs. 14.7).

**Table B–8. Number of Years Lived in Home**

| Number of Years Lived in Home | Participants with ECM Furnace (n=150) | Nonparticipant Furnace Replacers (n=82) |
|---|---|---|
| Average Number of Years | 17 | 20 |

Table B–9 compares household size of the two groups. As the table illustrates, the average household size for participants and nonparticipant furnace replacers is comparable (2.8 vs. 2.9). These results are equivalent to the previous analysis.

**Table B–9. Average Household Size**

| | Average Number of People in Age Category | |
|---|---|---|
| Age Category | Participants with ECM Furnace (n=150) | Nonparticipant Furnace Replacers (n=82) |
| 17 and Younger | 0.7 | 0.7 |
| 18–65 | 1.7 | 1.7 |
| Over 65 | 0.4 | 0.5 |
| Overall | 2.8 | 2.9 |

Table B–10 compares the respondent's highest level of education among the two groups. As the table illustrates, participants are more likely to be college graduates than their counterparts in the nonparticipant replacer control group (45.4 percent vs. 22.0 percent). This trend is the same as the previous analysis, except that the difference in college graduation

rates between participants and nonparticipant furnace replacers was smaller (46.0 percent vs. 30.6 percent).

**Table B–10. Education Level***

| Education Level | Participants with ECM Furnace (n=150) | Nonparticipant Furnace Replacers (n=82) |
|---|---|---|
| Some High School | 2.7% | 4.9% |
| High School Graduate | 18.0% | 31.7% |
| Some Technical School or College | 17.3% | 24.4% |
| Technical School Graduate | 10.0% | 17.1% |
| College Graduate | 24.7% | 15.9% |
| Advanced Degree | 20.7% | 6.1% |
| Refused | 6.7% | 0.0% |

* The shaded cells highlight the most prevalent responses within each of the homeowner groups.

Table B–11 compares the household income levels of the two groups. As the table illustrates, participants are more likely to have household incomes greater than $100,000 than their counterparts in the nonparticipant furnace replacer control group (21.3 percent vs. 11.0 percent). The higher income level of participants is a possible explanation for their higher rate of continuous fan operation before the installation of the ECM furnace given that those with higher incomes are more likely to be able to afford the higher electricity bills associated with continuous operation. The same trend held in the previous analysis, except that the difference in the percent having $100,000+ incomes between participants and nonparticipant furnace replacers was larger (22.0 percent vs. 2.8 percent).

**Table B–11. Income Level***

| Income Level | Participants with ECM Furnace (n=150) | Nonparticipant Furnace Replacers (n=82) |
|---|---|---|
| Less than $10,000 | 0.0% | 2.4% |
| $10,000–$14,999 | 1.3% | 3.7% |
| $15,000–$19,999 | 0.7% | 4.9% |
| $20,000–$29,999 | 4.7% | 7.3% |
| $30,000–$39,999 | 6.7% | 6.1% |
| $40,000–$49,999 | 8.7% | 12.2% |
| $50,000–$74,999 | 15.3% | 20.7% |
| $75,000–$99,999 | 16.0% | 18.3% |
| $100,000+ | 21.3% | 11.0% |

| Income Level | Participants with ECM Furnace (n=150) | Nonparticipant Furnace Replacers (n=82) |
|---|---|---|
| Refused | 25.3% | 13.4% |

* The shaded cells highlight the most prevalent responses within each of the homeowner groups.

Table B–12 compares the gender of respondents among the two groups. As the table illustrates, males comprise the majority of respondents in both groups but a lesser proportion among participants compared to nonparticipant furnace replacers (62.7 percent vs. 67.1 percent). In the previous analysis, males also comprised the majority of respondents in both groups but a greater proportion among participants compared to nonparticipant furnace replacers (60.0 percent vs. 52.8 percent).

**Table B–12. Gender***

| Gender | Participants with ECM Furnace (n=150) | Nonparticipant Furnace Replacers (n=82) |
|---|---|---|
| Male | 62.7% | 67.1% |
| Female | 37.3% | 32.9% |

* The shaded cells highlight the most prevalent responses within each of the homeowner groups

## *APPENDIX C: PARTICIPANT INTERVIEW GUIDE*

### Introduction

Hello, may I please speak to _____. My name is _____. I am a researcher calling on behalf of the State of Wisconsin's Focus on Energy Program about the new furnace that was installed <*insert installation period*> in which you received a $150 rebate. We would like to ask you a few questions about how you operate this new furnace. This is important because it will help make Wisconsin's Focus on Energy Program better.

*Confirm: (1) installation of new furnace and (2) speaking with the best person in home about furnace operation.*

### Heating Season Fan Operation – New Furnace (HN)

We are studying how people operate their furnace fans. This is the fan in your furnace that blows air through your ducts and vents. Let's first talk about how you operate the fan on your new furnace during the heating season. This is the time of the year when temperatures are cold enough that you need to run your furnace to heat your home.

HN1. Which of the following two statements best describes how you operate the fan on your new furnace during the heating season?

- ❑ The fan always blows air through your ducts and vents, 24 hours a day, regardless of whether or not your furnace is running and delivering warm air to your home. [CONTINUOUS]

  *Confirm response: (1) "fan constantly blows air through ducts and vents, every day for 24 hours a day during the heating season" and/or (2) talk about fan setting on thermostat to see if it is always set to ON and never set to AUTO during the heating season.*

- ❑ The fan blows air through your ducts and vents only when your furnace is running and delivering warm air to your home.

  HN2. Do you ever operate the fan on your new furnace during the heating season so that it blows air through your ducts and vents when your furnace is not running and delivering warm air to your home?

  - ❑ Yes [SPORADIC]

    *Confirm response: (1) "fan sometimes blows air through ducts and vents when furnace is not running and delivering warm air" and/or (2) talk about fan setting on thermostat to see if it is moved back and forth from AUTO to ON during the heating season.*

  - ❑ No [AUTO]

    *Confirm response: (1) "fan does not blow air through ducts and vents unless furnace is running and delivering warm air" and/or (2) talk about fan setting on thermostat to see if it is always set to AUTO and never set to ON during the heating season.*

*If CONTINUOUS or SPORADIC operation:*

HN3. Why do you operate the furnace fan this way? [Probe for specific reasons]

_____

*If SPORADIC operation:*

HN4. Please describe the types of situations when you do this? [Probe for specific situations]

_____

HN5. On average, how many days per month do you do this during the heating season?

_____

HN6. Thinking about the typical day when you do this during the heating season, about how many hours do you do this on average?

_____

**Heating Season Fan Operation – Old Furnace (HO)**

HO1. Did you also operate the fan this way on your old furnace during the heating season?

❑ Yes

*Confirm response: "So you operated the fan on your old furnace so that it <insert appropriate operation method description from below>." If operation method is SPORADIC for both old and new furnace, then probe for extent to which SPORADIC operation of the old furnace is the same or different from that of the new furnace.*

❑ No

*Use approach from HN1 to classify.*

*Ask HD1 if old furnace heating operation is not the same as new furnace; otherwise, go to CN1*

**Heating Season Fan Operation – Difference in New vs. Old (HD)**

HD1. Just to confirm, you said that you operate the fan on your new furnace during the heating season such that <*insert appropriate operation method description from below*>; which is different than how you operated the fan on your old furnace during the heating season. Is this correct?

❑ Yes

HD2. Why did you make this change? [Probe for specific reasons]

_____

❑ No

*Clarify with respondent.*

| ***Operation Method Descriptions*** | |
|---|---|
| CONTINUOUS → | It <u>always</u> blows air through your ducts and vents, 24 hours a day, regardless of whether or not your furnace is running and delivering warm air to your home. |
| AUTO → | It blows air through your ducts and vents <u>only</u> when your furnace is running and delivering warm air to your home. |
| SPORADIC → | It <u>occasionally</u> blows air through your ducts and vents when your furnace is <u>not</u> running and delivering warm air to your home. |

**Central Air Conditioner Ownership (CA)**

CA1. Does your home have central air conditioning?

- ❑ Yes

  CA2. Did your home have central air conditioning before your new furnace was installed?

  - ❑ Yes
  - ❑ No

- ❑ No

*Ask CN1 if have central air conditioning; otherwise, go to NN1*

**Cooling Season Fan Operation – New Furnace (CN)**

Now let's talk about your new system again. But this time, let's talk about how you operate the fan during the cooling season. These are the times of the year when temperatures are warm enough that you decide to run your central air conditioner to cool your home.

CN1. Which of the following two statements best describes how you operate the fan on your new system during the cooling season?

- ❑ The fan always blows air through your ducts and vents, 24 hours a day, regardless of whether or not your central air conditioner is running and delivering cool air to your home. [CONTINUOUS]

  *Confirm response: (1) "fan constantly blows air through ducts and vents, every day for 24 hours a day during the cooling season" and/or (2) talk about fan setting on thermostat to see if it is always set to ON and never set to AUTO during the cooling season.*

- ❑ The fan blows air through your ducts and vents only when your central air conditioner is running and delivering cool air to your home.

  CN2. Do you ever operate the fan on your new system during the cooling season so that it blows air through your ducts and vents when your central air conditioner is not running and delivering cool air to your home?

  - ❑ Yes [SPORADIC]

    *Confirm response: (1) "fan sometimes blows air through ducts and vents when furnace is not running and delivering cool air" and/or (2) talk about fan setting on thermostat to see if it is moved back and forth from AUTO to ON during the cooling season.*

  - ❑ No [AUTO]

    *Confirm response: (1) "fan does not blow air through ducts and vents unless furnace is running and delivering cool air" and/or (2) talk about fan setting on thermostat to see if it is always set to AUTO and never set to ON during the cooling season.*

*If CONTINUOUS or SPORADIC operation:*

CN3. Why do you operate the furnace fan this way? [Probe for specific reasons]

_____

*If SPORADIC operation:*

CN4. Please describe the types of situations when you do this? [Probe for specific situations]

_____

CN5. On average, how many days per month do you do this during the cooling season?

_____

CN6. Thinking about the typical day when you do this during the cooling season, about how many hours do you do this on average?

_____

*Ask CO1 if had central air conditioning before new furnace was installed; otherwise, go to SN1*

**Cooling Season Fan Operation – Old Furnace (CO)**

CO1. Did you also operate the fan this way on your old system during the cooling season?

❑ Yes

*Confirm response: "So you operated the fan on your old system so that it <insert appropriate operation method description from below>." If operation method is SPORADIC for both old and new system, then probe for extent to which SPORADIC operation of the old system is the same or different from that of the new system.*

❑ No

*Use approach from CN1 to classify.*

*Ask CD1 if old system cooling operation is not the same as new system; otherwise, go to SN1*

**Cooling Season Fan Operation – Difference in New vs. Old (CD)**

CD1. Just to confirm, you said that you operate the fan on your new system during the cooling season such that *<insert appropriate operation method description from below>*; which is different than how you operated the fan on your old system during the cooling season. Is this correct?

❑ Yes

CD2. Why did you make this change? [Probe for specific reasons]

_____

❑ No

*Clarify with respondent.*

***Operation Method Descriptions***

| | |
|---|---|
| CONTINUOUS → | It always blows air through your ducts and vents, 24 hours a day, regardless of whether or not your central air conditioner is running and delivering cool air to your home. |
| AUTO → | It blows air through your ducts and vents only when your central air conditioner is running and delivering cool air to your home. |
| SPORADIC → | It occasionally blows air through your ducts and vents when your central air conditioner is not running and delivering cool air to your home. |

**Shoulder Fan Operation – New Furnace (SN)**

Now, let's talk about your new system again. But this time, let's talk about how you operate the fan during the periods between the heating and cooling seasons. These are the times of the year, particularly spring and fall, when you are not running your furnace to heat your home and not running your central air conditioner to cool your home.

SN1. Which of the following three statements best describes how you operate the fan on your new system during the periods between the heating and cooling seasons?

- ❑ The fan is always blowing air through your ducts and vents, 24 hours a day. [CONTINUOUS]

  *Confirm response: (1) "fan constantly blows air through ducts and vents, every day for 24 hours a day during the periods between the heating and cooling seasons" and/or (2) talk about fan setting on thermostat to see if it is always set to ON and never set to AUTO during the periods between the heating and cooling seasons.*

- ❑ The fan is never blowing air through your ducts and vents. [AUTO]

  *Confirm response: (1) "fan never blows air through ducts and vents during the periods between the heating and cooling seasons" and/or (2) talk about fan setting on thermostat to see if it is always set to AUTO and never set to ON during the periods between the heating and cooling seasons.*

- ❑ The fan is occasionally blowing air through your ducts and vents, but not all of the time. [SPORADIC]

  *Confirm response: (1) "fan sometimes blows air through ducts and vents during the periods between the heating and cooling seasons" and/or (2) talk about fan setting on thermostat to see if it is moved back and forth from AUTO to ON during the periods between the heating and cooling seasons.*

*If CONTINUOUS or SPORADIC operation:*

SN2. Why do you operate the furnace fan this way? [Probe for specific reasons]

_____

*If SPORADIC operation:*

SN3. Please describe the types of situations when you do this? [Probe for specific situations]

_____

SN4. On average, how many days per month do you do this during the periods between the heating and cooling seasons?

_____

SN5. Thinking about the typical day when you do this during the periods between the heating and cooling seasons, about how many hours do you do this on average?

_____

*Ask SO1 if had central air conditioning before new furnace was installed; otherwise, go to NO1*

**Shoulder Fan Operation – Old Furnace (SO)**

SO1. Did you also operate the fan this way on your old system during the periods between the heating and cooling seasons?

❑ Yes

*Confirm response: "So you operated the fan on your old system so that it <insert appropriate operation method description from below>." If operation method is SPORADIC for both old and new system, then probe for extent to which SPORADIC operation of the old system is the same or different from that of the new system.*

❑ No

*Use approach from SN1 to classify.*

*Ask SD1 if old system shoulder operation is not the same as new system; otherwise, go to CP1*

**Shoulder Season Fan Operation – Difference in New vs. Old (SD)**

SD1. Just to confirm, you said that you operate the fan on your new system during the periods between the heating and cooling seasons such that <*insert appropriate operation method description from below*>; which is different than how you operated the fan on your old system during the periods between the heating and cooling seasons. Is this correct?

❑ Yes

SD2. Why did you make this change? [Probe for specific reasons]

_____

❑ No

*Clarify with respondent*

***Operation Method Descriptions***

| | |
|---|---|
| CONTINUOUS → | It always blows air through your ducts and vents, 24 hours a day. |
| AUTO → | It never blows air through your ducts and vents. |
| SPORADIC → | It occasionally blows air through your ducts and vents, but not all of the time. |

**Non-Heating Season Fan Operation – New Furnace (NN)**

Now, let's talk about how you operate the fan on your new furnace during the non-heating season. This is the time of the year when you are not running your furnace to heat your home.

NN1. Which of the following three statements best describes how you operate the fan on your new furnace during the non-heating season?

- ❑ The fan is always blowing air through your ducts and vents, 24 hours a day. [CONTINUOUS]

  *Confirm response: (1) "fan constantly blows air through ducts and vents, every day for 24 hours a day during the non-heating season" and/or (2) talk about fan setting on thermostat to see if it is always set to ON and never set to AUTO during the non-heating season.*

- ❑ The fan is never blowing air through your ducts and vents. [AUTO]

  *Confirm response: (1) "fan never blows air through ducts and vents during the non-heating season" and/or (2) talk about fan setting on thermostat to see if it is always set to AUTO and never set to ON during the non-heating season.*

- ❑ The fan is occasionally blowing air through your ducts and vents, but not all of the time. [SPORADIC]

  *Confirm response: (1) "fan sometimes blows air through ducts and vents during the non-heating season" and/or (2) talk about fan setting on thermostat to see if it is moved back and forth from AUTO to ON during the non-heating season.*

*If CONTINUOUS or SPORADIC operation:*

NN2. Why do you operate the furnace fan this way? [Probe for specific reasons]

_____

*If SPORADIC operation:*

NN3. Please describe the types of situations when you do this? [Probe for specific situations]

_____

NN4. On average, how many days per month do you do this during the non-heating season?

_____

NN5. Thinking about the typical day when you do this during the non-heating season, about how many hours do you do this on average?

_____

**Non-Heating Season Fan Operation – Old Furnace (NO)**

NO1. Did you also operate the fan this way on your old furnace during the non-heating season?

❑ Yes

*Confirm response: "So you operated the fan on your old furnace so that it <insert appropriate operation method description from below> ". If operation method is SPORADIC for both old and new furnace, then probe for extent to which SPORADIC operation of the old furnace is the same or different from that of the new furnace.*

❑ No

*Use approach from NN1 to classify.*

*Ask ND1 if old furnace non-heating operation is not the same as new furnace; otherwise, go to CP1*

**Non-Heating Season Fan Operation – Difference in New vs. Old (ND)**

ND1. Just to confirm, you said that you operate the fan on your new furnace during the non-heating season such that *<insert appropriate operation method description from below>*; which is different than how you operated the fan on your old furnace during the non-heating season. Is this correct?

❑ Yes

ND2. Why did you make this change? [Probe for specific reasons]

_____

❑ No

*Clarify with respondent.*

***Operation Method Descriptions***

| | |
|---|---|
| CONTINUOUS → | It always blows air through your ducts and vents, 24 hours a day. |
| AUTO → | It never blows air through your ducts and vents. |
| SPORADIC → | It occasionally blows air through your ducts and vents, but not all of the time. |

## Contractor Promotion (CP)

CP1. Did the furnace salespeople or contractors that you dealt with tell you anything about the amount of electricity used by the fan motor of your new furnace or about how to operate the fan on your new furnace?

1 Yes → (Go to CP2)
2 No → (Go to FF1)
98 (Don't know) → (Go to FF1)

CP2. What did they tell you? [Probe for specifics]

_____

## Furnace Filter Changing Behavior (FF)

FF1. About how often is the filter on your furnace changed? [Probe for frequency and times of the year]

_____

## Demographics (DE)

Finally, I would like to ask you a few questions about your household. These questions are for classification purposes only. All of your answers are confidential.

DE1. Do you own or rent this residence?

1 Own/buying
2 Rent/lease
97 (Other) Please describe: _____
98 (Don't know)
99 (Refused)

DE2. Which of the following best describes your home? Is it a . . .

1 Single family home (house on separate lot, includes modular homes)
2 Row or townhouse (adjacent walls to another house)
3 Duplex or triplex
4 Unit in a multi-family structure with 4 or more attached units (example: fourplex, single family house converted to flats apartment house, high-rise condominium, garden apartments)
5 Mobile home or house trailer
97 (Other) Please describe: _____
98 (Don't know)
99 (Refused)

DE3. What is the approximate square footage of your home? This includes finished space and does not include garages or unfinished basements.

_____ Square feet [Enter 98 for DK and 99 for Refused]

**Demographics (DE) – Continued**

DE4. Is your home a . . . [Read list, Record one number]

| | | | |
|---|---|---|---|
| 1 | One story home (ranch) | 4 | Bi-level |
| 2 | Two story home | 5 | Tri-level |
| 3 | Three story home | | |
| 97 | (Other) Please describe: _____ | | |
| 98 | (Don't know) | | |
| 99 | (Refused) | | |

DE5. How many bedrooms does your home have?

_____ Bedrooms [Enter 98 for DK and 99 for Refused]]

DE6. How many years have you lived at your home?

_____ Years [If less than one year, record 0. Enter 998 for DK and 999 for Refused]

DE7. In approximately what year was your home built?

_____ Year Built [Enter 9998 for DK and 9999 for Refused]

DE8. Thinking of the people who live in your home full-time (including yourself) how many are:

| | | |
|---|---|---|
| a | _____ | 17 years old or younger |
| b | _____ | Between the ages of 18 and 65 |
| c | _____ | Over 65 years old |
| d | _____ | Total [Confirm total] |

[Enter 98 for DK and 99 for Refused]

DE9. What is the highest level of education you have completed?

| | |
|---|---|
| 1 | Some high school |
| 2 | High school graduate |
| 3 | Some technical school or college |
| 4 | Technical school graduate (associates degree) |
| 5 | College graduate (bachelors degree) |
| 6 | Advanced degree (masters degree or higher) |
| 98 | (Don't know) |
| 99 | (Refused) |

DE10. Which of the following income categories best describes your total annual household income in 2007, before taxes? Please stop me when I get to the right category. Is it . . .

| | | | |
|---|---|---|---|
| 1 | Less than $10,000 | 7 | $50,000 - $74,999 |
| 2 | $10,000 - $14,999 | 8 | $75,000 - $ 99,999 |
| 3 | $15,000 - $19,999 | 9 | $100,000 or more |
| 4 | $20,000 - $29,999 | 98 | (Don't know) |
| 5 | $30,000 - $39,999 | 99 | (Refused) |
| 6 | $40,000 - $49,999 | | |

DE11. [RECORD GENDER] 1 Male 2 Female

Those are all the questions I have. Thank you for your help on this very important research study.

## *APPENDIX D: NONPARTICIPANT FURNACE REPLACER INTERVIEW GUIDE*

### Introduction

Hello, may I please speak to _____. My name is _____. I am a researcher calling on behalf of the State of Wisconsin's Focus on Energy Program. This state-sponsored program offers Wisconsin residents information and rebates for making energy efficiency improvements. The reason for my call is that we are conducting a research study on how people operate their furnace fans. This study is very important to making Wisconsin's Focus on Energy Program better. Would you have a couple of minutes to talk about how you operate your furnace fan?

*Confirm: (1) installation of new furnace and (2) speaking with the best person in home about furnace operation.*

### Heating Season Fan Operation – New Furnace (HN)

We are studying how people operate their furnace fans. This is the fan in your furnace that blows air through your ducts and vents. Let's first talk about how you operate the fan on your new furnace during the heating season. This is the time of the year when temperatures are cold enough that you need to run your furnace to heat your home.

HN1. Which of the following two statements best describes how you operate the fan on your new furnace during the heating season?

- ❑ The fan always blows air through your ducts and vents, 24 hours a day, regardless of whether or not your furnace is running and delivering warm air to your home. [CONTINUOUS]

  *Confirm response: (1) "fan constantly blows air through ducts and vents, every day for 24 hours a day during the heating season" and/or (2) talk about fan setting on thermostat to see if it is always set to ON and never set to AUTO during the heating season.*

- ❑ The fan blows air through your ducts and vents only when your furnace is running and delivering warm air to your home.

  HN2. Do you ever operate the fan on your new furnace during the heating season so that it blows air through your ducts and vents when your furnace is not running and delivering warm air to your home?

  - ❑ Yes [SPORADIC]

    *Confirm response: (1) "fan sometimes blows air through ducts and vents when furnace is not running and delivering warm air" and/or (2) talk about fan setting on thermostat to see if it is moved back and forth from AUTO to ON during the heating season.*

  - ❑ No [AUTO]

    *Confirm response: (1) "fan does not blow air through ducts and vents unless furnace is running and delivering warm air" and/or (2) talk about fan setting on thermostat to see if it is always set to AUTO and never set to ON during the heating season.*

*If CONTINUOUS or SPORADIC operation:*

HN3. Why do you operate the furnace fan this way? [Probe for specific reasons]

_____

*If SPORADIC operation:*

HN4. Please describe the types of situations when you do this? [Probe for specific situations]

_____

HN5. On average, how many days per month do you do this during the heating season?

_____

HN6. Thinking about the typical day when you do this during the heating season, about how many hours do you do this on average?

_____

**Heating Season Fan Operation – Old Furnace (HO)**

HO1. Did you also operate the fan this way on your old furnace during the heating season?

❑ Yes

*Confirm response: "So you operated the fan on your old furnace so that it <insert appropriate operation method description from below>." If operation method is SPORADIC for both old and new furnace, then probe for extent to which SPORADIC operation of the old furnace is the same or different from that of the new furnace.*

❑ No

*Use approach from HN1 to classify.*

*Ask HD1 if old furnace heating operation is not the same as new furnace; otherwise, go to CN1*

**Heating Season Fan Operation – Difference in New vs. Old (HD)**

HD1. Just to confirm, you said that you operate the fan on your new furnace during the heating season such that <*insert appropriate operation method description from below*>; which is different than how you operated the fan on your old furnace during the heating season. Is this correct?

❑ Yes

HD2. Why did you make this change? [Probe for specific reasons]

_____

❑ No

*Clarify with respondent.*

| ***Operation Method Descriptions*** | |
|---|---|
| CONTINUOUS → | It <u>always</u> blows air through your ducts and vents, 24 hours a day, regardless of whether or not your furnace is running and delivering warm air to your home. |
| AUTO → | It blows air through your ducts and vents <u>only</u> when your furnace is running and delivering warm air to your home. |
| SPORADIC → | It <u>occasionally</u> blows air through your ducts and vents when your furnace is <u>not</u> running and delivering warm air to your home. |

## Central Air Conditioner Ownership (CA)

CA1. Does your home have central air conditioning?

- ❑ Yes

  CA2. Did your home have central air conditioning before your new furnace was installed?

  - ❑ Yes
  - ❑ No

- ❑ No

*Ask CN1 if have central air conditioning; otherwise, go to NN1*

**Cooling Season Fan Operation – New Furnace (CN)**

Now let's talk about your new system again. But this time, let's talk about how you operate the fan during the cooling season. These are the times of the year when temperatures are warm enough that you decide to run your central air conditioner to cool your home.

CN1. Which of the following two statements best describes how you operate the fan on your new system during the cooling season?

- ❑ The fan always blows air through your ducts and vents, 24 hours a day, regardless of whether or not your central air conditioner is running and delivering cool air to your home. [CONTINUOUS]

  *Confirm response: (1) "fan constantly blows air through ducts and vents, every day for 24 hours a day during the cooling season" and/or (2) talk about fan setting on thermostat to see if it is always set to ON and never set to AUTO during the cooling season.*

- ❑ The fan blows air through your ducts and vents only when your central air conditioner is running and delivering cool air to your home.

  CN2. Do you ever operate the fan on your new system during the cooling season so that it blows air through your ducts and vents when your central air conditioner is not running and delivering cool air to your home?

  - ❑ Yes [SPORADIC]

    *Confirm response: (1) "fan sometimes blows air through ducts and vents when furnace is not running and delivering cool air" and/or (2) talk about fan setting on thermostat to see if it is moved back and forth from AUTO to ON during the cooling season.*

  - ❑ No [AUTO]

    *Confirm response: (1) "fan does not blow air through ducts and vents unless furnace is running and delivering cool air" and/or (2) talk about fan setting on thermostat to see if it is always set to AUTO and never set to ON during the cooling season.*

*If CONTINUOUS or SPORADIC operation:*

CN3. Why do you operate the furnace fan this way? [Probe for specific reasons]

_____

*If SPORADIC operation:*

CN4. Please describe the types of situations when you do this? [Probe for specific situations]

_____

CN5. On average, how many days per month do you do this during the cooling season?

_____

CN6. Thinking about the typical day when you do this during the cooling season, about how many hours do you do this on average?

_____

*Ask CO1 if had central air conditioning before new furnace was installed; otherwise, go to SN1*

**Cooling Season Fan Operation – Old Furnace (CO)**

CO1. Did you also operate the fan this way on your old system during the cooling season?

❑ Yes

*Confirm response: "So you operated the fan on your old system so that it <insert appropriate operation method description from below>." If operation method is SPORADIC for both old and new system, then probe for extent to which SPORADIC operation of the old system is the same or different from that of the new system.*

❑ No

*Use approach from CN1 to classify.*

*Ask CD1 if old system cooling operation is not the same as new system; otherwise, go to SN1*

**Cooling Season Fan Operation – Difference in New vs. Old (CD)**

CD1. Just to confirm, you said that you operate the fan on your new system during the cooling season such that *<insert appropriate operation method description from below>*; which is different than how you operated the fan on your old system during the cooling season. Is this correct?

❑ Yes

CD2. Why did you make this change? [Probe for specific reasons]

_____

❑ No

*Clarify with respondent.*

***Operation Method Descriptions***

| | |
|---|---|
| CONTINUOUS → | It always blows air through your ducts and vents, 24 hours a day, regardless of whether or not your central air conditioner is running and delivering cool air to your home. |
| AUTO → | It blows air through your ducts and vents only when your central air conditioner is running and delivering cool air to your home. |
| SPORADIC → | It occasionally blows air through your ducts and vents when your central air conditioner is not running and delivering cool air to your home. |

## Shoulder Fan Operation – New Furnace (SN)

Now, let's talk about your new system again. But this time, let's talk about how you operate the fan during the periods between the heating and cooling seasons. These are the times of the year, particularly spring and fall, when you are not running your furnace to heat your home and not running your central air conditioner to cool your home.

SN1. Which of the following three statements best describes how you operate the fan on your new system during the periods between the heating and cooling seasons?

- ❑ The fan is always blowing air through your ducts and vents, 24 hours a day. [CONTINUOUS]

  *Confirm response: (1) "fan constantly blows air through ducts and vents, every day for 24 hours a day during the periods between the heating and cooling seasons" and/or (2) talk about fan setting on thermostat to see if it is always set to ON and never set to AUTO during the periods between the heating and cooling seasons.*

- ❑ The fan is never blowing air through your ducts and vents. [AUTO]

  *Confirm response: (1) "fan never blows air through ducts and vents during the periods between the heating and cooling seasons" and/or (2) talk about fan setting on thermostat to see if it is always set to AUTO and never set to ON during the periods between the heating and cooling seasons.*

- ❑ The fan is occasionally blowing air through your ducts and vents, but not all of the time. [SPORADIC]

  *Confirm response: (1) "fan sometimes blows air through ducts and vents during the periods between the heating and cooling seasons" and/or (2) talk about fan setting on thermostat to see if it is moved back and forth from AUTO to ON during the periods between the heating and cooling seasons.*

*If CONTINUOUS or SPORADIC operation:*

SN2. Why do you operate the furnace fan this way? [Probe for specific reasons]

_____

*If SPORADIC operation:*

SN3. Please describe the types of situations when you do this? [Probe for specific situations]

_____

SN4. On average, how many days per month do you do this during the periods between the heating and cooling seasons?

_____

SN5. Thinking about the typical day when you do this during the periods between the heating and cooling seasons, about how many hours do you do this on average?

_____

*Ask SO1 if had central air conditioning before new furnace was installed; otherwise, go to NO1*

**Shoulder Fan Operation – Old Furnace (SO)**

SO1. Did you also operate the fan this way on your old system during the periods between the heating and cooling seasons?

❑ Yes

*Confirm response: "So you operated the fan on your old system so that it <insert appropriate operation method description from below>." If operation method is SPORADIC for both old and new system, then probe for extent to which SPORADIC operation of the old system is the same or different from that of the new system.*

❑ No

*Use approach from SN1 to classify.*

*Ask SD1 if old system shoulder operation is not the same as new system; otherwise, go to CP1*

**Shoulder Season Fan Operation – Difference in New vs. Old (SD)**

SD1. Just to confirm, you said that you operate the fan on your new system during the periods between the heating and cooling seasons such that <*insert appropriate operation method description from below*>; which is different than how you operated the fan on your old system during the periods between the heating and cooling seasons. Is this correct?

❑ Yes

SD2. Why did you make this change? [Probe for specific reasons]

_____

❑ No

*Clarify with respondent*

***Operation Method Descriptions***

| | |
|---|---|
| CONTINUOUS → | It always blows air through your ducts and vents, 24 hours a day. |
| AUTO → | It never blows air through your ducts and vents. |
| SPORADIC → | It occasionally blows air through your ducts and vents, but not all of the time. |

## Non-Heating Season Fan Operation – New Furnace (NN)

Now, let's talk about how you operate the fan on your new furnace during the non-heating season. This is the time of the year when you are not running your furnace to heat your home.

NN1. Which of the following three statements best describes how you operate the fan on your new furnace during the non-heating season?

- ❑ The fan is always blowing air through your ducts and vents, 24 hours a day. [CONTINUOUS]

  *Confirm response: (1) "fan constantly blows air through ducts and vents, every day for 24 hours a day during the non-heating season" and/or (2) talk about fan setting on thermostat to see if it is always set to ON and never set to AUTO during the non-heating season.*

- ❑ The fan is never blowing air through your ducts and vents. [AUTO]

  *Confirm response: (1) "fan never blows air through ducts and vents during the non-heating season" and/or (2) talk about fan setting on thermostat to see if it is always set to AUTO and never set to ON during the non-heating season.*

- ❑ The fan is occasionally blowing air through your ducts and vents, but not all of the time. [SPORADIC]

  *Confirm response: (1) "fan sometimes blows air through ducts and vents during the non-heating season" and/or (2) talk about fan setting on thermostat to see if it is moved back and forth from AUTO to ON during the non-heating season.*

*If CONTINUOUS or SPORADIC operation:*

NN2. Why do you operate the furnace fan this way? [Probe for specific reasons]

_____

*If SPORADIC operation:*

NN3. Please describe the types of situations when you do this? [Probe for specific situations]

_____

NN4. On average, how many days per month do you do this during the non-heating season?

_____

NN5. Thinking about the typical day when you do this during the non-heating season, about how many hours do you do this on average?

_____

**Non-Heating Season Fan Operation – Old Furnace (NO)**

NO1. Did you also operate the fan this way on your old furnace during the non-heating season?

❑ Yes

*Confirm response: "So you operated the fan on your old furnace so that it <insert appropriate operation method description from below> ". If operation method is SPORADIC for both old and new furnace, then probe for extent to which SPORADIC operation of the old furnace is the same or different from that of the new furnace.*

❑ No

*Use approach from NN1 to classify.*

*Ask ND1 if old furnace non-heating operation is not the same as new furnace; otherwise, go to CP1*

**Non-Heating Season Fan Operation – Difference in New vs. Old (ND)**

ND1. Just to confirm, you said that you operate the fan on your new furnace during the non-heating season such that *<insert appropriate operation method description from below>*; which is different than how you operated the fan on your old furnace during the non-heating season. Is this correct?

❑ Yes

ND2. Why did you make this change? [Probe for specific reasons]

_____

❑ No

*Clarify with respondent.*

***Operation Method Descriptions***

| | |
|---|---|
| CONTINUOUS → | It always blows air through your ducts and vents, 24 hours a day. |
| AUTO → | It never blows air through your ducts and vents. |
| SPORADIC → | It occasionally blows air through your ducts and vents, but not all of the time. |

## Contractor Promotion (CP)

CP1. Did the furnace salespeople or contractors that you dealt with tell you anything about the amount of electricity used by the fan motor of your new furnace or about how to operate the fan on your new furnace?

1 Yes → (Go to CP2)
2 No → (Go to FF1)
98 (Don't know) → (Go to FF1)

CP2. What did they tell you? [Probe for specifics]

_____

## Furnace Filter Changing Behavior (FF)

FF1. About how often is the filter on your furnace changed? [Probe for frequency and times of the year]

_____

## Demographics (DE)

Finally, I would like to ask you a few questions about your household. These questions are for classification purposes only. All of your answers are confidential.

DE1. Do you own or rent this residence?

1 Own/buying
2 Rent/lease
97 (Other) Please describe: _____
98 (Don't know)
99 (Refused)

DE2. Which of the following best describes your home? Is it a . . .

1 Single family home (house on separate lot, includes modular homes)
2 Row or townhouse (adjacent walls to another house)
3 Duplex or triplex
4 Unit in a multi-family structure with 4 or more attached units (example: fourplex, single family house converted to flats apartment house, high-rise condominium, garden apartments)
5 Mobile home or house trailer
97 (Other) Please describe: _____
98 (Don't know)
99 (Refused)

DE3. What is the approximate square footage of your home? This includes finished space and does not include garages or unfinished basements.

_____ Square feet [Enter 98 for DK and 99 for Refused]

**Demographics (DE) – Continued**

DE4. Is your home a . . . [Read list, Record one number]

| | | | | |
|---|---|---|---|---|
| 1 | One story home (ranch) | 4 | Bi-level | |
| 2 | Two story home | | 5 | Tri-level |
| 3 | Three story home | | | |
| 97 | (Other) Please describe: _____ | | | |
| 98 | (Don't know) | | | |
| 99 | (Refused) | | | |

DE5. How many bedrooms does your home have?

_____ Bedrooms [Enter 98 for DK and 99 for Refused]]

DE6. How many years have you lived at your home?

_____ Years [If less than one year, record 0. Enter 998 for DK and 999 for Refused]

DE7. In approximately what year was your home built?

_____ Year Built [Enter 9998 for DK and 9999 for Refused]

DE8. Thinking of the people who live in your home full-time (including yourself) how many are:

| | | |
|---|---|---|
| a | _____ | 17 years old or younger |
| b | _____ | Between the ages of 18 and 65 |
| c | _____ | Over 65 years old |
| d | _____ | Total [Confirm total] |

[Enter 98 for DK and 99 for Refused]

DE9. What is the highest level of education you have completed?

| | |
|---|---|
| 1 | Some high school |
| 2 | High school graduate |
| 3 | Some technical school or college |
| 4 | Technical school graduate (associates degree) |
| 5 | College graduate (bachelors degree) |
| 6 | Advanced degree (masters degree or higher) |
| 98 | (Don't know) |
| 99 | (Refused) |

DE10. Which of the following income categories best describes your total annual household income in 2007, before taxes? Please stop me when I get to the right category. Is it . . .

| | | | |
|---|---|---|---|
| 1 | Less than $10,000 | 7 | $50,000 - $74,999 |
| 2 | $10,000 - $14,999 | 8 | $75,000 - $ 99,999 |
| 3 | $15,000 - $19,999 | 9 | $100,000 or more |
| 4 | $20,000 - $29,999 | 98 | (Don't know) |
| 5 | $30,000 - $39,999 | 99 | (Refused) |
| 6 | $40,000 - $49,999 | | |

DE11. [RECORD GENDER] 1 Male 2 Female

Those are all the questions I have. Thank you for your help on this very important research study.

## *APPENDIX E: HVAC CONTRACTOR INTERVIEW GUIDE*

The last section of the interview guide addresses furnace fan operation (Q14-Q19), and it is these questions which are relevant to this study. The interview guide also collected information to support the ECM furnace net-to-gross analysis (Q1-Q13), and the results from these questions are presented in a separate report.[20]

# HVAC Contractor Interview Guide

**Contractor:** _____

**Contact:** _____

**Introduction**

Hello, may I please speak to _____. My name is _____. I am calling on behalf of the State of Wisconsin's Focus on Energy program to talk with you for 15-20 minutes about your involvement with selling ECM furnaces through the Efficient Heating and Cooling rebate program. The feedback you provide is very valuable to improving the program, and your individual responses will be kept confidential.

**Furnace Promotional Practices**

Let's start with how you promote ECM furnaces.

1. According to program records, you have sold about **XXX** ECM furnaces through the rebate program in 2007 and **YYY** in 2006. Does that sound about right?

2. Do you sell ECM furnaces outside the rebate program?

   *If yes:*
   - About how many did you sell outside the program in 2007?
   - Why do these units not get a rebate?

3. Thinking about all of the furnaces you installed in 2007, what percent were ECM furnaces? (*Confirm total sales*)

4. Do you promote ECM furnaces to all customers?

   *If yes:*
   - How? (*Probe for sales pitch*)

   *If no:*

[20] Net-to-Gross Savings Adjustments for ECM Furnaces," memorandum to Oscar Bloch, Wisconsin PSC, September 2008.

- Why not? (*Probe for attitudes toward ECMs*)

5. Why do customers choose to install ECM furnaces?

6. Why do customers choose not to install ECM furnaces?

7. Thinking about 90+ AFUE furnaces, what is the extra cost for an ECM furnace compared to a furnace without an ECM?

8. What are the factors that influence your sales of ECM furnaces?

9. What influence do your manufacturers and distributors have on your sales of ECM furnace?

10. Do you think that the market share trend for ECM furnaces is increasing, decreasing, or staying the same? What do you think is driving this trend?

11. How much do you use the $150 rebate as a sales tool for the ECM furnace?

12. What role does the $150 rebate have in the customer's decision to install an ECM furnace?

13. If the Efficient Heating and Cooling program and the $150 rebate were not available, do you think that you would have sold more, less, or the same number of ECM furnaces in 2007?

*Ask everyone:*
- Why?

*If more or less:*
- How much more or less?

*Clarify and confirm response:*
- That means that **XX** percent of the ECM furnaces you sold in 2007 would still have been sold even without the $150 rebate?

**Furnace Fan Operation**

Let's talk about what you tell customers who install a new furnace about furnace fan operation. Let's start with customers who install an ECM furnace.

14. How often do you recommend continuous fan operation to customers who install ECM furnaces?

15. Why do you recommend continuous fan operation to customers who install ECM furnaces? *(Probe for situations)*

Now let's talk about customers who install furnaces without ECMs.

16. How often do you recommend continuous fan operation to customers who install furnaces without ECMs?

17. Why do you recommend continuous fan operation to customers who install furnaces without ECMs? *(Probe for situations)*

Let's go back to ECM furnace purchasers for a minute.

18. Do you recommend continuous fan operation to ECM furnace purchasers who were previously operating their fan in auto mode with their old furnace?

    *If yes:*
    - Why?

    - Do you tell these customers that they will save money by changing from auto to continuous fan operation? If yes, how do they save money?

    *If no:*
    Why not?

Finally, let's talk about non-ECM furnace purchasers again.

19. Do you recommend continuous fan operation to non-ECM furnace purchasers who were previously operating their fan in auto mode with their old furnace?

    *If yes:*
    - Why?

    - Do you tell these customers that they will save money by changing from auto to continuous fan operation? If yes, how do they save money?

    *If no:*
    Why not?