# SAVING ENERGY WITH EFFICIENT RESIDENTIAL FURNACE AIR HANDLERS: A STATUS REPORT AND PROGRAM RECOMMENDATIONS

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## SUMMARY OF FINDINGS AND RECOMMENDATIONS

The air handlers of forced air gas furnaces provide the energy to move air through the furnace (and central air conditioner), and distribute it to the rooms of a house. The amount of electricity these require varies enormously, even within size categories, but averages about 3.4% of the site energy use of the furnace, or 10% of the source energy. Improving the motor and fan systems of residential furnaces and heat pumps promises substantial, cost-effective efficiency gains. Table 1 gives approximate savings for the average U.S. climate and three northern areas. (Note that this report does not include results for cooling-dominated climates, as appropriate efficiency metrics are not yet available.)

**Table 1. Regional Estimates of Savings from Better Furnace Fans and Motors**

| | | U.S. Average | New England | Wisconsin | Pacific Northwest, Mountains |
|---|---|---|---|---|---|
| | Electricity/kWh | $0.08 | $0.11 | $0.08 | $0.06 |
| Tariffs | Gas/therm | 0.8 | $0.96 | $0.70 | $0.90 |
| | Heating | 500 | 548 | 617 | 685 |
| Electricity Saved, kWh | A/C | 200 | 131 | 125 | 125 |
| | kWh/yr | 700 | 679 | 742 | 810 |
| Total | $/yr | $57 | $75 | $56 | $49 |
| | therms | 19 | 23 | 23 | 22 |
| Extra Gas Needed | $ | $15 | $22 | $9 | $20 |
| Net Saving | $ | $42 | $53 | $47 | $29 |
| GE Estimate | | $97 | $146 | $89 | $91 |

Note: These calculations were made using the methods of Table 4 (below) and Appendix A. As discussed in the text, we do not include areas where air conditioning loads dominate, because of uncertainties about fan energy for "southern" models. To be conservative, this report uses 250 W air conditioning power saving instead of the 325 W value used in earlier ACEEE reports. On average, GE (a major manufacturer of advanced fan motors) estimates 2.4 times the savings for its motors that ACEEE does for advanced motors—without including the GE estimates for ventilation without heating or cooling. See text for explanation.

With the assumptions of this report, an electrically efficient condensing gas furnace installed in New England would save about 550 kWh/yr during the heating season, and another 130 kWh in the air conditioning season. This is valued at $75 with air conditioning and $61 without. However, because the air handler is in the circulating air stream, the electricity it uses is a heat source for the house, augmenting the gas burned. If the furnace is to provide the same comfort level, wasting less high-cost electricity means burning slightly more gas. The 19 therms required for this cost about $22, for net heating season savings of about $53 with air conditioning or $38 without.

ACEEE recommends a performance-based approach based on how efficiently the air handler performs its task, rather than a prescriptive program specifying a particular motor class or other parameter(s). The performance approach is less likely to include inefficient furnace designs with good motors, and more likely to encourage innovations that will decrease costs. This will facilitate reducing incentives over time for the efficiency resources acquired.

Available efficiency metrics are sufficient for climates that are not cooling-dominated, and some groups are developing performance-based metrics that would be appropriate nationally.[1]

There are at least three paths for accelerating adoption of more efficient air handlers. First, there are significant market transformation opportunities for more efficient furnace fan motors. Programs are being planned for 2003. There are also opportunities in the current U.S. Department of Energy (DOE) furnaces and boilers rulemaking to include electricity use of furnaces in the federal standards. As market penetration for advanced electrical systems increases, states can consider adopting building code provisions that give an electricity budget to furnaces and the air handling systems used to distribute conditioned air to the building, as California is evaluating. By focusing on the total electricity used to distribute air, this may avoid problems of federal preemption through its furnace regulations. It will also send a signal to manufacturers about the need for more efficient air handlers, and to contractors, buildings, and installers that both proper duct design and efficient equipment are required by the code.

## ACKNOWLEDGMENTS

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[1] The issue is that the same fan supplies air for both heating and air conditioning seasons. For southern use in some cases, manufacturers specify furnaces sized with larger fans for larger evaporators; these will legitimately require more power. As an example, a 75,000 Btuh furnace might be sized for a 3-ton evaporator in the North, but a 5-ton evaporator (and a larger fan) in the South. Available directory data do not directly give matched evaporator size.

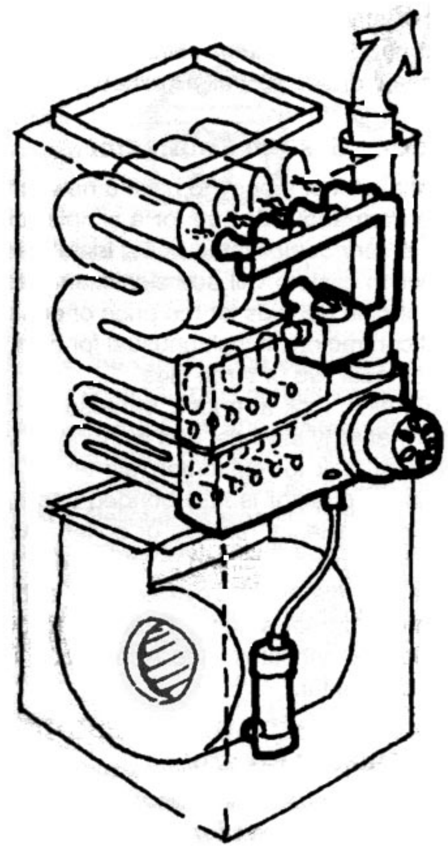
## INTRODUCTION

Forced air furnace air handlers drive air through the furnace and distribute it to the rooms of a house. The furnaces also provide air distribution for the central air conditioner air in hot weather. The amount of electricity these furnaces require varies enormously, even within size categories, but averages about 3.4% of the site energy use of the furnace in the heating season (Kendall 2002a),[2] or 10% of the source energy.[3] The average electricity use is significant. Because electricity has a premium price (roughly four times as much per Btu of heat energy delivered to the site), the cost of the electricity used in the heating season could approach 20% of the cost of heating in extreme cases of low gas and high electricity prices (Goldstein 2002).

The air handler of residential and light commercial split systems includes the cabinet (below the furnace in a conventional upflow furnace), the fan, and the fan motor, which is generally coaxial with the fan (see Figure 1). Improvements could result from changes in the cabinet and associated system aerodynamics, the fan, the motor, and/or the motor controls. Federal regulatory requirements drive furnace designs. These include requirements for gas efficiency, but not for the electricity used by the air handler. A manufacturer who chooses a design that uses several times more electricity to move air through the furnace may show the same gas efficiency (annual fuel utilization efficiency or AFUE) as one with much better internal aerodynamics, a more efficient motor, and an improved fan. In general, what isn't measured isn't valued, so an estimated 95% of all residential air handlers use relatively inefficient permanent split capacitor (PSC) fan motors. The rest use more efficient brushless permanent magnet motors (BPM, also called ECM, ICM, and other terms). To some extent, these are marketed for higher efficiency, but they are largely promoted for better control of temperature, humidity, and particulate matter. Indeed, the furnace fan is perhaps the most important opportunity to save electricity after the air conditioner and water heater have been optimized. The savings for homeowners in the average state are about 500 kWh/yr in heating mode and another 200 kWh/yr in cooling mode. This is more than a typical new refrigerator uses, which is around 490 kWh/yr.

[2] The variance is +/- 2.7% (3 std. dev.). Estimates for heating season only, according to the AFUE test procedure requirements. Additional electricity is used by the fan in the cooling season.
[3] As noted in Kendall 2002a, the GAMA estimates are likely to be low relative to field experience. They seem to be based on laboratory studies with system flow resistances (external static pressures) as per the ARI air conditioner and heat pump test (ARI 1994). These values are about one-half those observed in the field. Thus, in the field, furnaces are likely to use more electricity or fail to deliver rated airflow (which contributes to cold rooms at the end of the duct system).

**Figure 1. Schematic of Upflow Condensing Furnace with Furnace Fan as Lowest Element**




## TECHNOLOGY DESCRIPTION

More than 95% of residential furnaces use relatively conventional single-phase induction motors, generally permanent split capacitor (PSC) units. Typically, multiple taps give a selection of fixed speeds. A more efficient technology, the electronically commutated DC permanent magnet motor (BPM, ECPM, ECM,[4] ICM, DCPM, and other terms), has perhaps 2.5% of the overall market[5] but as much as 20% of the condensing furnace market (Kendall 2002b).[6] The ECPM costs substantially more today, but offers many benefits, including continuously variable speeds—and much higher efficiency. Table 2 summarizes efficiency estimates for ½ horsepower versions of the two motor types.

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[4] ECM™ is a trademark of one manufacturer.

[5] Industry sources suggest that roughly 150,000 BPM motors are sold annually for furnaces. These motors go into new furnaces (3.1 million/yr), Some are installed in heat pumps and other residential air handlers. The annual total is about 6 million units/yr. That would give BPM motors a 2.5% share. Partitioning among air handler types is not known.

[6] ACEEE analyses of the GAMA database indicate that these motors are essentially confined to "premium" products at AFUE 92% and better.

**Table 2. Efficiency of ½ Horsepower PSC and BPM Motors**

| Technology (1/2 hp example): | Multi-speed PSC | Variable-peed BPM |
|---|---|---|
| High-speed efficiency | 55–67% | 74–78% |
| Low-speed efficiency | 34–39% | >70% |

Source: Based on estimates by manufacturers. See Table 4 for details.

The efficiencies cited are motor conversion efficiencies, or "wire-to-shaft," rather than "wire-to-air" efficiencies. Conventionally, residential systems use high-speed fan operation in air conditioning mode and a lower speed for heating. This is done because the contrast between the supply air temperature and the desired room temperature is much smaller in cooling than heating: roughly 20°F in cooling and 50–70°F in heating with gas or oil. Thus, getting the same effect on indoor temperature requires moving a larger mass of air in cooling, which is accomplished through higher fan speeds. This leads to an irony: Because the air handler fan is located in the conditioned air stream, reducing electricity used in heating will (slightly) increase gas consumption. On the other hand, the decreased heat rejection by an BPM system in the cooling cycle decreases compressor work and electricity used for cooling, which improves efficiency.

BPMs are cost-effective at today's prices in many areas. In addition, BPMs are only one of several promising motor technologies (ADL 1999; Nadel et al. 2002). Manufacturers are developing advanced motors that could give nearly the efficiency of the BPM at lower cost.[7] There are multiple paths to improved motor performance at prices that are or will be very cost-effective.[8]

As discussed in Sachs et al. 2002, there are other routes toward improved air handler efficiency. These include better fans, reduced pressure drops within the furnace assembly, and the aerodynamics of the fan and the equipment plenums. These issues are addressed in Appendix B.

## MARKET BARRIERS

This section outlines major barriers to increased use of high-efficiency air handlers and air handler motors. These include:

- Split incentives. Many purchases (such as new construction) are made by parties (such as builders) with incentives to minimize first costs wherever possible, because operating savings accrue to someone else (e.g., the homeowner). Less visible energy-efficient alternatives, such as more efficient furnace fans, are less likely to be installed in these circumstances than more visible amenities such as upgraded kitchen cabinets.

[7] This information is from discussions with manufacturers, which were conducted under "non-disclosure" agreements.

[8] For this discussion, we ignore ancillary benefits of advanced motors, such as the ability to adaptively maintain design airflow with higher or lower static pressure, and the ability to respond to humidity anomalies by varying airflow (and thus evaporator surface temperature). These are value-added features for market differentiation.

- Other customary market barriers. In the retrofit market, dealer training and experience, stocking practices and availability, and related factors have limited the willingness of many dealers to recommend the higher price products. Indeed, despite evidence that relatively few consumers get more than one bid for replacing a furnace, dealers seem so afraid of being underbid by a competitor that they are reluctant to "sell up." They do not feel confident that they can show the greater value of higher-priced products, and thus do not make the effort.
- Product support concerns. Contractors are generally conservative small business people. Their business experience includes advanced products that were pushed onto the market before they were fully mature. These episodes cost them time and reputation among their customers. Most contractors are not comfortable with new technologies such as printed circuit boards to replace relays. Some have been known to warn customers of the high cost of out-of-warranty BPM motor repairs or replacements, presumably to get a sure sale of a base product instead of gambling on a more profitable "up-sale."
- Bundling and high incremental prices. Manufacturers frequently limit advanced fan systems to premium products, using the better motors to offer features such as quiet, soft fan starts, and improved humidity control (humidistat and fan speed modulation). A buyer who wants an efficient blower fan generally can't buy the efficient fan without the rest of the features in an expensive upgrade package. Consider the availability of energy-efficient air handlers for condensing furnaces. There are at least 2,700 condensing furnace models in the Gas Appliance Manufacturers Association (GAMA) directory. Approximately 280 models with AFUE 92% and above have efficient air handlers. They are premium products. If we drop our AFUE requirement to 90%, to include all condensing furnaces, there are about 5 additional models with high electrical efficiency (GAMA serial postings, October 2001–April 2002 edition).
- Low visibility. Furnace fan energy use, which is disclosed in public databases as "$E_{ae}$", is not regulated, so little attention has been paid to it. Although attention to electric efficiency can save consumers money in lifecycle costs, few understand the benefits (although the literature of some manufacturers gives very liberal estimates of the value of advanced fan motors).

## INCREMENTAL COSTS

As noted above, furnaces with advanced, electricity-efficient air handlers are essentially unavailable in today's market except as components in much higher-priced "premium" furnace models (typically with AFUE at least 92%, although there is limited availability in AFUE 80% models, too). Thus, a market survey is likely to show very high incremental costs for electrically efficient furnaces today.

A better approach for our purposes is to estimate the incremental cost of a more efficient motor by itself. For this, two kinds of cost estimates are pertinent: estimates of the price today, and estimates for a time when these are more than niche products, with the advantages of mainstream competition among motor makers, fan makers, and furnace manufacturers. ECPM motors are more expensive today than conventional inductive motors. In manufacturer quantities, a high-efficiency 1/2 horsepower (hp) multi-tap inductive motor costs about $25 and its ECPM counterpart costs at least four times more (see Attachment 1).

With greater manufacturing volume and more competitors, we expect the price to fall to $50–90 during this decade, but the price increment may not disappear. BPM motors are built to high precision. We expect a long-term (mature technology) incremental cost of $25–65, which would appear as a consumer price increase of approximately $50–130. Table 3 gives estimates for both costs and efficiency for the two motor types in HVAC fan applications.[9]

**Table 3. Efficiency and Estimated OEM Costs for ½ Horsepower PSC and ECPM Motors, Based on Conversations with Manufacturers**

| Size | 0.50 hp | | | | 1 hp | | | |
|---|---|---|---|---|---|---|---|---|
| Technology | Multi-Speed PSC[a] | | Variable-Speed (ECPM or Equal) | | Multi-Speed PSC[a] | | Variable-Speed (ECPM or Equal) | |
| | low | high | low | high | low | high | low | high |
| OEM price now | $25 | $25 | $105 | $115 | $30 | $35 | $120 | $125 |
| Mature price estimation | | | $50 | $70 | | | $60 | $90 |
| Mature price incremental cost | | | $25 | $45 | | | $30 | $65 |
| Efficiency, high Speed | 55% | 67% | 74% | 78% | | | | |
| Efficiency, low speed | 34% | 39% | >70% | >70% | | | | |

[a] PSC = Permanent Split Capacitor
[b] Variable-speed = electronically controlled, variable-speed

Other estimates of incremental costs are lower:

- An estimate of $15 incremental cost ($75 v. $60) for BPM v. PSC motors, for ½ hp motors for refrigerator fan applications, has recently been published, but may exclude the electronics required (Roth et al. 2002). The authors infer about a 2.5-year payback in typical installations in the size range of air handler motors.
- Nadel et al. (1998) infer that brushless permanent magnet motors will ultimately cost about $50/hp more than PSC motors.

Authorities except furnace manufacturers infer that incremental prices will steadily decline as market share rises. For comparison with similar technology elements, one recent report notes that adjustable-speed drives for integral-horsepower motors have dropped in price by 4–6%/yr for the past decade (McCoy 2002).[10]

[9] Efficiency data from manufacturers. Cost estimates by ACEEE, based on discussions with motor experts.
[10] Sales of integral-horsepower motors are dominated by smaller units (1–5 hp), for which the electronics required are comparable to those for BPM motors.

## ENERGY SAVINGS POTENTIAL AND ECONOMICS

Improving the motor and fan systems of residential furnaces and heat pumps promises significant, cost-effective efficiency gains. In this section, we present the results of ACEEE's analysis, and data from a promotional sheet prepared by one manufacturer of permanent magnet motors used in this application. Our methods are documented in Appendix A. From it, we estimate 500 kWh/yr national average savings in the heating season. Further, relative to earlier ACEEE reports, this analysis uses 250 W air conditioning power saving instead of 325. When multiplied by 900 average national full-load cooling hours, this gives 225 kWh/yr avoided in cooling season (see Appendix A for details).

We first look at Wisconsin in order to show the parameters considered, and then summarize the savings estimates for other non-cooling-dominated climates. According to the ACEEE analysis, during the heating season, an electrically efficient condensing gas furnace in Wisconsin should save about $44 in electricity charges for 615 kWh/yr (see Table 4). However, because the air handler is in the circulating air stream, the electricity it uses is a heat source for the house, augmenting the gas burned. If the furnace is to provide the same comfort level, wasting less high-cost electricity means burning slightly more gas. The 23 therms required for this cost about $18, for net heating season savings about $26. In the summer, the more efficient air handler will save an additional $9 or so in central air conditioner electricity in Wisconsin. Thus, net annual savings will be about $26 without central air conditioning, and $34 with central air conditioning.[11] The savings estimated by ACEEE are lower than those suggested by GE. This motor manufacturer postulated a 60,000 Btu furnace with a 5-ton air conditioner. The system the manufacturer modeled may have higher static pressures than we assumed. Field studies find much higher external static pressures and fan power consumption than assumed by the test procedure (Neme, Proctor, a and Nadel 1999; Proctor and Parker 2000). The ACEEE calculations do not include a correction for the difference between rating method and field experience, so they are conservative. Since many of the motor manufacturer's assumptions are unstated, it is hard to access the accuracy of those estimates.

[11] There may be small inconsistencies due to cumulative rounding errors.

**Table 4. Estimated Savings for Improved Furnace Fans in Wisconsin**

| Fan Estimate Tool | | | |
|---|---|---|---|
| ACEEE | GE | Units | |
| $0.071 | $0.073 | $/kWh | Residential tariff |
| 500 | 894 | kWh/yr | Estimates of per unit national savings, heating only |
| 0.95 | | | Estimated decrement for "southern" condensing models included in national data |
| 475 | | kWh/yr | Estimated national savings for Wisconsin-sized units |
| 1.30 | | | Multiplier for heating load hours |
| 617 | | kWh/yr | Climate-adjusted electricity savings |
| 1.00 | | | (Reserved) multiplier for ratio of field to test fan energy |
| 617 | | kWh/yr | ACEEE climate- & field-adjusted WI fan energy, heating only |
| | 1,046 | kWh/yr | GE East-North-Central savings estimate |
| $ 44 | $76 | $/yr | Gross annual electricity savings, per unit, heating only |
| $0.76 | | $/therm | Gas tariff |
| 3,412 | | Btu/kWh | On-site conversion factor |
| 2,103,793 | | Btu/yr | On-site electricity, in Btu |
| 0.9 | | | Conversion efficiency for gas |
| 2,337,548 | | Btu/yr | Gas supply required to make up for lost electricity waste |
| 23 | | therms/yr | Gas supply required to make up for lost electricity waste |
| $18 | | | Value of gas to replace avoided electricity |
| $26 | | | Heating savings, net of additional gas used in heating |
| 500 | | | Estimated cooling hours |
| 0.25 | | kW | Fan power and decreased compressor load difference in cooling, estimated |
| 125 | | kWh | Fan energy and compressor load savings in cooling season |
| $9 | $13 | | Savings during cooling hours, high fan speed |
| $35 | $89 | | Total annual savings (excluding ventilation) |

Note: Column 1 gives ACEEE estimates. Column 2 is based on GE (2001). Shaded squares are tariffs that can be varied to update table and the spreadsheet. Some details are discussed in Appendix A.

The same analysis applied to different heating-dominated regions and the U.S. average climate shows the variability of the economics of advanced fan systems in Table 1. The underlying assumptions are explained in Appendix A. With ACEEE's very conservative assumptions, advanced fan motors are cost-effective in all regions considered, with the possible exception of the mountainous areas of the Pacific Northwest. Even there, advanced motors may be cost-effective if the analysis assumes higher external static pressures than ACEEE used, extrapolating from Proctor and Parker (2000).

On average, GE estimates 2.38 times the savings for ECM motors that ACEEE does for advanced motors—without including the GE estimates for ventilation without heating or cooling. We do not know all the reasons for the discrepancies, but assume that GE did not include estimates of the value of gas required to make up for reduced electricity waste by the motor. The comparison strongly suggests, however, that the ACEEE analysis tends to underestimate the savings potential of advanced systems.

## PAST AND CURRENT PROMOTION EFFORTS

Tax credits for a prescriptive approach, specifying BPM motors, are available in Oregon. It offers a tax credit of $350 for furnaces installed on or after October 8, 2001 that have AFUE 90% or higher, and an air handler with an electronically commutated variable-speed motor (ECM, which we refer to as BPM in this report) (OEO 2003).[12] This replaces an earlier split incentive that gave credit individually for the condensing furnace and the BPM-equipped fan motor. Oregon also offers $150 incentives for premium-efficiency ducts. Participation in these programs is higher than expected (Stephens 2002).[13]

One drawback is the use of a prescriptive specification. It can encourage the use of “energy hogs” whose internal design requires large amounts of electricity to overcome resistance to airflow in the furnace. As important, a prescriptive specification gives no incentive for finding ways other than fan motor efficiency to improve electrical efficiency. This specification does not have the potential to credit better fan designs, for example, which might cost less.

In the second quarter of 2003, Massachusetts’ natural gas and electric utilities launched a pilot program to provide incentives to purchasers of furnaces with high electrical efficiency (Gas Networks 2003). This program uses an informal metric called “EUR” (electricity use ratio, the ratio of annual test procedure electricity use [kWh/yr] to furnace [input] capacity in thousands of Btuh). Empirically, ACEEE has found that there are few condensing furnace models with EUR values very close to 6. As important, there were 379 models with AFUE at least 92 and EUR not greater than 6. This is 23% of the total number of models (1,671), which balances the goal of high electrical efficiency with the program need for enough brands and models that most dealers and consumers can participate. ACEEE recommends that other heating-dominated areas consider a similar program.

Cooling-dominated climates will require a different approach. An efficient furnace sold in the North might have a fan sized for a given heating load and a 3-ton air conditioner’s airflow (1,200 cfm). With a different model number, the otherwise identical unit sold in the South would probably be equipped with a fan and motor sized to move enough air for a 5 ton air conditioner (2,000 cfm), since both house size and cooling loads would be greater in the South for a house of the postulated heat load. If regulations only limited kWh/year by furnace size (as originally proposed by DOE), a possible market response would be to discontinue the Southern models (which consume more fan power to meet higher air conditioning loads) and thus force installers to buy oversized furnaces to get large enough fans.

Finally, the Consortium for Energy Efficiency (CEE) is considering a furnace fan efficiency program. CEE seeks a single metric that can be utilized nationally, which is not yet available.

[12] Furnaces qualify for a tax credit of $350 if they have been installed on or after October 8, 2001.

[13] In one utility’s service territory, half the replacement sales qualify for incentives. Several contracting firms (installers) report that the only furnaces they will stock from now on are the ones eligible for the credit. It's not that they can't get others from their local distributors, but what they will "keep on the truck" is changing.

The EUR program developed by ACEEE meets needs in heating-dominated regions, but is not suitable in southern regions where air conditioning loads dominate.

## OTHER MEASURE SCREENING DATA

This section considers other parameters needed for screening measures when a resource acquisition program is under consideration.

### Measure Life

In terms of measure life, there are no public data to suggest that advanced fan and motor systems will last fewer or more years than conventional equivalents.[14] Projecting future performance from early experiences would lead to bias: early experiences with all new technologies seem to have some unexpected trials and tribulations. Indeed, advanced BPM motor systems have some inherent advantages over their PSC counterparts. Soft start reduces bearing loads, and greatly reduces inrush currents that heat motors. Mechanically, the BPM motors are simpler than PSCs. Because the advanced motors will be built in advanced factories, and because the variable-speed electronics are quite similar to those used in larger motor variable-speed drives, we do not expect significant future life differences between the technologies.

### Annual Energy Savings

According to GAMA (Kendall 2002c), 2,403,548 non-condensing furnaces and 733,843 condensing furnaces were sold in the United States in 2000, so condensing furnaces have approximately a 23% share of the national gas furnace market.[15] We assume that almost all of these are sold in climates that are not cooling-dominated. We also assume that advanced fan systems (as ECM motors) are installed in 20% of condensing furnaces (Kendall 2002b), which suggests that 146,770 units/yr have efficient fan motors. From these values, estimates can be made of both per unit and aggregated savings (see Table 5).

[14] We use 18 years average life from DOE (2002).
[15] A lower ratio, according to the same GAMA document, than in the surrounding states of Wisconsin, Iowa, and the two Dakotas.

**Table 5. Estimated Electricity Savings (kWh) from Full Adoption of Better Furnace Air Handler Systems**

| Value | Units | Explanation |
|---|---|---|
| 3,137,391 | furnaces | Annual furnace sales, total |
| 733,843 | furnaces | Annual furnace sales, condensing |
| 2,403,548 | furnaces | Annual furnace sales, non-condensing |
| 20% | | Market share of ECMs for condensing furnaces |
| 2,990,622 | furnaces | Annual furnace sales without efficient air handlers |
| 500 | kWh/yr | Per unit annual heating season electricity savings, national |
| 1,495,000,000 | kWh/yr | Heating season electricity savings, per cohort |
| 18 | yr | Expected lifetime |
| 26,910,000,000 | kWh/yr | Annual heating season electricity savings after full replacement |
| 27 | GWh/yr | Annual heating season electricity savings after full replacement |
| 2,990,622 | Furnaces | Annual furnace sales without efficient air handlers |
| 0.5 | | Assumed share of furnaces with central air conditioning |
| 1,500,000 | | Assumed number of furnaces with central air conditioning |
| 225 | kWh/yr | National average estimated fan savings in cooling |
| 337,500,000 | kWh/yr | Estimated national savings in cooling, per cohort |
| 18 | Yr | Expected lifetime |
| 6,075,000,000 | kWh/yr | Annual cooling season electricity savings after full replacement |
| 6 | GWh/yr | Annual cooling season electricity savings after full replacement |
| 33 | GWh/yr | Estimated annual savings after full replacement |

Note: Gross annual savings in heating and cooling seasons, uncorrected for supplemental gas required in winter. A "cohort" is one year's sales.

For perspective, 33 GWh/yr is approximately the output of 15 power plants of 300 MW each, running 90% of the hours of the year—a high availability estimate.

A similar train of thought gives an estimate of demand reduction if the estimated present saturation (20% of the 733,843 condensing furnaces sold annually plus a few non-condensing, estimated at 0.03 overall) of electrically efficient air handlers moves to 100%. In this scenario, upgrading air handler fans could avoid over 30 power plants (300 MW each) at the end of the replacement cycle. (Note that the base number, 47 million houses, is only about one-half gas furnace-heated; the rest is dominated by heat pumps.)

**Table 6. Estimated Avoided Summer Demand if all Houses with Central Air Conditioning Used Efficient Air Handlers**

| | | |
|---|---|---|
| 0.25 | kW | Avoided in air conditioning |
| 47,700,000 | | Single-family houses with central air today |
| 0.03 | | Estimated national fraction with CMS today |
| 11,570,000 | kW | Avoided when all upgraded to CMS |
| 0.90 | | Diversity at peak |
| 10,413 | MW | |
| 300 | MW/plant | |
| 35 | | 300 MW plants avoided (including hp-equipped houses with central air conditioning) |

Note: Since roughly half of these are considered to be gas furnace houses (the rest dominated by heat pumps), the estimated power plants avoided should be reduced 50% for furnace only calculations.

As noted above, this number includes heat pump-heated houses as well as gas furnace houses. Thus, a direct comparison with Table 5 would suggest that the number of power plants avoided calculated from energy savings (15) is comparable to those calculated from demand savings (about one-half of 35, or 18).

## FINDINGS

Tables 2 and 4 show that advanced air handlers offer substantial energy savings in many regions. Based on the assumption of 2,080 heating and 900 average cooling load hours, ACEEE infers the following savings in regions that are not cooling-dominated.

- 700 kWh/yr (500 heating season, 200 cooling season) of furnace fan energy would be avoided.
- This electricity is valued at $56/yr ($40 heating, $16 cooling). However, to maintain the same service level (Btu delivered to the house), an additional $15 of gas fuel (19 therms) is required to offset the reduced electricity waste.
- Each year's sales (one cohort) will avoid the energy need (kWh) for almost two power plants of about 300 MW size.
- Alternatively, each year's sales (one cohort) will also avoid the need for one power plant to meet peak demand, so (after the stock turns over in 18 years) there will be about 5,000 MW lower peak demand than with the present mix of air handlers, ignoring heat pumps (which contribute about as much).

## RECOMMENDED PROGRAM STRATEGIES

ACEEE recommends that states and utilities adopt a performance-based approach instead of requiring a particular motor technology. The "EUR" proposed by ACEEE is objective, based on available public data, and entirely suitable for northern climates. This approach will avoid incentivizing products that use advanced motors in highly inefficient ways, and it will encourage innovation.

The performance-based approach could be implemented in two basic ways: incentive programs or codes. In general, federal law pre-empts state actions for appliance standards, which is why the broader code-based approach recommends itself.

In the short run, financial incentives are likely to expand the market share of efficient systems relatively quickly. As detailed in the Past and Current Promotion Efforts section, for example, Oregon offers a state income tax credit of $350 for condensing furnaces with efficient (BPCM) motors and also $150 incentives for premium-efficiency ducts. Participation in these programs is higher than expected (Stephens 2002).

A group of interested parties including Massachusetts' gas and electric utilities sponsored an ACEEE project that developed the "EUR" metric as the basis for an incentive program. Because variable-speed (BPM) motors are primarily sold as premium products with other features "bundled" into the products, it has been difficult to estimate the incremental cost of the better air handler by itself. ACEEE concluded that the present incremental cost to the manufacturer is in the range of $85–110 (see Table 3 and Appendix A). Doubling this number, say to $200, is an estimate of the added consumer cost of the advanced motor by itself, if it were offered as an isolated option. In the second quarter of 2003, Massachusetts' natural gas and electric utilities launched a pilot program with incentives to purchasers of furnaces with high electrical efficiency. The furnace fan incentive is $200, plus $200 when it is installed with an AFUE 92 furnace (Gas Networks 2003).

The data required for determining eligibility of specific models for an incentive program are available on the GAMA website (http://www.gamanet.org/consumer/certification/certdir.htm) for individual models. In operation, this database can be downloaded and a list of eligible listed models can be quickly calculated. As an example, Sachs et al. (2002) found about 330 high electric efficiency condensing models, a manageable list. For new models, Appendix C provides a worksheet for calculating eligibility.

> ACEEE recommends consideration of incentive programs offering a credit comparable to that of Oregon ($350) for systems with AFUE at least 92% *and* electricity efficiency ratio EUR less than or equal to 6.[16]

Alternatively, a program restricted to electrical savings could be offered. In this case, an incentive in the range of $150 for furnaces with EUR less than 6.01 would be appropriate.

Because of its great concern with unnecessary electricity use, California is considering an overall forced air efficiency standard for adoption into the 2005 Building Code (Title 24). This could be formulated as air handler watts per square foot of conditioned space, or in other ways. If the electricity allowance is correctly set, this would require both efficient air handlers and low static pressure ducts.[17] We recommend that other states keep abreast of California actions. Once California finalizes its approach, other states should assess whether the same or a similar approach is appropriate.

[16] In ACEEE analyses of the GAMA Consumer Products database, we found that almost all condensing models with high electrical efficiency (EUR 6 or better) had AFUE of 92% or better; roughly 5 models lay in the AFUE range 90–91.9%. Thus there is little restriction of the present market in requiring 92%, and it has the advantage of preventing backsliding.

[17] Duct losses will also be regulated in order to prevent qualification of a system that simply leaks large amounts of air.

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## APPENDIX A. PROJECT METHODS

This appendix summarizes the data sources and analysis methods used in this report.

### Data Sources

*Electricity and Gas Tariffs*

ACEEE used U.S. Energy Information Agency data tables for both electricity and gas tariffs, using residential revenue per unit for each. For gas, we used national and state residential price data from the natural gas prices series (EIA date unknown, "Table: Residential Price by State"). For electricity, we used EIA 2000, "Table 2: U.S. Sales to Bundled Ultimate Consumers, Associated Revenue, and Average Revenue per Kilowatt-hour by Class of Ownership and Sector, 2000."

*Weather Data*

We drew estimated annual heating-load hours (HLH) and cooling-load hours (CLH) from ARI (1994), "Appendix A: Uniform Test Method for Measuring the Energy Consumption of Central Air-Conditioners."[18] For heating loads in specific regions, we adjusted state or region HLH by the ratio of that state or region's HLH (CLH) to the national average of 2,080 HLH. In contrast, CLH were interpolated from ARI (1994), Appendix A, as above. These values (in hours) were multiplied by the reduced demand (0.25 kW) to determine seasonal energy savings.

*Furnace Fan Electricity Use*

ACEEE used "$E_{ae}$" as the basic descriptor of electricity used by furnaces. "$E_{ae}$" is defined and listed, with other performance parameters, for all gas furnaces certified by GAMA (serial postings). According to the GAMA directory, $E_{ae}$ (kWh/yr) is the average annual auxiliary electrical energy consumption for a gas furnace or boiler. It is a measure of the total electrical energy supplied to a furnace or boiler during a one-year period (GAMA serial postings[19]). Various industry sources estimate that the furnace fan accounts for at least 90% of $E_{ae}$. There are two other significant electricity uses in condensing furnaces. First, there is the much smaller inducer fan that pulls air through the combustion chamber and the heat exchanger, and pushes the combustion products out through the pressurized vent. Two-stage furnaces may have two-stage inducers. Second, there are a thermostat and other controls, which may account for tens of kWh/yr (Pigg 2003). Derivation of the values in Table 3 above in the main report is given below in the Analysis Methods.

[18] Note: ARI adapted this material from the federal test procedure: Appendix M to Subpart B, pages 76707 through 76723, *Federal Register,* Vol. 44, No. 249, Thursday, December 27, 1979 and "Part 430—Energy Conservation Program for Consumer Products," pages 8311 through 8319 (omitting page 8312 and parts of 8311 and 8313), *Federal Register,* Vol. 53, No. 49, Monday, March 14, 1988. In particular, ARI used A6.1.3 (CLH) and A6.2.5 (HLH).
[19] Page 4, explanation of column 9, in the October 2001 version

## Analysis Methods

*Initial Screen*

ACEEE publishes a guide to efficient appliances (ACEEE annual editions[20]). Data for gas furnaces are drawn from GAMA (serial postings). ACEEE's 2001 compilation of "The Most Efficient Gas Furnaces" listed both AFUE[21] and $E_{ae}$. Across all furnace sizes, AFUE varied only between 94% and 97%, while $E_{ae}$ varied by ratios from 5:1 to 9:1 within size classes (such as 95 kWh/yr to 856 kWh/yr for the 43,000 to 59,000 Btuh size class, a ratio of 9:1). The present work started as an effort to explain the variability, and to investigate whether the energy efficiency potential of reduced electricity use by furnaces was worth pursuing.

*The GAMA Data*

The basic analysis for this report was done with data from the October 2001 edition of GAMA (serial postings), as cited above. Through a series of intermediate steps, we imported the directory into the Statistical Package for the Social Sciences (SPSS 2002). Our analyses were based on a subset of this database, limited to gas-fired condensing furnaces. Operationally, this data set includes all gas-fired furnaces with AFUE at least 90%. Table A1-1 presents summary statistics.

**Table A1-1. Approximate Number of Furnace and Boiler Models by Type and Efficiency Level**

| Characteristic | Approximate Number of Models[22] |
|---|---|
| All furnace and boiler models listed, gas & oil[23] | 26,539 |
| Gas-fired, forced-air furnaces | 7,850 |
| Gas-fired, forced-air furnaces, condensing[24] | 2,782 |

Source: Sachs and Smith 2002a, Appendix 4

This "universe" of 2,782 models is several times larger than the number of distinct designs; a manufacturer (e.g., Carrier) may list the same basic unit under a number of brand names (e.g., Carrier or Bryant) that are distributed through alternative channels. Still, these numbers suggest that condensing units now account for one-third of all gas furnace models. ACEEE

[20] Lists after 2001 delete furnaces with high gas efficiency but very poor electricity efficiency.
[21] AFUE is the prescribed federal efficiency metric for furnaces. This is carefully designed to *not* reflect variations in the amount of electricity used, but only an estimate of the seasonal efficiency of conversion of gas to heat for the building (ASHRAE 1993, Figure C-1).
[22] "Approximate Number of Models" is roughly the number of rows in the database. Because many manufacturers market the same (or very similar) products under many brand names, these numbers do not reflect the number of discrete designs. Kendall (2002b) estimated that there may be 10 times as many named models as discrete designs. The exact number of models has an uncertainty of about 2.5%. This is the discrepancy between the number of models reported by GAMA's online database tool, and the number successfully downloaded and exported. This difference is not considered significant. Working with GAMA, we were unable to resolve the minor discrepancies, which are attributed to multiple listings of a small number of products.
[23] This includes all gas- and oil-fired furnaces and boilers.
[24] Operationally defined as AFUE greater than or equal to 90%.

elected to work with these data rather than attempting to remove design redundancies, because we worked exclusively on condensing furnaces, which are a manageable data set.[25]

*Condensing Gas Furnace Electricity Consumption*

We began by plotting $E_{ae}$ (annual electricity consumption) as a function of furnace capacity (Btuh input) for condensing furnaces. We used input capacity rather than output because it is the conventional size descriptor for furnaces, and because there is little difference in the two numbers across the range of furnace efficiencies considered: Indeed, although total range is fairly small, 90% to 96+%, roughly 85% (of common updraft models) have efficiencies no higher than 93%.

The scatter plot of $E_{ae}$ (electricity use) v. furnace capacity suggested a "trough" or "valley" with few models. Empirically, this seemed to separate a graph region of systems with high electrical efficiency/low $E_{ae}$ from a graph area with much higher electricity use. When we plotted the data for the best 20% (lowest kWh/yr) in each size class against the most inefficient 20% (most kWh/yr) within capacity classes, there were clear differences.

There are large furnaces with $E_{ae}$ of a few hundred kWh/yr, and small ones that use much more. To develop a "dichotomous" or "off-on" electricity consumption metric that would be applicable for all sizes, we developed an informal unit, the *Electricity Use Ratio* or *EUR*. This is the ratio of the annual electricity use, $E_{ae}$, divided by the furnace capacity, in thousands of Btuh (kBtuh). For a furnace with $E_{ae}$ = 500 kWh/yr and 50,000 Btuh (50 kBtuh) capacity, EUR = 500/50 = 10. EUR has two operational virtues: (1) It recognizes that larger furnaces will use more electricity, since the larger furnaces are generally installed in bigger houses with larger duct systems and higher external static pressure. EUR "normalizes" electricity use across furnace capacities. (2) Everything needed for assessing EUR is available in the standard columns of the GAMA and California Energy Commission online databases for gas furnaces.

As shown in Figure 2 of this report, EUR can be used to select high electrical efficiency furnaces. The figure is a representative plot of the number of models at a given EUR for all furnaces with an AFUE of at least 92. In general, there are no or very few models at or near EUR = 6, but significant numbers for EUR < 6 and many models for EUR >> 6. This is also true for AFUE >= 90%, for all capacities and cabinet configurations. EUR < 6 is thus a natural break for program design purposes. Note that EUR < 6 is purely a performance measure. We suspect that almost all furnaces for which EUR < 6 have advanced motors, but that some furnaces with EUR > 6 also have ECM systems, but in combination with very high internal static pressures that require high wattages to move enough air. Because of idiosyncrasies in the test procedure, it is possible that low EUR is also associated with two-stage and modulating furnaces.[26] Table A1-2 tabulates these data by furnace size.

[25] We are, however, conscious that the artificially high number of models makes inferences of statistical robustness problematic.
[26] Kendall (2002a) includes this assertion, although without data being presented.

**Table A1-2. Average Electricity Consumption and Savings for Condensing Gas Furnace Models (AFUE >= 90)**

| Furnace Input Capacity (kBtuh) | Lower-Efficiency Furnaces EUR > 6 (N = 2,398) | High-Efficiency Furnaces EUR <= 6 (N = 384) | Difference, kWh/yr for $E_{ae}$ |
|---|---|---|---|
| 26–42 | 444 | 93 | 351 |
| 43–59 | 618 | 200 | 418 |
| 60–76 | 689 | 249 | 440 |
| 77–93 | 809 | 299 | 510 |
| 93–110 | 954 | 423 | 531 |
| 111–130 | 1,180 | 366 | 814 |
| | | Average: | 511 |

Source: Sachs and Smith 2002b

The average saving, across all sizes, is 511 kWh/yr. If adjusted for sales-weighted average capacity, we expect it might be somewhat higher. For purposes of this study, we use 500 kWh/yr as the average electricity saving in the heating season by high-efficiency furnace air handlers. This national average value, which is used in Table 3 of the body of this report and throughout this study, must be modulated for regional differences. In contrast, GE uses 894 kWh as the national average (GE 2001).

*Estimated decrement for "southern" condensing models included in national data.* Most condensing furnaces are sold in northern climates, but a few are sold in relatively warm climates (Kendall 2002c). This decrement adjusts for the condensing furnaces sold in southern climates by decreasing the average savings from condensing furnace installations.

*Multiplier for heating load hours* corrects for the ratio of heating load hours in the state or region of interest. It is based on graphical interpolation from ARI (1994), Appendix A.[27] For these purposes, this is sufficiently accurate.

*(Reserved) multiplier for ratio of field to test fan energy* reflects the relatively large differences between the annual electricity use under test conditions (365 W/1,000 cfm in ARI 1994) and that observed in several field studies, averaging 500 W/1,000 cfm (Proctor and Parker 2000). The Proctor and Parker data imply a multiplier of 500/365 = 1.37. As part of ACEEE's overall conservative approach, we set this multiplier to 1.0 in our analyses. This reflects some uncertainties about the differences between PSC and BPM responses to high static pressure situations.

*Conversion efficiency* for gas is assumed as 0.9 or 90%. This study is confined to condensing furnaces, for which operationally the lowest AFUE is 90%. The sales-weighted average may

[27] Note: ARI adapted this material from the federal test procedure: Appendix M to Subpart B, pages 76707 through 76723, *Federal Register,* Vol. 44, No. 249, Thursday, December 27, 1979 and "Part 430—Energy Conservation Program for Consumer Products," pages 8311 through 8319 (omitting page 8312 and parts of 8311 and 8313), *Federal Register,* Vol. 53, No. 49, Monday, March 14, 1988. In particular, ARI used A6.1.3 (CLH) and A6.2.5 (HLH).

be higher, which would make ACEEE's estimates of gas used conservative, reducing our savings estimate marginally.

*Estimated cooling hours* are derived by graphical interpolation from the ARI 210/1994, Appendix A, as for heating load hours, above.

*Fan power and decreased compressor load difference in cooling, estimated.* As shown in Table 2 of the main report, advanced motors have a smaller efficiency advantage at high speed than at lower speeds. In most common installations, higher speed is used for air conditioning, medium speed for heating, and low speed for ventilation mode when utilized. Combined with lower hours of utilization of air conditioning than heating in northern climates, savings reported are more modest. However, since most utilities face their peak demands in summer, the reduction in power required (kW) is significant.

From examination of manufacturers' literature, discussions with industry representatives, and professional judgment, ACEEE infers that the average PSC furnace fan will have about 190 W higher power requirement than an advanced motor. The reduced power represents heat *not* rejected to the building's air, and thus relieves some compressor load. For a COP ~ 3.3, this corresponds to an additional load reduction of 60 W or so, yielding a total demand reduction of 250 W (0.25 kW) per advanced furnace fan that supports a central air conditioner.[28]

*Fan energy and compressor load savings in cooling season.* This row estimates energy (kWh) savings rather than demand (kW) savings. It is derived by multiplying the demand reduction (kW) derived above by cooling-load hours (CLH) at the location.[29]

[28] In earlier analyses, ACEEE assumed 250 W reduced fan motor power + 75 W reduced parasitics, or 325 W total (Sachs et al. 2002). Following suggestions by Kendall (2002b), we have reanalyzed this factor and adopted a more conservative number.

[29] Note: ARI adapted this material from the federal test procedure: Appendix M to Subpart B, pages 76707 through 76723, *Federal Register,* Vol. 44, No. 249, Thursday, December 27, 1979 and "Part 430—Energy Conservation Program for Consumer Products," pages 8311 through 8319 (omitting page 8312 and parts of 8311 and 8313), *Federal Register,* Vol. 53, No. 49, Monday, March 14, 1988. In particular, ARI used A6.1.3 (CLH) and A6.2.5 (HLH).

## APPENDIX B. SOME FACTORS AFFECTING AIR HANDLER ELECTRICITY USE

Although this report focuses primarily on the air handler motor, other design decisions by the manufacturer strongly affect the power requirement for moving air through the system. Some of these, such as the fan design and internal pressure drops of the equipment, are part of the equipment design. Others, including the "aerodynamics" of the connection between the equipment and the ducts, and the pressure drops of the ductwork, are the responsibility of the installing contractor.

As the first factor controlled by the manufacturer, residential HVAC equipment generally uses sheet metal centrifugal fans with many thin, forward-curved, impeller blades. Such fans are compact, inexpensive, and easily manufactured. They meet static pressure requirements. However, conventional fan designs have relatively low peak efficiency, less than 70% (shaft to air). In addition, most designs do not maintain their efficiency across a very large flow ratio (varying cfm). With BPMs, manufacturers can consider other impeller designs. The speed modulation capability of advanced motors allows the use of closed-loop controls. With these, airflow and/or pressure differentials can be adjusted for optimum efficiency. Alternative fan designs being considered include higher precision polymer designs (perhaps with backward-curved airfoil blades[30]).

Second, the fan induces airflow through the internal components of the furnace/air conditioner system (filter and heat exchangers). The internal pressure drops (and thus the fan power required), are determined by the manufacturer's design preferences, including:

- Small size in order to make the unit suitable for as many sites as possible. For example, 21 inches is assumed to be the standard width for attic stairs, so horizontal units designed for attic installation (common in the South) must be no wider than 21 inches.
- Low cost. To the extent possible, sharing parts among sizes and models simplifies inventory, design, and manufacture. It achieves lower component prices through larger purchases and thus reduces costs.
- Meeting mandated requirements as cost-effectively as possible. This isn't just energy, but safety features, for example.
- Investing in features that maximize customers' perceived value and dealer profitability[31] cost-effectively.

Engineering requires design trade-offs. Consider the furnace heat exchanger. Many residential units have "clamshell" heat exchangers, with mirrored sheet metal stampings attached to each other to define passages for air and combustion gases. Other use tubular designs instead. If more compact furnace heat exchangers cost less but need more fan power, they still may be a good design choice, since there is no ratings penalty. The same argument carries over to the air conditioner evaporator (indoor coil of heat pumps). One might reduce

[30] The graphics in one manufacturer's "mini-split" system literature depict air-foil section blades, presumably made of plastic.

[31] Dealer profitability is tricky. It is not just mark-up, but perceptions about ease of selling, number of call-backs, etc.

the surface area by increasing the depth of the heat exchanger. This would allow easier retrofits where the existing coil is small. However, it could increase the flow resistance and thus the fan power required.

A related issue is that manufacturers often offer very similar furnaces with different furnace fans, as part of the same design "family." For example, one manufacturer offers two 90,000 Btuh condensing furnace models with variable-speed blowers. Moderate climate units for installations requiring a 3-ton air conditioner need about 1,200 cfm (400 cfm/ton) and require 670 kWh/year. Hot climate versions support 5 ton air conditioning systems that need about 2,000 cfm, requiring 1,070 kWh/yr. At this time, because fan inefficiency has no impact on ratings, manufacturers would consider changes only for other reasons, such as lower cost or noise reduction.

Finally, there are areas that are the responsibility of the installer, not the manufacturer. The contractor is responsible for the supply and return plenums. These determine the aerodynamics at the interface between the equipment and the distribution ductwork. The installer also designs the supply and return ductwork to the rooms of the house. Pressure drops (flow resistances) vary with material type, design, and installation—as do the critical air leaks to the exterior of the building. For perspective, the ductwork "external" pressure drops are generally roughly equal to the "internal" losses within the furnace and the evaporator coil. In these areas, the manufacturer's responsibility is now limited to assuring enough fan power to move the required volume of air against the pressure head prescribed in ARI 210/240 for air conditioners and heat pumps (ARI 1994, Table 6). This varies with unit size, from 0.1 inch of water (25 pa) for units through 28 kBtuh, to 0.30 inch of water (75 pa) for units between 106,000 and 134,000 Btuh (ARI 1994, Table 6).

## APPENDIX C. RULES FOR DETERMINING IF A MODEL QUALIFIES FOR THE INCENTIVE PROGRAM

- Open the *GAMA Consumers' Directory of Certified Efficiency Ratings for Heating and Water Heating Equipment* located at http://www.gamanet.org/consumer/consumer.htm.
- Select the "Consumers' Directory of Certified Efficiency Ratings for Heating and Water Heating Equipment."
  - For the online (interactive) version, scroll down to the Installation Option 1: Internet Install section and choose the most recent version. You'll be downloading the database to your computer. It will automatically create a directory on your C drive.
  - You can also download the print version (not recommended as the file is very large).
- When you have the database downloaded, go to the GAMA directory on your C drive and click on the large blue "G" icon that says "GAMA 2002" (or whatever year you have chosen to download).
  - When it opens, click the first two screens with "OK" buttons, then choose the "Residential Heating Equipment" option on the third screen.
- When the next screen opens, there will be a number of windows in the top half, and a list of models below it, in alphabetic order based on the manufacturer's name, and then by trade names. You now need to find the product specifications for the model that you are checking. You can do this two ways:
  - If you know the manufacturer's name, the trade name, and the model number, you can scroll down the list until you find the line where your model is shown (due to the large number of models this is not recommended) OR:
  - You can easily obtain the model's specifications by utilizing the database query facility:
    - Click "Create Query" (upper right box)
    - Click on the small upper left box that says "Mfr All" and remove the "X" as you don't want to select all manufacturers.
    - Fill in the following windows with information about your model:
      - Select the manufacturer's name (from pull-down menu in upper left window)
      - Type in the model number (blow trade name)
      - Click "Run Query"(upper right)
      - Your model should appear in the bottom half of the screen, with its product specification information. There may be more than one line, but the specifications should be (mostly) identical.
  - Write down the following specifications listed for your model:

    Input: ____________
    $E_{ae}$: ____________
    AFUE: ____________

  - Calculate EUR (Electricity Utilization Rate)

- EUR = $E_{ae}$/Input = __________ divided by __________ = __________

Does your model qualify under the incentive program?

- Does the AFUE of this model qualify for your local program (90, 92)?
- Is EUR less than or equal to 6?
- If you answered yes to these two questions, then your model qualifies under your local incentive program.

**Additional Information**

- Should you wish to run checks on other models, you will need to begin each query with the same commands, beginning with "'Run Query."
- You can print part or all of the output from your queries by selecting models in the lower window with the "Tag" or "Tag All" buttons (on right).
- When you have completed your queries, click on the "Close" button (on right) and then exit the next window.