Residential HVAC Fans and Motors Are Bigger than Refrigerators

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ABSTRACT

Improving the motor and fan systems in residential furnaces and heat pumps promises substantial, cost-effective efficiency gains. In the annual fuel utilization efficiency (AFUE) test heating cycle, the difference between an advanced fan/motor system in a well-designed unit and an ordinary one in a typical system is 500–700 kilowatt-hours per year (kWh/yr), more than the 490 kWh/yr electricity use of a typical 2001-compliant refrigerator.

An estimated 90% of residential furnaces and heat pumps sold use multi-speed, permanent split capacitor (PSC) air handler fan motors. Better units use advanced electronically commutated permanent magnet motors (ECPMs), otherwise called DC permanent magnet motors. With this type of motor installed, furnace fans are about 15–30% more efficient at high speeds used in cooling, and at least twice as efficient at lower speeds used in heating than PSC motors. In 2000, 5.7 million furnaces and heat pumps were shipped. If all had air handlers as efficient as ECPM motors, this would yield annual cohort savings of about 3.6 billion kWh/yr in heating mode and 1,800 MW of avoided demand in the cooling season, with customer paybacks of 2 or 3 years at projected technology costs. Changing over the entire equipment stock as existing equipment needs replacement would yield annual savings about 15 times these figures.

In order to grasp the potential energy savings that ECPMs might offer, a comparison of the savings associated with higher gas furnace efficiency is useful. For a typical house, the savings from ECPMs are equivalent to almost 10% of source or site energy, or 3% of the natural gas consumed. Since an incremental change of one unit AFUE (say, from 80% to 81%) only saves about 1% of the site energy used, the advanced fan motors are comparable to any likely change in standards short of a national standard for condensing furnaces. In the heating season, gas furnaces with ECPMs consume slightly higher amounts of gas to compensate for the reduced dissipation of electrical energy. However, overall, a national standard requiring high-efficiency furnace fan motors in new furnaces would result in considerable savings of electricity annually.

To achieve these savings through incentives or standards, either a prescriptive or a performance approach can be used. We recommend a performance criterion in the range of 0.2 watt per cubic feet per minute (cfm) at stipulated static pressure, which would encourage multiple paths to reduce parasitic energy consumption by air handlers.

Introduction

Improving the motor and fan systems of residential furnaces and heat pumps promises substantial, cost-effective efficiency gains. During the heating cycle, the difference between an advanced fan/motor system and an ordinary one is approximately the total energy consumption of a 2001-compliant refrigerator: about 600 kWh/yr. In the air conditioning mode in “average” climates, we estimate that the better air handler motors reduce demand by about 300W (including the benefits of reduced heat rejection by the fan motor), or 300 kWh in a 1,000 full-load hour cooling climate.

In this context, our goal is to show that better air handlers can save energy and reduce demand cost-effectively. The air handler of residential and light commercial split systems includes the cabinet (below the furnace in a conventional up-flow furnace), the fan, and the fan motor, which is generally coaxial with the fan (direct drive). Improvements could result from changes in the cabinet and associated system aerodynamics, the fan, the motor, and/or the motor controls.

This paper is based on analysis of public documents, supplemented by conversations with selected industry experts. We believe the results are conclusive enough to support launching coordinated incentive programs and undertaking laboratory studies to confirm the potential of improved systems.

Routes to Improved Performance

Motors

Approximately 90% of residential units use relatively conventional single-phase induction motors, generally PSC units. Typically, multiple taps give a selection of fixed speeds. A newer technology, the electronically commutated DC permanent magnet motor (ECPM, ECM[1] ICM, DCPM, and other terms), has 5–10% of the “premium” market. The ECPM costs substantially more today but offers many benefits, including continuously variable speeds—and much higher efficiency. Table 1 compares efficiency and estimated costs for ½ horsepower versions of the two motor types.

Table 1. Efficiency and Estimated Present Original Equipment Manufacturer (OEM) Costs for ½ Horsepower PSC and ECPM Motors

Technology (1/2 Horsepower Example)	Multi-Speed PSC	Variable-Speed ECPM
High Speed Efficiency	55–67%	74–78%
Low Speed Efficiency	34–39%	>70%
Estimated OEM Price (2001)	$25	$110
Estimated Mature Market OEM Price	$25	$70–75

The efficiencies cited are electrical energy 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 requires moving more 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 ECPM

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[1] ECM™ is the trademark of one manufacturer.

system in the cooling cycle decreases compressor work and electricity used for cooling, hence improved efficiency.

ECPMs are cost-effective at today's prices, as discussed in "Economics and National Implications," below. In addition, ECPMs are only one of several promising motor technologies (ADL 1999; Nadel et al. 2002). Manufacturers are introducing advanced induction motors that could give nearly the efficiency of the ECPM at low cost. Another technology, the switched reluctance motor, promises both lower costs and strongly competitive performance. Still other approaches have been proposed. Thus, there are multiple paths to improved motor performance at prices[2] that are or will be very cost-effective.

Fans

As discussed in Sachs (2001), most residential HVAC equipment uses sheet metal centrifugal fans with large numbers of thin, forward-curved impeller blades. These are compact, inexpensive, and easily manufactured. They easily meet static pressure specifications. 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 ECPMs, manufacturers can consider other impeller designs. The speed modulation capability of advanced motors allows the use of closed-loop controls. With these, air flow and/or pressure differentials can be adjusted for optimum efficiency. Alternative fan designs being considered include higher precision polymer designs (perhaps with backward-curved air-foil blades[3]). Alternatives may offer better efficiency and less noise. However, these fans may require tighter manufacturing tolerances, particularly between the housing and the fan. Also, they may be more expensive or larger.

Cabinets, Heat Exchangers, and the Ductwork: Strategies for Manufacturers

The fan induces airflow through the internal components of the furnace/air conditioner system (filter and heat exchangers), through the supply and return ductwork, and then to the rooms of the house. The *internal* and *external* (duct-related) pressure drops are roughly equal. The external resistances are determined by the design and construction of the heating, ventilating and air-conditioning (HVAC) system; 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 Air-conditioning and Refrigeration Institute (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 Pascal (pa)) for units through 28 kBtuh to 0.30 inches of water (75 pa) for units between 106,000 and 134,000 Btuh.

On the other hand, the internal pressure drops (and thus the fan power required) are determined by the manufacturer's design values, including:

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

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

- Small size, to make the unit suitable in as many sites as possible. For example, 21-inches is taken as 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 includes not just energy, but for example, safety.
- Investing in features that maximize customers' perceived value and dealer profitability[4] at minimum cost.

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. Others use tubular designs (fire tube) 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-conditioning (A/C) evaporator (indoor coil of heat pumps). One might reduce the surface area by increasing the depth of the heat exchanger. This would allow easier retrofits where the existing coil is small. However, it would increase the flow resistance and thus the fan power required. Since fan energy is not regulated, all of these are rational choices for meeting seasonal energy efficiency ratio (SEER) requirements, unless these decisions cause some disamenity (such as increased noise propagation through the ductwork or poor humidity control).

Another issue is that manufacturers often offer very similar furnaces with different furnace fans. For example, one manufacturer offers alternative 90,000 Btuh condensing furnaces with variable speed blowers. Moderate climate units for installations requiring a 3 ton air conditioner need about 1,200 cfm (400 cfm/ton) and require 670 kWh/year. Hot climate versions support 5 ton air conditioning systems that need about 2,000 cfm, requiring 1,070 kWh/yr. Table 2 represents a crude "sensitivity analysis" of the effects of changing air handling system parameters on wattage required as system input. Holding all other parameters constant, we changed each default by +/- 10%. Changes in fan efficiency, which may cost relatively little, have impacts as large as those for other parameters. 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.

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

Table 2. Sensitivity of Power Required to Changes in Required Airflow (cfm), External Static Pressure, Fan Efficiency, and Motor Efficiency[5]

Parameter	Default Conditions	Decrease Parameter by 10%		Increase Parameter by 10%	
		watts	% change	watts	% change
3 Ton Unit, Northern, cfm	1,200	195	-11%	240	10%
External+Internal Static Pressure, in.	0.65	195	-11%	240	10%
Fan Efficiency	60%	244	12%	198	-9%
Motor Efficiency	70%	240	10%	198	-9%
Watts Required	218				

Metrics for Air Handler Efficiency Standards and their Impacts

Eighty-five percent of the electricity used by motors in residences is by appliances covered by National Appliance Energy Conservation Act (NAECA) efficiency regulations.[6] At 7.9% of motor energy in the house, furnace fans use more energy than all other non-regulated motors combined (ADL 1999, p. 3–6). Regulatory requirements strongly influence unitary equipment design and marketing in at least two ways. First, products whose performance is below legal minima may not be legally sold. The federal requirements are subject to periodic review, which may lead to increasing the performance standards. Second, because performance on the tests must be disclosed and can be used to market products differentiated by efficiency, manufacturers want to hit specific performance levels as inexpensively as possible.

The two most relevant standards for furnace fans are SEER (for air conditioners and heat pumps), and AFUE (which estimates the fossil fuel use of furnaces and boilers). Each test describes performance by a single number based on laboratory measurements. Each is intended to represent performance under the diverse conditions prevailing in the United States by being calibrated to simulated "average" climate. Although these metrics have improved efficiency, they are not perfect. With experience and increasing numbers of field studies of the performance of systems installed in actual houses in different climates, and with some insights into what is *not* regulated, it has become clear that these metrics fail to capture available savings.

Air handlers for forced-air or ducted systems are a good example. In part, this is because the rating method for gas and oil furnaces and boilers only considers fossil fuel utilization by the heating unit. It ignores the electricity used for the controls, air handler fan motor, draft inducer motors, igniters, and other equipment. The Gas Appliance Manufacturers' Association (GAMA) publishes the kilowatt-hours consumed for the heating season, as represented by the AFUE test procedure (GAMA 2001). This is expressed as kilowatt-hours per year. An interesting observation about these data is their variability: within a capacity class, high-efficiency condensing gas furnaces show 5:1 to 8:1 variability in the kilowatt-hours per year reported by manufacturers (ACEEE 2001).

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[5] The initial conditions are described by the column "Default Conditions." We sequentially varied one parameter at a time by + 10% and – 10%, with the others held constant at the default conditions. Less efficient fans degrade performance slightly more than other changes.

[6] Examples include refrigerators, clothes and dishwashers, and compressor energy of air conditioners.

The SEER test for cooling performance introduces other anomalies. The test protocol for air conditioner and heat pump ratings allows a default value of 365 watts/1,000 cfm and stipulates greater external static pressure for increasing sizes (ARI 1994). This has two problems. First, the default value is lower than the roughly 470W/1,000 cfm value that field studies have discovered (Proctor and Parker 2000). Thus, the protocol understates the energy consumed. It also overestimates efficiency by understating the fan power that must be dissipated by the air conditioner. Second, the protocol allows the manufacturer to substitute a more efficient air handler if specified for use with that air conditioner model. However, the SEER calculation only credits the difference between actual power and the default value, which is less than the actual benefit. As an example, consider an ECPM design that draws 170 watts. It saves 470 – 170 = 300 watts, but is only credited with 365 – 170 = 195 watts. This reduces incentives to apply better fans and motors. Correction of these problems should be a priority before the next air conditioner efficiency rulemaking procedure.

Desirable Features for Air Handler Metrics

From the manufacturer's perspective, several externally imposed criteria dominate design decisions for air handlers. These include cost, AFUE and SEER requirements (including external static pressure), physical size constraints (for example, large horizontal units that must fit through 21-inch attic doors), and the evaporator (indoor coil) capacity to be supported by the particular furnace (larger "Southern" or smaller "Northern" models). As generalizations, space-constrained units will use more fan energy, as will Southern models. Larger capacity is likely to require more air flow and thus more energy. Because energy use is dependent on these parameters, they should be considered in the design of programs for greater air handler efficiency.

Unit size. Ideally, for furnace fans this is the size of the indoor coil (evaporator) designed to go with the unit. Because a given furnace may be designed for higher or lower air conditioning capacity, furnace capacity itself is likely to be a problematic parameter: the resulting criteria either would be too "loose" and fail to capture available savings or too "tight" and exclude designs that are required in the South.

Cabinet type. Downdraft and large horizontal furnaces may use more fan energy than up-flow designs. To the extent that there are legitimate reasons for selecting these equipment types, we should look for the most efficient versions, rather than excluding the cabinet type.

Evaporator size. As noted above, Southern designs need larger fans that use more energy than Northern designs.

To manufacturers, it is important that metrics impose the least compliance burden possible. Certification programs use two vehicles to assure compliance. The laboratory responsible for the program pulls random samples from warehouse stocks to verify performance. In addition, participating manufacturers have the right to buy and test competitor's equipment. From their perspective, *adding* additional certification parameters *multiplies* the random risk of failure if the manufacturers are designing for performance just above the standard. Variability in assembly and components causes their concern.

This is a significant issue for limitations through regulations, but has not been a barrier for voluntary programs. For example, the ENERGY STAR® dehumidifier program specifies the standard procedures by which efficiency is measured (in liters per day of water removed per kilowatt-hour of electricity used) for each of three size classes (ENERGY STAR 2002). Performance is self-certified by the manufacturer on a voluntary basis.

Given all of these considerations for program design, we recommend that voluntary programs for gas furnaces be based on the values of "E_{ae}" given in the GAMA directory. E_{ae} is defined as total electricity that a given furnace would use in a heating season corresponding to the gas consumption measured by AFUE. E_{ae} is not a perfect index, but it has one overwhelming advantage: it is already measured and disclosed. No additional work is required of the manufacturers to demonstrate that specific models meet program requirements. Its great variability within and between size classes (ACEEE 2001) also makes it relatively easy to establish performance levels that will make a large difference in the energy use of equipment installed through an incentives program.

There is no analogue to E_{ae} for heat pumps or air conditioners installed with their own air handlers, independent of the heating system.[7] ARI 210/240 gives default values for the electricity used by the air handler but does not require disclosure of actual use for those models not rated with better air handlers (such as those with ECPM motors). The self-certification approach to these would involve two elements. First, limiting the program to units for which the manufacturers do disclose the power required, in watts/1000 cfm. This would have the effect of limiting the program to advanced motor/fan systems such as ECPMs. Second, set different limits on power use for different equipment classes.

Table 3 illustrates why 200 watts/1,000 cfm may be generous for such a measure for 3-ton and 5-ton air conditioners. Actual watts/1,000 cfm is highly dependent on design decisions by the manufacturer: the internal static pressure drop across the filter, heat exchanger; and other components of the unit. For example, if the internal static for the 3-ton unit drops from 0.5 inches to 0.3 inches, the power requirement drops from 160 watts/1,000 cfm to 110 watts/1,000 cfm, a dramatic improvement—and one that has been demonstrated in prototypes.[8]

Of course, details are critical for market transformation program design. Initial programs must consider the performance and availability of models of different capacities and configurations. For furnaces, the required data are published in the GAMA directory. Data include unit capacity (MBtuh), E_{ae}, and AFUE. The model number encodes additional information from the manufacturer, generally including the presence of a variable-speed motor, the matching evaporator size, and the cabinet type (up-flow, horizontal, downflow, etc). E_{ae} is a measure of electricity consumption and thus can be used to differentiate efficient from less efficient designs. Therefore, E_{ae} is a performance measure rather than a prescriptive requirement. Preliminary indications are that the GAMA data could also be useful for developing programs for oil-fired furnaces with efficient air handlers.

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[7] This situation is not infrequent in the case of older houses with hydronic heating systems. In many such houses, there is a free-standing ducted air conditioner installed as a retrofit.

[8] Report from manufacturer who asked for anonymity.

Table 3. Air Handler Power Requirements for 3-Ton and 5-Ton Systems[9]

Stipulated Inputs			
Parameter	3-ton	5-ton	units
External Static Pressure	0.15	0.2	inches water
Internal Static Pressure	0.5	0.5	inches water
Total Static	0.65	0.7	inches water
Air Supplied Through System	1200	2000	cfm
Conversion Factor	6350	6350	(cfm) * (inches water)/hp
Power Needed, hp	0.12	0.22	hp delivered to air
Conversion Factor	746	746	watts/hp
Power Needed, watts	92	164	watts delivered to air
Fan Efficiency	65%	65%	
Calculated Values			
Power Required to Fan for 1,000 cfm	141	253	watts
Motor Input	190	340	watts
Motor Efficiency Required	74%	74%	
Watts/1,000 cfm	160	170	watts/1,000 cfm

For heat pumps and related equipment, the ARI data set is less explicit. In the short run, two approaches seem feasible.

First, prescriptive approach using just presence or absence of an advanced air handler motor. This should be decipherable from the manufacturers' model names. Since these units do not have the variability of alternative combustion gas to circulating air heat exchangers (furnace primary/secondary heat exchangers), and since they all use more-or-less standard "A-coils" or indoor coils, this may be sufficient for starting programs.

Second, performance approach based on voluntary disclosure by the manufacturers of air flow efficiency at rated static pressure, in watts/1,000 cfm. In this case, only manufacturers who disclose the information would be eligible to participate in programs.

Achievable Potential, per Unit

The near-term incremental cost to the consumer is estimated as about $170 (from Table 1). Table 4 gives crude payback estimates for cool, average, and hot climates, treating heating, cooling, and total annual costs. Estimates for cool, average, and hot climates all suggest a payback of 2–3 years. Note that these calculations are illustrative and based on flat consumer tariffs that do not include rising tail block or time-of-day rates. Such structures would improve payback even further.

In the "Discussion" (below) we suggest several reasons why market penetration, estimated at 5–10%, is very low when these relatively fast payback estimates are considered.

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[9] Assume ARI external static pressure requirements (ARI 210/240), stipulated internal static for filter and heat exchangers, 400 cfm/ton air supply, 65% fan efficiency, and 74% fan motor efficiency. This approach was suggested by Prof. S. Kavanaugh, Mechanical Engineering, University of Alabama.

Table 4. Estimated Payback for Improved (ECPM-Like) Air Handling Systems in Three Cooling Climate Zones[10]

Climate Zone	Heating	Cooling	Total
Cool	2.7	8.1	2.0
Average	4.3	5.4	2.4
Hot	10.6	3.2	2.5

Economics and National Implications

One indication of the national importance of improved residential air handling systems (which may include both use of advanced motors and adopting low internal static heat exchangers in use by some manufacturers today) is to compare the savings potential with other measures. Table 5 gives one perspective, comparing the savings potential of improved air handling with changes in the AFUE efficiency required.

Table 5. Savings Potential of Improved Air Handling Compared with Increases in AFUE, as Routes to Energy Conservation[11]

67,000,000	Btu/yr	Typical natural gas consumption
500	kWh/yr	Electricity saved by ECPM (as outlined in this paper)
10,000	Btu/kWh	Typical generation heat rate
5,000,000	Btu/yr	Source energy saved
7.5%		Savings, source basis
3,412	Btu/kWh	Site energy equivalent
1,706,000	Btu/yr	Site energy savings
2.5%		Savings, site basis
1.0%		Savings, from raising AFUE from 80% to 81%

Source: Sachs 2001

Adopting better air handling systems gives site energy savings greater than any likely tightening of AFUE beyond about 80%. Since after that manufacturers become concerned that flue condensate can cause problems.

Following the argument of Kubo, Sachs and Nadel (2001), we can aggregate single-unit savings to make national estimates. In 2000, 5.67 million gas furnaces and central heat pumps were shipped (Appliance Magazine 2001). From the data we used to calculate Table 4, an average climate unit with an improved fan would save about 500 kWh in heating and

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[10] As an approximation for heating zones, we used modest savings for average improvement (400 kWh/yr) and changed air handler energy to 800 kWh/yr in the cold climate and 200 kWh/yr in the hot climate. Because the same investment improves performance in both seasons, total payback is better than seasonal. We assumed \$0.08/kWh winter and \$0.10/kWh summer tariffs. Estimated error is +/- 30% for payback. Equivalent full load cooling hours from http://www.epa.gov/nrgystar/purchasing/calculators/cac-main.html#USAGE. "Cool" is average of climate zones 2 (500 hr/yr: CA, OR, WA, NV, ID, UT, NM, CO, NE, SD, MN, IA, MI, IL, IN, OH, PA, NY, NJ, CT) and 3 (700 hr/yr: WA, OR, ID, WY, MT, CO, ND, SD, MN, MI, WI, NY, VT, NH, ME, MA, CT, RI). "Average" is climate zone 4, which "SEER-like" (900 hr/yr: CA, NV, UT, AZ, NM, KS, NE, IA, IN, OH, KY, WV, MD, VA, DC, DE). "Hot" is climate zone 7 (1,500 hr/yr: TX, AR, LA, MS, AL, GA). Climate zones range from 1 (200 hr/yr) through 12 (2,500 hr/yr).

[11] Gas consumption from EIA, 1999, *A Look at Residential Energy Consumption in 1997,* DOE/EIA-0632 (97), Figure 2.10, p. 11; The current legal minimum AFUE is 78%, but few furnaces are sold with AFUE values below 80%, so the effective minimum on the market today is 80%.

290 kWh in cooling,[12] or 790 kWh/yr. For the year's cohort of more efficient climate control equipment, that would be 4.6 TWh saved each year if improved air handlers were required. This value should be reduced about 10%, to about 4.1 TWh, in order to account for present market penetration of ECPM systems. Assume further that this cohort lasts 15 years, on average. Thus, the total savings would be 62.4 TWh. If the mature market incremental price of better air handling systems were $120, then it would cost $680,400,000 to deploy a cohort. By simple division, this is about $0.011/kWh saved over the life of the investment. Values much larger would still compete well with the levelized costs of electricity from new plants. By the same logic, if this investment would reduce summer demand by 325 watts on average (Sachs, 2002), then the cohort would avoid 1,700 MW of capacity (assuming 10% penetration today), or about 6 power plants at 300 MW each.[13] The avoided capital cost is not remarkably cheap at $410/kW, but it's not bad for an investment that reduces both retail energy purchases and power plant fuel purchases.

Discussion

Why Such Low Market Penetration?

Given these factors, it is perhaps surprising that the market share of ECPM motors is estimated as only 5–10%. We believe that several factors combined to create the relatively low level of interest seen in the past:

Low visibility. Furnace fan energy use, although disclosed as "E_{ae}", is not regulated, so little attention has been paid to it.

Perverse incentives. High electricity use improves the rated efficiency of a furnace, and low electricity use is undervalued in the air conditioning ratings.

Bundling and high incremental prices. Manufacturers generally choose to include advanced fan systems with premium products, using the better motors to offer features such as quiet and soft fan starts and improved humidity control (humidistat and fan speed modulation).

Fear, uncertainty, and doubt. Contractors have been known to warn customers of the high cost of out-of-warranty ECPM motor repairs or replacements, presumably to get a sure sale of a base product instead of gambling on a more profitable "up-sale."

Usual market barriers. Many purchases (such as new construction) are made by parties with incentives to minimize first costs for systems that have relatively low consumer interest. 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.

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[12] Calculated 325 watt reduced fan power * 900 full-load equivalent cooling hours (moderate climate like Washington, DC).

[13] Colloquially, 300 MW = 1 Cheney, since the 2001 National Energy Plan effort led by Vice-President Cheney assumed 300 MW stations.

Next Steps

A market transformation program is operating in Oregon. The state offers an income tax credit of $225 for purchasers of residential condensing gas furnaces and an additional $125 if the furnace uses an ECPM motor. Wisconsin also offers an incentive for ECM fans (Edgar 2002). This is an excellent first cut, but the prescriptive approach has some disadvantages. In particular, it only looks at the motor design and ignores the savings available through other avenues discussed above.

As an alternative, a group of utilities and non-government organizations is preparing a gas furnace incentive program that is to be based on disclosed performance. It will have a set of performance rules giving maximum allowable kWh/yr for a given cabinet type and capacity (Btuh). It will also have a non-exclusive list of eligible models. For each of the six size categories of condensing furnaces employed in other efficiency analyses (ACEEE 2001), the best 20% of listed gas-fired condensing furnaces use, on average, about 300 kWh/yr less than the worst 20% (based on E_{ae}). All of the entities involved in the group to date are Northern, so the issue of fan power for larger evaporators in Southern models has not yet arisen. We believe that the best way to address that issue will be to "decode" model designations, which generally disclose the design-matched evaporator size as one or more characters in the model name.

If these or other programs succeed in raising market share for improved air handling systems, fan energy will be taken seriously in NAECA standards development for the next decade. Because the potential for energy (and demand) savings opportunities are so large, air handlers are important for national energy policy. Moving air handlers into standards will be opposed by some manufacturers. First, for the reasons discussed above, this is likely to require at least one more regulated parameter, such as watts/1000 cfm. Some manufacturers fear that additional parameters multiply the chances of failure in a random sample certification test, so they would incur additional costs to increase the tolerance band for average performance beyond the standard. Other industries have typically found that tightening quality leads to decreased total costs by cutting down on early failures. Another objection has been concern that motor regulation might further restrict the ability of the manufacturers to offer profitable differentiated products. This is a serious concern and should force all parties to focus on the primary NAECA interests in reduced energy consumption and power demand.

Thus, in a regulated environment, the best criterion is probably the simplest measure: watts/1,000 cfm delivered to stipulated external static pressure. This would introduce only a single new parameter, but it gives manufacturers maximum flexibility to trade off investments in better fans and motors, less restrictive heat exchangers, and other measures. In addition, this measure would allow the manufacturer to include good motors in baseline designs, while not "revealing" premium features. One could imagine that commodity models would not enable humidity control, adaptive matching to system static pressure, or other features that differentiate premium products.

With smart market transformation strategies, we can provide the benefits of improved systems to large numbers of customers, simultaneously increasing competition and reducing costs through economies of scale in manufacture, marketing, and inventory. With much larger annual sales and market penetration, the industry would prosper with regulated minimum air handling efficiency requirements, which would save large amounts of energy very cost-effectively.

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