Bridging the Efficiency Gap: Commercial Packaged Rooftop Air Conditioners

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ABSTRACT

The energy efficiency of many products has increased markedly over the past decade. A conspicuous exception to this trend is commercial packaged rooftop air conditioners, which have experienced little to no efficiency improvement since 1992 when the Energy Policy Act of 1992 imposed federal minimum standards. Packaged rooftop units have been estimated to use on the order of 76 billion kWh annually in the US, at a cost of roughly $5.6 billion. Sales of these units are growing, and the majority of units sold have energy efficiency ratios (EERs) at or just above the current national minimum efficiency standards. In this paper we document the static efficiencies of commercial packaged air conditioners, explore the reasons behind this efficiency gap, and assess opportunities for overcoming the barriers to efficiency improvements in these products.

Introduction

There are a total of almost 4.6 million buildings in the U.S. commercial sector, providing over 58.7 billion square feet of floorspace. The largest contribution to commercial cooling is from packaged rooftop air conditioning units, which fully or partially cool about 45 percent of this total floorspace (EIA 1998).

Package rooftop units are generally produced in a limited variety of configurations. They are essentially "off the shelf" products, available in standard designs and cooling capacities. A packaged rooftop unit typically has either all components in a single case or the condenser and compressor in a separate unit located outside, remote from the remainder of the unit (i.e. the evaporator and air handler). It is usually used for space cooling in buildings that are typically no more than four stories high. Figure 1 illustrates a typical rooftop installation.

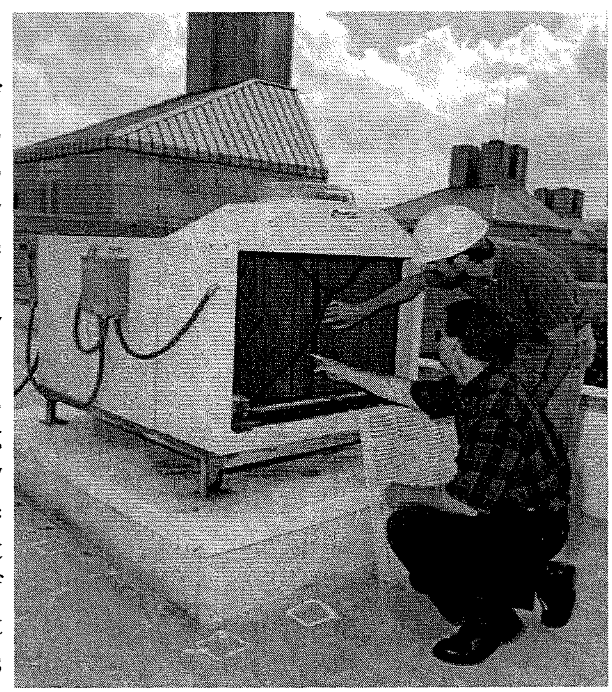

Figure 1. Typical Rooftop Unit (NREL Pix 06451)

Capacities of commercial units can be as great as 150 tons, but the Energy Policy Act of 1992 established energy efficiency standards for commercial units in the range of 5.5 tons (65 kBtu/h) to 20 tons (240 kBtu/h) (U.S. Congress 1992).[1] As units within this range constitute approximately 90 percent of all shipments of rooftop air conditioners, we focus on this particular capacity range.[2]

The market for packaged rooftop air conditioning products is very large, both in absolute dollar value and as a percentage of cooling units shipped on an annual basis. Data from the U.S. Census Bureau for 1998 indicate that the total value of packaged units shipped annually by U.S. manufacturers is approximately $2 billion, about 22 percent of the value of all air conditioning equipment shipments. The Census data also indicate an annual dollar value growth rate of approximately 10 percent per year over the past eight years (U.S. Census Bureau, February 2000).

Although sales of rooftop air conditioners have steadily increased over the past decade, the efficiency performance of this equipment has remained relatively constant, close to the minimum standard over this period. An evaluation of data on currently available models from the Air Conditioning and Refrigeration Institute (ARI 2000) indicates that 65 percent of available models in the 5.5 to 11.25 ton range are within the range from 8.9 EER -- the current federal minimum standard -- to 9.8 EER, with almost all of the remaining few percent distributed from 9.9 EER through 12 EER. Similarly, for models in the 11.25 to 20 ton range, over 65 percent are within the range from 8.5 EER -- the current federal minimum standard -- to 9.4 EER, and the remaining models are distributed from 9.5 EER through 11.5 EER (ARI 2000).

It is important to note that these distributions are for the spread of products produced, not for sales. A more accurate analysis would use sales-weighted data to compare the efficiencies of units installed annually. Unfortunately, such data are not readily available. Given general perceptions of model popularity, though, it is likely that the bulk of purchases take place in the lower efficiency ranges. It seems fair, therefore, to assume that these distributions are conservative; i.e., sales weighted data would skew the distribution even further toward lower efficiencies.

In contrast, residential-scale central air conditioners, which typically range from 1 to 5.5 tons, have a much wider spread of efficiency performance (ARI 2000); only 34 percent of residential air conditioner models are within the range from the federal minimum standard of 10.0 SEER to 11.0 SEER, and the remaining models are distributed from 11.1 SEER up to a high of 18 SEER. These spreads are illustrated in Figure 2 below.[3]

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[1] The current federal standard for 5.5 to 11.25 ton units is 8.9 EER, and for 11.25 to 20 tons is 8.5 EER.

[2] Approximately 70 percent of rooftop air conditioning units also include a heating capability, but this is generally a relatively simple component which is selected on the basis of the energy sources available for the particular application. The focus of this paper is on the cooling component only.

[3] For consistency in comparison among commercial and residential efficiencies, the residential equipment data are graphed as EER values, that have been obtained from the ARI data. Residential equipment standards are in terms of SEER.

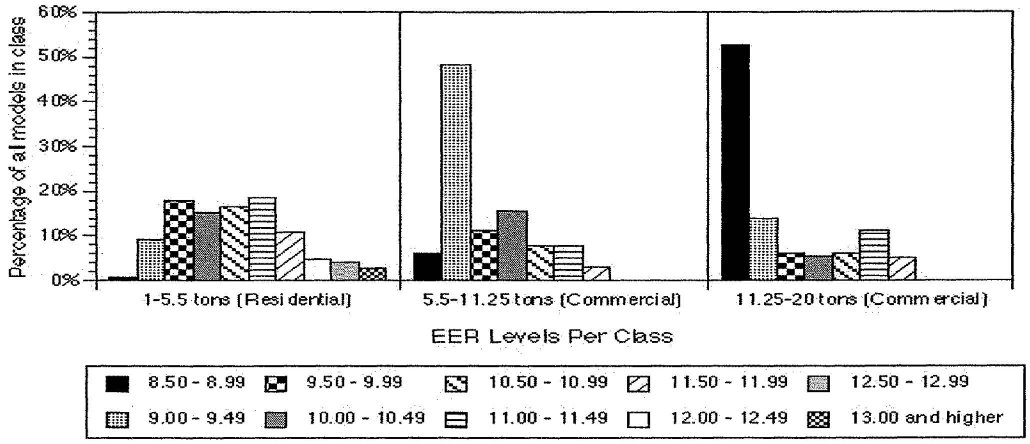

Figure 2. Distribution of Models as a function of EER.

The following table illustrates the difference in the spread of efficiencies for these two types of equipment. More than two-thirds of commercial packaged rooftop air conditioners are within ten percent of the federal standard. In sharp contrast, less than one-third of residential models' SEER values are within ten percent of the federal standard, and more than one third have SEER values greater than twenty percent of the standard. The most efficient commercial units have EERs just above 30% of the standard, while most manufacturers of residential equipment produce models that exceed the federal standard by 50% to 80%.

Equipment Type	Percent of Models Exceeding the Federal Standard by						
	10%	15%	20%	25%	30%	40%	50%
Comm. Pkgd. Rooftop A/Cs 5.5 - 11.25 tons (current standard = 8.9 EER)	27.5	18.4	9.8	3.0	1.0	0	0
11.25 - 20 tons (current standard = 8.5 EER)	30.6	23.2	21.2	14.1	8.2	0	0
Residential Central A/Cs 1 - 5.5 tons (current standard = 9.7 SEER)	67.8	55.2	45.6	28.6	18.9	6.7	1.8

Table 1. Distribution of Models Exceeding the Federal Standard, by Percent.

Clearly, commercial rooftop air conditioning equipment lags similar residential equipment in offering buyers a wide range of efficiency alternatives. Furthermore, packaged rooftop units have been estimated to use on the order of 76 billion kWh annually in the U.S., at a cost of roughly $5.6 billion. These insights are compelling enough to warrant investigation into the cause of the gap.

One might argue that the existing distribution of commercial sector efficiencies is sufficient, and there is no need for greater spread in the market. However, the preliminary screening analysis by the Department of Energy's Office of Energy Efficiency and Renewable Energy supports this focus on improvement of efficiencies of commercial packaged rooftop air conditioning equipment (DOE 2000). The DOE screening analysis tabulates large energy and financial savings for the period from 2004, when higher uniform national standards could become effective, through 2030. For equipment in the 5.5 to 11.25 ton range primary energy savings of approximately 1.2 quadrillion Btu are estimated relative to the current minimum standard. The savings over this period have a national net present value of $673 million and can be achieved with an increase of only 0.4 of an EER to EER 9.3. For larger equipment in the 11.25 to 20 ton range, primary energy savings of approximately 3.2 quadrillion Btu would be realized by an increase of only 1.9 of an EER relative to the current minimum standard of EER 8.5. The projected savings over the period (2004 - 2030) have a national net present value of $1.46 billion.

Method

Although information on the market for rooftop air conditioning equipment provides some detail on the total quantities and dollar values of shipped units for various cooling capacity ranges, little information is available on the sales of equipment at different efficiency levels. Due to the highly competitive nature of the industry, most manufacturers consider sales-weighted information to be proprietary. Because of this, the principal published sources of information for this paper come from analysis of information available from ARI and DOE. ARI lists thousands of models from all its member manufacturers, and enables the user to sort the data according to the criteria of interest, including efficiency (ARI 2000). These data have been used as the proxy for the preferred, but unavailable, sales-weighted data. Often, energy policy analyses primarily use economic tools to try to describe the market, but we chose an alternative approach.

To better understand the trends in the commercial packaged rooftop air conditioner market, we conducted a series of interviews with individuals in a variety of roles throughout the industry. The principal emphasis of our interviews was to develop a better understanding of the role (or perhaps more accurately the "non-role") of efficiency in decisions made at each level, from manufacturing to purchasing, in the rooftop air conditioner market. The ultimate goal was to understand how the barriers to increased efficiency in this market might be addressed.

In order to cover the full range of participants influencing the market, our interviewing process included manufacturers, manufacturers' representatives, distributors, equipment specifiers, contractors, developers, owners, and occupants. We also contacted industry analysts and efficiency advocates to learn their views on the industry. While the interviewing effort was not statistically comprehensive, some very consistent conclusions have emerged. The proprietary nature of market information on actual sales has not prevented industry participants and observers from developing firm opinions on market characteristics based on their personal experience. Some of their explanations for the limited range of available commercial rooftop efficiencies are outlined below.

First cost

There is a widely held view among our respondents that efficiency is not a principal consideration — and often is not a consideration at all — in the selection of rooftop air conditioning units in either new construction or replacement applications. The fundamental message from those interviewed at all points in the market chain was loud and clear: *first cost* is the primary (often sole) purchase criterion, and the higher cost of more efficient units is the major barrier to selection of more efficient commercial rooftop air conditioning equipment. This message did not come as a surprise as previous experience with the commercial building industry led us to expect it, but its across-the-board consistency was impressive.

The reasons given for this overwhelming emphasis on first cost stem largely from the roles of each of the participants in development of new commercial construction, renovation of existing buildings, or maintenance of operational facilities. The most frequently cited underlying reason for the emphasis on lowest first cost is that in most instances the person selecting the air conditioning equipment does not bear the operating cost. This is a textbook case of the split-incentive problem: the person paying for the equipment is generally not the person paying for its operation, so consideration of operating cost is not likely to be part of the purchaser's decision process. Several examples of this situation were mentioned during the interviews:

- If the buyer is a building owner with plans to lease the building, the tenants will be paying the energy bills.
- If the buyer is constructing the building on speculation (i.e., with the intent of selling or renting to someone else), then the next owner or tenants will be paying the energy bills.
- If the buyer is a primary contractor building to a budget or an HVAC subcontractor working to a fixed price bid, the motivation to profit on the job makes minimizing first cost the priority.

Manufacturers and distributors recognize that all of these buyers emphasize minimum first cost, so manufacturers fighting to retain and expand their market share naturally respond to market demand and produce equipment that can provide the required performance at the lowest cost. If efficiency is not on the buyers' horizons, it will at best be a secondary consideration in the manufacturers' view.

However, there are some instances where efficiency *is* a consideration in the equipment selection. In the most frequently cited such situation, when the buyer will also be occupying the building and paying operating costs, efficiency can become much more important in the design and equipment selection. In these cases, life cycle cost is a valid economic decision-making variable. For example, some retail chains with many facilities throughout a region or nationwide have the planning resources and technical sophistication to incorporate operating costs, and hence equipment efficiency, into their overall design and construction process. Although efficiency is still not the principal consideration for these buyers, our interviews revealed that they often select more efficient equipment in order to reduce life cycle cost. Furthermore, these buyers will often standardize across their facilities, and while designating more efficient equipment to meet high cooling loads of southern locations may also specify the same efficient equipment for their other facilities throughout the country. Representatives of both manufacturers and large retail chains confirmed that this does create some demand for higher efficiency equipment, and this phenomenon may account for the number of commercial models in the higher efficiency levels.

Other Trends, Barriers, and Influences

Our interviews revealed other factors, in addition to first cost, that affect decisions made by manufacturers and buyers of packaged rooftop air conditioning units. Although these factors are almost always lower in priority than the desire to minimize first cost, some respondents felt them to be significant.

Design alternatives. In contrast to a residential owner, a commercial building owner or builder has a number of options to improve overall HVAC system efficiency, treating the air conditioning unit only as one component within the system. There are alternatives to higher air conditioner efficiency that can improve system performance, including strategies that are less expensive than investing in more efficient equipment. Some strategies rely on operational elements, such as more sophisticated control systems and external components such as economizers. Other strategies include careful design and commissioning of the air handling system to ensure the most efficient performance. Manufacturers recognize that these alternative design strategies are available to design engineers, and therefore have less incentive to develop higher efficiency units.

Although operational design elements can improve overall system efficiency, if not maintained regularly they have a history of performance degradation such that their benefits are frequently lost early in the system lifetime. Unfortunately the majority of rooftop air conditioners and their air distribution systems receive little, if any, maintenance attention throughout their lifetime and the overall system savings are rarely realized. Building tenants also have difficulty properly operating sophisticated controls. More efficient package units would potentially minimize these operational problems.

Financial incentives. Utility rebates on high-efficiency equipment can motivate manufactures to offer and buyers to select more efficient packaged rooftop air conditioning units. However, some respondents felt that any effects such programs have on efficiency were short-lived, as utility rebate programs were limited in scope and are now being scaled back. The Consortium for Energy Efficiency (CEE), a non-profit market transformation group, maintains its High Efficiency Commercial Air Conditioning (HECAC) initiative which promotes higher-efficiency equipment to its member utilities.

Other buyer priorities. Our respondents had opinions about why residential buyers would look for higher efficiency products, but these factors were cited as being far less an influence for commercial systems. In residential construction and renovation, the builder or buyer often has other considerations that influence their decisions on equipment efficiency. Among those priorities suggested in our interviews were the following:

- Life cycle cost - a buyer's desire to reduce utility bills, because the buyer is the operator.

- Reliability - a buyer's desire for more reliable equipment. We were told that some manufacturers offer longer warranties for more efficient residential equipment, and buyers equated longer warranties with more reliable equipment. We didn't hear this at all for commercial equipment.
- Quality - a buyer's desire to have "better, higher quality" equipment would lead him to buy higher performance equipment.
- Product differentiation - a builder's desire to differentiate himself from the competition through high efficiency building performance.
- Non-economic motives - a buyer's or builder's desire to reduce energy consumption for environmental or ethical reasons.

Although some of these factors can be found occasionally in commercial markets, virtually all respondents considered them to be quite rare and to not create significant demand for higher efficiency commercial equipment.

Federal Standards

Current policy instruments include both federal uniform national standards and market transformation activities such as the CEE HECAC initiative. Although some argue that market transformation programs can take the place of national standards, we conclude from our investigation that both approaches have an important, effective role in improving efficiency levels for commercial packaged air conditioners. The Department of Energy has just taken action which will lead to a higher standards as a foundation for these improvements.

The Department of Energy, Office of Energy Efficiency and Renewable Energy, has performed a preliminary screening of the need for new uniform national standards for certain commercial air conditioning equipment, including the packaged rooftop air conditioners addressed in this paper. This screening analysis has been undertaken as a consequence of new efficiency recommendations by the American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc. (ASHRAE) and Illuminating Engineering Society of North America (IES) in the revised ASHRAE/IES Standard 90.1 which contains energy standards for these products (ASHRAE/IES 1999).

In the May 15, 2000 Federal Register DOE presents its preliminary conclusions (FRN 2000). For central rooftop air source air conditioners in the 5.5 to 11.25 ton range DOE concludes that the efficiency level in ASHRAE/IES Standard 90.1-1999, increased to EER 10.3, is an appropriate candidate for immediate adoption as a uniform national standard and DOE "is inclined to" adopt this level.

For central rooftop air source air conditioners in the 11.25 to 20 ton range DOE concludes that there appear to be significant, cost-effective energy savings that might result from standards that are more stringent than the efficiency level, EER 9.7, in ASHRAE/IES Standard 90.1-1999. DOE therefore "is inclined to propose consideration of an addendum to ASHRAE/IES Standard 90.1-1999, and to undertake a more thorough evaluation to determine whether a rulemaking is justified under the terms of EPCA" (the Energy Policy and Conservation Act of 1975, as amended by the Energy Policy Act of 1992).

The conclusions from the DOE screening analysis are based on a societal cost/benefit calculation -- the nationwide energy and net cost savings which would result from more stringent standards — than the levels in ASHRAE/IES Standard 90.1-1999. The analysis considers many factors, including appropriate climate data and inventories of building in different regions of the country, but their conclusions are based upon aggregation of the effects of these factors into a single nationwide cost/benefit value. It does not indicate that the minimum level provides the lowest societal life cycle cost for individual regions throughout the country, but instead only indicates that overall more people nationwide will benefit than not by the proposed efficiency level. Consequently there are numerous combinations of regional conditions (primarily regarding climate and electricity prices) where higher equipment efficiency would result in even greater energy and cost savings than those of a single proposed national standard.

One of the principal factors compelling higher efficiency equipment is electricity prices -- as is the case in the northeast, where the current average regional cost of 9.8 cents/kWh is almost 30 percent higher than the national average (DOE 2000). Another factor is the climatic variation among regions, with the southeast experiencing significantly greater sensible and latent cooling loads and a longer cooling season than much of the remainder of the country. These examples alone argue for the need for equipment that is more efficient than the national standard, in order to achieve the additional energy and net cost savings within these regions.

As a result of these considerations, the proposed actions to establish new federal uniform national standards create the opportunity to reemphasize the need for a broader range of equipment efficiencies in commercial packaged rooftop air conditioners. DOE's actions have once again spotlighted the energy and cost savings that can be realized through more efficient equipment, and the regional differences addressed in its analysis highlight the further savings that individual regions can realize.

Conclusions

The fundamental marketplace conclusion we have drawn from this effort is that, although there may be the *need* for market transformation, there are limited opportunities for market transformation efforts alone to change the commercial packaged rooftop air conditioner market as it currently stands. The emphasis on lowest first cost prevails, and as long as the buyer is not the utility bill payer, the potential for reducing operating costs through purchasing more efficient equipment will not be a principal factor in selection of equipment. There are some buyers who remain owners and occupants, and they do create some demand for higher efficiency equipment; however, they are only one part of the market and are unlikely to create sufficient demand for higher efficiency models to induce substantially expanded manufacture of higher efficiency products. We would expect the clustering of equipment near the minimum federal standard to characterize the industry for the foreseeable future.

Beyond this initial conclusion we feel that there are substantial opportunities for a range packaged rooftop air conditioning equipment with efficiencies substantially above the uniform national standard. In particular, the screening analysis by DOE not only indicates that there is a need for higher national standards than are currently in force, but that there are large variations in regional conditions which justify the purchase of more efficient equipment.

Therefore, we see the opportunity for a synergy between standards and market transformation activities. Market transformation activities are an important policy tool, but the emphasis that we have found on first cost as the predominant decision criterion shows that minimum efficiency standards are likely to be the most effective means of improving market efficiency overall. Beyond this market transformation activities can stimulate the production of higher efficiency units, thus enlarging the spread of efficiencies available to address regional social cost/benefit variations. Secondarily, they can potentially reduce the manufacturing cost of ;higher efficiency products, thus lowering their purchase price.

In large part, though, the main barrier to efficiency improvement is not a traditional market barrier, but rather the sole focus on first cost that buyers hold. Unless efficient products are the cheapest available, they will not be purchased. Rebate programs to lower first cost can be effective while in place, but would not succeed in having a lasting impact when discontinued..

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