DATA DIGEST

Are Fans Blowing Your Energy Budget?

DOE report points the way to design-based energy savings

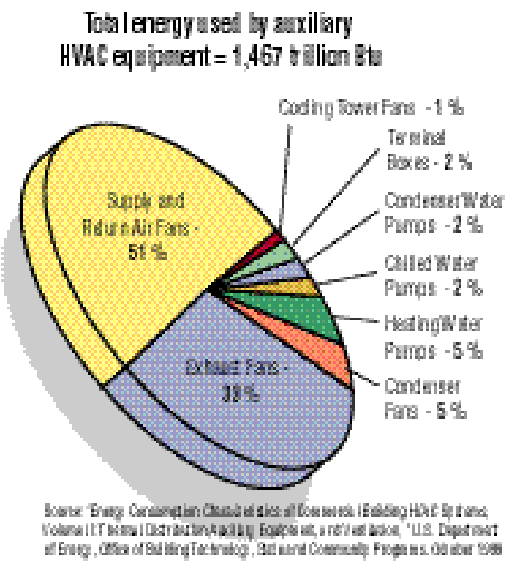

FIGURE 1. National energy consumption of auxiliary HVAC components in commercial buildings.

By JAMES R. BRODRICK

When we consider heating and cooling systems, we think mostly of chillers and boilers—the so-called primary equipment. The fans and pumps that support chillers and boilers, distribute heating and cooling, and ventilate commercial buildings often are overlooked in broad energy analyses.

HVAC systems can employ several auxiliary components, including supply and return fans, exhaust fans, heating water pumps, air-conditioner condenser fans, cooling-tower fans, condenser pumps, and chilled-water pumps.

Late last year, the U.S. Dept. of Energy (DOE) released a report called "Energy Consumption Characteristics of Commercial Building HVAC Systems, Volume II: Thermal Distribution, Auxiliary Equipment, and Ventilation." The report estimates that, in the aggregate, these "auxiliary" fans and pumps consume about 1.5 quadrillion Btu each year—the equivalent of the energy used by 23 million automobiles each year.

The report contends that, while chillers and other primary equipment are becoming much more energy-efficient, auxiliary energy use appears to be increasing. For one thing, indoor-air-quality concerns have led to additional filtration and increasing ventilation rates. New design trends, such as greater

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Methodology

"Energy Consumption Characteristics of Commercial Building HVAC Systems, Volume II: Thermal Distribution, Auxiliary Equipment, and Ventilation" is the second of the U.S. Dept. of Energy's (DOE) planned three-volume report on energy consumption in commercial building HVAC systems. Volumes I (on primary HVAC systems) and III (on opportunities for energy savings) have not yet been published.

The study is based on new energy use estimates developed by the DOE. The study's results were obtained by evaluating the following data sets:

- Distribution of commercial building floor space, which was based on the 1995 Commercial Building Energy Consumption Survey (DOE/EIA-0625[95]).
- Models for cooling and heating loads, which were based on 400 prototype building models from the Lawrence Berkeley National Laboratory ("481 Prototypical Commercial Buildings for Twenty Urban Market Areas," Huang, LBL, June 1990).
- Models of HVAC-equipment design loads and operating characteristics, which were based on data collected by Burlington, Mass.-based Xenergy, Inc. (*www.xenergy.com*). For 25 years, Xenergy has consulted on energy auditing and statistical modeling for both the government and utilities.

The data for the DOE's HVAC study was developed by Xenergy from site-measured, audited building information collected by 12 large, regional electric utility companies between 1986 and 1995.

The data was analyzed with the company's proprietary XenCAP energy-analysis software. XenCAP requires detailed building data obtained by trained energy auditors who visited the subject buildings. The auditors collected information from interviews, blueprints, equipment records, and observation.

XenCAP calculates the annual energy consumption of each piece of equipment included in a building's input record. Estimated energy consumption is compared to actual energy consumption as deduced from actual energy bills. XenCAP then reconciles the calculated energy consumption with the actual energy consumption by adjusting various modeling parameters. The adjusted model is checked by a quality-control engineer who can make manual adjustments if necessary. Typical adjustments involved changes to building heat loss factors, internal heat-gain factors, lighting operating schedules, heating and cooling-equipment efficiencies, and others. The final product is a model of energy consumption that matches a company's actual energy bills.

Using the above-mentioned data sets, the DOE study reported here developed energy-use estimates for more than 1500 technology/market segments representing different building types, regions, system types, and equipment.

The 125-page report was written by Detlef Westphalen and Scott Koszalinski of Arthur D. Little Inc. for the DOE's Office of Building Technology, State and Community Programs. It is available for download in its entirety in .PDF format from the DOE Website at: *www.eren.doe.gov/buildings/documents*.

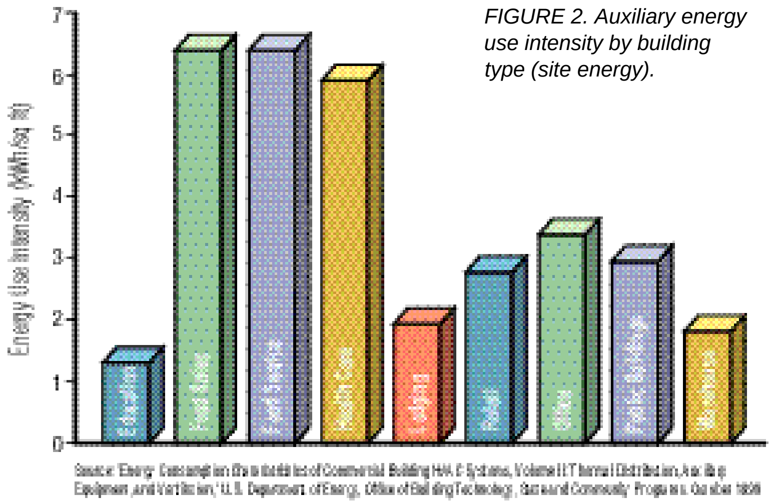

FIGURE 2. Auxiliary energy use intensity by building type (site energy).

use of series fan boxes and reduced duct cross section also tend to increase fan energy use.

That is not to say that such an increase is inevitable. In recent years, costs have dropped and reliability has improved for variable-speed drives, which can substantially reduce fan energy use.

QUANTIFYING AUXILIARY-ENERGY USE

As shown in Figure 1, according to the study, fans alone use 91 percent of all auxiliary energy. Supply and return fans consume half of the total energy, while exhaust fans use one-third. Space-heating support equipment (heating water pumps) accounts for relatively little consumption (5 percent), while space-cooling support equipment (condenser fans, cooling-tower fans, and condenser and chilled-water pumps) account for about 10 percent.

Figure 2 shows auxiliary-energy-use intensity per square foot for nine building types. Buildings used for food sales, food service, and health care use the most auxiliary energy per square foot. These buildings typically have long hours of operation, coupled with high ventilation requirements. Retail, office, and public buildings demand a middle level of auxiliary energy. Buildings used for education, lodging, and warehousing tend to either operate for fewer hours or have low HVAC loads, making them the least energy intensive.

Auxiliary-energy use also was affected by the type of primary HVAC system used. Table 1 and the associated Figure 3 show what types of HVAC systems are typical in the nine building types profiled in the study. Packaged systems serve the most floor space (about 20 billion sq ft). They are prevalent in retail, office, and public buildings. About a quarter of commercial floor space is heated but not cooled. Such systems are found most often in educational, retail, and public buildings, as well as warehouses. Another quarter of the floor space is served by central systems, which are common in health-care, retail, and office buildings. Hotels and other commercial lodging buildings often have individual air-conditioning and heating systems.

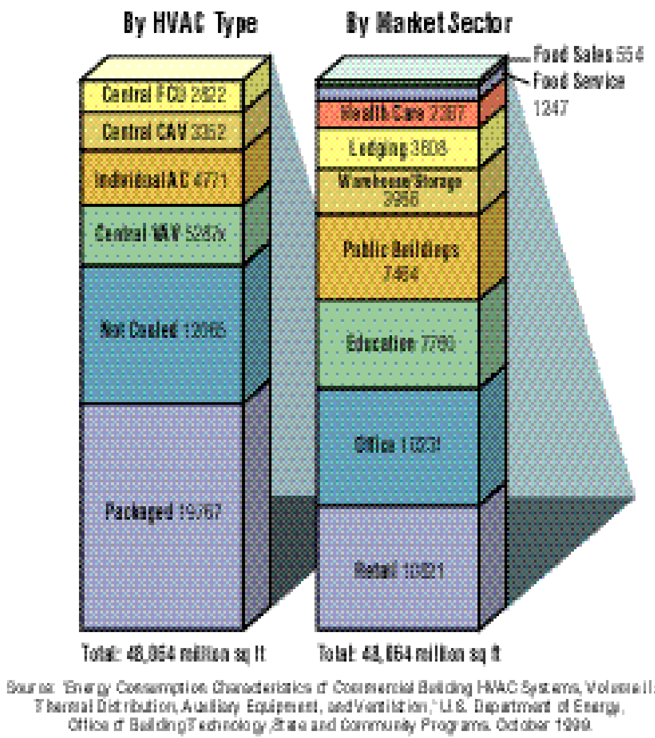

FIGURE 3. Types of HVAC systems typical in the nine building types profiled by the study. Floor space estimate is national total. Energy estimate is national total for all components in each system.

TABLE 1.

Conditioned Floor Space in Commercial Buildings by HVAC-System Type (million sq ft).

	EDUCATION	FOOD SALES	FOOD SERVICE	HEALTH CARE	LODGING	RETAIL	OFFICE	PUBLIC BUILDINGS	WAREHOUSE/ STORAGE	TOTAL
Individual AC	805	0	83	134	1,669	333	1257	371	119	4771
Packaged	2204	534	1100	557	283	5820	4450	3337	1482	19,767
Central VAV	551	0	0	401	85	1081	2322	847	0	5287
Central FCU	466	0	0	334	707	831	484	0	0	2822
Central CAV	212	0	0	802	85	249	1161	741	102	3352
Not Cooled	3522	20	64	159	779	2507	561	2168	2285	12,065
Total	**7760**	**554**	**1247**	**2387**	**3608**	**10,821**	**10,231**	**7464**	**3988**	**48,064**

Source: "Energy Consumption Characteristics of Commercial Building HVAC Systems, Volume II: Thermal Distribution, Auxiliary Equipment, and Ventilation," U.S. Dept. of Energy, Office of Building Technology, State and Community Programs. October 1999.

TABLE 2.

Auxiliary-energy consumption and floor space served by system type.

	FLOOR SPACE 10^6 sq ft	%	ENERGY CONSUMPTION TBtu	%	ENERGY INTENSITY kBtu/sq ft
Individual AC	4771	10	84	6	18
Packaged	19,767	41	761	52	38
Central VAV	5287	11	214	15	40
Central FCU	2822	6	79	5	28
Central CAV	3352	7	173	12	52
Not Cooled but Heated	12,065	25	155	10	13
Total	**48,064**	**100**	**1467**	**100**	**31**

Note: TBTU = trillion Btu. kBTU = Thousand Btu.

Source: "Energy Consumption Characteristics of Commercial Building HVAC Systems, Volume II: Thermal Distribution, Auxiliary Equipment, and Ventilation," U.S. Dept. of Energy, Office of Building Technology, State and Community Programs. October 1999.

Since packaged systems are the most prevalent overall, auxiliary equipment associated with them consumes more than half of the total auxiliary energy nationally (Table 2). However, auxiliary consumption per square foot of conditioned floor area is highest for central constant-air-volume (CAV) systems. The fans in these systems operate at full power whenever the system is operating. Buildings that are heated—but not cooled—use the least auxiliary energy because heating-only systems have relatively little auxiliary equipment.

Total hours of operation is a significant factor in auxiliary-energy use. This differs widely with different commercial buildings. Table 3 shows the effective full-load hours (EFLH)—averaged over five weather zones—of the supply and return fans in three building types: office, retail, and lodging.

Table 3 also shows the amount of auxiliary energy consumed by all components and the amount of floor space served by the different systems in each building category.

Of all the system types, central systems use the most energy in office buildings (49 percent versus 32 percent for the commercial sector as a whole) and serve more office floor space (39 percent versus 24 percent for the sector).

In retail buildings, packaged systems represent 54 percent of the floor space (relative to 41 percent for all commercial buildings) and 67 percent of the energy consumption (compared to 52 percent for the sector). Individual systems are common in lodging. Individual systems serve 46 percent of the floor space (compared to 10 percent for the sector) and use 46 percent of the energy in lodging buildings (compared to only 6 percent in all commercial buildings).

MAKING A START

The DOE still is working on volumes I (primary HVAC systems) and III (opportunities for cost savings) of this three-volume series. When Volume I is published, it will be possible to compare this data on energy use by auxiliary equipment to energy use by primary equipment.

When trying to identify energy savings, it is clear from this study of auxiliary HVAC equipment that fans should be the focus. But this requires more than simply replacing a part. Changes must be made in system design, testing, balancing, controls, and operation. This involves the design engineer, the installing contractor, the operating staff, and the component manufacturers. These parties can significantly reduce fan energy use through proper system design, installation procedures, commissioning, and maintenance.

In many cases, the weakest link in this chain is operating staffers since they rarely focus on peak-efficiency points. Obtaining operating staff commitment to reducing auxiliary-equipment energy use may require an education effort that demonstrates how impressive the numbers become when energy use figures for all the fans in a building are considered together, rather than individually.

In addition, some observers note that the quality of newly installed mechanical-systems equipment may be declining because of a desire to save money in the construction phase. However, this lack of investment results in more cost to the owner in terms of energy use and repairs over the lifespan of the building. An education effort aimed at committing owners to higher first costs and lower lifetime costs may be required.

The designing engineer is perhaps in the best place to create truly significant savings for clients by considering the results of this study of auxiliary equipment energy use. ■

TABLE 3.

System types, operating hours, and auxiliary-energy use in office, retail, and lodging

	OFFICE			RETAIL			LODGING		
	EFLH* (Hours)	FLOOR SPACE (10^6 sq ft)	ENERGY (TBtu)	EFLH8 (Hours)	FLOOR SPACE (10^6 sq ft)	ENERGY (TBtu)	EFLH* (Hours)	FLOOR SPACE (10^6 sq ft)	ENERGY (TBTU)
Individual AC	1050	1257	21	1250	333	6	900	1644	32
Packaged	3450	4450	162	3800	5820	215	3300	283	10
Central VAV	1900	2322	111	2450	1081	34	1950	85	2
Central FCU	2100	484	15	2400	831	21	2250	707	19
Central CAV	3800	1161	57	4300	249	9	3700	85	2
Not Cooled but Heated	3450	561	7	3800	2507	33	3300	779	5
Total	**—**	**10,231**	**373**	**—**	**10,821**	**318**	**—**	**3608**	**70**

Note: Effective full load hours of supply and return fans only. Floor space is national total. Energy is national total for all components in each system. TBTU = trillion Btu. kBTU = Thousand Btu.

Source: "Energy Consumption Characteristics of Commercial Building HVAC Systems, Volume II: Thermal Distribution, Auxiliary Equipment, and Ventilation," U.S. Dept. of Energy, Office of Building Technology, State and Community Programs. October 1999.