Commercial Packaged Refrigeration: An Untapped Lode for Energy Efficiency

Toru Kubo, American Council for an Energy-Efficient Economy
Steven Nadel, American Council for an Energy-Efficient Economy
Margaret Suozzo, American Council for an Energy-Efficient Economy

ABSTRACT

Refrigeration systems account for approximately 7% of commercial sector energy use. Over the past two decades, efforts to reduce energy use by commercial refrigeration systems have concentrated on "built-up systems" which are commonly used in supermarkets. However, several studies indicate that "packaged systems" account for more energy use than built-up systems, suggesting greater attention should be given to improving the efficiency of these systems.

For most packaged refrigeration systems, energy use can be reduced by 20-50% with simple payback periods of only a few years. A number of barriers inhibit the use of more efficient designs, however, such as third-party decision-makers, purchaser and manufacturer emphasis on first cost, and limited availability of information on the comparative energy use of products.

This paper focuses on the following types of packaged systems that may be ripe for near-term action: beverage vending machines, ice-makers, reach-ins (refrigerators & freezers), and beverage merchandisers. In each section we summarize the technical opportunities, market structure, market barriers, and past efforts to influence efficiency for each system, and conclude with recommended next steps towards capturing available energy-saving opportunities.

Introduction

Most of the energy conservation efforts in the commercial sector have focused on HVAC and lighting equipment, since together these comprise approximately 65% of the primary energy use in the commercial sector (ADL 1996). While refrigeration represents about 7% of the commercial sector energy use, several studies have indicated that most refrigeration equipment can reduce its energy use by 20-50% with relatively low incremental costs (ADL 1996). As such, efforts to capture this potential could lead to significant aggregate energy savings.

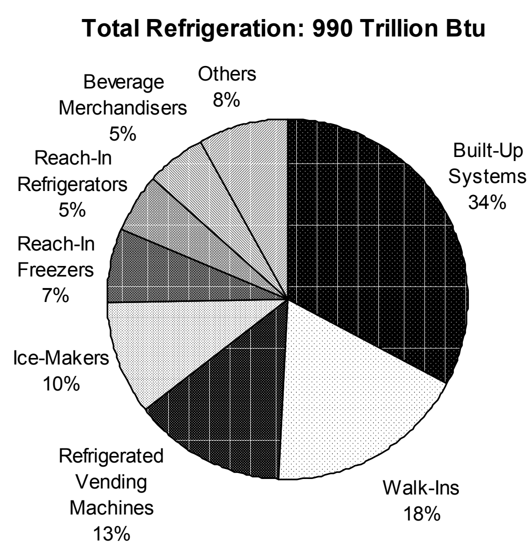

Figure 1. Primary Energy Usage by Equipment Type
Source: ADL 1996

The two major categories of commercial refrigeration products include packaged and built-up systems. Packaged systems, alternatively called "self-contained" systems, incorporate components of the refrigeration system along with the refrigerated compartment in a single package. The whole component is built at the factory and then shipped to the site. Built-up systems, alternatively called "remote" or "centralized" systems, typically involve a single compressor or compressor rack that serves a number of refrigerated cases, and are usually custom designed and built on-site.

To date, more attention has been given to the energy use of built-up systems. However, packaged systems comprise approximately two-thirds of commercial refrigeration energy use (as opposed to approximately one-third for built-up systems), and are the focus of this paper (Easton 1993, ADL 1996). In particular, this paper highlights five of the major packaged systems shown in Figure 1; refrigerated vending machines (which includes both beverage and snack machines, the latter of which is not discussed below), ice makers, reach-in refrigerators and freezers, and beverage merchandisers. For estimates of energy savings from available technology, this paper heavily draws on Arthur D. Little's (ADL) study on commercial refrigeration, prepared for DOE (i.e., ADL 1996). To the authors' knowledge, this is the most detailed study to date on technical opportunities for energy savings from commercial refrigeration equipment.

Beverage Vending Machines

The 2.5 million beverage vending machines in place in the U.S. consume approximately 7.5 billion kWh per year and cost American businesses nearly $600 million annually to power. These products have approximately a 10-year life, so new vending machine sales are on the order of 250,000 per year (Horowitz et al. 1998). Note that refrigerated vending machines that vend snacks are not addressed in this section, but are addressed in Figure 1 above.

Energy Savings Opportunities

The two major energy consuming systems in beverage vending machines are the lighting and refrigeration systems. Lighting accounts for roughly 30-40% of machine energy use. The system typically consists of two T12 fluorescent lamps and a magnetic ballast, and hence does not make use of widely available, more efficient technology such as T8 lamps and electronic ballasts. Furthermore, the lights contained in existing machines are generally left on continuously, even during off-peak periods, such as nights and weekends. While there may be some advertising value in this for those machines located outdoors (e.g., at gas stations and road stops), it is likely to be minimal for the many machines located inside buildings. Low cost technologies, such as timers or motion detectors, could easily be employed to reduce the time that the lights are on and consuming energy. Cooling the vending machine accounts for the remaining 60-70% of the energy use of the machine and several options for improving the refrigeration system and vending machine envelope (e.g., through improved evaporator and condenser fan motors, more efficient compressors, and improved insulation) have been explored by ADL (1996) and others.

The literature on vending machine energy consumption is limited and somewhat incomplete, which in turn impacts estimates of energy savings. Three published studies include: (1) a 1996 ADL study funded by DOE that proposes specific component substitutions and estimates energy and cost impacts; (2) an E SOURCE report that summarizes various reported daily energy consumption levels based on field and laboratory measurements; and (3) a 1996 Canadian Electricity Association (CEA) technology profile. Additionally, two national laboratories have compiled data on vending machine baseline energy use, efficiency options, and cost impacts. Table 1 provides a summary of potential energy savings from each of these sources.

Table 1. Summary of Studies of Vending Machine Energy Savings

	ADL-1 (1996) (best available)		ADL-2 (1996) (high output lighting)		CEA (1996)	E SOURCE (1996)	LABS
Characterization	Measures with <2-yr Payback	Measures with <5-yr Payback	Measure with <2-yr Payback	Measures with <5-yr Payback	High Baseline	Average Baseline	Average Baseline
Baseline Energy Use (kWh/yr)	2,763	2,763	3,165	3,165	4,050	3,650	3,600
Baseline Energy Cost ($/yr)	$207	$207	$237	$237	$304	$274	$270
Number of Cans per Machine	400	400	400	400	372	450	400
Energy Savings (%)	33%	44%	41%	51%	21%	24%	28%
Lighting, electronic ballasts	9%	9%	21%	21%	NA	24%	15%
Refrigeration, basic	24%	35%	21%	30%	NA	NA	13%
Energy Savings (kWh/yr)	910	1,213	1,312	1,615	851	878	990
Energy Savings (kWh/yr/can)	2.28	3.03	3.28	4.04	2.29	1.95	2.48
Energy Cost Savings ($/yr)	$68	$91	$98	$121	$64	$66	$74
New Annual Energy Use (kWh/yr)	1,853	1,550	1,853	1,550	3,200	2,772	2,610
Machine Lifetime (years)					10	10	NA
Machine Price ($)	NA	NA	NA	NA	$1,667	$2,000	NA
Incremental Cost ($)	$102	$290	$102	$290	$167	$50	$40
Average Simple Payback	1.49	3.19	1.04	2.39	2.61	0.76	0.54

Notes: ADL-1 and ADL-2 differ only in that one assumes typical T-12 lamps in the baseline, which consumes approximately 2.8 kWh/day and the other assumes high output lighting in the baseline at 3.9 kWh/day.
LABS combines preliminary findings of researchers at two national laboratories in 1997.
Typical lighting improvements include more efficient lamp/ballast combinations and typical refrigeration/ envelope measures include thicker insulation, more efficient compressors and fan motors.
Source: ACEEE 1998.

Collectively, these studies suggest that through the adoption of more efficient, low-cost lighting and refrigeration technologies, potential energy savings from more efficient vending machines ranges from about 20-50%, with simple paybacks in the range of 1-3 years. The incremental cost to make these improvements ranges from $40-$290 per machine, which is less than 10% of the cost of a new machine. However, as discussed below, several market barriers make realizing these potential savings very difficult.

Market Structure

The beverage vending machine market basically consists of four market actors: (1) beverage vending machine manufacturers (e.g., Vendo, Dixie-Narco, and Royal Vendors); (2) beverage manufacturers (e.g., Coca-Cola, Pepsi, and Snapple); (3) bottlers and distributors (e.g., Coca-Cola Bottling Company, various others); and (4) end-users. Vending machine manufacturers design the machines (with the exception of the front panel design), select and purchase machine components, and assemble the machines. Beverage manufacturers are principally concerned that vending machine users are exposed to the company's logo and get a cold product, and as such will specify particular product performance or testing for light output, product temperature, etc. that the vending machine manufacturer must incorporate. However, beverage manufacturers do not purchase vending machines. Instead, bottlers and distributors (of which the beverage company may own some portion) purchase the machines. They then place the vending machines at the end-user's site for free, and enter into a service agreement, which includes arrangements regarding sharing receipts from the coin-box. In virtually all cases, the site owner, not the machine owner, pays the electric bill (Horowitz, et al. 1998).

Market Barriers to Efficiency Improvements

While the technical opportunities for improving vending machine efficiency are large, the market barriers are substantial. These barriers include split incentives, lack of information, and lack of available products. Since the vending machine owner (i.e., the distributor) does not pay the electric bill, he/she has virtually no interest in efficiency gains. In fact, distributors have been known to balk even at measures with a $1 added machine cost, let alone the $40-290 required to effect substantial improvements in machine efficiency. The end-user, on the other hand, should have some interest in efficiency improvement, but most end-users (e.g. hotels, office buildings, gas stations, universities, etc.) lack the knowledge that energy-savings opportunities exist. Furthermore, they lack information on the cost to power vending machines (roughly $250 per year) or the knowledge that energy-savings opportunities exist. These barriers lead to a current market in which there is virtually no incentive for efficiency investments and no demand, despite the sizable potential and relatively short payback periods. Additionally, even if end-users were sufficiently educated about the benefits, and thus interested in purchasing more efficient vending machines, there is no easy way to distinguish more efficient machines from less efficient machines. And the more-efficient machines are not presently produced, since vending machine manufacturers do not perceive a demand for these products. Furthermore, in some cases, the more efficient components needed to produce the more efficient machines are not readily available due to a lack of demand for these components. For example, lamp manufacturers do not widely produce efficient five-foot high-output lamps – which are a key component for improving the efficiency of lighting in vending machines – in part because vending machine companies are unwilling to commit to widely using these lamps.

Past and Current Efforts to Influence Efficiency

A number of efforts have tried but not succeeded in influencing vending machine energy efficiency. As early as 1994, EPA began to investigate beverage vending machines as a possible target for an ENERGY STAR® labeling program. Several initial efforts languished, but in 1997-1998 some momentum had been created and several vending machine manufacturers expressed interest in labeling as a way of distinguishing their products. Initial discussions with vending machine manufacturers about energy performance included both lighting and refrigeration improvements. Significant technical work performed under cooperative research and development agreements (CRADAs) between DOE and major beverage companies demonstrated sizable energy savings from both systems. Nonetheless, major beverage companies were reluctant to support a comprehensive ENERGY STAR® program for a few reasons. First, any energy improvements would impose added costs, which the beverage companies were unwilling to absorb or to pass-on to their distributors. Second, they were concerned that once labeled products were introduced, many customers would demand to replace their existing machines with ENERGY STAR® models – a demand which the companies perceived they could not meet at a reasonable cost. Furthermore, although vending machine manufacturers were agreeable in prior discussions to the inclusion of refrigeration system improvements, ultimately they felt that such improvements (such as high efficiency compressors) were not "drop-in" replacements for existing systems, but instead would require several years of testing.

In an attempt to meet the various concerns of the beverage companies, distributors, and machine manufacturers, EPA proposed a specification in 1998 that focused only on lighting efficiency improvements. Specifically, it included a requirement that the machines lighting system be based on T8 lamps and electronic ballasts, or a more efficient alternative; and be fitted with a mechanism that provides the end-user with the ability to turn off the lighting for a desired period of time. This specification was estimated to result in savings of about 350 kWh or 10% of current machine energy use and payback within 1.6 years. Even with this limited scope, beverage companies have yet to agree to a specification, although discussions are still on-going. A meeting is planned in the Summer of 2000 for the vending industry to consider standardizing the lighting in all new vending machines. If accepted, the industry will further consider an energy-efficient lighting-based specification for an ENERGY STAR® label (Dolin 2000).

In 1996, the Canadian Standards Association (CSA) issued a voluntary standard for beverage vending machines that includes uniform procedures for measuring energy consumption and maximum daily energy consumption levels. Most existing machines meet the standard, so it eliminates only the least efficient models on the market. The Canadian government is currently considering a pending national standards amendment that may include vending machines. The vending machine standard is likely to be based on the CSA standard. However, it is unlikely that vending machines will be accepted this round, as the amendment will probably focus on other higher-profile products. Instead, it is anticipated that the next amendment process, which is expected to be initiated later this year or early next year, will include vending machines (Oprisan 2000).

In 1998, ASHRAE published a test method for measuring daily energy consumption of vending machines, based on the test method in the CSA standard. At this point, the test method does not account for controls, although the relevant ASHRAE committee intends to begin exploring options to address this during the Summer of 2000 (Martin 2000). This test procedure is now being widely used by vending machine manufacturers. This is good news, in that it provides a mechanism for interested parties to reliably compare the energy performance of various vending machines; however, the results of the test method are not published in one place; hence, end-users cannot easily find the information.

Additional developments at the California Energy Commission (CEC) can help to alleviate this problem. The CEC is in the process of preparing an appliance rulemaking that would require vending machine manufacturers to report vending machine energy use for products sold in the California market. The CEC anticipates little opposition to the requirement (Martin 2000). This data would be an invaluable source of information for purchasers as well as energy-efficiency program planners.

Future Steps Toward Efficiency

Several steps can be taken to enable end-users to make better choices about efficient vending machines and to motivate manufacturers, beverage companies and bottlers to produce and promote more efficient products. First, the CEC can expedite its appliance rulemaking process to make energy performance listings available as readily as possible. The importance of this information cannot be undervalued. Second, EPA should work toward "closing the deal" with vending machine manufacturers and beverage companies on an ENERGY STAR®

specification. Such a specification can initially address lighting only, but it should also establish a process and a timeline toward agreement in the next few years on refrigeration improvements. Finally, although every reasonable effort should be made to promote the success of voluntary government-industry agreements, if the development of an ENERGY STAR® vending machine program continues to meet resistance, advocates should encourage states, California in particular, to develop and mandate minimum efficiency standards that require greater efficiency in these machines.

Ice-Makers

The estimated 1.2 million automatic commercial ice-makers in service in the U.S. consume an estimated 9.4 billion kWh annually, and cost American businesses more than $700 million in electricity (ADL 1996).

Energy Savings Opportunities

Energy use for commercial ice-makers varies considerably from product to product – depending on capacity, coolant, and storage capability – but in general, energy use per pound of ice produced decreases as the capacity of the machine increases. Ice-makers consist of two major subsystems: the refrigeration system and water supply system. All ice-makers use vapor compression refrigeration to produce ice. Most of the energy savings potential exists in the refrigeration system. According to ADL (1996), energy savings of 18% can be realized with an average simple payback of 2.1 years through high efficiency compressors and fan motors, thicker insulation and other measures. A comparison of the most and least efficient units on the market today also illustrates the potential for cost-effective energy savings. Such an analysis for each type of ice-maker and various harvest rates is summarized in Table 2, and shows that the best models achieve energy savings of 18-46% over the worst models, with a payback period of 1.1 years or less.

Table 2. Payback Analysis of Worst and Best Energy Efficiency Models

Ice Harvest	Worst Model		Best Model		Energy Savings	Payback
(lbs/24hrs)	Energy Use (kWh/100lbs-ice)	Market Price ($)	Energy Use (kWh/100lbs-ice)	Market Price ($)	(%)	(years)
Air Cooled Ice Making Head Unit						
200	11.1	1,410	7.9	1,463	29%	0.9
500	8.3	1,940	5.8	1,940	30%	0 (instant)
1000	7.8	3,020	5.1	3,285	35%	1.1
Water Cooled Ice Making Head Unit						
500	7.0	2,585	4.6	1,940	34%	0 (instant)
1000	7.1	3,020	3.8	2,820	46%	0 (instant)
Air Cooled Remote Condensing Unit						
500	8.4	1,895	6.1	1,895	27%	0 (instant)
1000	7.6	2,970	4.9	3,235	36%	1.1
Air Cooled Self Contained Unit						
150	13.0	1,565	10.7	1,485	18%	0 (instant)
Water Cooled Self Contained Unit						
250	9.0	1,830	7.2	1,775	20%	0 (instant)

Sources: ARI 1998, 1999; Catalogs of major manufacturers.

Notes: Assumes 50% discount from list price (based on communication with local distributors), 3,000 operating hrs/yr, and an electricity rate of $0.07/kWh.

Market Structure

Ice-makers are commonly used in hospitals, hotels, food service, and food preservation. The electricity use of ice makers in various market segments is shown in Figure 2. Ice-cube makers account for more than 80% of ice-maker sales, but models are also available that produce ice flakes, chips, crushed ice and nugget ice. End-users usually purchase ice-makers from manufacturers' regional distributors. There are six major manufacturers: Crystal Tips, Hoshizaki America, IMI Cornelius, Manitowoc Equipment Works, Mile High Equipment, and Scotsman Ice Systems. All are members of the Air-Conditioning & Refrigeration Institute (ARI), which sets voluntary testing standards for ice-cube machines based on an ASHRAE test method that considers ice harvest rate, water use, and energy consumption. ARI certifies all models that are tested with their standards and publishes the "Directory of Certified Automatic Commercial Ice-Cube Machines and Ice Storage Bins" which is updated every six months. As a result of this ARI initiative, ice-makers stand out among commercial refrigeration systems as the only equipment with comprehensive data on comparative energy usage of different models.

Market Barriers to Efficiency Improvements

The annual energy cost for a 800 pounds of ice per 24 hour model is as much as $480. Since the end-user who owns the ice-maker usually pays the energy bill, ice-maker manufacturers tend to pay more attention to energy efficiency (as well as water-use efficiency) than they do for other refrigeration products. Several manufacturers in fact promote energy efficiency as a selling point over other manufacturer models. However, the focus on energy efficiency varies widely among manufacturers, and as such, it is very difficult to gain consensus on higher efficiency standards or voluntary labeling programs. Furthermore, end-users are often unaware of how significant the difference in life cycle costs can be, and tend to focus on design, size, and additional functions at the time of purchase.

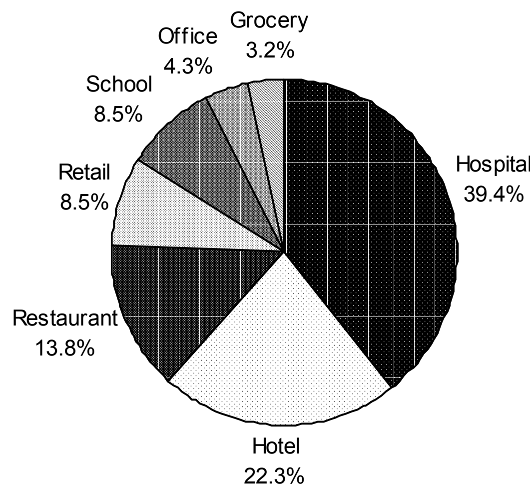

Figure 2. End-use Segment of Ice-makers by Electricity Consumption
Source: ADL 1996

Past and Current Efforts to Influence Efficiency

As mentioned earlier, the most significant step to energy efficiency improvement has been achieved by ARI, which developed a certification program and lists all eligible models in a directory updated every six months. Using this database, LBNL developed purchasing recommendations for the Federal Energy Management Programs (FEMP). The first recommendations were made in 1996, which they updated in 1999 with input from ACEEE and EPA. FEMP generally recommends the top 15-25% of models on the market, with respect to energy-efficiency, but adjusts the criteria so at least two manufacturers have complying models in each category. Using the most recent ARI directory (March 2000), 19.3% of available models meet FEMP recommendations. Table 3 shows the current FEMP recommendations.

The CSA developed its own voluntary standards using the ARI database, which the Canadian Government adopted as mandatory, effective December 31, 1998 (CSA 1998a). Again using the most recent ARI database, 83.7% of available models meet the Canadian standard. This standard eliminates 16.3% of the least efficient ice-cube makers from the Canadian market. Assuming the efficiency distribution of the ice-maker stock is similar to the distribution of the models in the ARI directory, these least-efficient models consume 2.2 billion kWh (24% of energy use by ice-makers) in the U.S. If these least-efficient models were to be replaced by models of average energy-use above the CSA standard, adopting such a standard in the U.S. would save about 0.9 billion kWh annually.

EPA has been developing an ENERGY STAR® ice-makers program, but so far negotiations with manufacturers have been going poorly. Although manufacturers who produce the most efficient models – Manitowoc and Mile High – showed initial interest in the program, when ARI declined to support the program, these manufacturers chose to back the association's decision. Difficulty in gaining support from the trade association has led EPA to put the program temporarily on hold.

Table 3. FEMP Recommendations for Cube-Ice-Makers

Condenser Type	Ice Harvest Rate (lbs per 24 hrs.)	Energy Consumption (kWh per 100 lbs. Ice)	
		Recommended	Best Available
Ice-Making Head Units			
Air-Cooled	101-200	9.4 or less	8.6
Air-Cooled	201-300	8.5 or less	7.9
Air-Cooled	301-400	7.2 or less	7.1
Air-Cooled	401-500	6.1 or less	5.8
Air-Cooled	501-1000	5.8 or less	5.4
Air-Cooled	1001-1500	5.5 or less	5.1
Water-Cooled	201-300	6.7 or less	5.9
Water-Cooled	301-500	5.5 or less	4.7
Water-Cooled	501-1000	4.6 or less	3.8
Water-Cooled	1001-1500	4.3 or less	4.1
Water-Cooled	> 1500	4.0 or less	3.7
Self-Contained Units			
Air-Cooled	101-200	10.7 or less	9.5
Water-Cooled	101-200	9.5 or less	7.5
Water-Cooled	201-300	7.6 or less	7.2
Remote Condensing Units			
Air-Cooled	301-400	8.1 or less	7.9
Air-Cooled	401-500	7.0 or less	6.1
Air-Cooled	501-1000	6.2 or less	5.4
Air-Cooled	1001-1500	5.1 or less	4.6
Air-Cooled	> 1500	5.3 or less	4.9

Source: FEMP 2000

Future Steps Towards Efficiency

Several steps should be taken to promote improvements in ice-maker efficiency. First, the ENERGY STAR® program should consider going forward in developing the criteria for qualifying ice-makers and launch the program. In our opinion, if an ENERGY STAR® program is started, several of the manufacturers that have a substantial number of qualifying models will elect to participate. EPA and regional partners should also consider an education and promotion campaign to inform end-users about the economic advantages of ENERGY STAR® ice-makers, as well as their lower environmental impacts.

Second, EPA, DOE, and regional program operators could investigate partnership programs with hospitals and major hotel, restaurant, and grocery store chains to encourage mass-purchases of energy-efficient models. Well documented and publicized mass-purchase programs could lead to increased interest in lower life-cycle cost systems among other businesses and in turn create demand for more energy-efficient models.

Third, if ENERGY STAR® does not move forward with an ice-maker specification and if manufacturer efforts to improve energy-efficiency appear stagnant, it is appropriate for state and federal governments to follow the Canadian Government and establish minimum efficiency standards.

Reach-Ins and Beverage Merchandisers

Reach-in refrigerators and freezers (including beverage merchandisers) account for approximately 17% of commercial refrigeration energy use and about 26% of packaged commercial refrigeration energy use. Reach-in systems include standard reach-in cabinets (with doors on one side), roll-in units (the bottom is level with the outside floor, permitting wheeled carts to be rolled in), and pass-thru units (with doors on opposite sides). Beverage merchandisers are a special type of reach-in with glass doors and sometimes glass sides to permit customers to see beverages they are thinking of purchasing (see Figure 3 for illustrative examples). The estimated inventory of reach-in refrigerators, freezers, and beverage merchandisers totals 2.9 million units, and consume 4.9, 6.0, and 4.7 billion kWh per year, respectively (ADL 1996).

Reach-in Refrigerator & Freezer

Roll-in Refrigerator & Freezer

Beverage Merchandiser

Figure 3. Illustrations of Common Food Service Refrigeration Systems
Source: Manufacturer websites

Energy Saving Opportunities

As with the other commercial refrigeration equipment, there are substantial opportunities to improve the efficiency of reach-ins. For example, ADL (1996) found that energy use of reach-in refrigerators and freezers can be reduced by approximately 45% using measures with an average simple payback of just over two years. For beverage merchandisers, reductions of 55% are possible with an average simple payback of just over two years. The ADL findings for reach-in refrigerators and beverage merchandisers are summarized in Tables 4 and 5.

Table 4. Reach-In Refrigerator Energy Savings

Technology	Electricity Savings (%)	Cost Premium ($)	Savings ($) (@ $.0782/kWh)	Payback (years)
High-efficiency compressors	12	16	40	0.4
Non-electric antisweat	20	93	67	1.4
Condenser fan ECM motor	3.3	22	11	2.0
Evaporator fan ECM motor	7	48	23	2.1
ECM/variable speed compressor	16	150	54	2.8
Thicker insulation	2	100	8	13
Total for measures with <2 year payback	35	131	118	1.1
Total for measures with <5 year payback	45	313	152	2.1

Source: ADL 1996
Note: Savings not additive due to interactions between measures.

Table 5. Beverage Merchandiser Energy Savings

Technology	Electricity Savings (%)	Cost Premium ($)	Savings ($) (@ $.0782/kWh)	Payback (years)
High-efficiency compressors	9.0	16	26	0.6
Electronic ballasts	10	30	30	1.0
Evap. Fan ECM	29	120	85	1.4
ECM/var. Spd. Compressors	14	150	42	3.6
Cond fan ECM motor	4.5	60	14	4.4
Thicker insulation (1 1/2" to 2 1/2")	3.0	56	9	6.2
Total for Measures with <2 year payback	44	166	134	1.2
Total for Measures with <5 year payback	55	376	168	2.2

Source: ADL 1996
Note: Savings not additive due to interactions between measures.

Market Structure

The reach-in market is highly fragmented due to the diversity of system types; complex distribution, sales and service chains; and the large variety and size of food stores, food service establishments and other users. Typically, manufacturers work through regional sales offices or manufacturer's representatives to sell equipment to equipment dealers, beverage and food distributors, or franchises. These various parties in turn sell equipment to end-users (or in the case of beverage merchandisers, equipment is usually provided on consignment). In addition, there is also a sizable used equipment market.

For reach-in refrigerators and freezers, equipment tends to be grouped into two lines – "standard line" units, representing about 70% of the market, and "specification line" units representing the remaining 30% of the market. Standard-line units, which tend to be less expensive, are primarily sold to commercial food establishments. Specification-line units have improved cosmetics and durability (but not necessarily energy consumption) and are sold primarily to institutional food service establishments (Easton 1993).

The market structure for beverage merchandisers resembles that of vending machines. Beverage-Air and True dominate over 90% of the manufacturing. Nearly all beverage merchandisers are purchased direct from manufacturers by bottling companies for use in convenience stores, supermarkets, retail stores and small food service establishments. Major bottlers such as Coca-Cola's and Pepsi's bottling companies account for about 85-90% of sales. Smaller bottlers account for less than 10% (ADL 1996).

Market Barriers to Efficiency Improvements

While opportunities for improving energy efficiency are large, the barriers hindering adoption of these measures are also large. Among the major barriers are: (1) a focus by most purchasers on first cost; (2) limited information about and awareness of energy use differences between competing products; and (3) the fact that manufacturers make little effort to differentiate equipment on the basis of energy efficiency, with the result that many options for improving efficiency are not incorporated into commercial models.

As is the case with vending machines, the largest barrier to improved beverage merchandiser efficiency is that the bottlers who purchase the systems do not pay the electricity bill for operating the units. Thus, bottlers have no incentive to purchase energy-efficient models and simply look for lowest-cost. Accordingly, manufacturers do not include efficiency measures in their designs if they increase initial cost, despite the short payback periods available.

Past and Current Efforts to Influence Efficiency

Only limited efforts have been undertaken to date to try to improve the efficiency of reach-in units. In the 1980s, the CEC adopted regulations requiring manufacturers who sell commercial refrigerators and freezers in California to provide energy performance and other basic information to the commission (based on ASHRAE test procedures). These regulations cover refrigerators with interior volumes up to 39 cubic feet and freezers with volumes up to 30 cubic feet. The CEC compiles this information in a database and posts this database on their web page (CEC 2000). The CEC is now in the process of updating its regulations in order to refine coverage and requirements and close a few loopholes.

During the 1996-1998 period the CSA developed an *Energy Performance Standard for Food Service Refrigerators and Freezers, CSA 827* (CSA 1998b). The standard includes testing requirements (building on ASHRAE standard 117), minimum efficiency levels, and recommended efficiency levels (labeled "high efficiency"). The minimum levels were selected to allow about 75% of existing units to pass while the high-efficiency levels include the top 25% of existing units. The CSA standard is summarized in Table 6. However, a glitch in the analysis process for glass-door units (including beverage merchandisers) led to much weaker standards for these products. According to an ACEEE analysis, nearly all glass-door units in the CSA database meet the high-efficiency levels (Nadel 1998). In addition to this standard for food service refrigeration, CSA also has a standard for commercial refrigeration display cabinets and merchandisers (CSA 1995). The latter standard mostly covers supermarket refrigeration systems with centralized compressor banks, but also includes packaged beverage merchandisers. Thus, two CSA standards address beverage merchandisers. When CSA 827 was developed, the intent was that beverage merchandisers would be deleted from CSA 657. However, this step has not yet happened.

Although CSA standards are voluntary, provincial governments and the Canadian federal government frequently enact regulations making specific CSA standards mandatory. In 2000, the Canadian federal government hired a contractor to look at the Canadian market and see if it would justify making CSA 827 a mandatory Canadian federal standard. The schedule for this proceeding has not been developed yet, but if a standard is set, it is unlikely to be formally adopted until at least 2001 (Oprisan 2000).

Table 6. Efficiency Levels in CSA Standard

Equipment Type	Maximum Annual Energy Consumption (kWh)	
	Minimum Efficiency Standard	High Efficiency Threshold
Refrigerators		
Reach-in	59V + 1010	54V + 470
Reach-in wine cooler	51V + 300	47V + 10
Milk or beverage type	31V + 450	28V + 260
Worktop table/undercounter	87V + 780	79V + 210
Freezers		
Reach-in	172V + 930	156V – 1270
Ice cream cabinet	86V + 1270	78V + 755
Worktop table/undercounter	367V + 2200	334V – 400
Refrigerator/Freezers		
Reach-in vertical split	92AV + 1900	84AV + 1160

Notes: 1. Volume is measured in cubic feet. Adjusted volume (AV) is equal to the refrigerator volume plus 1.63 times the freezer volume.
2. Columns show formulas for calculating maximum energy use. Thus, for a 40 cf reach-in unit, the minimum efficiency standard is (59*40 + 1010), which is 3370 kWh/yr.
3. Solid-door values are shown. Glass-door values are all double the solid-door values.

Source: CSA 1998b

Also in 1999, EPA began investigating the possibility of establishing an ENERGY STAR® program for reach-in refrigerators and freezers. EPA is still in the investigation stage, undertaking research and talking with manufacturers. Discussions to date have focused on using the CSA high-efficiency level to determine eligibility for ENERGY STAR®. EPA is likely to make a decision on whether to proceed with a program, and on program details, before the end of 2000. For beverage merchandisers (which EPA calls "visi-coolers"), EPA has also begun collecting information, but a decision to proceed with an ENERGY STAR® program is unlikely to be made until several other packaged refrigeration programs (e.g., vending machines and reach-ins) are underway.

Future Steps Toward Efficiency

In order to build on these efforts, we recommend that several steps be taken. First, additional data on equipment performance is needed to provide a foundation for efforts to promote improved equipment efficiency. A database of such information can be a useful tool for purchasers and can provide a solid foundation for setting an ENERGY STAR® standard. Some manufacturers probably have these data but do not report them to the CEC. Other manufacturers will need to test their equipment. In order to make these data available, we recommend that the CEC begin to enforce its requirement that manufacturers report performance data to the CEC.

Second, EPA should go forward and develop an ENERGY STAR® program for reach-in units. For solid door units, the CSA "high efficiency" levels will be a useful starting point. For glass-door units, additional data and analysis will be needed. In addition, we recommend that CSA re-evaluate its standard for glass door units based on additional data that the CEC collects and/or based on laboratory testing of otherwise identical units with and without glass doors.

Third, a substantial information and education campaign should be initiated to better inform equipment sellers, purchasers, and end users about the range of equipment efficiencies on the market, and about the benefits of purchasing ENERGY STAR® certified products. Such a campaign can involve manufacturers of high-efficiency equipment and energy efficiency programs operated by utilities and state and federal governments. Especially for beverage merchandisers, end-users must become aware of the low energy efficiency of these systems and pressure bottlers to provide better systems that reduce utility bills. This effort could turn bottlers to demand that manufacturers produce more energy-efficient models.

Other Types of Packaged Refrigeration Equipment

In addition to the equipment types discussed above, there are many other types of packaged refrigeration equipment including walk-in coolers and freezers; drinking water coolers and dispensers; milk, beverage and ice cream cabinets; preparation tables; and undercounter units, and fish and poultry files. In this section we briefly discuss some of these.

Walk-In Coolers and Freezers

Figure 4. Illustration of Walk-in Systems
Source: Manufacturer website

Walk-in coolers and freezers are room-sized insulated compartments which are refrigerated (see Figure 4). They are used primarily by restaurants, convenience stores, cafeterias and food wholesalers for refrigerated storage of food and non-food items (e.g., flowers). As illustrated in Figure 1, walk-ins account for approximately 18% of commerical refrigeration energy use.

Despite their large energy use, relatively little work has taken place to reduce their energy use. In 1996, ADL examined walk-ins and concluded that the energy use of a typical walk-in refrigerator or freezer can be reduced by approximately one-third, with a simple payback of approximately 1.1 years for refrigerators and 2.8 years for freezers (ADL 1996). Around the same time, CSA considered forming a subcommittee to develop a standard for walk-ins, but the project never was started due to funding cutbacks by electric utilities.

One reason that walk-ins are so difficult to address is that there is no standard test procedure to measure walk-in energy use, in part because their large size makes testing difficult. Also, some walk-in systems are custom-built and cannot be considered packaged systems. Still, packaged walk-in systems are a substantial portion of the market and opportunities to reduce their energy use should be addressed. As a first step in these efforts, we recommend that a test-procedure be developed, and a database of testing results be assembled. Based on this database, programs can be developed to encourage purchase of the more efficient units.

Drinking Water Dispensers

Water dispensers, typically found in office environments, consume more than 4 billion kWh of electricity per year and cost American companies about $300 million annually to operate (EPA 2000). Energy use varies considerably between units that serve both hot and cold water and those that serve cold water only. A preliminary analysis for EPA by The Cadmus Group found that hot/cold dispensers consume about 2 kWh per day, whereas cold only dispensers (gravity and pressurized) consume an order of magnitude less energy (The Cadmus Group 2000). The majority of these losses occur during standby. EPA estimates that approximately 90% of hot/cold dispenser energy use and 60% of cold-only dispenser energy consumption is due to standby losses. Small low-cost improvements, such as insulation and timers, can reduce these losses by more than 50% (EPA 2000).

Very little prior work has been done to improve water dispenser efficiency in the U.S.: there is no energy test procedure and no documentation of energy use for these products. In Canada, however, CSA published an energy efficiency standard for water coolers in 1999. The test method for the standard is based in part on an ARI test procuedure, which focuses on water dispenser capacity. The CSA standard requires testing of both standby and daily energy consumption; these are combined with capacity into a theoretical energy factor (EF) rating. The standard, which sets a mimum EF, is not likely to become a national standard before 2001.
While CSA was developing its standard, EPA was also working on developing a draft ENERGY STAR® program specification for these products. (This specification requires roughly a 30-40% increase in efficiency from the average unit consumption.) The CSA and EPA activities were not coordinated. As a result the initial ENERGY STAR® specification included a different criteria (standby only) and a simplified test method relative to the CSA standard.

Manufacturer comments on the draft specification have led EPA to consider two modifications. First, EPA is considering referencing the CSA standard for testing as many manufacturers are already using this method. Second, EPA will consider, based on manufacturer-submitted data, an initial (less stringent) tier 1 specification, recognizing the most efficient products to date, with the 30-40% reduction as a tier 2 level to take effect in a few years. EPA will be working with the industry throughout the Summer of 2000 to resolve these issues and anticipates a program launch in the Fall (Sanchez 2000).

Milk and Beverage Cabinets and Undercounter Units

Milk, beverage and ice cream cabinets, and undercounter units probably account for only a few percent of commercial refrigeration energy use. However, they have enough similarities with reach-in units that both are included in the CSA food service refrigeration standard, including both recommended minimum efficiency and high-efficiency values (see Table 6).

Conclusion

Commercial packaged refrigeration system efficiency has received little attention to date, but these systems possess significant energy savings potential. Total savings using currently available cost-effective technology totals approximately 155 trillion Btu for the five major packaged systems discussed above, a reduction of 38% from current energy use (ADL 1996). Most of these savings can be realized within a 2-year payback period. Savings from more efficient packaged refrigeration systems could reduce carbon emissions from fossil fuel combustion by an estimated 2.5 million metric tons annually – equivalent to removing 3.4 million cars off of the road annually.

Across equipment types, there are several key recommendations that we offer to achieve these energy savings and greenhouse gas emission reductions:

1) Develop standard test procedures for measuring energy use of packaged equipment, where these methods are not already available.
2) Compile testing data established under standard test procedures, and develop a database of comparative energy use information.

3) Finalize and promote voluntary initiatives, notably ENERGY STAR® labeling, to increase both demand and supply for more efficient products. The ENERGY STAR® label and information used in developing the program criteria can be used to: (1) educate end users about the benefits of more efficient products; and (2) to recognize manufacturers that produce products meeting the criteria..
4) Where voluntary efforts are not making progress, develop, enact and regularly update mandatory minimum efficiency standards to eliminate energy wasting models.

Packaged refrigeration systems are untapped lodes for energy-efficiency. It is up to the various players – manufacturers, bottlers, end users, electric utilities, governments, trade associations, and public organizations – to cooperate in removing market barriers and begin mining this valuable resource.

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