Energy Savings Potential for Commercial Refrigeration Equipment

Final Report
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1. Executive Summary

Primary energy usage in the commercial refrigeration sector is estimated as 990 trillion Btu.[1] The contribution to this sum of the different commercial refrigeration sectors is shown in Figure 1-1 below.

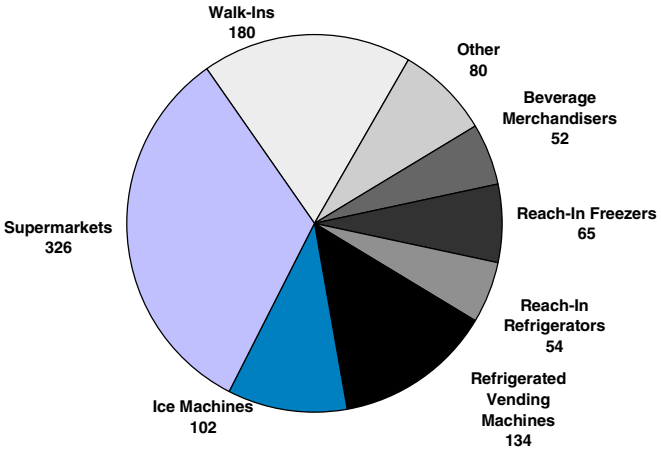

Figure 1-1: Primary Energy Usage in Commercial Refrigeration (trillion Btu)

Note: "Others" includes Roll-Ins, Under-counter, non-beverage self-contained merchandisers and display cases, and single-compressor remote systems serving display cases in small grocery applications.

The analyses described in this report indicate that there are large opportunities for savings in the commercial refrigeration sector. Primary energy savings of about 266 trillion Btu (29% for the equipment types examined) were identified based on improvements in current technology assuming implementation of the most economically attractive technologies for all equipment in the installed based. The split of these savings amongst the studied equipment types is shown in Figure 1-2 below.

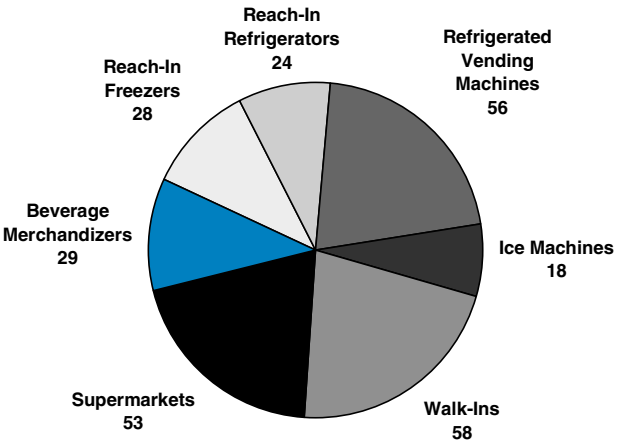

Figure 1-2: Commercial Refrigeration Savings Potential (trillion Btu)

[1] Primary energy use is calculated based on a heat rate of 10,867 Btu/kWh, which takes into account power production, distribution, and transmission losses.

Much of this savings potential is associated with high efficiency fan motors and high efficiency compressors, technologies with paybacks of less than 2 years when used for new equipment. High efficiency fan motors can also be implemented on a retrofit basis (with longer payback if the existing motors are still functional).

Additional savings are associated with hot gas defrost, use of hot gas or liquid for antisweat heating, and defrost control. Implementation of these technologies is projected to have payback periods typically within 5 years.

Table 1-1 below shows the identified energy savings distributed among technologies.

Table 1-1: Identified Energy Savings Potential

	Savings Potential (Trillion Btu)	Payback Range (Years)
Evaporator Fan ECM Motor	85	0.5 - 3
ECM/Variable Speed Compressor	48	2 - 5
High-Efficiency Compressors	39	0.5 - 2
High-Efficiency Fan Blades	30	0.1 - 1
Condenser Fan ECM Motor	25	0.5 - 8
Floating Head Pressure	25	0.3 - 3
Electronic Ballasts	24	1 - 2.5
Non-Electric Antisweat	20	1 - 1.5
Thicker Insulation	20	1 - 1.5
Ambient Subcooling	12	2 - 11
Hot Gas Defrost	10	1.5 - 3
Liquid-Suction Heat Exchangers	10	4 - 14
Evaporative Condensers	10	*
Antisweat Heater Controls	10	2 - 6
Other Ice Machine Process Improvements	9	1 - 6
Evaporator Fan Shutdown	7	1 - 2
External Heat Rejection	6	7
Economizer Cooling	6	20
Heat Reclaim	3	2 - 5
Defrost Control	3	3
Mechanical Subcooling	2	5

*No payback in most locations due to non-energy costs

The use of alternate refrigeration cycles which are not now commonly used in refrigeration equipment does not, at this point, appear to have significant potential for reducing primary energy use. Examined alternative cycles include absorption and chemisorption. The use of waste heat to drive these cycles does have the potential to reduce primary energy usage, however.

The phaseout of CFC refrigerants and the future phaseout of HCFC refrigerants requires that equipment be redesigned and that much existing refrigeration equipment be replaced. This provides an opportunity to accelerate the implementation of efficiency-

improving technologies. However, the theoretical efficiency of possible alternative refrigerants is not significantly higher than that of currently-used refrigerants. The supporting analysis takes into account the secondary refrigerant loop which would be required for implementation of ammonia and flammable refrigerants in commercial refrigeration.

The use of gas-fired equipment will not result in significant primary energy savings. Table 1-2 below shows the comparison of electric and gas technologies for low temperature supermarket applications. Gas-fired technologies are more economical in some areas with high-priced electricity, and they provide advantages in peak load reduction, which have associated infrastructure cost benefits.

Table 1-2: Comparison of Electric and Gas Refrigeration Options

	Electric Use[1] (kW/ton)	Equipment Gas Use (mBtu per ton-hr)	Primary Energy Use[2] (mBtu/ton-hr)	Primary Energy COP
Electric	2.3	0	25	0.48
Gas-Engine	0.25	22	25	0.48
Chemisorption[4]	0.56	42[3]	48	0.25
Advanced Absorption	0.46	21[3]	26	0.46

Supermarket Low Temperature: -20°F; 110°F Condenser
[1] Includes parasitics for heat rejection, burner fan, solution pumps
[2]Calculated based on 10,867 Btu/kWh and zero distribution losses for gas
[3]Assuming 82% burner efficiency.
[4]Assuming use of a single-stage cycle. Two-stage cycles may have primary energy COP's ranging from 0.4 to 0.46.

1.1 Supermarket Refrigeration

Supermarket refrigeration accounts for 326 trillion Btu of primary energy usage annually.

Supermarket refrigeration is divided into two distinct segments which have different technology and which are governed by different issues. The more visible part of these systems are the display cases which hold food for the self-service shopping style of supermarkets. The display cases have their own electric loads, and they must be cooled by the store's refrigeration system. Display case selection is merchandising-based. The mechanical equipment, including compressors, condensers, and associated controls, is engineering-based.

The potential for energy consumption reductions associated with machine room equipment is limited to about 5% of overall supermarket refrigeration energy usage (see Table 1-3 corresponds to about 13 trillion Btu. The limited savings opportunities reflect the sensitivity to energy efficiency in machine room equipment selection decisions.

Reduction of 1% of overall usage with a two year payback[2] is possible with increased use of evaporative condensers, a technology which currently has little market penetration. This technology should not have a cost premium with respect to air-cooled condensers, but the savings will be overshadowed by water and maintenance costs for about two thirds of US locations. Additional reductions of 2.5% with paybacks of less than five years could be achieved by further use of floating head pressure, mechanical subcooling, and heat reclaim, technologies which currently have varying degrees of market penetration.

Table 1-3: Supermarket Energy Savings: Machine Room Technologies

	Energy Savings			Economics 45,000 sq. ft. Supermarket (New Construction) Medium Energy Costs $0.053/kWh; $5.04/kW; $5.60/MMBtu Gas		
	Refrigeration Electricity Savings (%)	Store Electricity Savings (%)	U.S. Primary Energy Savings (10^{12}Btu)	Cost Premium ($)	Savings ($)	Payback Period (years) (Raleigh, NC)
Evap. Condenser	3.1	1.5	10	($7,100)	($560)	N/A
Floating Head Pressure	3.1	1.5	4	$8,000	$3,200	2.5
Heat Reclaim	N/A	N/A	3	$13,700	$5,400	2.5
Mechanical Subcooling	1.4	0.7	2	$8,000	$1,600	4.9
Ambient Subcooling	0.5	0.25	1	$6,100	$560	11
Total < 5 year payback	4.5	2	9	$30,000	$10,000	3

Energy savings potential in the display case area are summarized in Table 1-4 below. Savings of 14% (45 trillion Btu[3]) of total supermarket refrigeration primary energy use are possible with improvements in this area. Savings of 9% can be achieved with less than 2 year payback with high-efficiency evaporator fan motors and hot gas defrost. Additional savings of 4% can be achieved with less than 5 year payback with liquid-suction heat exchangers, antisweat control, and defrost control. Insulation thickness increases are ineffective because wall losses are not the dominant case load and because of the associated volume decrease.

[2] Payback periods presented in this report are based on new construction or purchase of new products. For retrofit, the payback period will generally be longer.

[3] Savings potential assuming 100% penetration in existing base. The savings potentials reported in this section are based on this assumption.

Table 1-4: Supermarket Energy Savings: Display Case Technologies

	Energy Savings			Economics 45,000 sq. ft. Supermarket (New Construction) Medium Energy Costs $0.053/kWh; $5.04/kW; $5.60/MMBtu Gas		
	Refrigeration Electricity Savings (%)	Store Electricity Savings (%)*	U.S. Primary Energy Savings (10^{12} Btu)	Cost Premium	Savings ($)	Payback Period (years)
Hot Gas Defrost	3.1	1.5	3	$3,800	$2,600	1.4
Antisweat Ht. Control	5.7	2.8	5	$7,500	$4,800	1.6
Evap. Fan ECM Motor	8.2	4.1	26	$12,600	$7,700	1.6
Defrost Control	1.3	0.6	2	$3,300	$1,100	3.0
LSHX* Low Temp.	2.4	1.2	4	$10,000	$2,400	4.1
LSHX* Med. Temp.	1.8	0.9	4	$25,000	$1,800	14
Insulation Improvement	0.3	0.15	1	$11,000	$315	35
Total < 2 years payback	17	8.5	35	$24,000	$15,100	1.6
Total < 5 year payback	21	10	40	$37,000	$18,600	2.0

*LSHX = Liquid Suction Heat Exchangers

Reference No.

1.2 Beverage Merchandisers

Primary energy usage reductions of about 45%, representing 17 trillion Btu, are possible with beverage merchandisers (see Table 1-5 below). Reductions of 41% are possible within a two-year payback with the use of ECM motors for evaporator fans and high efficiency compressors. Additional reductions of 4% can be achieved within a five year payback with ECM motors for condenser fans. Long paybacks are associated with increased R-value insulation or increased insulation thickness.
Supermarket Energy Savings: Display Case Technologies

Table 1-5: Beverage Merchandiser Energy Savings

	Energy Savings		Economics Medium Energy Costs $0.0782/kWh		
	Refrigeration Electricity Savings (%)	U.S. Primary Energy Savings (10^{12} Btu)	Cost Premium	Savings ($)	Payback Period (years)
High-Efficiency Compressors	9	5	$16	$26	0.6
Electronic Ballasts	10	5	$30	$30	1.0
Evap. Fan ECM	29	15	$120	$85	1.4
ECM/Var. Spd. Compressors	14	7	$150	$42	3.6
Cond Fan ECM M otor	4.5	2	$60	$14	4.4
Thicker Insulation*	3.0	2	$56	$9	6.2
Total < 2 years payback	44	23	$166	$134	1.2
Total < 5 year payback (with ECM/Var. Spd. Compressor)	55	29	$376	$168	2.2

*Increase from 1 1/2” to 2 1/2”

1.3 Reach-In Freezers

Primary energy usage reductions of about 40%, representing 29 trillion Btu, are possible with reach-in freezers (see Table 1-6 below). Reductions of 30% are possible within a two-year payback with the use of high efficiency compressors and non-electric antisweat heating. Additional reductions of 10% can be achieved within a five year payback with ECM motors for evaporator fans, hot gas defrost, and defrost controls. Long paybacks are associated with increased R-value insulation or increased insulation thickness. Additional energy reductions with impractical payback periods could be achieved with the use of liquid-suction heat exchangers.

Table 1-6: Reach-In Freezer Energy Savings

	Energy Savings		Economics Medium Energy Costs $0.782/kWh		
	Refrigeration Electricity Savings (%)	U.S. Primary Energy Savings (10^{12} Btu)	Cost Premium ($)	Savings ($)	Payback Period (years)
High-Efficiency Compressors	16	10	$24	$65	0.4
Non-Electric Antisweat	14	9	$67	$58	1.2
ECM/Var. Spd. Compressors	19	12	$160	$77	2.1
Cond. Fan ECM Motor	2.7	2	$24	$11	2.2
Evap. Fan ECM Motor	2.3	1.5	$24	$9	2.6
Hot Gas Defrost	6.3	4	$83	$26	3.2
Thicker insulation**	3.8	2.5	$84	$15	5.5
LSHX*	3.4	2	$75	$14	5.5
Total < 2 years payback	30	20	$91	$123	0.7
Total < 5 year payback (with ECM/Var. Spd. Compressor)	44	28	$382	$178	2.1

*Liquid-Suction Heat-Exchanger
**Increase from 2 1/4" to 3 1/4"

1.4 Reach-In Refrigerators

Primary energy usage reductions of about 50%, representing 27 trillion Btu, are possible with reach-in refrigerators (see Table 1-7 below). Reductions of 47% are possible within a two-year payback with the use of ECM motors for evaporator fans, high efficiency compressors, and non-electric antisweat heating. Additional reductions of 3% can be achieved within a five year payback with ECM motors for condenser fans. Long paybacks are associated with increased R-value insulation or increased insulation thickness.

Table 1-7: Reach-In Refrigerator Energy Savings

	Energy Savings		Economics Medium Energy Costs $0.782/kWh		
	Refrigeration Electricity Savings (%)	U.S. Primary Energy Savings (10^{12} Btu)	Cost Premium ($)	Savings ($)	Payback Period (years)
High-Efficiency Compressors	12	6	$16	$40	0.4
Non-Electric Antisweat	20	11	$93	$67	1.4
Cond Fan ECM Motor	3.3	2	$22	$11	2.0
Evap. Fan ECM Motor	7	4	$48	$23	2.1
ECM/Var. Speed Compressor	16	9	$150	$54	2.8
Thicker insulation**	2	1	$100	$8	13
Total < 2 years payback	35	19	$131	$118	1.1
Total < 5 year payback (with ECM/Var. Spd. Compressor)	45	24	$313	$152	2.1

*Increase from 2 1/4” to 3 1/4”

1.5 Ice Machines

Primary energy usage reductions of about 20%, representing 13 trillion Btu, are possible with ice machines (see Table 1-8 below). Reductions of 15% are possible within a two-year payback with the use of ECM motors for condenser fans, high efficiency compressors, and reduced evaporator thermal cycling. Additional reductions of 5% can be achieved within a five year payback with thicker insulation and mechanical harvest assist to reduce ice meltage during harvest.

Table 1-8: Ice Machine Energy Savings

	Energy Savings		Economics Medium Energy Costs $0.0782/kWh		
	Refrigeration Electricity Savings (%)	U.S. Primary Energy Savings (10^{12} Btu)	Cost Premium ($)	Savings ($)	Payback Period (years)
Reduced Evap. Thermal Cycling	4.2	4	$20	$16	1.2
High-Efficiency Compressors	5.6	6	$40	$22	1.8
Cond Fan ECM Motor	5.4	6	$46	$21	2.2
Thicker insulation**	3.0	3	$40	$12	3.4
Reduced Meltage During Harvest	4.6	5	$100	$18	5.6
Total < 2 years payback	10	10	$60	$38	1.6
Total < 5 year payback (with ECM/Var. Spd. Compressor)	18	18	$146	$71	2.1

*Increase from 1/2” to 1”

1.6 Refrigerated Vending Machines

Primary energy usage reductions of about 32%, representing 45 trillion Btu, are possible with refrigerated vending machines (see Table 1-9 below). Reductions of 30% are possible within a two-year payback with the use of ECM motors for evaporator fans, and high efficiency compressors. Additional reductions of 1% can be achieved within a five year payback with high efficiency condenser fan motors.

Table 1-9: Refrigerated Vending Machine Energy Savings

	Energy Savings		Economics Medium Energy Costs $0.0782/kWh		
	Refrigeration Electricity Savings (%)	U.S. Primary Energy Savings (10^{12} Btu)	Cost Premium ($)	Savings ($)	Payback Period (years)
High-Efficiency Compressors	9	12	16	$20	0.8
Electronic Ballasts	9	12	$30	$20	1.5
Evap. Fan ECM Motor	14	19	$56	$31	1.8
Improved Insulation	5.4	7	$54	$12	4.5
ECM/Var Speed Compressors	15	20	$150	$32	4.6
Cond Fan ECM Motor	3	4	$56	$7	8
Total < 2 years payback	32	43	$102	$70	1.5
Total < 5 year payback	42	56	$290	$91	3.2