Evaluation of
Potential Best Management Practices
-
Commercial Ice Machines

Prepared for

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NOTE: For a full introduction to the
CUWCC's Potential Best Management Practice (PBMP) process,
refer to earlier reports that detail the purpose and
status of that process since its inception in 2004:

http://www.cuwcc.org/products/pbmp-reports.aspx

Commercial Ice Machines

1. Introduction

The use of ice for drinks, preserving and cooling food, and various other commercial purposes is common today, but it was not always so. Before the development of the commercial ice machine industry, ice was produced at large central ice plants and delivered to the commercial user in the form of either blocks or crushed ice. The crushed and block ice market is still a viable industry, but commercial ice machines have replaced delivered ice in routine commercial activities. The purpose of this paper is to summarize the operational characteristics of commercial ice machines and to examine the potential for both water and energy savings from a California-based perspective. To do this, five items will be examined, including:

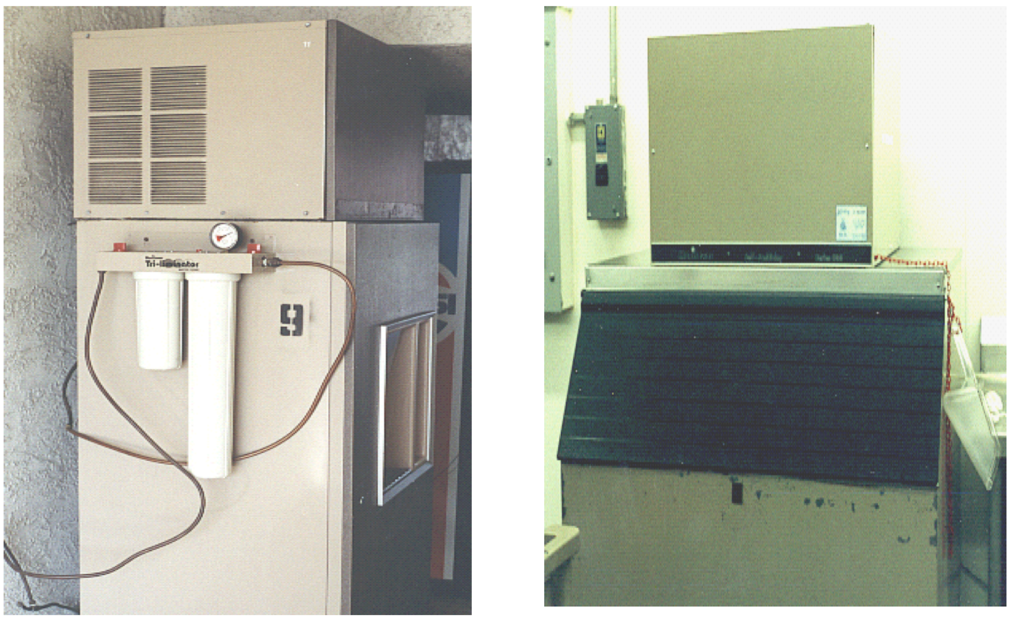
1. Types of Ice-making Equipment
2. Ice Machine Market Dynamics
3. Regulations and Incentives
4. Energy and Water Use Chrematistics
5. Potential Future Water and Energy Savings

2. Types of Ice-making Machines

There are several ways to classify ice machines. The three most common are (a) by the type of cooling media used, (b) by the type of ice they produce, and (c) by the configuration of the units.

a. Cooling Media – Either water or air can be used to remove waste heat produced by the compressor in the ice machine's refrigeration unit. This allows the working fluid (freon) to liquefy.

Figure 1. Typical Ice Making Machine



Air Cooled Ice Making Machine

Water Cooled Ice Making Machine

For water-cooled equipment, there are three configurations commonly employed:

(1) Once-through or pass-through cooling, which involves connecting the ice machine directly to a potable water supply. The water is simply passed through a heat exchanger coil where it absorbs and removes the waste heat. In this process, the water is discharged to a drain and wasted. This system is the most commonly found method of cooling with water and it wastes very large quantities of it.

(2) Chilled water loop systems, which are found where a central chilled water system is used for air conditioning. The machine is connected to the recirculating chilled water loop and the waste heat is rejected to the chilled water and later removed by the air conditioning equipment.

(3) A third method involves connecting the ice machine to a cooling tower water loop so that the heat is rejected directly to a cooling tower.

For air-cooled machines, air is used to remove waste heat in much the same way that a home air conditioner or refrigerator does, i.e., by drawing air over the cooling coils with a fan to cool the compressed refrigerant gas (Freon) so that it will condense back to a liquid. The compressor coils can either be located inside the working space along with the ice machine or outside much like a home air conditioner. Units that reject heat directly to the space in which they are located include those with air-cooled ice-making heads (IMH's) and those with self-contained air-cooled units, such as under-the-counter ice makers. When the coils (condensing units) are located outside of the building space, they are referred to as remote condensing units. The actual compressor pumps can either be located (1) at the ice-making head inside the building or (2) outside with the condensing coil. Remote condensing units are typically located on the roof or along an outside wall of the building.

b. Type of Ice Produced – Ice machines can make (1) cube, (2) flake, or (3) nugget ice. Each has characteristics that make it desirable in certain applications.

(1) Cube ice is a hard, clear ice that has found popularity in use for drinks of all kinds. It melts slowly and does not leave a mineral residue since the precipitated minerals are washed away by the ice machine in the freezing process. Cube ice is made by recirculating water over a freeze plate that is directly cooled by the evaporation of the refrigerant (freon). The recirculating water is pumped over the surface to flush away minerals that precipitate as ice freezes. At the end of the cycle, the ice is released by warming the plate and the water in the recirculation trough is purged to dispose of the minerals removed from the ice in the freezing process. The process is controlled by an electronic control panel.

It takes 12 gallons of water to constitute 100 pounds of ice, but since water is also purged by the ice machine to remove minerals, more than 12 gallons is actually used to produce this ice. Total water use for cube ice can range from as low as 15 gallons per 100 pounds of ice to over 50 gallons per 100 pounds depending on the model of machine and the setting for its purge cycle. The line pressure of the water supply can also impact water use since there is no pressure regulator on ice machine fill valves. Figure 2 shows the freeze plant, control panel and recirculation pump and trough in a typical cube ice-making machine.

Figure 2. Air Cooled Ice Machine Freeze Plate (evaporator plate), Recirculation Pump, and Control Panel.

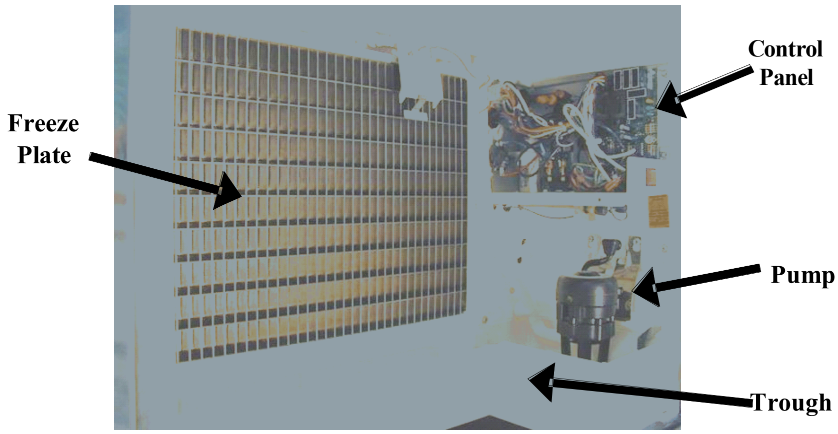


Photo Courtesy of Charles Bohlig , East Bay Municipal Utility District, 2007

In some cases, the purge water is passed through a waste chill recovery heat exchanger that can be retrofitted to a commercial ice machine to pre-cool the makeup water for the unit. This does not reduce water use, but does save energy.

(2) Flake ice finds wide use in salad bars, cooling food displays and general applications where a clear, hard cube is not needed. Flake ice machines tend to be the most energy- and water-efficient types. The product is a flake of "soft" ice produced in one of two ways. For most commercial use, the ice-making head contains cylinders wrapped by cooling (evaporator) coils. Water is fed to the inside of the tube and ice forms on the inside surface. An auger continuously scrapes the sides of the tube to remove the ice as it forms. For very large flake ice machines, a cylinder and scraper blade system is used in place of the auger. Since there is no recirculation and purge system like that of the cube machines, water is not discharged to the drain in the ice-making process. However, since the ice is harvested in a wet state, the product does contain some unfrozen water. This can range from one to three or four gallons per 100 pounds of ice depending on the machine.

(3) Nugget ice has increased in popularity in recent years as it is used more and more at drink fountains. Nugget ice machines form ice in the same manner as flake machines, but the ice is formed into a unique shape by extruding the flakes through a tube or dye. The ice forms a number of chunks or nuggets that, among other things, can be conveyed through a tube to an ice bin or soft drink machine located several feet away. These nuggets (or "chewblets" as one manufacturer calls them) are both chewable and become saturated with the drink they are cooling.

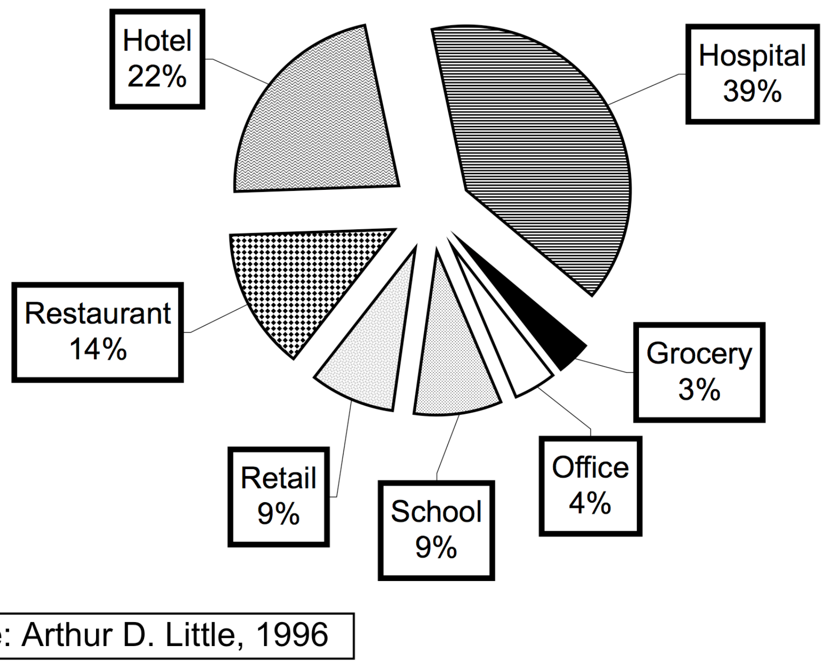
c. Configuration – There are three main configurations of the equipment described above. For the self contained unit, the ice bin and ice-making equipment are all contained in one unit. These systems tend to be smaller, often under-the-counter units and seldom exceed 350 pounds of ice per day in capacity. The second type places the ice-making head unit on top of an ice bin. (The bin and ice-making head are sold separately.) The third configuration uses a remote condensing unit. A variation is the nugget ice machine that can extrude the nuggets to a bin located several feet away.

3. Market Dynamics

The market for ice-making machines tends to increase in proportion to population. The hospital, food service and hotel industries purchase approximately 75 percent of all ice machines nationally, but ice machines are also found in other businesses and institutions (See Figure 3.)

According to information from Pacific Gas & Electric Company (PG&E) Food Service Technology Center (FSTC) (Zabrowski, 2007), about 20 percent of the installed inventory of ice machines in California are water-cooled; the balance are air-cooled. According to the Air Conditioning and Refrigeration Institute (ARI), once-through water cooling of ice machines uses from 75 to 200 gallons of cooling water for every 100 pounds of ice made.

Figure 3. Commercial Ice Machine Distribution by Business Sector

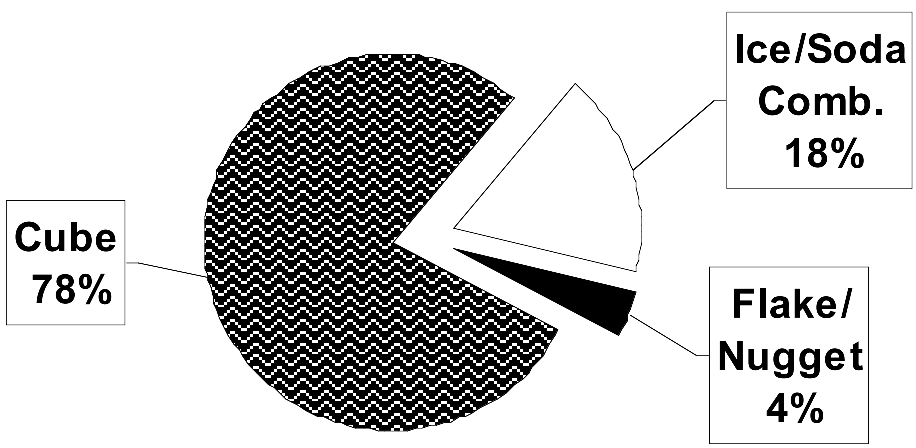


In 2003, total nationwide ice machine sales were approximately 360,000 units, of which about 78 percent were cube machines; the remainder were flake and nugget machines or combination machines such as soda machines (See Figure 4). According to a 2004 PG&E study, there are about 1.2 million ice machines in the United States. PG&E estimates that about 174,000 are in California, or about 9 percent of the total[1]. Allowing for population growth, we estimate that California currently has an installed base of about 180,000 machines. As shown in Figure 5, about 90 percent of the ice machine market is dominated by four manufacturers.

In recent years there has been an increase in sales of nugget-type ice machines for soft drink use since this ice absorbs some of the drink flavor and is chewable; but according to information from PG&E FSTC (Zabrowski, May 2008), the percent increase is small, however. The importance of this trend is that nugget ice machines tend to be both more energy and water efficient.

The amount of ice consumed by various individual operations varies greatly, but ice machine manufacturers have developed estimates for each of those applications. Table 1 summarizes this information.

Figure 4. National Sales by Type of Ice Machine



[1] This figure was based on older studies performed in 1996 by Arthur D. Little.

Figure 5. Commercial Ice Machine Sales by Manufacturer

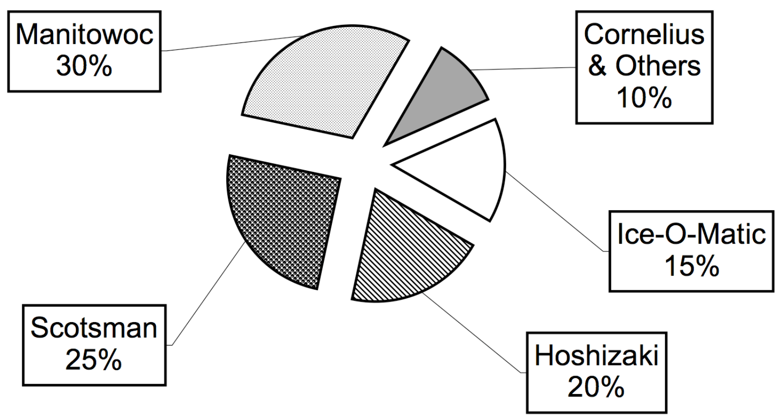


Table 1. Approximate Ice Use by Activity or Product

Type of Use	Unit	Ice Use per Activity
Restaurant *(Either stand alone or at a hotel)*	Per Meal	1.5 lb. per person served
	Cocktail Bar	3 lb. per person served
	Salad Bar	40 lb. per day per cubic ft.
Cafeteria	Per Person	1 lb per person served
Hospital	Per Patient	10 lb per patient per day
Hotel	Per Guest	5 lb per guest per day
Catering	Per Person	1 lb per person served
Cold Soft Drinks & Tea	10-12 oz.	6-8 oz. per drink
	20 oz.	8-10 oz. per drink
	32 oz.	16 oz. per drink

Source: Information based on Ice-O-Matic and Cornelius Web sites.

4. Regulations and Incentives

Various governmental entities and other organizations have developed ratings, rebates and regulations regarding commercial ice machine energy and water use. These are summarized below.

- U.S. Department of Energy (DOE) - Documents and recommendations from the U.S. DOE still incorrectly show water-cooled machines as being the most energy efficient without regard to embedded energy in or cost for cooling water. The Federal Energy Policy Act of 2005 (EPAct 05) also includes water-cooled ice machines in its ice machine standards. These standards only cover cube-type ice machines since ARI data is not yet available for flake and nugget machines. http://www.oe.energy.gov/DocumentsandMedia/EPACT05ConferenceReport0.pdf

- Consortium for Energy Efficiency (CEE) - CEE has produced a three-tier analysis of cube-type machines which ranges from older Federal Energy Management Program standards for Tier 1 to Tier 3. Again, only cube-type machines were considered. It should be noted that the CEE rating discourages the use of machines with once-through water cooling in recognition of the embedded energy and costs associated with once-through cooling. http://www.cee1.org/com/com-kit/ice-specs.pdf

- U.S. Environmental Protection Agency (EPA) – The U.S. EPA has issued Energy Star standards for cube-making ice machines that follow CEE Tier 2. The Energy Star standards do not contain water-cooled equipment of any type, again in recognition of the wastefulness of once-through equipment. http://www.energystar.gov/index.cfm?c=comm_ice_machines.pr_comm_ice_machines

- California Energy Commission (CEC) – In March 2004, the CEC issued an update on appliance regulations, including standards for ice machines. These regulations contained both water- and air-cooled units and is based upon CEE Tier 1, a performance tier that most machines exceed today. http://www.energy.ca.gov/2006publications/CEC-400-2006-002/CEC-400-2006-002-REV2.pdf

- California Energy Rebates - Several electric utility companies make rebates available for energy-efficient ice machines, including flake and nugget machines. All rebated machines are air-cooled. http://www.fishnick.com/saveenergy/rebates/ice_machines.pdf

- Local Regulations – Several cities, including Austin and San Antonio, Texas, Phoenix, Arizona, and Seattle, Washington, have instituted restrictions on the use of water-cooled ice machines.

5. Energy and Water Use Characteristics

The ARI reports water and energy use for cube-type ice machines for the top five manufacturers. In addition to the ARI data, the U.S. EPA, the CEE, the FSTC, and others have performed analyses of ice machine energy and water use.

Water Use - Based on the most current data from ARI, over 70 percent of air-cooled ice machines currently use 20 gallons of water or less to make 100 pounds of ice (Figure 6). This is in contrast to ice machines existing at the time that the CEE (through its Commercial Kitchens Initiative program) established its own criteria; those criteria were later used by the U.S. EPA to set Energy Star standards. At that time, only 51 percent of machines met this water use criteria (which is recognized in the CEE analysis as Tier 3).

All data used for previous analyses of cube-type ice machines were based on ARI data. That data is provided by the manufacturers themselves and is not independently verified by any monitoring authority. In 2007, however, the FSTC and the East Bay Municipal Utility District (EBMUD)[2] conducted a field study of ice machines to determine their actual energy and water use, and to compare that data with that listed in the ARI database. Eight cube-type ice-making machines were subjected to field measurement under "real world" operating conditions. This field study showed that test results were very close to ARI database information. Water use data from the field had wider variations and, overall, was a little higher than reported by the ARI. For example, one small 340 pound per day machine used 141 percent more water than the ARI data would indicate, but the remaining seven machines were within a range of 19 percent lower to 20 percent higher (see Figure 7). The conclusion was that ARI data is reasonably representative of actual performance.

It is also significant to note that the water-cooled machines in the study used between 187 and 193 gallons of water for every 100 pounds (12 gallons) of ice produced. Allowing for 25 gallons of use per 100 pounds of ice in the ice-making heads (inclusive of the 12 gallons frozen as cubes), total cooling water use is then calculated to be between 162 and 178 gallons of cooling water per 100 pounds of ice for the two test units whose production is rated at 440 and 1130 pounds of ice per day, respectively. This is a much higher rate of water use than that shown in ARI data for most of today's new ice machines models rated to produce similar amounts of ice.[3]

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[2] Along with funding support from PG&E, Seattle Public Utilities and Eugene (OR) Electric.

[3] As noted earlier, however, the machines in the field study were older machines and not fully representative of models currently being sold in the marketplace.

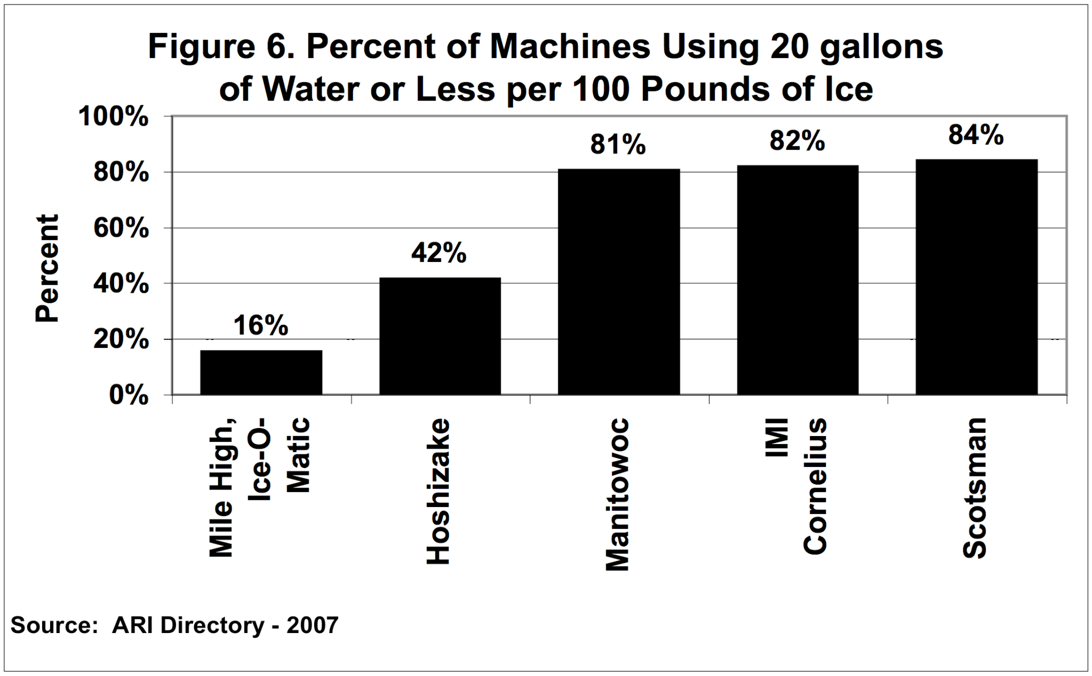


Figure 6. Percent of Machines Using 20 gallons of Water or Less per 100 Pounds of Ice
Percent
100%
80%
60%
40%
20%
0%
16%
42%
81%
82%
84%
Mile High, Ice-O-Matic
Hoshizake
Manitowoc
IMI Cornelius
Scotsman
Source: ARI Directory - 2007

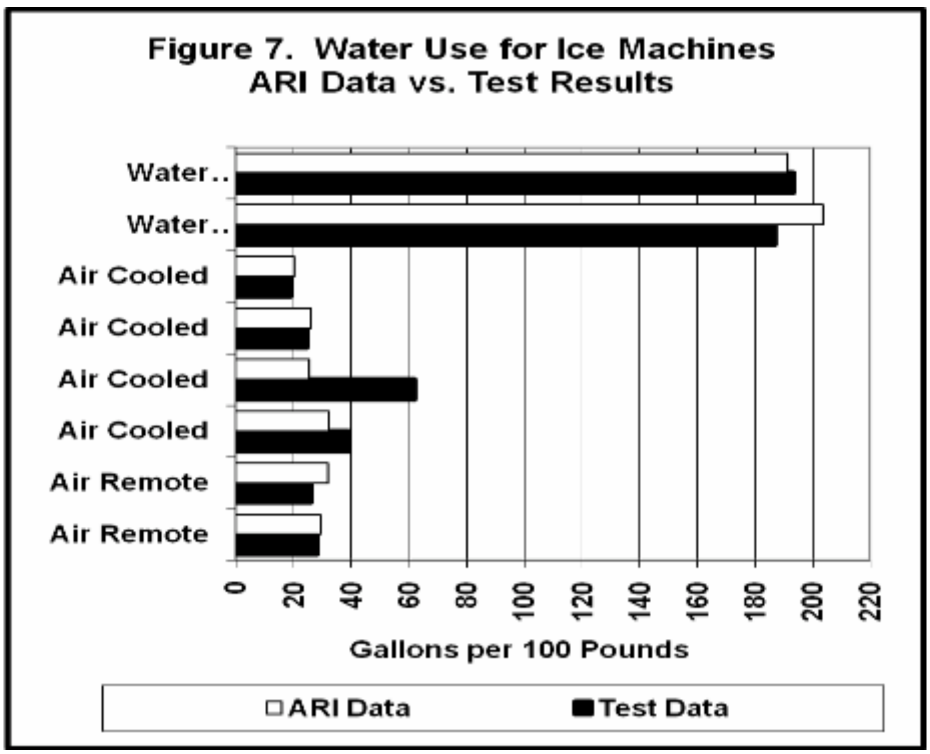


Figure 7. Water Use for Ice Machines ARI Data vs. Test Results
Water..
Water..
Air Cooled
Air Cooled
Air Cooled
Air Cooled
Air Remote
Air Remote
0
20
40
60
80
100
120
140
160
180
200
220
Gallons per 100 Pounds
ARI Data
Test Data

Another factor in this comparison (i.e., study results to ARI data) is that since ice machines are tested and rated at a line (water) pressure of 30 psi and are not equipped with pressure regulators, they may actually be operating in the "real world" at higher water use rates than the ARI data indicates. This is especially true where food service facilities are on the ground floor and are served with municipal water at significantly higher water pressures than 30 psi.

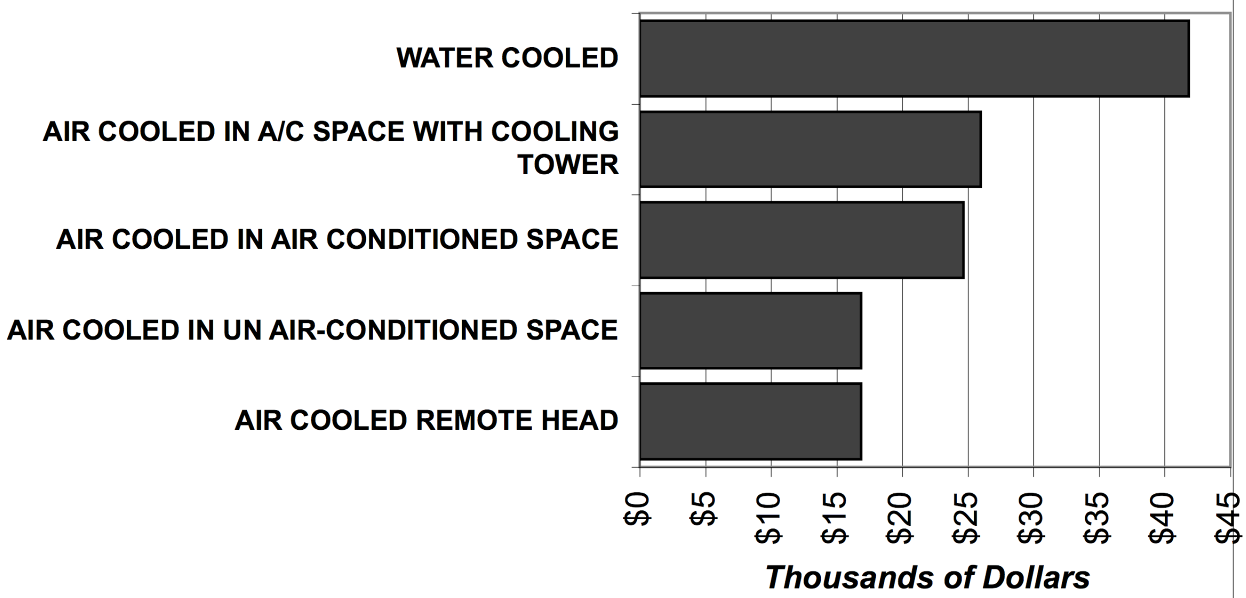
Only 14 percent of the over 135 water-cooled models in the December 2007 ARI database were listed as using over 162 gallons of water per 100 pounds for cooling. Overall, the ARI range of water use for cooling ranged from a low of 72 gallons per 100 pounds of ice for machines in the 1100 to 1500 pound per day capacity range to a high of 240 gallons per 100 pounds of ice for a machine rated at 264 pounds per day.

Energy Use – According to estimates made in 1996 by Arthur D. Little, between nine and ten billion kilowatt hours are consumed each year by ice machines installed in the U.S. From an end user's standpoint, water-cooled machines typically consume slightly less energy than air-cooled models, but they must use significant volumes of water for that cooling. In addition, energy efficiency continues to improve for air-cooled machines as product development results in the introduction of better designs and technologies. Because of this ongoing energy use differential between water-cooled and air-cooled machines, the DOE has actively promoted the use of water-cooled units.

Combined Effects – Water and Energy Use - However, the DOE analysis failed to consider both (a) the energy that is embedded in the water being used to cool the ice machines or (b) the water and sewer costs associated with delivery and disposal of that water. Examination of lifetime energy consumption and operating costs for water- and air-cooled machines shows that when total consumption (electricity, water and sewer) is taken into account, water-cooled ice machines result in higher energy use and are actually more costly to the end-user in almost all circumstances.

The average life of an ice machine is approximately 8.5 years, according to recent CEC studies. If one assumes that combined water and sewer costs to the end-user (customer) are $7.00 per thousand gallons ($5.24 per hundred cubic feet) and electricity costs are 10.5 cents per kilowatt hour, total utility costs at the end of the 8.5 years for a water-cooled unit using 150 gallons of cooling water will be twice that of an air-cooled unit meeting CEE Tier 3 efficiency (the most efficient CEE tier). For example, based on the above assumptions, a water-cooled machine averaging 800 pounds of ice a day would cost $41,800 to operate over the 8.5-year period, while an air-cooled unit producing the same amount of ice would cost as little as $16,800 over the same period. Refer to Figure 8.

Figure 8. Life Cycle Cost for Machine Producing 800 Lbs/Day of Ice for the 8.5 Year Life of Unit



Even when the unit is located inside an air conditioned space cooled with an air conditioning system using a cooling tower, total utility costs are significantly lower for an air-cooled machine as shown by Figure 8.

As noted earlier, another major consideration in any evaluation is the energy embedded in the cooling water used by a water-cooled ice machine. The total energy used to capture and convey water from its source, provide treatment and distribution to its end use and, finally, treat it as wastewater, is a significant impact on cost and efficiency. Table 2 summarizes energy use for water and wastewater operations in Northern and Southern California. The significant difference in energy use between Southern and Northern California is the result of the high energy requirement to convey and supply raw water to the south.

Table 2. Energy Use for Water Delivered and Wastewater Treated
(kWh per Million Gallons of Water)

Operation	Northern California	Southern California
Supply and Conveyance	150	8,900
Treatment	100	100
Distribution	1,200	1,200
Wastewater Treatment	2,500	2,500
Total	3,950	12,700

Source: California Energy Commission, 2005 Integrated Energy Policy Report

According to current U.S. Census Bureau data, the total 2007 population of California was 37.7 million persons, of which 21.6 million lived in Southern California (http://en.wikipedia.org/wiki/Southern_California). This means that 57 percent of California's population consumed energy for water delivery and treatment at the highest level.

Water used for cooling ice machines is ultimately returned to the wastewater collection system. However, since this wastewater does not add any organic material or suspended solids to the waste load, energy normally associated with removal of these waste products is not required by the treatment plant. If it is assumed that, overall, 80 percent of all wastewater treatment energy is associated with removal of biochemical oxygen demand and solids, then only 20 percent (500 kilowatt hours of energy[4]) are used for every million gallons of wastewater treated. Table 3 takes this figure and the distribution of today's California population into account to compute the California-wide energy use factor for treatment of ice machine cooling water. That computed to 6.94 kWh/1,000 gallons of water. Therefore, for an ice machine using 150 gallons of water for cooling (while producing 100 lbs. of ice), this is equal to an embedded energy factor of 1.04 kWh/100 pounds of ice. This is in addition to that used by the ice machine itself to produce those 100 lbs. of ice.

Table 3. Water Volume-Based Energy Use
(kWh per Million Gallons of Water)

Operation	Northern California	Southern California
Supply and Conveyance	150	8,900
Treatment	100	100
Distribution	1,200	1,200
20 percent Wastewater Treatment	500	500
Total	1,900	10,700
Percent of Population	43 percent	57 percent
Pop. Adjusted kWh/million gallons	**6,937 kWh/million gallons of water**	
Energy Use per 1,000 gals of water	**6.94 kWh/1,000 gallons of water**	

Examination of ARI data from December 2007 shows that water-cooled ice machine energy use per 100 pounds of ice is about 1.2 kWh less per 100 pounds than that of comparable air-cooled machines, but this does *not* consider the (embedded) energy required for the 150 gallons of cooling water associated with each 100 pounds of ice produced. As calculated earlier, this embedded energy is equal to 1.04 additional kWh per 100 pounds of ice for the cooling water.

To more closely examine the differences in energy use, ice-making head machines were compared at three different capacities: 350 pounds per day, 800 pounds per day and 1,000 pounds per day. ARI energy use (kWh) per 100 pounds of ice was averaged across the five different makes of ice machines with capacity close to the three ranges. Embedded energy for the cooling water was assumed to be 1.04 kWh per 100 pounds of ice as described in the paragraph above

The result of this energy use analysis is summarized in Table 4.

Table 4. Comparison of energy use among various standards and average ARI data
(Kilowatt Hours per 100 Pounds of Ice Produced)

	Ice Machine Type and Energy Use							
	A	B	C	D	E	F	G	H
Production Capacity *Pounds of ice per day*	**FEMP Water Cooled**	**ARI Avg. Water Cooled**	**FEMP Water Cooled + Embedded Cooling Water Energy**	**ARI Avg. Water Cooled + Embedded Cooling Water Energy**	**ARI Avg. Air Cooled**	**Tier 3 Air Cooled**	**Tier 2 Air Cooled**	**California CEC & Tier 1 Air Cooled**
300	5.9	5.5	6.9	6.5	6.7	6.2	6.5	8.3
800	4.7	4.7	5.7	5.7	5.9	5.1	5.4	6.0
1000	4.5	4.7	5.5	5.7	5.9	5.0	5.2	5.8
Average	5.0	5.0	6.1	6.0	6.2	5.4	5.7	6.7

As Table 4 shows, when embedded energy for cooling water is included, total energy use for a water-cooled ice machine is about 0.6 kWh higher (per 100 pounds of ice) than the air-cooled Tier 3 machine (Column F minus Column B) Furthermore, the average air-cooled machine (based on current ARI data) is about 0.8 kWh higher than the Tier 3 machine (Column E minus Column F). In general, implementing Tier 3 would reduce average energy use by 0.8 kWh or more when considering the age of equipment in use and the ratio of air-cooled to water-cooled machines on the market at this time.

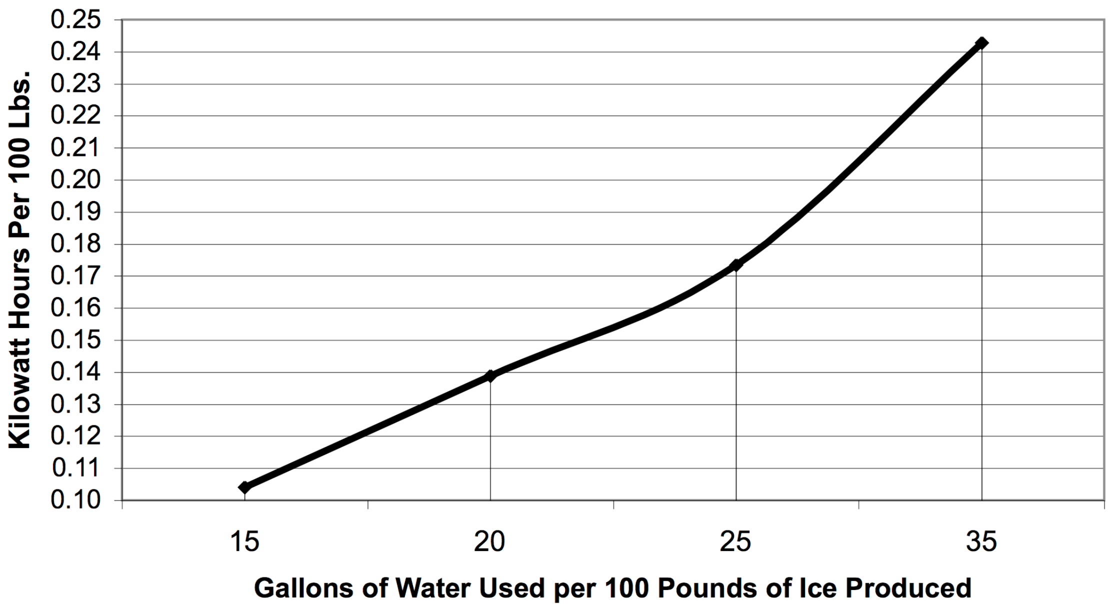
In summary, by implementing Tier 3 of the CEE standards, ice machines would reduce energy use by approximately 0.8 kWh per 100 pounds and water use by 5.0 gallons per 100 pounds of ice. The use of Tier 2 standards would not impact water use by air-cooled machines, but could decrease energy use by 0.5 kWh per 100 pounds of ice (Column E minus Column G). Based on current ARI data, though, Tier 3 energy standards are more difficult to meet today because there are fewer models to choose from based on energy efficiency. However, the current California Energy Commission standard (which is the same as the CEE Tier 1 standard) actually reflects older energy standards and much less efficient equipment. Applying the CEE Tier 1 standards to the current mix of machines on the market could actually *increase* energy consumption. In both the Tier 1 and Tier 2 cases, simply eliminating water-cooled units will both decrease energy use (when embedded energy is considered) and significantly decrease water use as well.

Flake and nugget ice machines are inherently more water-efficient. These machines do not purge water as do cube machines. Currently, ARI does not list these machines and, as a result, meaningful data on their efficiency (or lack of it) is not available. However, based upon limited manufacturer data, we know that for every 100 pounds of ice (12 gallons of water) produced, they also produce one to three gallons of unfrozen water. Their energy use is also very low.

Based on analysis of the qualified ice machines on the California rebate list, the average 350 pound flake and nugget machines use around 6.0 kWh per 100 lbs. of ice, similar to CEE Tier 3 efficiency for cube machines. For 800 pound machines, energy use is typically less than 5.0 kWh per 100 lbs and for larger machines, energy use is below 4.0 kWh per 100 lbs. This means that most flake machines already meet Tier 3 criteria.

There is also embedded energy in the water used to make the ice itself. This includes the water in the ice plus the purge water in the case of cube-ice. Volumes range from 15 to 35 gallons per 100 pounds of ice produced, depending on the make and model of the ice-making machine. Although small in comparison to the energy needed to actually produce the ice, it averages about 0.14 kWh per 100 pounds of ice. (See Figure 9).

Figure 9. Embedded Energy in Ice-Making Water



Finally, as with embedded energy in water, there is embedded water in energy generation as well. For conventional coal and gas fired steam electric power plants cooled from fresh water sources, some 0.3 to 0.5 gallons of water are evaporated for ever kilowatt hour of energy produced. The CEC reports that 71 percent of in-state generation is fueled with gas, coal and nuclear. Some of this is cooled with sea water, but the majority uses fresh water. Of the 22 percent of power imported, much is also steam-generated electric capacity. From this, it is concluded that approximately 0.25 gallons of fresh water are evaporated for every kilowatt hour of generation in California.

6. Potential Future Water and Energy Savings

Water savings (direct and indirect) can be derived from three sources. The first is the elimination of once-through cooling, which yields direct, significant savings. The second is moving to CEE Tier 3 water use levels for future ice-making machines, including the promotion of the more efficient flake and nugget machines, all of which yield direct savings of water. The third is the indirect water savings realized through reduced energy generation.

The following analysis is based on an estimated 180,000 ice machines currently installed in California, of which 36,000 are estimated to be water-cooled. For the purpose of this analysis, these water-cooled machines are assumed (1) to use 150 gallons of cooling water for every 100 pounds of ice made and (2) that the average daily production from all units is 600 pounds per day per unit. Two water use rates for ice-making are assumed, 25 gallons per 100 pounds of ice and 20 gallons per 100 pounds of ice, with a net savings of 5 gallons per 100 pounds of ice. This assumption reflects Tier 2 (the Energy Star Standard) and Tier 3 standards, respectively, which, together, cover the majority of the market available today.

Again, for the purpose of this analysis, the energy savings for air-cooled equipment are assumed to be 0.8 kWh per 100 pounds produced by moving from the ARI average for air-cooled machines to Tier 3 or to flake and nugget ice-making equipment. The energy savings in embedded energy by eliminating cooling water for water-cooled equipment is assumed to be 1.0 kWh per 100 pounds. If water-cooled equipment were to be converted to CEE Tier 3, there would be a small net increase in energy needed to make ice at the machine (about 0.6 kWh per 100 pounds of ice). Therefore, the net energy savings for water-cooled machines, including embedded energy, would be about 0.4 kWh per 100 pounds of ice produced.

This set of assumptions reflects a conservative approach by assuming that the equipment being replaced or substituted for is not the more wasteful, small, self-contained units. The potential statewide savings in water and energy use by the equipment itself (direct savings) and through the reduction in embedded energy use (indirect savings) are both shown in Table 5.

Table 5. Summary of Total Potential Annual Water and Energy Savings in California
(by moving to a CEE Tier 3 mandate, which does not permit water-cooled machines)

Savings at Ice Machine (Direct Savings)				
Type	Number of installed machines	Water (acre-feet/year)	Energy (millions of kWh/year)	Notes
Water-cooled machine savings	36,000	36,300	-47	
Air-cooled machine savings	144,000		252	
All machines	180,000	6,000		
Total at machine		**42,300**	**205**	
Embedded Savings (Indirect Savings)				
Type	Number of installed machines	Water (acre-feet/year)	Energy (millions of kWh/year)	Notes
Water-cooled machine savings	36,000		82*	*Savings of embedded energy in reduced cooling water
All machines	180,000		14	
Total embedded		**230****	**96**	**Water savings resulting from reduced energy production
Net Savings – Direct & Indirect		**42,530**	**301**	Includes Embedded Savings

In summary, Table 5 shows that by eliminating once-through water cooling, about 36,000 acre-feet of water can be saved each year; the net energy savings would be about 300 million kilowatt hours per year when embedded energy is taken into account. Adding the savings realized by moving to Tier 3 or to flake and nugget machines will increase the projected statewide water savings to a total of about 42,300 acre-feet per year[4].

If one assumes that water is worth $600 per acre-foot, the 42,300 acre-feet saved annually would be valued at $25.3 million.

[4] This does not take into account the net savings in other *operating costs* (borne by the end user) by eliminating once-through cooling. Typically, over the lifetime of the machine, operating costs to the end user for air-cooled equipment are about half that of the equivalent water-cooled equipment.

7. Possible Implementation Strategies

There are three primary strategies available to promote the installation of more water- and energy-efficient ice making equipment.

(a) Actively promote (without financial incentives) the purchase or lease of more energy- and water-efficient equipment: This strategy could partially accomplish the goal as the current trend for ice making equipment continues to encourage more efficient machines. However, promotion alone is hard to quantify and there is no certainty as to how effective it might be.

(b) Provide financial incentives such as rebates and/or tax credits: This has the advantage of allowing water and energy utilities to track the purchase and installation of efficient machines, but these types of programs are expensive to implement and their impact is not always universal.

It should be noted that because of the average 8.5 year lifespan of a typical machine, most existing ice machines are likely to be replaced within 12 years. This fact, together with the general trend to more efficient machines, means that such incentives could be subject to a large degree of freeridership.

Ice machines generally cost from $2,250 to almost $5,000, depending on its ice making capacity. If a 1,000 pound water-cooled machine, making 750 pounds of ice per day on average, was replaced with an air-cooled machine, the water savings would be approximately 1,125 gallons a day (1.25 acre-feet per year). Using an 8.5 year average physical life, lifetime water savings would be 10.625 acre-feet of water. From these estimates, an incentive amount can be derived that could be used for the development of utility programs.

Even if only 20 percent of the existing 36,300 water cooled ice machines were replaced under an incentive program, the savings would be over 9,000 acre-feet a year from 7,000 machines replaced. If an incentive equal to approximately 20 percent of the cost of an ice machine was given, the incentive would be in the range of $700 per machine. The total cost would then be approximately $49 million, resulting in a two year payback based on water valued at $600 per acre-foot.

(c) Establish statewide regulations (possibly through the California Energy Commission) that mandate CEE Tier 3 energy and water efficiency standards for all new equipment: As noted earlier, ice machines have an average physical life of 8.5 years. With the current CEC standards modified to require CEE Tier 3 machines, replacement with efficient machines will be certain as the existing installed base wears out. We estimate that, with this strategy, almost all machines will meet Tier 3 standards within 12 years, but many will be replaced before the 8.5 years since most machines in use today are several years old. This will also have the advantage of certainty and will be the least costly of the three options to implement.

Bibliography

1. Air Conditioning and Refrigeration Institute (ARI), ARI Standard Ratings for Automatic Commercial Ice-Cube Machines, December 2007, http://www.ari.org/sections/section_groups/AutoIceMakers/

2. Bohlig, Charles M., Water Efficiency in Commercial Food Service, East Bay Municipal Utility District, ebmud.com, February 2006

3. California Code of Regulations, Title 20, Division 2, Chapter 4, Article 4, Section 1601-1608: Appliance Efficiency Regulations

4. Consortium for Energy Efficiency, Inc., Frequently Asked Questions, http://www.cee1.org/com/com-kit/com-kit-main.php3, 98 North Washington St., Suite 101, Boston MA 02114-1918, 2003

5. California Code of Regulations, Title 20, Division 2, Chapter 4 Article 4 Section 1601-1608: Appliance Efficiency Regulations

6. California Energy Commission, Appliance Efficiency Regulations, CEC – 4---2006-002, Rev 1, December 2006 http://www.energy.ca.gov/2006publications/CEC-400-2006-002/CEC-400-2006-002-REV2.PDF

7. California Energy Commission, California's Energy-Water Relationships, CEC-700-2005-011-SF, November 2005

8. California Urban Water Conservation Council, Spreadsheet Calculators of Machine Life Cycle Cost, http://www.cuwcc.org/Comm_Food_Service/Hoffmans_Ice-Maker_LifeCycle_Cost_Calc.xls

9. Consortium for Energy Efficiency, Inc., CEE Tier 2 Analysis for Air-Cooled Ice Cube Making Machines, http://www.cee1.org/com/com-kit/com-kit-main.php3, 98 North Washington St., Suite 101, Boston MA 02114-1918, 2005

10. Consortium for Energy Efficiency, Inc., Commercial Ice Machines, 98 North Washington St., Suite 101, Boston MA 02114-1918, 2007

11. Femstrom, Gary, B, Analysis of Standards Options for Commercial Packaged Refrigerators, Freezers, Refrigerator-Freezers, and Ice Machines: Codes and Standards Enhancement Initiative for PY2004: Title 20 Standards Development, Prepared for Pacific Gas and Electric Company by the Consortium for an Energy Efficient Economy, 2004.

12. Follett Corporation, Chewblet Icemakers, 801 Church Lane, Easton, PA 18044 http://www.follettice.com

13. Food Service Technology Center, Qualified Ice Machines, December 21, 2007, 12949 Alcosta Blvd. Suite 101, San Ramon, CA 94583, http://www.fishnick.com/saveenergy/rebates/ice_machines.pdf

14. Harris, Richard, The Triple Bottom Line to Savings: Water, Energy and Waste Reduction, East Bay Municipal Utility District (PowerPoint Presentation), 2006

15. Hoffman, H. W. (Bill) – *ICI Water Conservation Newsletter*, City of Austin (a quarterly publication for all non-residential water users) http://www.waterwiseaustin.org

16. Hoffman, H. W. (Bill), A look at New Commercial Water Saving Technologies, Texas Water 2006, Texas Section – American Water Works Association, April, 2006

17. Karas, Angelo, and Fisher, Don, A Field Study to Characterize Water and Energy Use of Commercial Ice Cube Machines and Quantify Savings Potential, Food Service Technology Center, 12949 Alcosta Blvd. Suite 101, San Ramon, CA 94583, December 2007

18. Krebs, Martha, Ph.D., California Water-Energy Issues, California Energy Commission, January 2006

19. Nadel, Steven, Packaged Commercial Refrigeration Equipment, A Brier Paper for Program Planners and Implementers, Washington DC: American Council for an Energy-Efficient Economy, 2002

20. PNM, Purchasing Advisor - Your guide to energy products for commercial buildings – Ice Makers, Alvarado Square Albuquerque, N.M., 87158-0001 http://www.pnm.com/contact/home.htm

21. San Francisco Public Utilities Commission, Air-cooled Ice Machine Rebate Program, 2003

22. Sherer, Mike, The Cold Hard Facts, Food Service Equipment Reports, August 2007 http://www.fermag.com/sr/v11i08_sr_ice_machines.htm

23. US Environmental Protection Agency, Energy Star Requirements for Commercial Ice Machines, July 2007, http://www.energystar.gov/index.cfm?c=comm_ice_machines.pr_comm_ice machines_

24. Wikipedia, California Census Information for 2007, http://en.wikipedia.org/wiki/Southern_California

25. Zabrowski, David, Personal Communications, December, 2007, Food Service Technology Center 12949 Alcosta Blvd. Suite 101, San Ramon, CA 94583

26. Zabrowski, David, Personal Communications, June, 2008, Food Service Technology Center 12949 Alcosta Blvd. Suite 101, San Ramon, CA 94583