A Field Study to Characterize Water and Energy Use of Commercial Ice-Cube Machines and Quantify Saving Potential

Food Service Technology Center
December 2007

Prepared by:

Angelo Karas
Don Fisher

Fisher-Nickel, inc.
12949 Alcosta Blvd.
San Ramon, CA 94583
www.fishnick.com

Prepared for:

East Bay Municipal Water District
375 Eleventh Street
Oakland, California 94607

and

Pacific Gas & Electric Company
Customer Energy Efficiency Programs
PO Box 770000
San Francisco, California 94177

and

Seattle Public Utilities
700 Fifth Avenue, Suite 4900
PO Box 34018 Seattle, WA 98124-4018

The information in this report is based on data generated at Pacific Gas and Electric Company's Food Service Technology Center.

Disclaimer

NEITHER FISHER-NICKEL, INC. NOR THE PG&E FOOD SERVICE TECHNOLOGY CENTER NOR ANY OF ITS EMPLOYEES MAKES ANY WARRANTY, EXPRESSED OR IMPLIED, OR ASSUMES ANY LEGAL LIABILITY OF RESPONSIBILITY FOR THE ACCURACY, COMPLETENESS, OR USEFULNESS OF ANY DATA, INFORMATION, METHOD, PRODUCT OR PROCESS DISCLOSES IN THIS DOCUMENT, OR REPRESENTS THAT ITS USE WILL NOT INFRINGE ANY PRIVATELY-OWNED RIGHTS, INCLUDING BUT NOT LIMITED TO, PATENTS, TRADEMARKS, OR COPYRIGHTS.

Acknowledgments

The PG&E Food Service Technology Center (FSTC) acknowledges the support provided by Charles Bohlig, East Bay Municipal Utility District (EBMUD), the Eugene Water and Electric Board, and the California Urban Water Conservation Council.

The FSTC recognizes the commitment of the participating establishments to increasing the energy efficiency of their facilities and eagerness to support conservation initiatives. The enthusiasm of the facility staffs to accommodate our on-site visits and needs was appreciated.

Policy on the Use of PG&E Food Service Technology Center Test Results and Other Related Information

- Fisher-Nickel, inc. and the Food Service Technology Center (FSTC) do not endorse particular products or services from any specific manufacturer or service provider.
- The FSTC is *strongly* committed to testing food service equipment using the best available scientific techniques and instrumentation.
- The FSTC is neutral as to fuel and energy source. It does not, in any way, encourage or promote the use of any fuel or energy source nor does it endorse any of the equipment tested at the FSTC.
- FSTC test results are made available to the general public through technical research reports and publications and are protected under U.S. and international copyright laws.
- In the event that FSTC data are to be reported, quoted, or referred to in any way in publications, papers, brochures, advertising, or any other publicly available documents, the rules of copyright must be strictly followed, including written permission from Fisher-Nickel, inc. *in advance* and proper attribution to Fisher-Nickel, inc. and the Food Service Technology Center. In any such publication, sufficient text must be excerpted or quoted so as to give full and fair representation of findings as reported in the original documentation from FSTC.

Legal Notice

Reference to specific products or manufacturers is not an endorsement of that product or manufacturer by Fisher-Nickel, inc., the Food Service Technology Center or Pacific Gas & Electric Company (PG&E). Retention of this consulting firm by PG&E to develop this report does not constitute endorsement by PG&E for any work performed other than that specified in the scope of this project.

Background

Ice machines are installed throughout the food service and hospitality industry, from bars, delis, and restaurants, to hotels, hospitals, and other institutional kitchens. Ranging from ice-cube, to nugget and flake-type machines, this installed base of ice machines represents one of the largest inventories of food service equipment. The Air-Conditioning and Refrigeration Institute (ARI) publishes the ARI Directory of Certified Automatic Commercial Ice-Cube Machines and Ice Storage Bins [ref 1] containing energy and water usage test data. Interrogating this database quickly reveals large differences in water and energy consumption per 100 pounds of ice produced between different manufacturers and models of both air-cooled and water-cooled machines. This directory has the potential to be utilized by utilities to help customers select water/energy efficient models or as a basis for financial incentives to promote equipment that is more efficient. Of course, regardless of any variance between the actual and rated water and energy usage rates, a facility's ice demand directly affects the net water and energy consumption.

Key variables that can affect ice-cube machine water usage rate are the system water pressure, which may or may not be regulated, and the water purge time setting, which can be adjusted by field service personnel to deviate from the factory standard setting to compensate for varying water quality. The energy consumption rate is affected by ambient air temperature (and water temperature for water-cooled machines), as higher temperatures will result in an increase in the consumption rate.

ARI standards establish rating criteria and procedures for measuring and certifying product performance. The Standard Ratings presented in the ARI directory are determined in accordance with ARI Standard 810 using test conditions of an ambient air temperature of 90°F, a water inlet temperature of 70°F and a water inlet pressure of 30 ± 3 psig. Since these conditions along with standard machine settings controlling purge water quantity can vary in the field, there has been an uncertainty on the part of utilities to project annual water, sewer and energy usage and/or cost saving based solely on the data published in the ARI directory.

A general sizing guideline for ice machines is to choose a unit that would operate with a duty cycle of 75% based on the rated harvest capacity and the assumed daily ice requirement, which balances machine size and cost with the reserve capacity needed for high-demand days. However, from site survey experience, it is known that ice machine usage can vary dramatically from one installation to another; some machines may be undersized and may seldom turn off in order to meet the demand, and others may seldom turn on because they have high production capacity or low demand.

Larger capacity machines are inherently more energy efficient than lower capacity units are. Employing higher capacity machines not only yields a direct energy efficiency benefit during ice production but also the opportunity to operate the machine off the afternoon peak electrical demand period (using a time-clock control), provided the storage bin is large enough to hold the reserve amount. In order to determine the potential for shifting ice production from peak periods to non-peak periods, more data on the characteristic usage profiles in the different types of facilities is needed.

Objectives

1) To measure actual water and energy usage in representative commercial ice-cube machine installations.
2) To compare the field-measured water and energy usage rates to ARI and/or manufacturer supplied (laboratory) testing data.
3) Determine for each machine the annual water, wastewater, and energy consumption and saving that could be achieved by retrofitting with models that are more water/energy-efficient.
4) Capture field data that can be used to quantify the energy saving potential for reductions in regional water distribution (pumping) and wastewater treatment.

Scope

The project involved field-testing of eight ice-cube machines, consisting of two water-cooled and six air-cooled units, in selected food service facilities to investigate the variability in the water and energy usage rate and compare with ARI published data. Measured duty cycles were used to determine whether there was typically enough reserve capacity to allow the machines to be operated off-peak (e.g., 12 – 6 pm). Embedded energy in water and wastewater, as well as potential peak demand charge reduction, specific to local utility companies, can be calculated based on the measured usage.

Evaluation Method

Sites were selected based on convenience of location, ease of measurement, and cooperation of the owners. Water and electrical energy usage data was collected from each ice machine for a period of approximately one month. Water consumption was measured with a single-jet paddlewheel turbine water meter installed at the inlet line of each machine and used in tandem with an electronic data logger that recorded time-stamped pulses from each meter. An energy data logger was installed in the circuit breaker panel feeding each machine to record power and energy consumption.

Ice production was directly weighed for three consecutive harvest cycles and then averaged. The cumulative number of completed harvest cycles was compiled from the electrical data profiles. The quantity of water that was harvested into ice was calculated by multiplying the number of cycles by the ice harvest weight per cycle. The difference between the total measured inlet water quantity and water used for harvested ice was the amount of wastewater that was purged (and used for condenser cooling for the water-cooled units).

Average daily water and energy consumption and duty cycle values were calculated from 12 am to 12 am the following day. For sites that were not open seven days a week (sites #6 and #8), they include averaged data from facility off-days. The daily averages were multiplied by 360 days per year to calculate the projected annual consumption totals. Calculated water use rates and energy consumption rates were compared to those found in the ARI directory. Utility rate costs of $5.00/CCF (combined water and sewer charges) and $0.15/kWh were applied to estimate operating cost and cost saving potential.

The measured average and maximum duty cycle were used to determine the potential for off-peak operation. A 75% or lower maximum duty cycle would be required if the machine were to be consistently turned off for six hours per day during the peak electric utility hours, while a 75% average would normally allow for off-peak operation but may need to be overridden on high duty cycle days.

The potential saving that could be realized by installing a new, high-efficiency replacement machine was calculated using the Consortium for Energy Efficiency (CEE) Tier 3 air-cooled high-efficiency performance specifications [ref 2]. The high-efficiency specifications applicable to the machines in this field study comprise a water use rate of 20 gal/100 lb (specified as a maximum), an energy consumption rate of (*5.86 – 0.0009*[Harvest Rate]) kWh/100 lb* for ≥450 lb/day Ice-Making Head machines, and *4.34 kWh/100 lb* for ≥1000 lb/day Remote-Condensing Unit machines without a remote compressor.

In some cases, the recommended replacement machine ice harvest rate capacity was considerably higher than the machine it would be replacing. This takes advantage of larger machine energy efficiency and capacity for off-peak operation.

Results and Discussion

The results of the field monitoring have been summarized on an individual basis in this section of the report. The tabulated results for each facility include the ARI Standard Ratings for each machine, measured water and energy consumption, and the difference between the measured and ARI standard values of water and energy usage rates. Typical day profiles show the electrical power through the harvest cycles and cumulative water consumption over the course of the day. A complete data and results table is presented in Appendix A.

Average duty cycles ranged between 35% and 87% with single-day maximums ranging between 48% and 100%. Operating power, which is the available amount for peak load shifting, ranged from 0.8 to 4.8 kW. Average daily ice production, indicative of each facility's demand, ranged from 158 to 1147 lb/day. Comparing water use and energy consumption rates, there was a deviation above and below ARI performance data figures, though on average, the values agreed well. Water use rate ranged from 19% under (26.1 vs. 32.1 gal/100 lb) to an extreme of 142% over (61.9 vs. 25.6 gal/100 lb), and the electrical consumption rate ranged from 28% under (3.6 vs. 5.0 kWh/100 lb) to 37% over (7.1 vs. 5.2 kWh/100 lb).

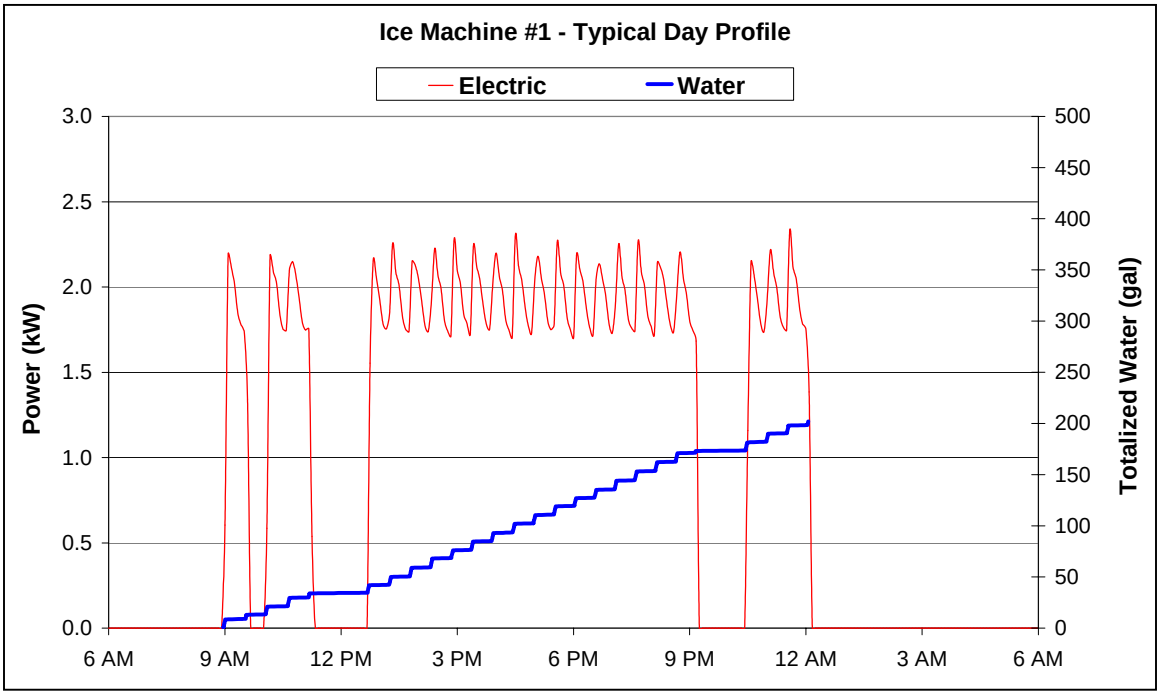
While considerable saving potential was evident for the less efficient machines, the potential saving calculations for the more efficient machines did not show water and/or energy use reduction when compared to the CEE high-efficiency values. These situations were denoted "N/A" in the results tables. In terms of energy consumption, this was likely due to the cooler air and/or water temperatures experienced during the field test. Although not monitored, it was observed that all of the machines were operating at average ambient temperatures less than the 90°F ARI standard rating condition. A high efficiency replacement machine operating under the same conditions may have energy consumption rates that are lower than ARI-listed values, but the potential saving cannot be quantified in advance by this study.

Regarding water consumption saving, all but machine #6 (which used 18.6 gal/100 lb) showed some saving potential. It was found that none of the monitored machines had water pressure regulators installed. Machines #1 and #4, the two that had the highest water consumption percentage difference as compared to the ARI rating were examined further to determine inlet pressure and control settings. Both variables appeared to be contributing to the higher water use by these two machines.

Ice Machine #1: This air-cooled ice-cube machine was located in a quick-service restaurant that is open for lunch and dinner seven days a week. The recorded average water consumption was 212 gal/day, and the average electrical consumption was 24.6 kWh/day. Projected annual cost of operation is $1,840. With an average duty cycle of 48% and a maximum of 61%, off-peak load shifting could be effectively applied to this machine. The machine performed with an energy consumption rate 25% lower than the ARI rating, while the water use rate was 20% higher than the ARI value. Parameters potentially causing higher water consumption were investigated. The water inlet pressure was measured to be 70 psig. The internal control board switches that can be adjusted for water flush (harvest) duration were found set to the factory setting of 60 seconds, while the water sump pump-out frequency setting switches were adjusted to repeat on every cycle as opposed to the factory setting of every tenth cycle.

Manufacturer	Hoshizaki	
Model	KM-1300MAH	
Type	Air-cooled; Ice-Making Head	
Approximate Age	8 yrs.	
ARI Listed Ice Harvest Rate	1,059	lb/24 hr
Average Daily Water Consumption	211.9	gal/day
Average Daily Energy Consumption	24.6	kWh/day
Average Daily Harvest Cycles	23.2	cycle/day
Average Harvest Weight	23.4	lb/cycle
Average Ice Production	545	lb/day
Average Duty Cycle	47.6	%
Minimum Daily Duty Cycle	37.2	%
Maximum Daily Duty Cycle	60.8	%
ARI Listed Water Use Rate	32.3	gal/100 lb
Measured Water Use Rate	38.9	gal/100 lb
Difference from ARI	+ 6.6	gal/100 lb
Percentage Difference from ARI	+ 20.4	%
ARI Listed Energy Consumption Rate	6.0	kWh/100 lb
Measured Energy Consumption Rate	4.51	kWh/100 lb
Difference from ARI	- 1.49	kWh/100 lb
Percentage Difference from ARI	- 24.8	%
Projected Annual Ice Production	196,100	lb/yr
Projected Annual Water Use	76,290	gal/yr
Projected Annual Water Cost *($5.00/CCF)*	$ 510	/yr
Potential Annual Water Saving *(with a 20 gal/100 lb machine)*	37,060	gal/yr
Potential Annual Water Cost Saving *($5.00/CCF)*	$ 248	/yr
Projected Annual Energy Use	8,855	kWh/yr
Projected Annual Energy Cost *($0.15/kWh)*	$ 1,328	/yr
Recommended New Machine Capacity	1,200	lb/24 hr
Potential Annual Energy Saving *(with a 4.78 kWh/100 lb machine)*	N/A	kWh/yr
Potential Annual Energy Cost Saving *($0.15/kWh)*	N/A	kWh/yr

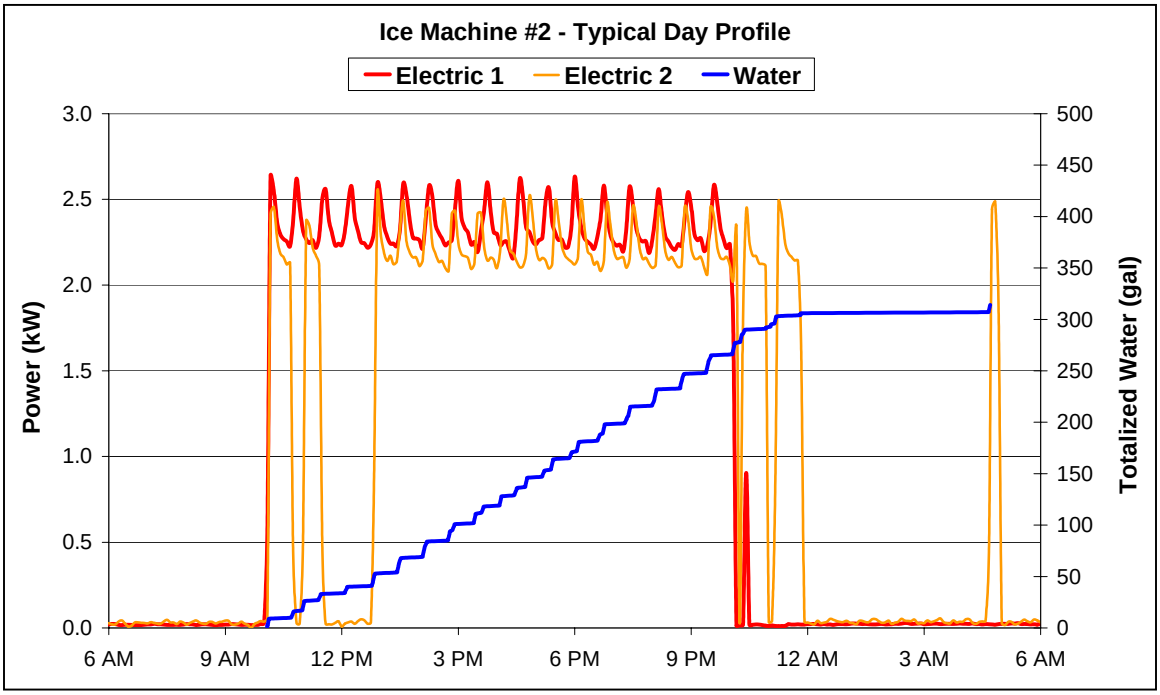
Machine #1


Ice Machine #1 - Typical Day Profile
Electric
Water
Power (kW)
Totalized Water (gal)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
500
450
400
350
300
250
200
150
100
50
0
6 AM
9 AM
12 PM
3 PM
6 PM
9 PM
12 AM
3 AM
6 AM

Ice Machine #2: Located in a full-service restaurant that is open for lunch and dinner seven days a week, this ice-cube machine configuration utilized one bin with two stacked air-cooled ice machine heads using remote condensers. The average water consumption was 321 gal/day, and the average electrical consumption was 55.4 kWh/day. This translated to a projected annual operating cost of $3,770. The average duty cycle was 50%, with a maximum of 65%, which allows for load shifting to off-peak operation. Field measured usage rates were very similar to the ARI listed values; the measured water use rate was 5% lower while the measured electrical consumption rate was 5% higher.

Manufacturer	Hoshizaki	
Model	KM-1200SRE (x 2)	
Type	Air-cooled; Remote Condensing Unit	
Approximate Age	10 yrs.	
ARI Listed Ice Harvest Rate	1,130 (x2)	lb/24 hr
Average Daily Water Consumption	321.4	gal/day
Average Daily Energy Consumption	55.4	kWh/day
Average Daily Harvest Cycles	37.3	cycle/day
Average Harvest Weight	30.8	lb/cycle
Average Ice Production	1,147	lb/day
Average Duty Cycle	49.7	%
Minimum Daily Duty Cycle	38.7	%
Maximum Daily Duty Cycle	64.9	%
ARI Listed Water Use Rate	29.5	gal/100 lb
Measured Water Use Rate	28.0	gal/100 lb
Difference from ARI	- 1.5	gal/100 lb
Percentage Difference from ARI	- 5.0	%
ARI Listed Energy Consumption Rate	4.6	kWh/100 lb
Measured Energy Consumption Rate	4.83	kWh/100 lb
Difference from ARI	+ 0.23	kWh/100 lb
Percentage Difference from ARI	+ 5.0	%
Projected Annual Ice Production	413,000	lb/yr
Projected Annual Water Use	115,700	gal/yr
Projected Annual Water Cost *($5.00/CCF)*	$ 773	/yr
Potential Annual Water Saving *(with a 20 gal/100 lb machine)*	33,090	gal/yr
Potential Annual Water Cost Saving *($5.00/CCF)*	$ 221	/yr
Projected Annual Energy Use	19,950	kWh/yr
Projected Annual Energy Cost *($0.15/kWh)*	$ 2,990	/yr
Recommended New Machine Capacity	1,200 (x2)	lb/24 hr
Potential Annual Energy Saving *(with a 4.34 kWh/100 lb machine)*	2,026	kWh/yr
Potential Annual Energy Cost Saving *($0.15/kWh)*	$ 304	/yr

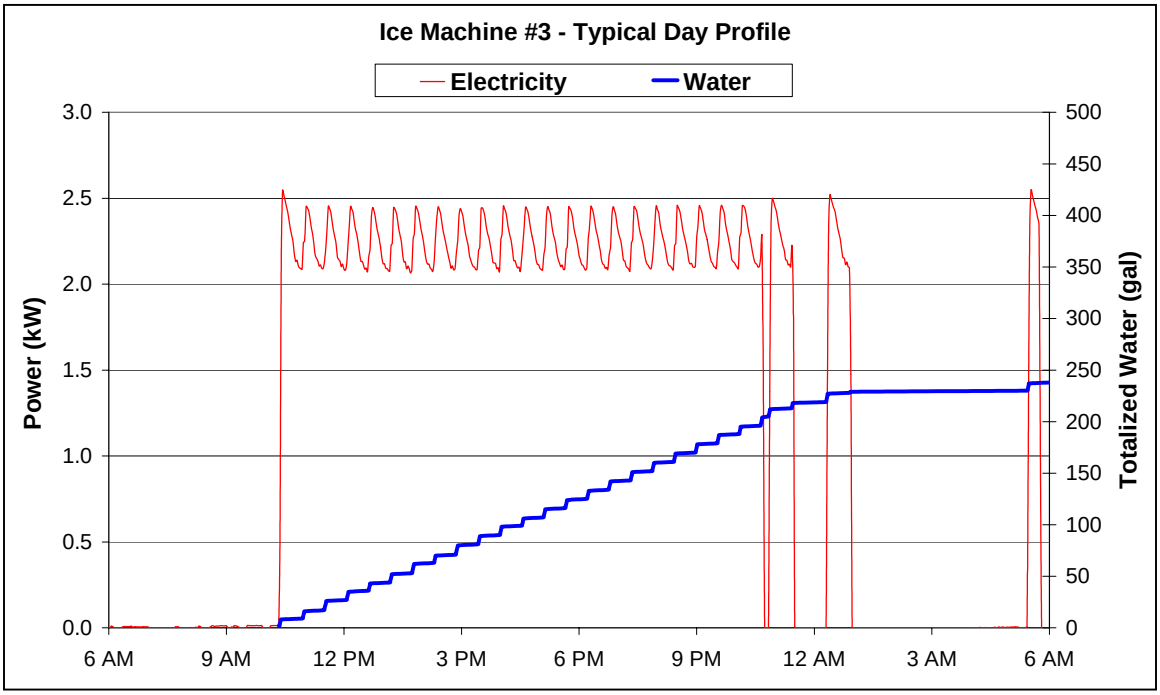
Machine #2


Ice Machine #2 - Typical Day Profile
Electric 1
Electric 2
Water
Power (kW)
Totalized Water (gal)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
500
450
400
350
300
250
200
150
100
50
0
6 AM
9 AM
12 PM
3 PM
6 PM
9 PM
12 AM
3 AM
6 AM

Ice Machine #3: This air-cooled, remote-condensing ice-cube machine was located in a full-service restaurant operating seven days a week. (The restaurant also employed a second ice-cube machine during busy days.) The average water consumption was 224 gal/day, and the average electrical consumption was 31.0 kWh/day. Annual operating cost was projected to be $2,210. The average duty cycle was 60%, with a maximum of 91%. Load shifting for this machine is possible during average days, but would likely need to be overridden during heavy use, high duty cycle days. As tested, the machine operated with considerably lower water and electricity consumption rates than the ARI listed values—19% and 28% lower respectively.

Manufacturer	Hoshizaki	
Model	KM-1300SRF	
Type	Air-cooled; Remote Condensing Unit	
Approximate Age	10 yrs.	
ARI Listed Ice Harvest Rate	1,133	lb/24 hr
Average Daily Water Consumption	224.2	gal/day
Average Daily Energy Consumption	31.0	kWh/day
Average Daily Harvest Cycles	29.8	cycle/day
Average Harvest Weight	28.8	lb/cycle
Average Ice Production	858	lb/day
Average Duty Cycle	59.5	%
Minimum Daily Duty Cycle	41.0	%
Maximum Daily Duty Cycle	90.8	%
ARI Listed Water Use Rate	32.1	gal/100 lb
Measured Water Use Rate	26.1	gal/100 lb
Difference from ARI	- 6.0	gal/100 lb
Percentage Difference from ARI	- 18.6	%
ARI Listed Energy Consumption Rate	5.0	kWh/100 lb
Measured Energy Consumption Rate	3.61	kWh/100 lb
Difference from ARI	- 1.39	kWh/100 lb
Percentage Difference from ARI	- 27.8	%
Projected Annual Ice Production	308,800	lb/yr
Projected Annual Water Use	80,710	gal/yr
Projected Annual Water Cost *($5.00/CCF)*	$ 540	/yr
Potential Annual Water Saving *(with a 20 gal/100 lb machine)*	18,950	gal/yr
Potential Annual Water Cost Saving *($5.00/CCF)*	$ 127	/yr
Projected Annual Energy Use	11,150	kWh/yr
Projected Annual Energy Cost *($0.15/kWh)*	$ 1,670	/yr
Recommended New Machine Capacity	1,600	lb/24 hr
Potential Annual Energy Saving *(with a 4.34 kWh/100 lb machine)*	N/A	kWh/yr
Potential Annual Energy Cost Saving *($0.15/kWh)*	N/A	/yr

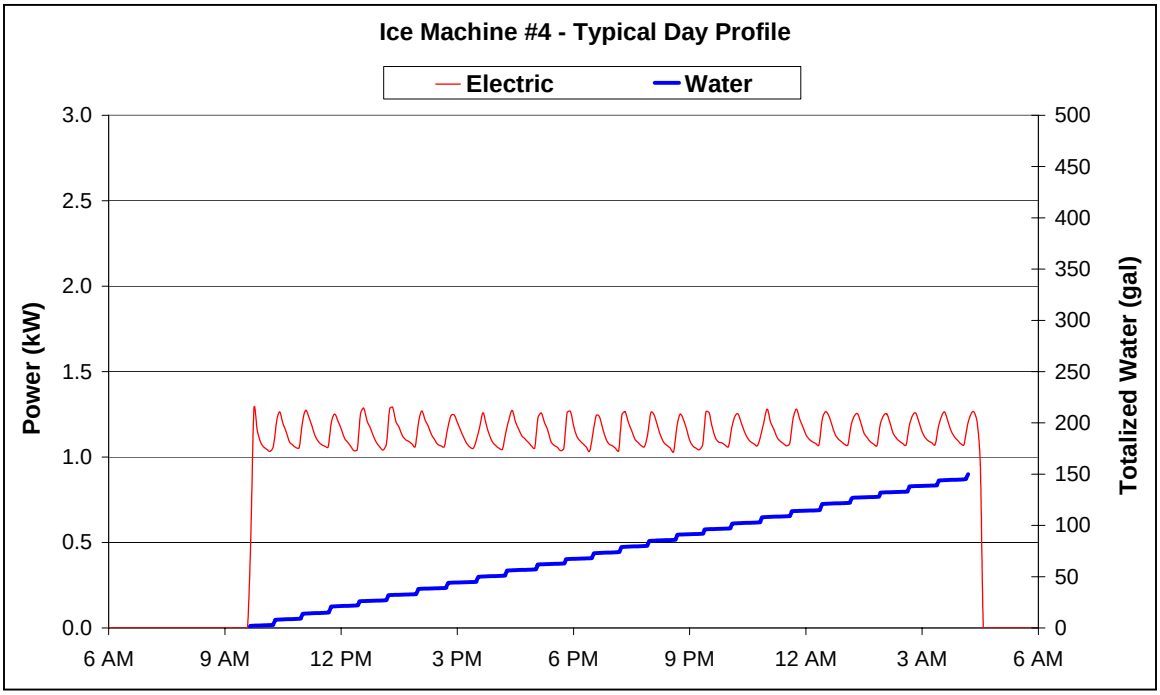
Machine #3


Ice Machine #3 - Typical Day Profile
Electricity
Water
Power (kW)
Totalized Water (gal)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
500
450
400
350
300
250
200
150
100
50
0
6 AM
9 AM
12 PM
3 PM
6 PM
9 PM
12 AM
3 AM
6 AM

Ice Machine #4: This air-cooled ice-cube machine was located in a diner that served breakfast and lunch seven days a week. The average water consumption was 110 gal/day, and the average electrical consumption was 16.1 kWh/day. Projected annual cost of operation was $1,135. The average duty cycle was 59%, with a maximum of 85%. This usage indicates that the machine cannot always be switched off during peak periods, although a larger capacity, more efficient replacement machine would decrease the duty cycle—in addition to providing water and energy saving. After calculating a water use rate 142% higher than the ARI listed value the machine was further examined. Water pressure was measured to be 70 psig, and the purge timer setting was measured to be 2.5 minutes as compared to the ARI Standard Condition of 30 psig and the factory setting of the minimum purge time of 1 minute.

Manufacturer	Hoshizaki	
Model	KM-451DU	
Type	Air-cooled; Ice-Making Head	
Approximate Age	15 yrs.	
ARI Listed Ice Harvest Rate	340	lb/24 hr
Average Daily Water Consumption	110.4	gal/day
Average Daily Energy Consumption	16.1	kWh/day
Average Daily Harvest Cycles	19.3	cycle/day
Average Harvest Weight	9.2	lb/cycle
Average Ice Production	178	lb/day
Average Duty Cycle	58.5	%
Minimum Daily Duty Cycle	41.0	%
Maximum Daily Duty Cycle	84.7	%
ARI Listed Water Use Rate	25.6	gal/100 lb
Measured Water Use Rate	61.9	gal/100 lb
Difference from ARI	+ 36.3	gal/100 lb
Percentage Difference from ARI	+ 141.7	%
ARI Listed Energy Consumption Rate	8.8	kWh/100 lb
Measured Energy Consumption Rate	9.02	kWh/100 lb
Difference from ARI	+ 0.22	kWh/100 lb
Percentage Difference from ARI	+ 2.5	%
Projected Annual Ice Production	64,260	lb/yr
Projected Annual Water Use	39,760	gal/yr
Projected Annual Water Cost *($5.00/CCF)*	$ 266	/yr
Potential Annual Water Saving *(with a 20 gal/100 lb machine)*	26,910	gal/yr
Potential Annual Water Cost Saving *($5.00/CCF)*	$ 180	/yr
Projected Annual Energy Use	5,795	kWh/yr
Projected Annual Energy Cost *($0.15/kWh)*	$ 869	/yr
Potential Annual Energy Saving *(with a 5.41 kWh/100 lb machine)*	2,318	kWh/yr
Recommended New Machine Capacity	500	lb/24 hr
Potential Annual Energy Cost Saving *($0.15/kWh)*	$ 348	/yr

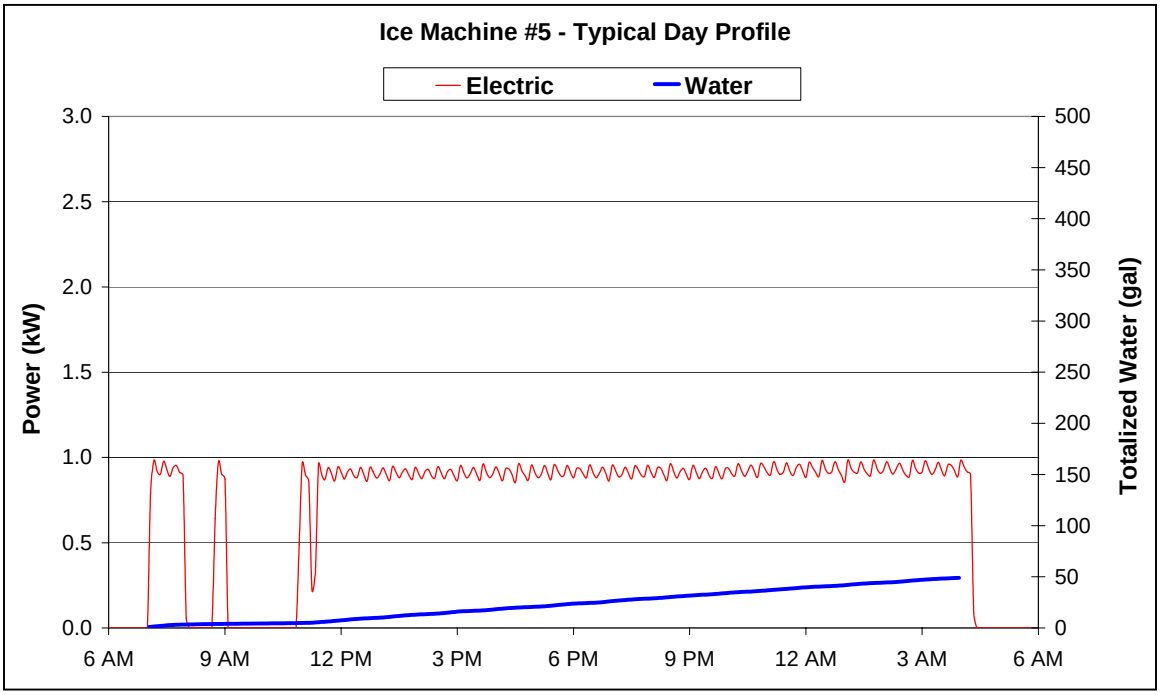
Machine #4


Ice Machine #4 - Typical Day Profile
Electric
Water
Power (kW)
Totalized Water (gal)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
500
450
400
350
300
250
200
150
100
50
0
6 AM
9 AM
12 PM
3 PM
6 PM
9 PM
12 AM
3 AM
6 AM

Ice Machine #5: This air-cooled ice-cube machine was located in a restaurant and bar that was open seven days a week. The average water consumption was 53 gal/day, and the average electrical consumption was 18.0 kWh/day, which translated to a combined projected operating cost of $1,100 per year. The average duty cycle was 83%, with a maximum of 100%, which indicated that the machine was working very long to meet the demand and that a larger (and more efficient) machine would be needed to apply load shifting. ARI listed usage rate values closely matched those measured in the field.

Manufacturer	Manitowoc	
Model	QY0374A	
Type	Air-cooled; Ice-Making Head	
Approximate Age	10 yrs.	
ARI Listed Ice Harvest Rate	275	lb/24 hr
Average Daily Water Consumption	52.7	gal/day
Average Daily Energy Consumption	18.0	kWh/day
Average Daily Harvest Cycles	66.1	cycle/day
Average Harvest Weight	3.3	lb/cycle
Average Ice Production	215	lb/day
Average Daily Duty Cycle	82.8	%
Minimum Daily Duty Cycle	45.5	%
Maximum Daily Duty Cycle	100	%
ARI Listed Water Use Rate	26	gal/100 lb
Measured Water Use Rate	24.5	gal/100 lb
Difference from ARI	- 1.5	gal/100 lb
Percentage Difference from ARI	- 5.8	%
ARI Listed Energy Consumption Rate	8.3	kWh/100 lb
Measured Energy Consumption Rate	8.39	kWh/100 lb
Difference from ARI	0.09	kWh/100 lb
Percentage Difference from ARI	+ 1.1	%
Projected Annual Ice Production	77,380	lb/yr
Projected Annual Water Use	18,960	gal/yr
Projected Annual Water Cost *($5.00/CCF)*	$ 127	/yr
Potential Annual Water Saving *(with a 20 gal/100 lb machine)*	3,485	gal/yr
Potential Annual Water Cost Saving *($5.00/CCF*)	$ 23	/yr
Projected Annual Energy Use	6,492	kWh/yr
Projected Annual Energy Cost *($0.15/kWh)*	$ 974	/yr
Recommended New Machine Capacity	500	lb/24 hr
Potential Annual Energy Saving *(with a 5.41 kWh/100 lb machine)*	2,306	kWh/yr
Potential Annual Energy Cost Saving *($0.15/kWh)*	$ 346	/yr

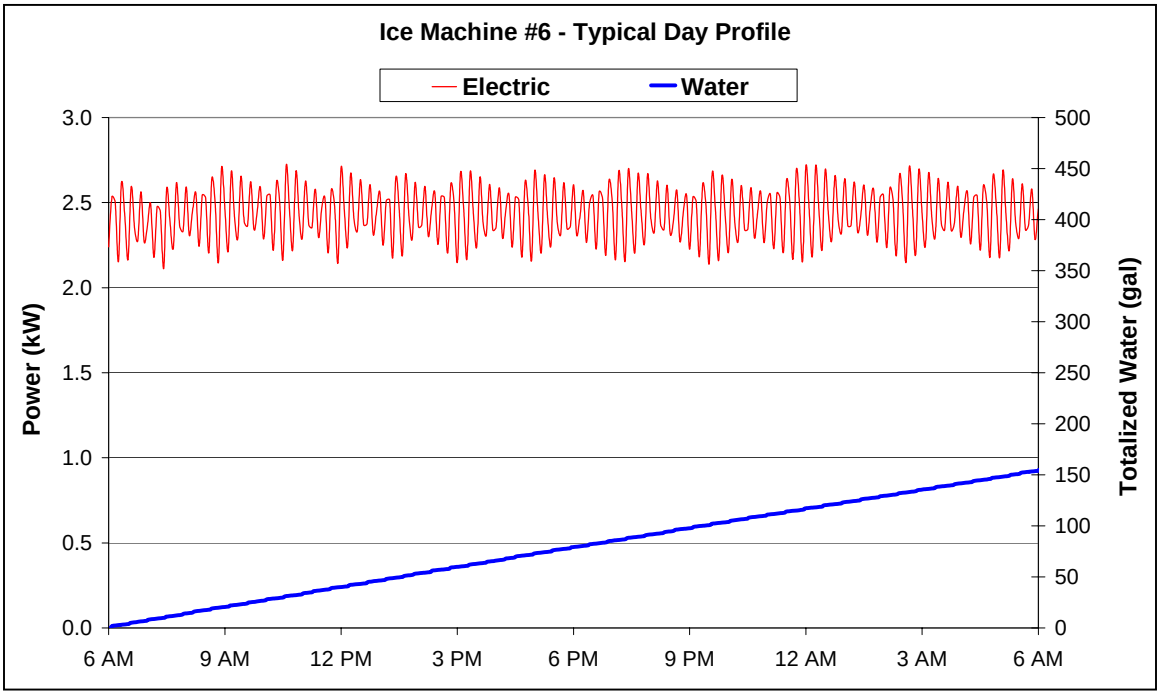
Machine #5


Ice Machine #5 - Typical Day Profile
Electric
Water
Power (kW)
Totalized Water (gal)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
500
450
400
350
300
250
200
150
100
50
0
6 AM
9 AM
12 PM
3 PM
6 PM
9 PM
12 AM
3 AM
6 AM

Ice Machine #6: This air-cooled ice-cube machine is located in a corporate cafeteria that is open five days a week. The average water consumption was 130 gal/day, and the average electrical consumption was 50.7 kWh/day. Projected annual cost of operation was $3,050. The average duty cycle was 87%, with a maximum of 100%. During the week, the typical-day duty cycle for the machine was usually 100%. The facility uses the machine to full or near-full capacity and uses a flaker ice machine for cold buffet table service.

Manufacturer	Manitowoc	
Model	QY1004A	
Type	Air-cooled; Ice-Making Head	
Approximate Age	5 yrs.	
ARI Listed Ice Harvest Rate	830	lb/24 hr
Average Daily Water Consumption	129.8	gal/day
Average Daily Energy Consumption	50.7	kWh/day
Average Daily Harvest Cycles	85.4	cycle/day
Average Harvest Weight	8.1	lb/cycle
Average Ice Production	694	lb/day
Average Duty Cycle	86.6	%
Minimum Daily Duty Cycle	26.7	%
Maximum Daily Duty Cycle	100	%
ARI Listed Water Use Rate	20.4	gal/100 lb
Measured Water Use Rate	18.7	gal/100 lb
Difference from ARI	- 1.7	gal/100 lb
Percentage Difference from ARI	- 8.3	%
ARI Listed Energy Consumption Rate	6.9	kWh/100 lb
Measured Energy Consumption Rate	7.31	kWh/100 lb
Difference from ARI	0.41	kWh/100 lb
Percentage Difference from ARI	+ 5.9	%
Projected Annual Ice Production	249,900	lb/yr
Projected Annual Water Use	46,740	gal/yr
Projected Annual Water Cost *($5.00/CCF)*	$ 312	/yr
Potential Annual Water Saving *(with a 20 gal/100 lb machine)*	N/A	gal/yr
Potential Annual Water Cost Saving *($5.00/CCF)*	N/A	/yr
Projected Annual Energy Use	18,260	kWh/yr
Projected Annual Energy Cost *($0.15/kWh)*	$ 2,739	/yr
Recommended New Machine Capacity	1,000	lb/24 hr
Potential Annual Energy Saving *(with a 4.96 kWh/100 lb machine)*	5,861	kWh/yr
Potential Annual Energy Cost Saving *($0.15/kWh)*	$ 879	/yr

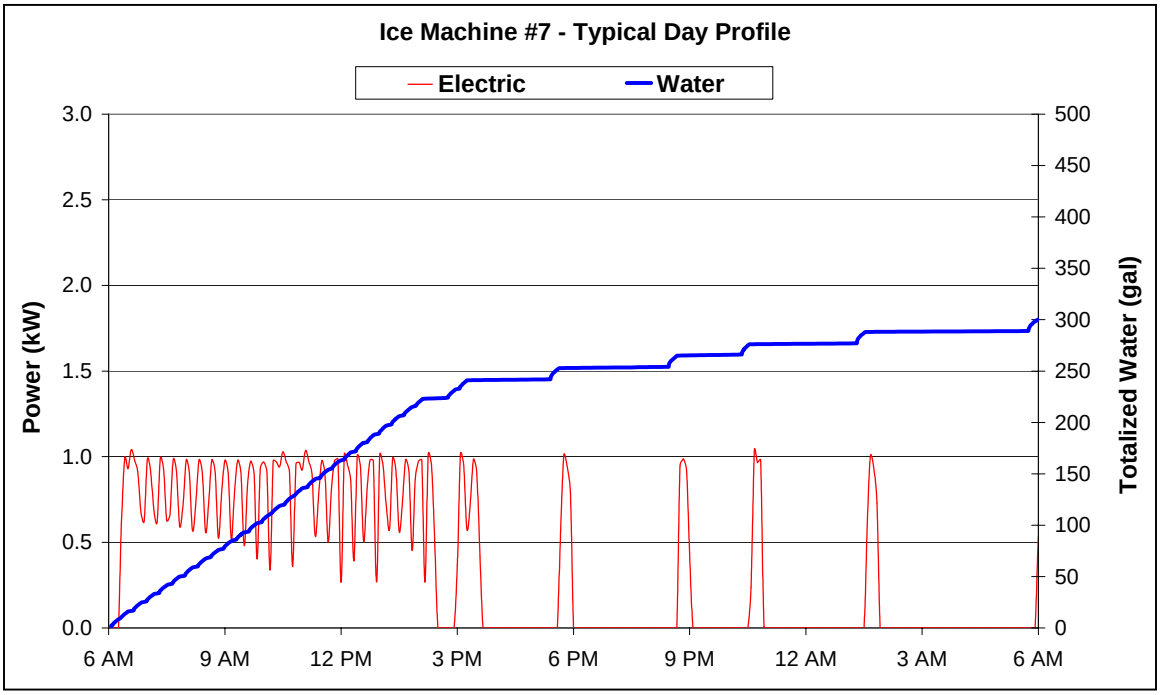
Machine #6


Ice Machine #6 - Typical Day Profile
Electric
Water
Power (kW)
Totalized Water (gal)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
500
450
400
350
300
250
200
150
100
50
0
6 AM
9 AM
12 PM
3 PM
6 PM
9 PM
12 AM
3 AM
6 AM

Ice Machine #7: This water-cooled ice-cube machine was located in a casual dining restaurant operating twelve hours per day during breakfast and lunch, seven days a week. The average water consumption was 295 gal/day, and the average electrical consumption was 8.6 kWh/day. Projected annual operating cost was $1,170. The 35% average and 48% maximum duty cycles are low enough to easily allow for timed peak-load shifting strategy.

Manufacturer	Manitowoc	
Model	QY0425W	
Type	Water-cooled; Ice-Making Head	
Approximate Age	10 yrs.	
ARI Listed Ice Harvest Rate	440	lb/24 hr
Average Daily Water Consumption	295	gal/day
Average Daily Energy Consumption	8.6	kWh/day
Average Daily Harvest Cycles	34.3	cycle/day
Average Harvest Weight	4.6	lb/cycle
Average Ice Production	158	lb/day
Average Duty Cycle	34.5	%
Minimum Daily Duty Cycle	27.4	%
Maximum Daily Duty Cycle	47.6	%
ARI Listed Water Use Rate	203.4	gal/100 lb
Measured Water Use Rate	186.7	gal/100 lb
Difference from ARI	- 16.7	gal/100 lb
Percentage Difference from ARI	- 8.2	%
ARI Listed Energy Consumption Rate	5.5	kWh/100 lb
Measured Energy Consumption Rate	5.44	kWh/100 lb
Difference from ARI	- 0.06	kWh/100 lb
Percentage Difference from ARI	- 1.0	%
Projected Annual Ice Production	56,870	lb/yr
Projected Annual Water Use	106,200	gal/yr
Projected Annual Water Cost *($5.00/CCF)*	$ 710	/yr
Potential Annual Water Saving *(with a 20 gal/100 lb machine)*	94,800	gal/yr
Potential Annual Water Cost Saving *($5.00/CCF)*	$ 634	/yr
Projected Annual Energy Use	3,095	kWh/yr
Projected Annual Energy Cost *($0.15/kWh)*	$ 464	/yr
Recommended New Machine Capacity	500	lb/24 hr
Potential Annual Energy Saving *(with a 5.41 kWh/100 lb machine)*	19	kWh/yr
Potential Annual Energy Cost Saving *($0.15/kWh)*	$ 3	/yr

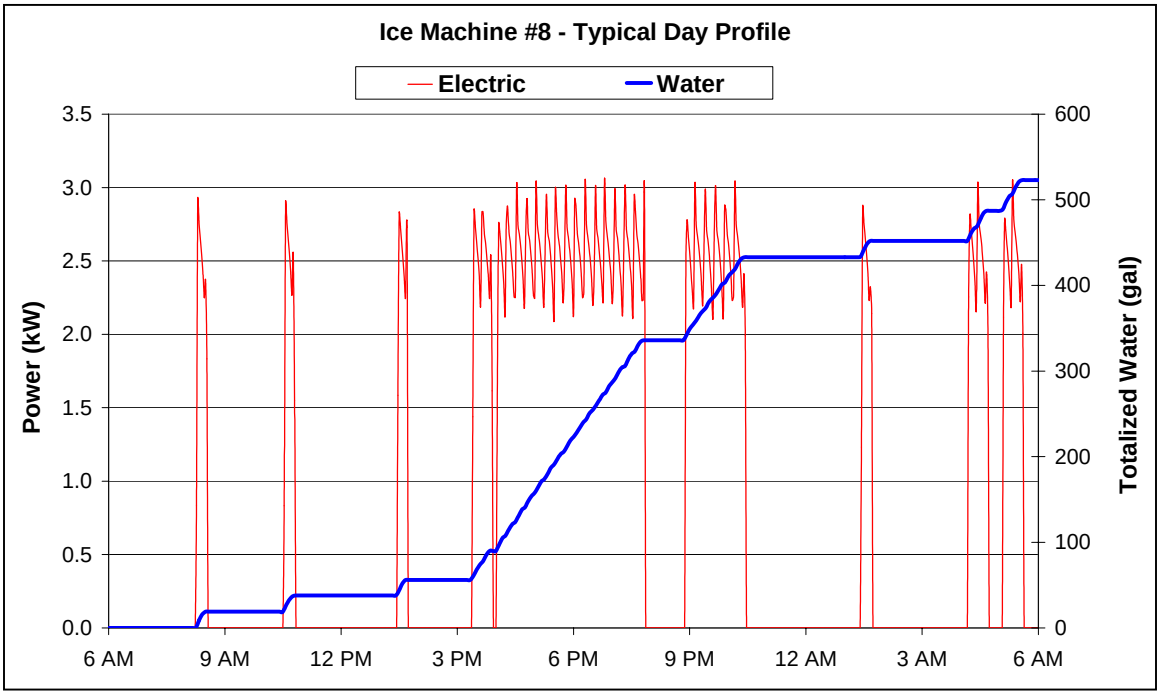
Machine #7


Ice Machine #7 - Typical Day Profile
Electric
Water
Power (kW)
Totalized Water (gal)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
500
450
400
350
300
250
200
150
100
50
0
6 AM
9 AM
12 PM
3 PM
6 PM
9 PM
12 AM
3 AM
6 AM

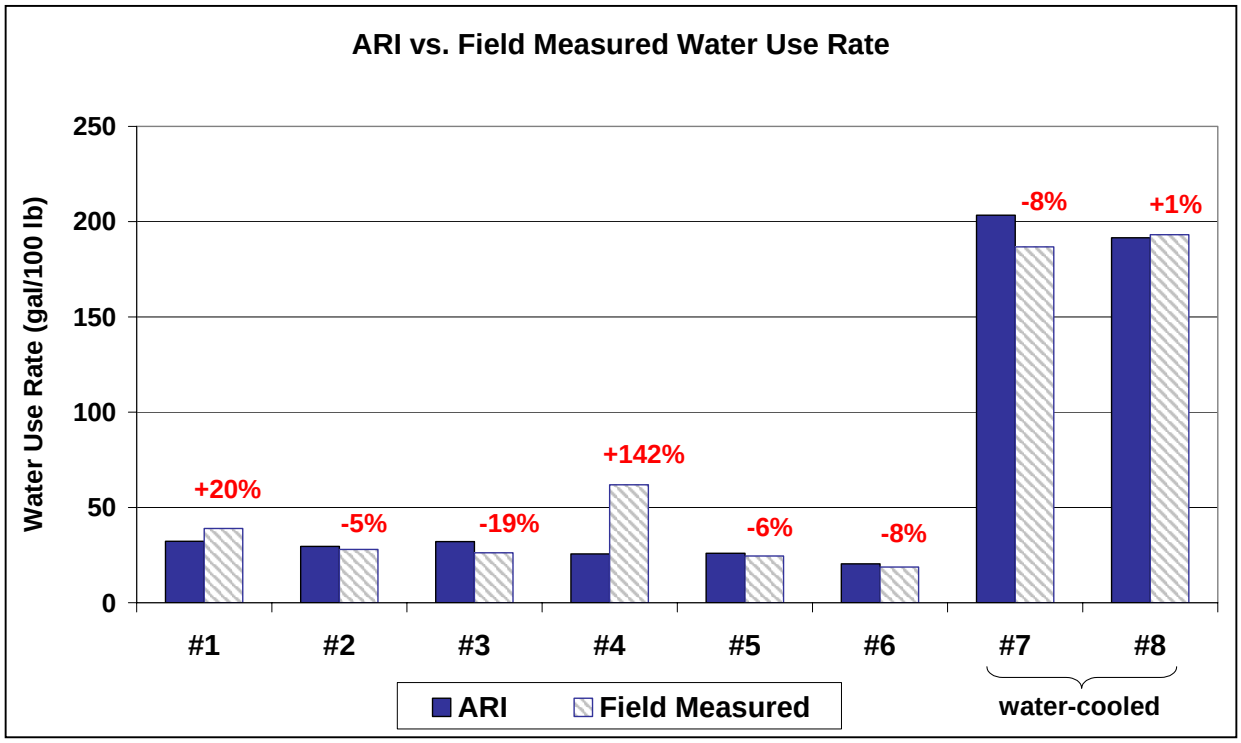
Ice Machine #8: This water-cooled ice-cube machine was located in a golf club restaurant, which was open for dinner six days a week. The average water consumption was 592 gal/day, and the average electrical consumption was 21.8 kWh/day, which result in a projected annual operating cost of $2,600. The average duty cycle was 35% and had a maximum of 79%. Effective peak load shifting with a timer is achievable with this machine. This machine exhibited the highest percentage difference over the ARI listed energy consumption rate. It also showed the greatest potential for water saving to be gained from a high water efficiency replacement.

Manufacturer	Manitowoc	
Model	GY1205W	
Type	Water-cooled; Ice-Making Head	
Approximate Age	15 yrs.	
ARI Listed Ice Harvest Rate	1,130	lb/24 hr
Average Daily Water Consumption	592	gal/day
Average Daily Energy Consumption	21.8	kWh/day
Average Daily Harvest Cycles	33.8	cycle/day
Average Harvest Weight	9.1	lb/cycle
Average Ice Production	307	lb/day
Average Duty Cycle	35.3	%
Minimum Daily Duty Cycle	6.4	%
Maximum Daily Duty Cycle	78.5	%
ARI Listed Water Use Rate	191.6	gal/100 lb
Measured Water Use Rate	193.1	gal/100 lb
Difference from ARI	+ 1.5	gal/100 lb
Percentage Difference from ARI	+ 0.8	%
ARI Listed Energy Consumption Rate	5.2	kWh/100 lb
Measured Energy Consumption Rate	7.11	kWh/100 lb
Difference from ARI	+ 1.91	kWh/100 lb
Percentage Difference from ARI	+ 36.7	%
Projected Annual Ice Production	110,400	lb/yr
Projected Annual Water Use	213,300	gal/yr
Projected Annual Water Cost *($5.00/CCF)*	$ 1,425	/yr
Potential Annual Water Saving *(with a 20 gal/100 lb machine)*	191,200	gal/yr
Potential Annual Water Cost Saving ($5.00/CCF)	$ 1,278	/yr
Projected Annual Energy Use	7,848	kWh/yr
Projected Annual Energy Cost *($0.15/kWh)*	$ 1,177	/yr
Recommended New Machine Capacity	1,200	lb/24 hr
Potential Annual Energy Saving *(with a 4.78 kWh/100 lb machine)*	2,569	kWh/yr
Potential Annual Energy Cost Saving *($0.15/kWh)*	$ 385	/yr

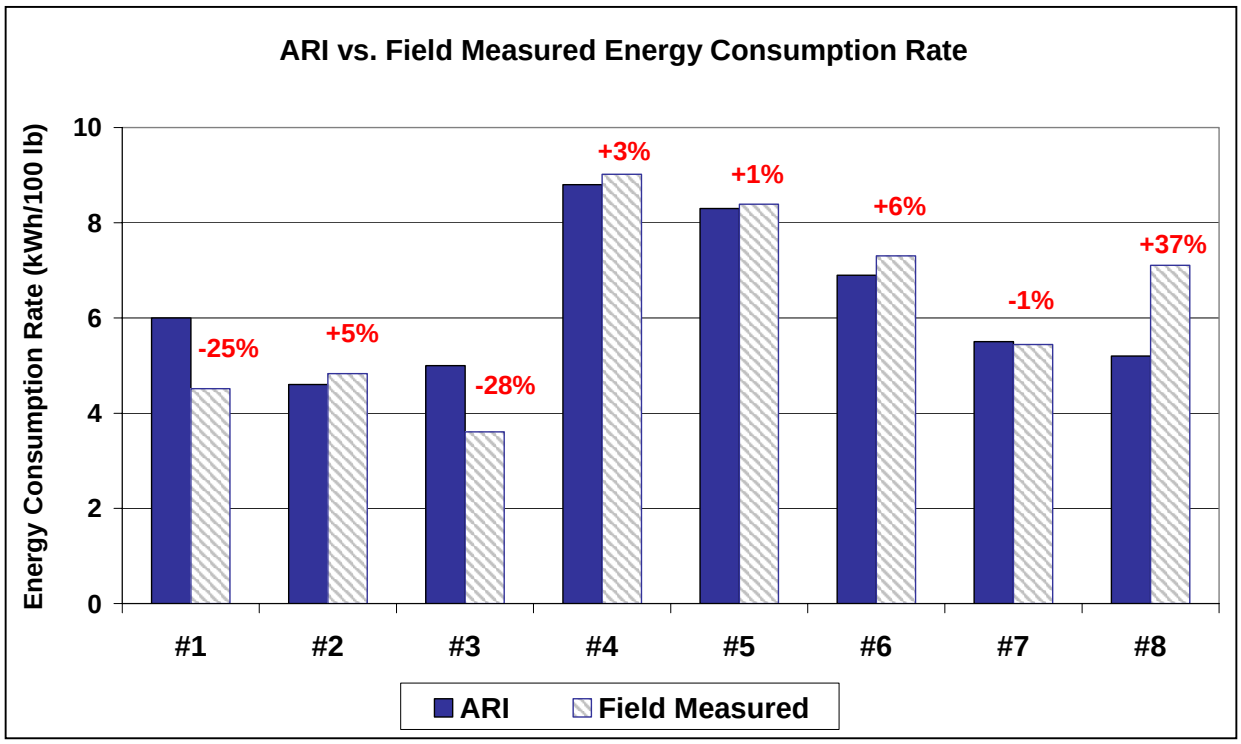
Machine #8


Ice Machine #8 - Typical Day Profile
Electric
Water
Power (kW)
Totalized Water (gal)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
600
500
400
300
200
100
0
6 AM
9 AM
12 PM
3 PM
6 PM
9 PM
12 AM
3 AM
6 AM

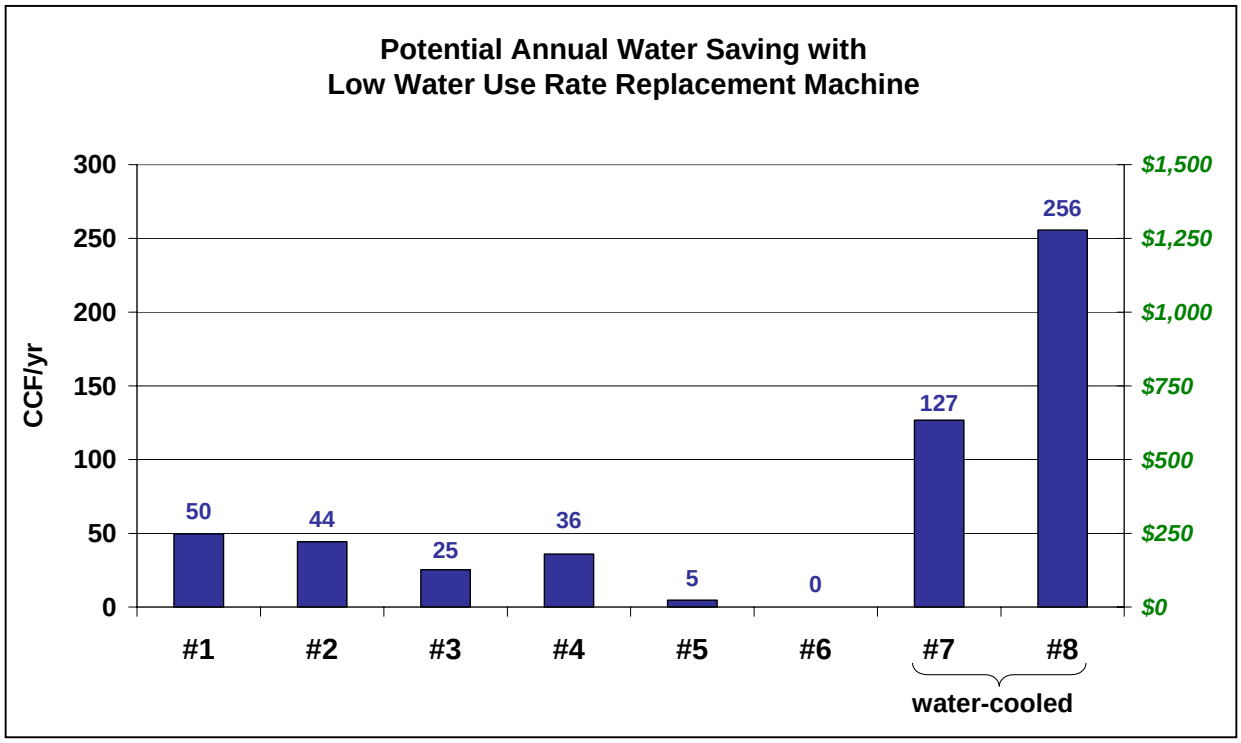
The following graph shows the difference between the ARI listed and field-measured water use rates. Note that machines #7 and #8 are water-cooled.



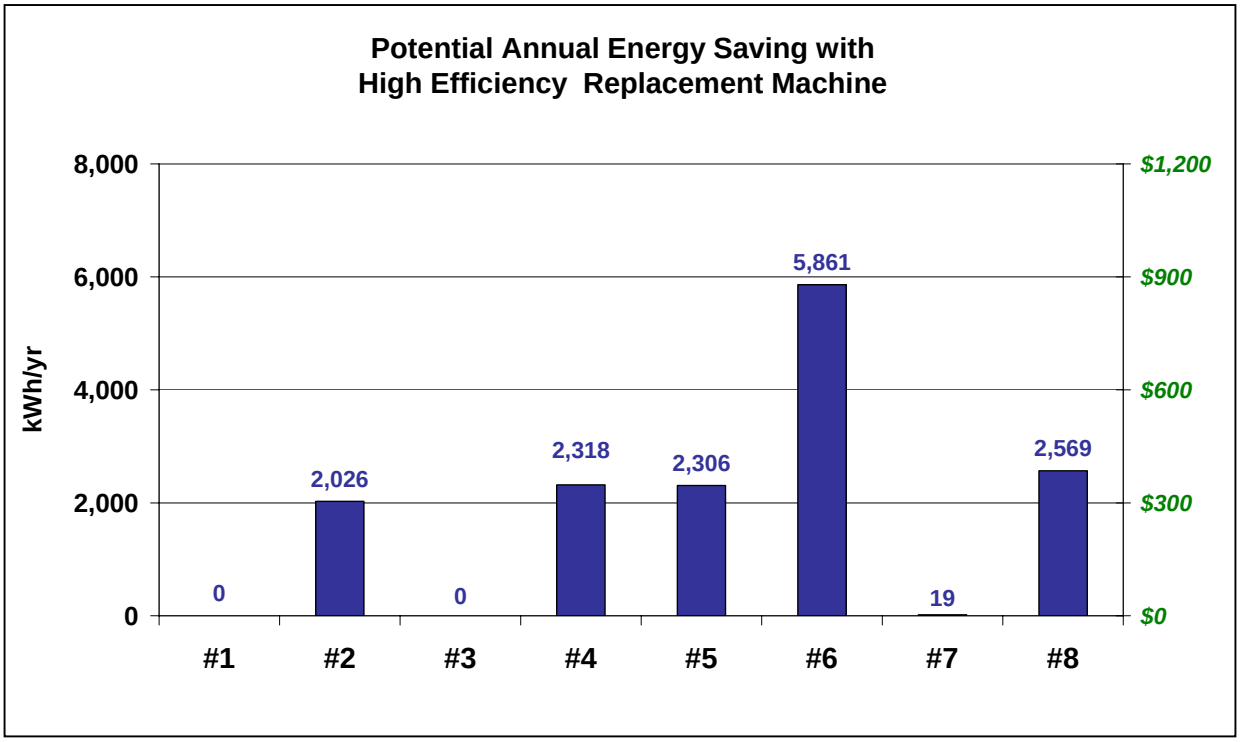
This graph shows the difference between the ARI listed and field-measured electrical energy use rates.



This graph represents the potential annual water saving for each facility that can be achieved by using an ice-cube machine with a water use rate of 20 gal/100 lb ice. Annual cost saving based on a combined water utility rate of $5.00/CCF is shown on the right axis.



This graph represents the potential energy saving that can be achieved by using a CEE high-efficiency specification machine. Energy cost saving based on a utility rate of $0.15/kWh is shown on the right axis. Machine #1 and #3 were already relatively efficient and showed no reportable saving.



Conclusions and Recommendations

This field study successfully characterized the water and energy use of eight individual ice-cube machines operating in commercial food service operations. The data documented the water and energy saving potential that would be realized by replacing a given unit with a more water/energy efficient model. The measured average and peak duty cycles, combined with the actual electric load profile, provide insight into the potential for off-peak operation of each ice machine. Field test results showed that some machines compared well with ARI listed consumption rates while others had significant differences in either water or energy. In general, the results of this study should provide utilities (as well as manufacturers and end users) with increased confidence in using ARI data to estimate water and energy use for a given ice machine application. The ARI water usage also can be used by utilities to calculate the energy saving potential for reductions in regional water distribution (pumping) and wastewater treatment with a similar degree of confidence and accuracy.

Most of the machines operated during the day through peak utility rate periods and were off at night (aside from occasional cycles initiated to top off the bin), and these off periods were long enough to build-up enough ice to supply peak periods when shut down. The data show that load shifting through use of a timer is a viable strategy, though the storage bin must have sufficient holding capacity to accommodate ice demand through the timed shutdown periods. Five of the eight machines showed potential for off-peak operation. Three of these machines are straightforward candidates (i.e., peak duty cycles below 70%) for a simple time clock based control, while the machines with higher duty cycles may need to be overridden for high-demand days or replaced with higher capacity models.

As expected, replacement of water-cooled machines with air-cooled models will yield the most water saving. If room heat gain from an air-cooled replacement might be a concern, using a remote-condensing air-cooled unit would result in the heat being rejected outdoors. When specifying new or replacement machines, it is recommended that models with the highest practical harvest rate capacity and inherently higher energy efficiency be selected. It is recommended that pressure regulators be installed and properly adjusted to manufacturer’s specification to ensure minimum water consumption. In warmer climates, remote-condenser or split-system ice machines should be specified to reject heat outdoors and away from areas that are normally air-conditioned. Quieter operation at the ice machine head because of the remote condenser would be an added benefit—especially with remote-condensing units with remote compressors.

References

1. Air-Conditioning and Refrigeration Institute. ARI Directory of Certified Automatic Commercial Ice-Cube Machines and Ice Storage Bins, Standard 810/820. 2007.

2. Consortium for Energy Efficiency. Commercial Ice-Cube Machine Specifications. www.cee1.org. 2006.

Appendix A: Data and Results Table

	#1	#2	#3	#4	#5	#6	#7	#8
Machine Specifications								
Manufacturer	Hoshizaki	Hoshizaki	Hoshizaki	Hoshizaki	Manitowoc	Manitowoc	Manitowoc	Manitowoc
Model	KM-1300MAH	KM-1200SRE	KM-1300SRF	KM-451DU	QY0374A	QY1004A	QY0425W	GY1205W
Water / Air Cooled	Air-Cooled	Air-Cooled	Air-Cooled	Air-Cooled	Air-Cooled	Air-Cooled	Water-Cooled	Water-Cooled
Ice Type	Cuber	Cuber	Cuber	Cuber	Cuber	Cuber	Cuber	Cuber
Machine Head Type[1]	IMH	RCU	RCU	IMH	IMH	IMH	IMH	IMH
Approximate Age (yrs)	8	10	10	15	10	5	5	15
ARI Standard Ratings								
Ice Harvest Rate (lb/24 hr)	1059	1130 (x 2)	1133	340	275	830	440	1130
Potable Water Use Rate (gal/100 lb)	32.3	29.5	32.1	25.6	26	20.4	26.4	19.6
Condenser Water Use Rate (gal/100 lb)	N/A	N/A	N/A	N/A	N/A	N/A	177	172
Energy Consumption Rate (kWh/100 lb)	6.0	4.6	5.0	8.8	8.3	6.9	5.5	5.2
Ice Storage Bin Capacity (lb)	360	860	660	310	310	960	310	750
Electrical Data								
Energy Consumption (kWh/day) Avg.	24.6	55.4	31.0	16.1	18.0	50.7	8.6	21.8
Min.	18.6	43.6	20.5	10.0	10.0	16.0	6.8	4.2
Max.	29.7	71.8	49.4	25.9	22.0	59.1	11.8	47.5
Power (kW)	1.9	4.8	2.3	1.2	0.9	2.4	0.8	2.6
Duty Cycle (%) Avg.	47.6%	49.7%	59.5%	58.5%	82.8%	86.6%	34.5%	35.3%
Min.	37.2%	38.7%	41.0%	41.0%	45.5%	26.7%	27.4%	6.4%
Max.	60.8%	64.9%	90.8%	84.7%	100.0%	100.0%	47.6%	78.5%
Harvest Cycles (cycle/day)								
Avg.	23.2	37.3	29.8	19.3	66.1	85.4	34.3	33.8
Min.	18	30	22	13	39	28	26	6
Max.	27	46	43	27	85	102	47	70
Water Consumption (gal/day)								
Avg.	211.9	321.4	224.2	110.4	52.7	129.8	294.9	592.4
Min.	164	227	154	67	31	45	210	110
Max.	253	428	350	163	68	155	410	1459
Production Measurement (lb/cycle)								
Sample 1	23.38	30.78	28.81	9.15	3.25	8.14	4.68	9.13
Sample 2	23.25	30.84	28.82	9.28	3.22	8.10	4.52	9.04
Sample 3	23.70	30.77	28.82	9.26	3.29	8.15	4.62	9.06
Average	23.4	30.8	28.8	9.2	3.3	8.1	4.6	9.1

[1] *Ice Making Head (IMH); Remote Condensing Unit (RCU)*

	#1	#2	#3	#4	#5	#6	#7	#8
Avg. Energy Use per Cycle (kWh/cycle)	1.058	1.488	1.040	0.832	0.273	0.594	0.251	0.645
Avg. Water Use per Cycle (gal/cycle)	9.12	8.63	7.53	5.71	0.80	1.52	8.60	17.53
Average Production (lb/day)	545	1147	858	178	215	694	158	307
Projected Production Capacity (lb/day)	1144	2307	1442	305	260	802	458	869
Water to Ice (gal/day)	65.3	137.6	102.9	21.4	25.8	83.2	18.9	36.8
Water Purged (gal/day)	146.6	183.8	121.3	89.0	26.9	46.6	276.0	555.6
Wastewater/Ice water ratio	2.2	1.3	1.2	4.2	1.0	0.6	14.6	15.1
Water Use Rate								
ARI Listed (gal/100 lb)	32.3	29.5	32.1	25.6	26	20.4	203.4	191.6
Measured (gal/100 lb)	38.9	28.0	26.1	61.9	24.5	18.7	186.7	193.1
Difference from ARI (gal/100 lb)	6.6	-1.5	-6.0	36.3	-1.5	-1.7	-16.7	1.5
Percentage Difference from ARI	20.4%	-5.0%	-18.6%	141.7%	-5.8%	-8.3%	-8.2%	0.8%
Avg. Daily Difference from ARI (gal/day)	35.9	-17.1	-51.2	64.7	-3.2	-11.8	-26.4	4.6
Energy Consumption Rate								
ARI Listed (kWh/100 lb)	6.0	4.6	5.0	8.8	8.3	6.9	5.5	5.2
Measured (kWh/100 lb)	4.51	4.83	3.61	9.02	8.39	7.31	5.44	7.11
Difference from ARI (kWh/100 lb)	-1.49	0.23	-1.39	0.22	0.09	0.41	-0.06	1.91
Percentage Difference from ARI	-24.8%	5.0%	-27.8%	2.5%	1.1%	5.9%	-1.0%	36.7%
Avg. Daily Difference from ARI (kWh/day)	-8.1	2.6	-11.9	0.4	0.2	2.8	-0.1	5.8
Annual Projections								
Operation (day/yr)	360	360	360	360	360	360	360	360
Projected Annual Ice Production (lb/yr)	196,136	412,983	308,826	64,260	77,377	249,923	56,867	110,445
Projected Annual Water Use (gal/yr)	76,292	115,690	80,714	39,757	18,960	46,735	106,173	213,264
Projected Annual Water Cost ($/yr)	$510	$773	$540	$266	$127	$312	$710	$1,425
Projected Annual Energy Use (kWh/yr)	8,855	19,949	11,146	5,795	6,492	18,258	3,095	7,848
Projected Annual Energy Cost ($/yr)	$1,328	$2,992	$1,672	$869	$974	$2,739	$464	$1,177
Total Projected Operating Cost ($/yr)	$1,838	$3,766	$2,211	$1,135	$1,101	$3,051	$1,174	$2,603
Cost Yield (lb/$)	106.7	109.7	139.7	56.6	70.3	81.9	48.4	42.4
Potential New Machine Replacement								
Recommended Capacity (lb/24 hr)	1,200	1,200	1,600	500	500	1,000	500	1,200
New Water Use Rate[2] (gal/100 lb)	20	20	20	20	20	20	20	20
Potential Water Saving[2] (gal/yr)	37,064	33,093	18,949	26,905	3,485	*- 3,250*	94,800	191,175
Percentage Water Saving	48.6%	28.6%	23.5%	67.7%	18.4%	*- 7.0%*	89.3%	89.6%
Potential Water Cost Saving ($/yr)	$248	$221	$127	$180	$23	*- $22*	$634	$1,278
New Energy Consumption Rate[2] (kWh/100 lb)	4.78	4.34	4.34	5.41	5.41	4.96	5.41	4.78
Potential Electrical Saving (kWh/yr)	*- 521*	2,026	*- 2,257*	2,318	2,306	5,861	19	2,569
Percentage Electrical Saving	*- 5.9%*	10.2%	*- 20.3%*	40.0%	35.5%	32.1%	0.6%	32.7%
Potential Electric Cost Saving ($/yr)	*- $78*	$304	*- $339*	$348	$346	$879	$3	$385

[2] *Based on Consortium for Energy Efficiency (CEE) Tier 3 Commercial Air-Cooled Ice-Cube Machine Specifications*