Ice Machine Field Study: Energy and Water Saving with Ice Machine Upgrade and Load Shifting

FSTC Report 501310087

Food Service Technology Center
September 2011

Prepared by:

Angelo Karas
David Cowen
Don Fisher

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

Prepared for:

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

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

Disclaimer

Policy on the Use of 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 foodservice 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 FSTC. 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 the FSTC.

Acknowledgments

The Food Service Technology Center (FSTC) acknowledges the support provided by Western Pacific Distributors and Manitowoc throughout this study.

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

Legal Notice

Contents

Figures

Tables

Background

Nearly every foodservice operation has at least one ice machine. Ranging from cube, to nugget and flake-type machines, together this installed base represents one of the largest inventories of foodservice equipment and thus a considerable area for energy and water saving potential. While technological advancements have facilitated lower energy and water consumption rates, the introduction of an ENERGY STAR®[1] classification for ice machines has provided the industry a catalyst for even greater progress. The Air-Conditioning, Heating, and Refrigeration Institute (AHRI) publishes the AHRI Directory of Certified Automatic Commercial Ice-Cube Machines and Ice Storage Bins[2] containing ice harvest rate (i.e., production capacity) and energy and water usage rate data for current models that can be utilized by specifiers and end-users to select water/energy efficient models and by utilities as a basis for financial incentives to promote equipment that is more efficient.

In general, larger capacity ice machines are inherently more energy efficient than lower capacity units. When considering only capacity, a general sizing guideline has been to choose a unit that would operate with an average duty cycle of 75% based on the ice harvest rate and the assumed daily ice requirement, which balances machine size and cost with the reserve capacity needed for high-demand days. When energy consumption is also taken into consideration, a higher capacity model with higher efficiency might be justified.

A prior field study[3] completed by the Food Service Technology Center characterized the water and energy use of eight individual ice-cube machines in commercial foodservice operations and documented the estimated water and energy saving potential that would be realized by replacing a given unit with a more water/energy efficient model. In addition, the measured duty cycles combined with the actual electric load profiles reflected the ice utilization patterns and provided insight into the potential for load shifting (i.e., time-based operation) of each ice machine. In continuation of that previous effort, this case study was undertaken with focus placed on the replacement of an older non-ENERGY STAR® ice machine with an ENERGY STAR® qualified ice machine to quantify the resultant energy, water and associated utility cost saving, and the additional electricity cost saving by load shifting ice production exclusively to non-peak utility periods.

Load Shifting Approach

Most foodservice operations establish their maximum electrical load in the afternoon during the utility-defined peak period, which results in the highest possible demand charge on a given utility rate schedule. The demand charge is assessed on a per-month basis and is based on the maximum demand at any time in that month. In addition, these demand rate structures can include separate time-of-use energy rates, making it even more valuable to reduce power draw during the peak period. Because of the intrinsic nature of the ice storage bin, the ice machine is the only refrigeration appliance in the foodservice industry that can be potentially turned off for a significant period of time (using either an external timer switch or an on-board control if so equipped) without a performance compromise even when a facility is in busiest operation. Given that ice machines in most foodservice facilities operate through the afternoon when electric rates and/or demand charges are at their highest, they are consistently applicable to load shifting.

If a facility has an existing ice machine with sufficient production and/or storage capacity to meet the afternoon ice requirement and therefore support a load shifting strategy, simply installing a timer switch to halt ice production during the utility peak period would result in a demand charge and time-of-use energy charge reduction at very little cost. If there is not enough capacity for sustained load shifting during the entire peak period, then a lesser amount of shift time can be utilized – thereby reducing at least a portion of the higher energy charge (and potentially the facility peak demand if coincident with the ice machine off time). An intermediate approach would be to incorporate a scheme to override the time control only if the ice supply falls or will fall short. Ultimately, the ideal solution would be to install a larger machine with higher production capacity and a storage bin large enough to hold the required reserve ice amount. In this scenario, the higher capacity machine would not only yield a direct energy-efficiency benefit during ice production but also the opportunity to operate entirely outside the utility peak period. This upsizing approach was the method employed in this case study.

Objectives

1) Replace an existing, older, standard-efficiency ice machine (Manitowoc QY0454A) with a new, energy-efficient, ENERGY STAR® qualified model (Manitowoc IY0504A) with slightly higher production capacity and a larger storage bin in a bar establishment in Danville, CA.
2) Test the field performance and confirm and quantify the efficiency gains of the new machine.
3) Test the feasibility and performance of the new machine with complete non-peak, load shifted operation.

Scope

The test site for this field study was chosen because it had an older model, average-sized ice-cube machine (typical production capacity of 400-500 lb/24 hr for a quick-service or small full-service restaurant) and was assumed to have an ice consumption rate low enough to facilitate sustained peak load shifting. After consultation with the equipment supplier and facility owner, the research staff had confidence that the replacement machine, having a slightly higher production capacity and slightly larger storage bin, could be shifted to operate entirely during non-peak times.

While the case study results are intended to be generally applicable to other examples, they would have to be weighed accordingly when compared with differing sites and machines, e.g., either larger or smaller facilities with different ice demand and machines with differing energy and water consumption rates, production capacity, and duty cycle. Additionally, the applicable utility rate structures specific to any facility would have to be taken into consideration. For the purposes of this report, test results of the normal operation (with machine upgrade) and load shifted operation are presented separately.

Procedure

Both ice machines evaluated in the field study were air-cooled, ice-making-head (i.e., the condensing unit and ice-making mechanism with evaporator plate are housed in a single enclosure that is placed over a separate ice storage bin) ice-cube makers. The existing Manitowoc QY0454A ice machine was confirmed to be in proper working order and had the condenser coil filter cleaned prior to testing. The machine was instrumented with an energy meter, water meter and data loggers and was monitored for a period of three weeks. It was then replaced with the new, Manitowoc IY0504A, which was also instrumented and monitored for three weeks. For each machine, the average ice harvest weight, production capacity (under field conditions) and duty cycle were determined. Average harvest weight per cycle was determined by weighing the ice production through six cycles.

The IY0504A was then switched to non-peak period operation. This machine featured computerized control, which was programmed for ice production only between the hours of 6:00 p.m. to 12:00 a.m. In other words, it was locked out during PG&E’s peak period between 12 noon and 6:00 p.m. so that the unit would not be operational when electric rates and/or demand charges are at their highest. The unit was then monitored for an additional week while confirming adequate daily ice production as well as ice accessibility (i.e., a comfortably reachable ice height in the bin) while load shifted.

Machine Upgrade Results

Test results for the ice machines highlighting the energy and water consumption differences are summarized in Table 1. The existing QY0454A ice machine exhibited an energy consumption rate of 6.54 kWh per 100 lb of ice, an average cycle power of 1.05 kW, a duty cycle of 64%, a water use rate of 28.0 gal/100 lb of ice and a calculated field ice production capacity over a 24-hour period of 390 lb. The replacement IY0504A ice machine operated with an energy consumption rate of 4.34 kWh per 100 lb of ice and an average cycle power of 0.89 kW, representing a 34%, 2.2 kWh per 100 lb reduction in energy and a 15%, 0.16 kW reduction in power. The duty cycle was 37%, reflecting a 42% run time reduction. The calculated ice production capacity was 497 lb per 24 hours, and water use was 24.0 gal/100 lb, a 4.0 gal/100 lb, 14% reduction. Overall, the increase in efficiency of the IY0504A ice machine over that of the existing QY0454A machine translates to an annual energy and water cost saving of $303 for this foodservice operation. Annual energy and water consumption values were normalized using a nominal value of 200 lb/24 hr, approximately the average ice usage throughout the monitoring period.

Table 1. Machine Upgrade Results Summary.

	QY0454A Ice Machine	IY0504A Ice Machine
Rated Production Capacity (lb/24 hr) [1]	380	410
Rated Bin Capacity (lb) [1]	310	430
Average Cycle Power (kW)	1.05	0.89
Average Duty Cycle (%)	64	37
Average Cycle Time (min)	15.7	13.5
Average Cycle Harvest Weight (lb)	4.25	4.65
Average Cycle Water Use (gal)	1.19	1.12
Estimated In-Site Production Capacity (lb/24 hr) [2]	390	497
Energy Consumption Rate (kWh/100 lb) [2]	6.54	4.34
Potable Water Use Rate (gal/100 lb) [3]	28.0	24.0
Projected Annual Energy Use (kWh) [4]	4,710	3,130
Projected Annual Water Use (gal) [4]	20,130	17,290
Annual Energy Cost [5]	$847	$563
Annual Water Cost [6]	$135	$116
Average Cycle Power Reduction (kW)	--	0.16
Energy Saving (kWh/100 lb)	--	2.20
Energy Percentage Saving	--	33.6%
Annual Energy Saving (kWh)	--	1,580
Annual Energy Cost Saving	--	$284
Water Saving (gal/100 lb)	--	4.0
Water Percentage Saving	--	13.8%
Annual Water Saving (gal)	--	2,840
Annual Water Cost Saving	--	$19
Annual Energy and Water Cost Saving	--	$303
Peak Demand Reduction (kW) [8]	--	1.05

[1] AHRI Automatic Commercial Ice-Cube Machines and Storage Bins database
[2] Under existing air and water temperature conditions
[3] Under existing water pressure conditions without regulation and including initial start purge volume
[4] Normalized to 200 lb/24 hr average daily use, 360 d/yr
[5] Calculated using electric utility cost of $0.18/kWh
[6] Calculated using water utility cost of $5.00/CCF
[7] Attributable to higher production capacity and to new technology
[8] With load shifting: Off during PG&E peak period of 12:00 p.m. – 6:00 p.m.

Load Shifting Results

The replacement of the existing Manitowoc QY0454A ice machine with the higher efficiency IY0504A resulted in a 0.16 kW, 15% load reduction – from 1.05 kW down to 0.89 kW. Operated with load shifting, the new machine effectively reduced the facility's on-peak load by the entire 1.05 kW. Figure 1 shows the power profile of the QY0454A, and Figure 2 shows the power profile of the IY0504A with load shifting, each highlighting the machine operating state over the utility peak period. The power profile of the IY0504A ice machine shown in Figure 2 confirms a successful load shift strategy, with no schedule override needed. In this example, even with no afternoon ice production, the machine and bin combination were proven to have ample ice supply at all times.

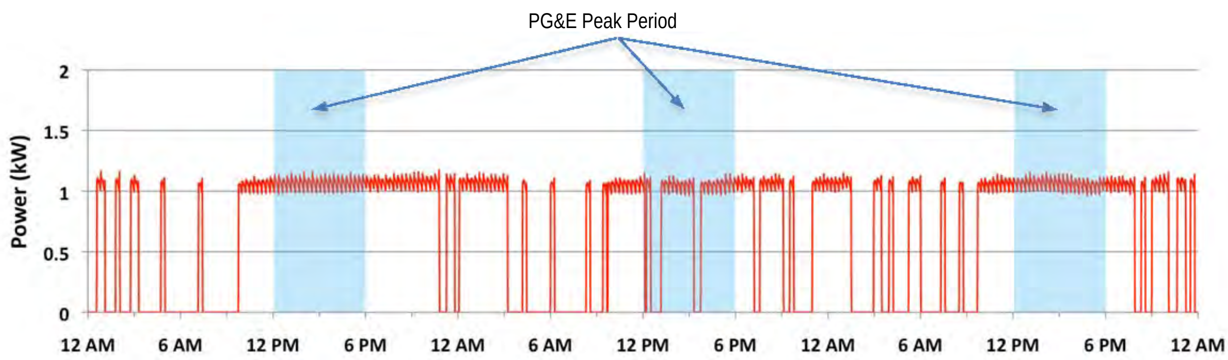

Figure 1. Manitowoc QY0454A Ice Machine Power Profile: Normal Operation.

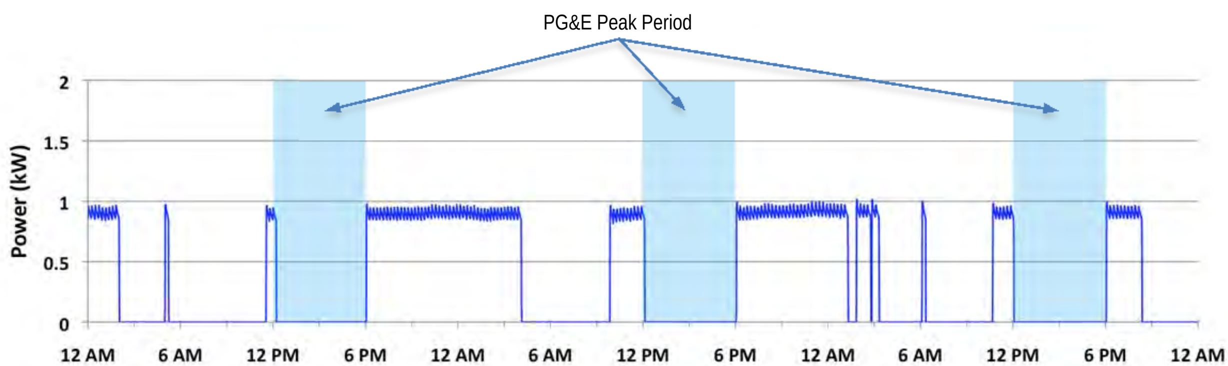

Figure 2. Manitowoc IY0504A Ice Machine Power Profile: Load Shifted Operation.

Although the facility that participated in this study was not on a time-of-use rate structure and did not have a demand charge associated with its rate schedule, in this example, the field data from the Manitowoc IY0504A ice machine (operating at 0.89 kW for a nominal 12 hr/d) was applied to a PG&E E-19 rate schedule[4] to calculate potential saving from a load shifting strategy (not including the additional time-of-use and demand charge saving derived from the power reduction of the higher efficiency machine). The E-19 rate schedule has a time-of-use and demand charge associated with it and is the rate schedule typically applied to a full-service casual restaurant in the PG&E service territory.

Table 2 and Table 3 show the calculated time-of-use energy and demand charges for the Manitowoc IY0504A ice machine with and without load shifting. Estimated energy savings were categorized by summer and winter periods and calculated for normal and shifted operation. Within those periods, weekdays were separated from weekends and holidays to accurately represent this time-of-use rate structure. Appendix A and B summarize the rates and explain the time-of-use periods for this example. Table 4 summarizes the calculated combined energy and demand cost saving with load shifting. Simply shifting ice production off of the peak period would yield an estimated combined annual energy and demand charge cost saving of $224.

Table 2. Calculated Load Shift Energy Charge Saving (PG&E Rate Schedule E-19).[1]

Weekdays	Summer Normal	Summer Shifted	Winter Normal	Winter Shifted
Days of Operation	181	181	184	184
Power (kW)	0.89	0.89	0.89	0.89
On-Peak (hr/d)	6	0	N/A	N/A
Part-Peak (hr/d)	5.5	1.5	11.5	1.5
Off-Peak (hr/d)	0.5	10.5	0.5	10.5
On-Peak Cost	$97	$0	N/A	N/A
Part-Peak Cost	$63	$17	$120	$16
Off-Peak Cost	$5	$101	$5	$98
Total Cost	$165	$118	$124	$113
Total Cost Saving		$48		$11
Weekend/Holiday Days	**Summer Normal**	**Summer Shifted**	**Winter Normal**	**Winter Shifted**
Off-Peak (hr/d)	12.0	12.0	12.0	12.0
Off-Peak Cost	$52	$52	$53	$53
Total Cost	$52	$52	$53	$53
Total Cost Saving	$0.00	$0.00	$0.00	$0.00

[1] See Appendix A for detailed PG&E utility rate schedule information.

Table 3. Calculated Load Shift Demand Charge Saving (PG&E Rate Schedule E-19).[1]

Monthly	Summer Normal	Summer Shifted	Winter Normal	Winter Shifted
Months	6	6	6	6
Power (kW)	0.89	0.89	0.89	0.89
On-Peak Charge	$10.78	$0.00	$0.00	$0.00
Part-Peak Charge	$2.50	$2.50	$1.09	$1.09
Maximum Charge	$8.25	$0.00	$8.25	$0.00
Total Demand Charge Cost	$132	$15	$56	$7
Total Cost Saving		$117		$49

[1] See Appendix A for detailed PG&E utility rate schedule information.

Table 4. Calculated Annual Load Shift Cost Saving (PG&E Rate Schedule E-19).[1]

	Normal	Shifted
Total Annual Energy Charge	$394	$336
Total Annual Energy Charge Saving		$58
Total Annual Demand Charge	$188	$22
Total Annual Demand Charge Saving		$166
Annual Combined Charge	$582	$358
Annual Combined Charge Saving		$224
Cost Saving (%)		38%

1 See Appendix A for detailed PG&E utility rate schedule information.

Conclusions and Recommendations

The new Manitowoc IY0504A ice machine demonstrated considerable energy and water saving under normal operation and provided ample production with load shifting off of peak. The added benefits of load shifting (applicable to ice-making-head machines, i.e., without remote condensing) were lower heat gain to the space during the warmest part of the day and the eliminated noise throughout the afternoon. If the facility in this study were on a time-of-use rate (which will take effect in 2013) the total cost saving of installing the more efficient ice machine combined with load shifting would be approximately $500 per year.

From the utilities perspective, there would be a 1,580 kWh/yr energy saving with an avoided peak demand of 1.05 kW. California has an estimated installed base of at least 100,000 ice machines in foodservice; assuming a probable demand contribution average of 1.0 kW each, the potential on-peak demand reduction of 100 Megawatts is a very attractive number for California utilities. Although this reduction isn't applicable to the entire installed base through the entire peak period, most existing ice machines could be shut off for at least a portion of the peak period and would be suitable candidates for utility demand response programs.

Purchasing a new ice machine with the intention of operating it solely off of peak requires that it and the storage bin be properly sized to provide sufficient ice reserve supply during busy hours. From site survey experience and prior field study results, it is known that ice machine usage can vary dramatically from one installation to another; some machines may be undersized and seldom turn off in order to meet the demand, and others may seldom turn on because they have high production capacity or low demand. It is therefore important to seek advice from the manufacturers, their representatives, or other consultants to determine the appropriate machine/bin size. Whether in new or existing facilities, the potential to combine peak demand reduction with overall energy/water saving through the purchase and installation of a new, high-efficiency ice machine presents an attractive utility cost-saving opportunity.

References

1. ENERGY STAR®. www.energystar.gov

2. Air-Conditioning, Heating, and Refrigeration Institute. AHRI Directory of Certified Automatic Commercial Ice-Cube Machines and Ice Storage Bins, Standard 810/820. 2007. www.ahrinet.org

3. Fisher-Nickel Inc. 2007. *A Field Study to Characterize Water and Energy Use of Commercial Ice-Cube Machines and Quantify Saving Potential.* Prepared for East Bay Municipal Water District, Pacific Gas & Electric Company – Customer Energy Efficiency Programs and Seattle Public Utilities. www.fishnick.com

4. Pacific Gas & Electric Company, Utility Rates – www.pge.com/nots/rates/tariffs/rateinfo.shtml

Appendix A: Utility Rate Schedule

Rate Schedule	Customer Charge	Season	Time-of-Use Period	Demand Charge (per kW)			Time-of-Use Period	Total Energy Charge (per kWh)		
A-1	Single Phase Service per meter/day =$0.29569 Polyphase Service per meter/day =$0.44353	**Summer**		-				$0.19712		
		Winter		-				$0.14747		
A-1 TOU	Single Phase Service per meter/day =$0.29569 Polyphase Service per meter/day =$0.44353	**Summer**		-			On peak	$0.22231		
							Part Peak	$0.19644		
							Off Peak	$0.18101		
		Winter		-			Part Peak	$0.15284		
							Off Peak	$0.14179		
A-6 TOU	Single phase service per meter/day =$0.29569; Polyphase service per meter/day =$0.44353. Plus Meter charge =$0.20107per day for A6 or A6X; =$0.05914 per day for A6W[5/]	**Summer**		-			On peak	$0.44703		
							Part Peak	$0.20182		
							Off Peak	$0.12183		
		Winter		-			Part Peak	$0.16794		
							Off Peak	$0.12503		
				Secondary	**Primary**	**Transmission**		**Secondary**	**Primary**	**Transmission**
A-10 (Table A)	$3.94251 per meter per day	**Summer**		$11.05	$10.39	$7.96		$0.13666	$0.13007	$0.11470
		Winter		$7.02	$6.49	$4.58		$0.10643	$0.10142	$0.09101
A-10 TOU (Table B)	$3.94251 per meter per day	**Summer**		$11.05	$10.39	$7.96	Peak	$0.15633	$0.14785	$0.13193
							Part-Peak	$0.13692	$0.13055	$0.11498
							Off-Peak	$0.12536	$0.11982	$0.10487
		Winter		$7.02	$6.49	$4.58	Part-Peak	$0.11110	$0.10513	$0.09457
							Off-Peak	$0.10182	$0.09784	$0.08759
E-19 TOU	Meter charge: =$4.11992/day for E19 V or X; =$3.97799/day for E19W[4/]; =$13.55236/day for E19S mandatory; =$19.71253/day for E19P mandatory; =$39.42505/day for E19T mandatory	**Summer**	Max. Peak	$12.11	$10.86	$7.88	Peak	$0.14581	$0.14472	$0.10854
			Part Peak	$2.81	$2.51	$1.78	Part Peak	$0.10333	$0.10111	$0.08958
			Maximum	$9.27	$8.07	$6.24	Off Peak	$0.08611	$0.08243	$0.07824
		Winter	Part Peak	$1.22	$0.92	$0.00	Part Peak	$0.09345	$0.08873	$0.08270
			Maximum	$9.27	$8.07	$6.24	Off Peak	$0.08372	$0.07920	$0.07487

[1/] Peak Day Pricing (PDP) (Consecutive Day and Four-Hour Event Option). All Usage During PDP Event. See specific tariff for further details.

[2/] Peak Day Pricing (PDP) (Consecutive Day and Four-Hour Event Option). See specific tariff for further details.

[3/] Average rates based on estimated forecast. Average rates provided only for general reference, and individual customer's average rate will depend on its applicable kW, kWh, and TOU data.

[4/] Effective May 1, 2006, the voluntary TOU one time reprogramming charge of $87 if there is a TOU meter already present, and one time $443 meter installation charge if there is no TOU meter, were eliminated.

[5/] The lower daily TOU meter charge continues to apply to customers who were on Rate W as of May 1, 2006. Rate X applies to all other customers.

This table provided for comparative purposes only. See current tariffs for full information regarding rates, application, eligibility, average rate limiter and additional options.

Rate Schedule	Customer Charge	Season	PDP[1/] Charges	PDP[2/] Credits DEMAND (per kW)			PDP[2/] Credits ENERGY (per kWh)			"Average" Total Rate[3/] (per kWh)
				Secondary	Primary	Transmission	Secondary	Primary	Transmission	
A-1	Single Phase Service per meter/day =$0.29569 Polyphase Service per meter/day =$0.44353	**Summer**	-	-			-			$0.18098
		Winter	-	-			-			
A-1 TOU	Single Phase Service per meter/day =$0.29569 Polyphase Service per meter/day =$0.44353	**Summer**	$0.60	-			($0.01096)			
							($0.01096)			
							($0.01096)			
		Winter		-			-			
A-6 TOU	Single phase service per meter/day =$0.29569; Polyphase service per meter/day =$0.44353. Plus Meter charge =$0.20107per day for A6 or A6X; =$0.05914 per day for A6W[5/]	**Summer**	$1.20	-			($0.08786)			$0.17459
							($0.01757)			
							-			
		Winter		-			-			
A-10 (Table A)	$3.94251 per meter per day	**Summer**	-	-	-	-	-	-	-	$0.16013
		Winter								
A-10 TOU (Table B)	$3.94251 per meter per day	**Summer**	$0.90	($1.54)	($1.60)	($1.79)	($0.01055)	($0.01103)	($0.00915)	**Secondary** $0.16022
							($0.01055)	($0.01103)	($0.00915)	**Primary** $0.14738
							($0.01055)	($0.01103)	($0.00915)	
		Winter		-	-	-	-	-	-	**Transmission** $0.12684
E-19 TOU	Meter charge; =$4.11992/day for E19 V or X; =$3.97799/day for E19W[4/]; =$13.55236/day for E19S mandatory; =$19.71253/day for E19P mandatory; =$39.42505/day for E19T mandatory	**Summer**	$1.20	($6.10)	($5.87)	($5.67)	($0.00355)	($0.00179)	($0.00000)	**Secondary** $0.13982
				($1.30)	($1.26)	($1.28)	($0.00071)	($0.00036)	($0.00000)	**Primary** $0.12742
				-	-	-	-	-	-	
		Winter		-	-	-	-	-	-	**Transmission** $0.11448

1/ Peak Day Pricing (PDP) (Consecutive Day and Four-Hour Event Option). All Usage During PDP Event. See specific tariff for further details.

2/ Peak Day Pricing (PDP) (Consecutive Day and Four-Hour Event Option). See specific tariff for further details.

3/ Average rates based on estimated forecast. Average rates provided only for general reference, and individual customer's average rate will depend on its applicable kW, kWh, and TOU data.

4/ Effective May 1, 2006, the voluntary TOU one time reprogramming charge of $87 if there is a TOU meter already present, and one time $443 meter installation charge if there is no TOU meter, were eliminated.

5/ The lower daily TOU meter charge continues to apply to customers who were on Rate W as of May 1, 2006. Rate X applies to all other customers.

This table provided for comparative purposes only. See current tariffs for full information regarding rates, application, eligibility, average rate limiter and additional options.

Appendix B: Time-of-Use Periods

A-1, A-10 and E-19 Time-of-Use Periods		
Summer Period A (May-October)		
Peak:	12:00 noon to 6:00 pm	Monday through Friday (except holidays)
Partial-Peak:	8:30 am to 12:00 noon	Monday through Friday (except holidays)
	6:00 pm to 9:30 pm	Monday through Friday (except holidays)
Off-Peak:	9:30 pm to 8:30 am	Monday through Friday (except holidays)
	All Day	Saturday, Sunday, and Holidays
Winter Period B (November-April)		
Partial-Peak:	8:30 am to 9:30 pm	Monday through Friday (except holidays)
Off-Peak:	9:30 pm to 8:30 am	Monday through Friday (except holidays)
	All Day	Saturday, Sunday, and Holidays