Thousands and Thousands of Kilowatt-hours Saved: Results from The Energy Efficiency McDonalds (TEEM) Demonstration Project in Bay Point, California

Tor Allen, Pacific Energy Center(PG&E), Richard Young, Food Service Technology Center (PG&E), Tony Spata, McDonalds Corporation, Vern Smith, Architectural Energy Corp

Abstract

Food service operations use more energy per square foot than any other commercial buildings and yet, the opportunity to build energy efficient restaurants is often overlooked due to a lack of information and education within the industry.

To meet this challenge and stimulate energy-efficient restaurant design, McDonald's Corporation, the nation's largest restaurant chain, and Pacific Gas and Electric (PG&E), one of the largest combined fuel utilities, are working together in a program called The Energy Efficient McDonald's, or TEEM. TEEM will identify, demonstrate and evaluate energy-saving technologies with the goal of integrating cost-effective energy-efficient technologies into McDonalds universal building specification and giving existing store operators the opportunity to improve their operations.

Technologies installed at the TEEM store in Bay Point include: direct evaporative cooler, evaporative precooler, high-efficiency air conditioners, high-efficiency and two-speed exhaust fans, advanced glazing systems, tubular skylights, low-cost dimming controller & electronic ballasts, T-8 fluorescent fixtures, low-temperature occupancy sensors for walkin cooler/freezer, and an energy management system.

An extensive data collection system has been collecting data since the store opened in June 1996. This paper will present the performance results of the energy efficient measures installed using measured data analysis techniques.

Introduction

Food service operations use more energy per square foot than any other commercial buildings and yet, the opportunity to build energy efficient restaurants is often overlooked due to a lack of information and education within the industry.

To meet this challenge and stimulate energy-efficient restaurant design, McDonald's Corporation, the nation's largest restaurant chain, and Pacific Gas and Electric (PG&E), one of the largest combined fuel utilities, are working together in a program called The Energy Efficient McDonald's, or TEEM. TEEM will identify, demonstrate and evaluate energy-saving technologies and promote energy efficiency.

Energy-use reductions applied across all the units of a big national chain add up to energy savings of national significance. TEEM's primary long-term goal is to make McDonald's the most energy-efficient restaurant chain in the nation. In the process it will help the rest of the industry to conserve energy, and will provide significant economic and human benefits.

The TEEM program includes:

- Designing, constructing, and monitoring a demonstration restaurant in Bay Point, California
- Designing a modified DOE2 building energy-use simulation model and calibrating it using restaurant monitoring results
- Identifying cost-effective, energy-efficient technologies that perform well in a McDonald's application
- Transferring TEEM energy-saving information to end users within the PG&E and McDonald's systems
- Adding energy-efficient technologies to the building options available to the owner-operators
- Integrating cost effective energy-efficient technologies into McDonald's universal building specification

Technologies chosen for TEEM are basic, realistic measures that work in both new and existing restaurants and are compatible with the complexity of a food service operation. They are proven, off-the-shelf products that reduce HVAC and lighting loads without sacrificing comfort or convenience. Most can be used in existing restaurants as well as in new construction. The list includes evaporative coolers, advanced glazing systems, high-efficiency and two-speed exhaust fans, high-efficiency air conditioners, electronic dimming ballasts, low temperature occupancy sensors, tubular skylights, and CO2 occupancy sensors. Further savings are achieved by a centralized energy management system that controls the lighting and HVAC systems.

As a partnership between McDonald's and PG&E, with the support of several sponsoring manufacturers, TEEM's cost has been minimal to the participants. No special grants or significant budget items were needed to initiate the program. For example, the increased cost of construction for the demonstration TEEM was primarily offset by the fact that the sponsoring manufacturers donated all of the energy-saving technologies.

Likewise, PG&E provided design input, site monitoring, and modeling expertise through its Food Service Technology Center, Pacific Energy Center, and Research and Development departments, as part of the utility's Customer Energy Efficiency programs. McDonald's corporate and regional offices and the demonstration restaurant's owner-operator all assisted in various important ways.

TEEM's main economic benefit is lower operating costs. By reducing energy costs up to 25 percent, McDonald's has the potential to reduce overall costs by as much as one percent, which translates to tens of millions of dollars annually system-wide.

Store Description

The building envelopes for the McDonald's Series 2000 and the TEEM restaurant are the same, except for the glazing. Figure 1 below shows the planview (plus partially reflected ceiling plan) and orientation of the 4000 sq.ft. Bay Point TEEM. Bay Point is located approximately 30 miles east of San Francisco.

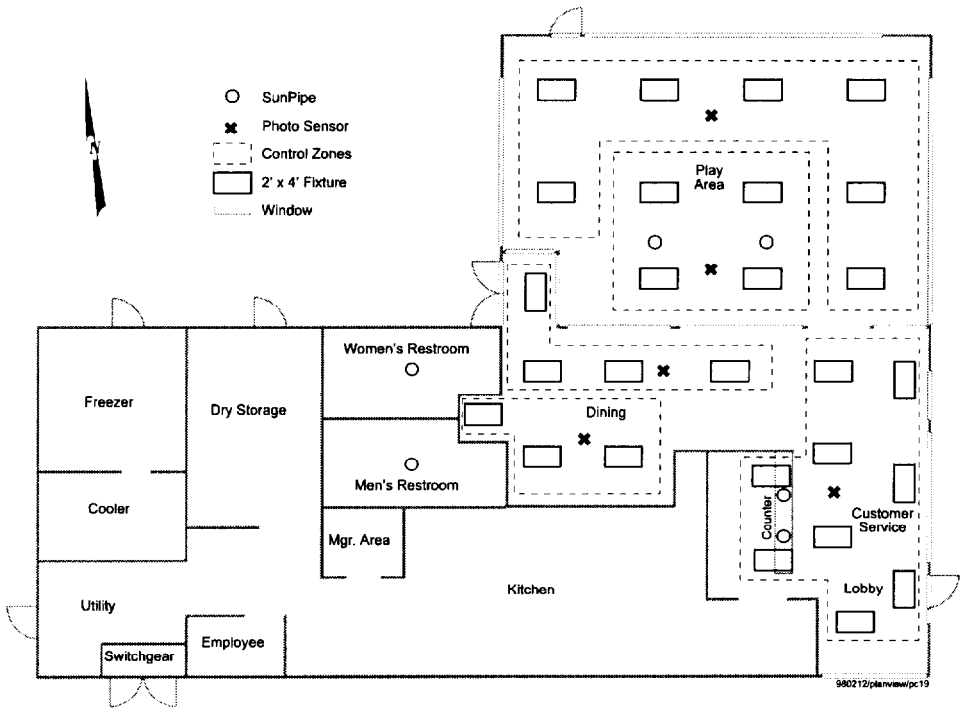


Figure 1. Plan View & partial reflected ceiling plan of controlled lighting areas

Methodology

In order to evaluate the performance of the individual energy efficiency measures (EEMs), an extensive data acquistion system (DAS) was installed. Data points included; zone temperatures/humidity, electrical loads, gas loads, water consumption, interior light levels, HVAC system temperatures, and weather conditions. Data was recorded at 15-minute intervals for over a year.

Evaluation of each individual EEM presented in this paper was done using measured data and associated analysis techniques including: on/off testing and comparison testing (with another similar store). Our goal in this paper is to present the technologies and their performance evaluations, in a way that can be easily applied to other stores.

Results

Comparison of the Bay Point TEEM energy bills with a base case McDonald's restaurant located a few miles away show that the TEEM store is saving almost 25% of the annual cost to operate (Figure 2). The performance of the individual EEMs are discussed in this section. For some measures, energy consumption was not monitored.

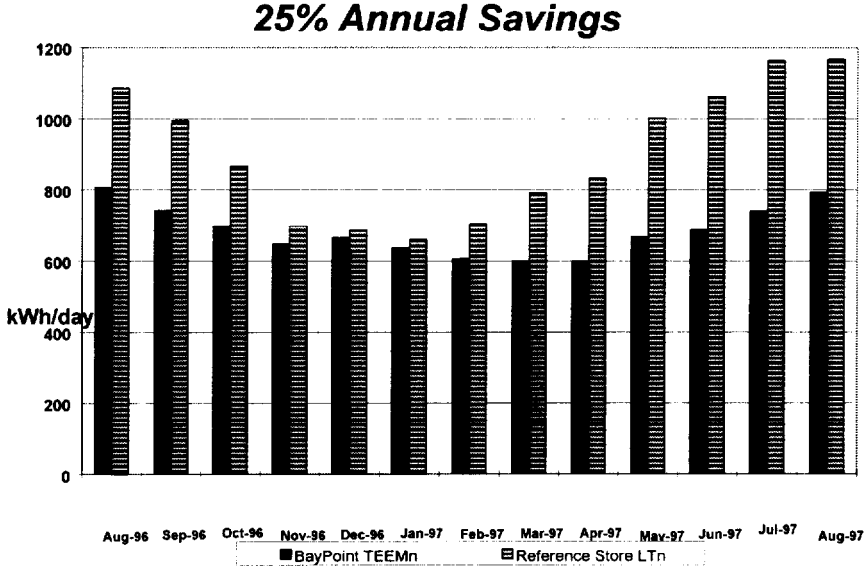


Figure 2. Annual Electric Energy Consumption - Bay Point vs. Reference Store

ELECTRONIC CONTROLLABLE BALLASTS

Electronic controllable ballasts save energy by dimming the fluorescent lights(T8s) in response to the amount of daylight in the space. Controllable ballasts can reduce the daytime lighting load by 50%. At the Bay Point California TEEM store, the controllable ballast system paid for itself in the first year, saving over 7,000 kWh/yr. in the PlayPlace and dining areas. The ballast system used at Bay Point utilize a simple 'plug and play' type of connector, making the installation a snap (Figures 3 & 4). In addition, this system can use a single photosensor to control lighting fixtures on different electrical circuits, making zoning and rezoning a simple task. Controllable ballasts are ideal for new construction but should also be considered during a retrofit to an existing restaurant. Figure 5 shows a typical dimming load profile in response to available daylight.

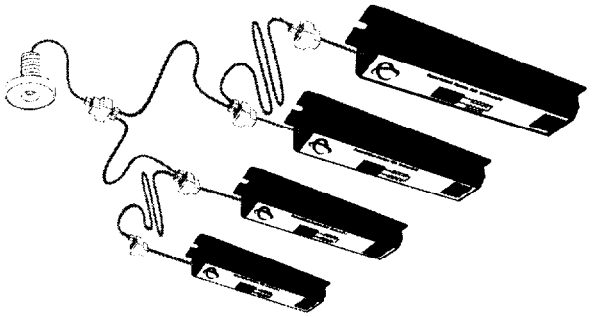


Figure 3. Easy install dimming system

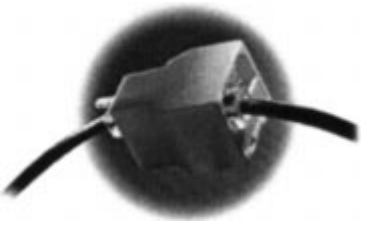
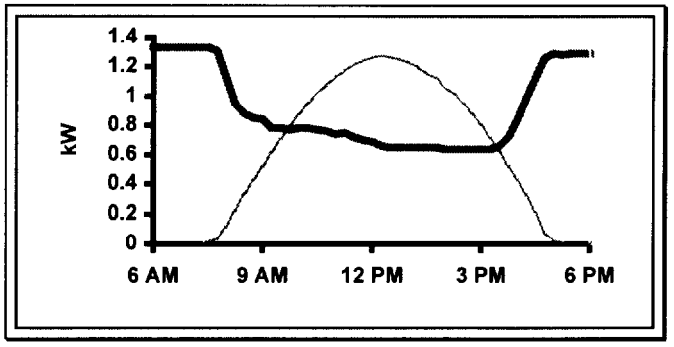


Figure 4. 'Snap' low voltage connector



Lighting Energy Savings

- PlayPlace - 3,224 kWh/yr. or 33%
- Front Dining & Service Counter - 3,102 kWh/yr. or 46%
- Rear Dining - 698 kWh/yr. or 16%

Fig. 5. Typical Daily Energy Profile for PlayPlace Lights.

SUNPIPES

Sunpipes are tubular skylights that bring daylight into a restaurant. They are particularly effective in windowless spaces such as restrooms, kitchens and storerooms but they are also useful in brightening up darker areas of the dining room as well as improving the lighting quality at the service counter. Tubular skylights save energy when used in combination with controllable ballasts by increasing the amount of natural lighting within the restaurant. A sectional view of a tubular skylight is shown here in Figure 6.

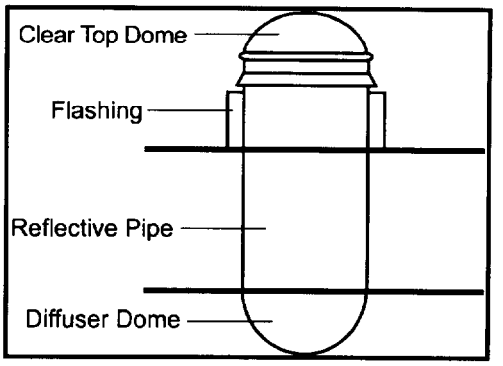
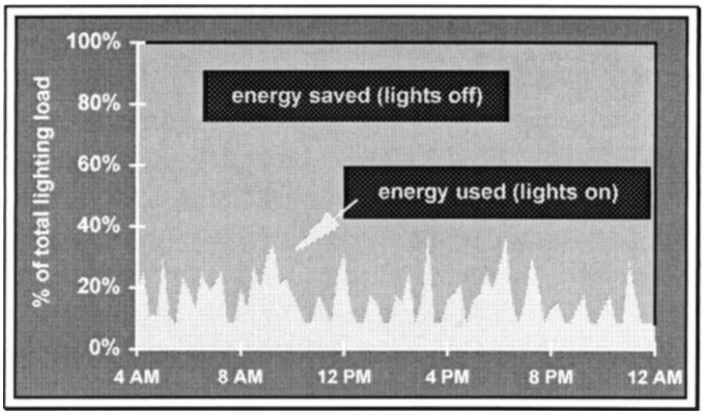


Fig.6. Tubular Skylight

LOW TEMPERATURE OCCUPANCY SENSORS

Low temperature occupancy sensors save energy by automatically turning the lights off in the walk-in cooler and freezer when they are unoccupied. At the Bay Point TEEM store, the low temperature occupancy sensors paid for themselves in less than a year, saving **3,265 kWh/yr. - an 80% reduction in energy use**! Additional savings were achieved by reducing the heat load on the refrigeration compressors. These sensors and several related products are suitable for both new construction and retrofit applications. The energy profile of a typical day for freezer lights controlled with a low temperature occupancy sensor is shown in Figure 7 above.



INFRARED CONTROLLED VALVES

Infrared controlled valves save water and heating energy, and improve sanitation through hands-off control of hand sinks and flushometers. The hands-off operation of the kitchen hand sink at TEEM guarantees that the staff have clean hands after washing.

INFRARED CONTROLLED HAND DRYERS

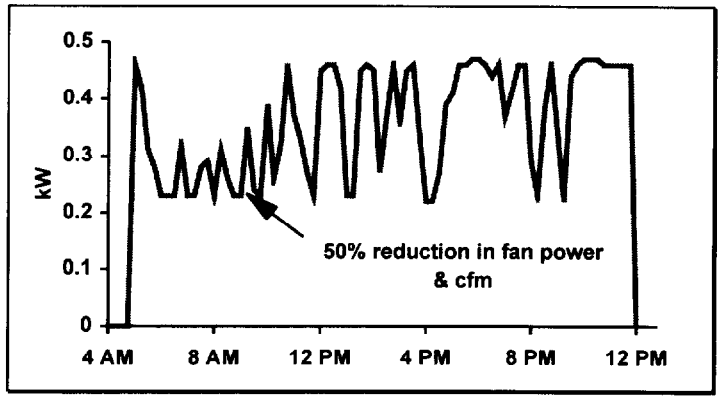
Infrared control saves energy by reducing the on-time of an electric hand dryer. An infrared hand dryer saves about 1 kWh per 150 customers.

ADVANCED (SPECTRALLY SELECTIVE) GLAZING

Advanced glazing saves energy and increases customer comfort by reducing the amount of heat that enters the restaurant through the windows as much as 50%. At the Bay Point TEEM, the spectrally selective film, suspended within the double paned glazing, allowed the designers to reduce the size of the HVAC system by 33% which paid for the added cost of the film. A spectrally selective film is also available for retrofit to existing windows. In a retrofit application, the energy payback is 3 to 5 years, but the customer comfort payback is immediate!

TWO-SPEED EXHAUST FANS

A two-speed exhaust fan saves energy by turning down the exhaust when the clamshell griddle is in standby. At the Bay Point TEEM, the two-speed exhaust fan paid for itself in less than a year, saving 800 kWh/yr. or 25% of the fan energy and reducing the needed make-up air by an average of 25% or about 400 cfm. A two-speed exhaust fan is relatively easy to install, making it suitable for retrofit as well as new construction. The energy profile of a typical day for a two-speed exhaust fan is shown here in Figure 8.



HIGH EFFICIENCY AIR CONDITIONING

High efficiency air conditioning systems save energy by cooling the restaurant using less energy than standard air conditioning units. At the Bay Point TEEM store, the high efficiency HVAC units on the kitchen and dining room save 4,500 kWh/yr. so the units paid for themselves in a little over a year. For the dining areas, two standard 7.5 ton units (9.0 EER) were replaced with 5 ton units (11 SEER). The tonnage reduction was possible due to the installation of the spectrally selective glazing. The 10 ton kitchen unit was upgraded from 9 to 10 EER. High efficiency air conditioning should be specified for new construction or during replacement of old HVAC units on existing restaurants.

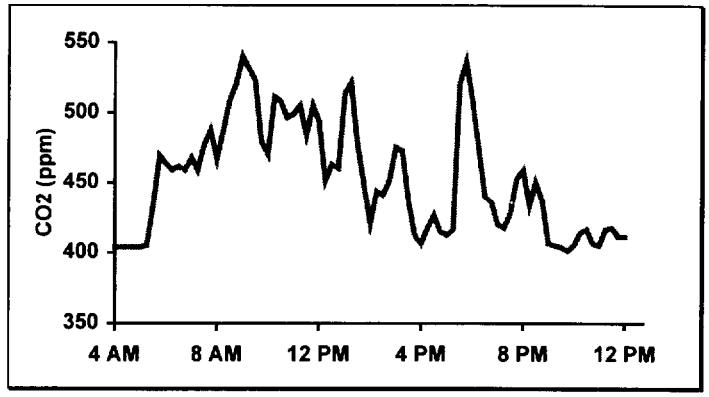
ENERGY MANAGEMENT SYSTEM

The energy management system (EMS) saves energy by automatically controlling the building's energy-using systems - like lighting, refrigeration and HVAC - eliminating human oversight and poor energy management. The energy management system can also be used to gain information about the store's operational and energy use patterns and it can even be used to diagnose equipment failure. At the Bay Point TEEM store, the EMS will pay for itself in a little under 4 years, saving more than 32,000 kWh/yr. through very effective management of the building's HVAC and exterior lighting loads. The cost and complexity of installing an EMS make them best suited for new construction

applications. A 24-hour service center is available to store manager via an 800 phone number, where programming changes to operational schedules and thermostat setpoints can be monitored tuned remotely by a technically trained staff. This feature takes the switches and timers out of the store employee's hands, reducing the risk of system overide or random thermostat setpoints, as seen at other stores.

CO_2 MONITORING

A carbon dioxide (CO_2) monitor is a very effective way of measuring how many people are in a space. The CO_2 monitors at the Bay Point TEEM are being used to study the changes in CO_2 levels in the dining area, kitchen and PlayPlace during the course of the day. This data will help McDonald's building engineers to design an HVAC control system that heats or cools based on the number of customers in the restaurant. A perfect application might be in the PlayPlace, where occupancy can vary greatly throughout the day. **The 'occupancy' for a typical Saturday at TEEM is shown here in Figure 9.**



EVAPORATIVE COOLING

The evaporative cooling technologies installed in the TEEM restaurant include a direct evaporative cooler serving the PlayPlace (Figure 10), a evaporative precooler on the kitchen DX unit (Figure 11), and add-on evaporative precoolers on the dining unit condensers (Figure 12), essentially retrofitting them into evaporative condensers.
Table 1 lists the predicted performance and predicted savings for each system when compared to the system performance when operated without the evaporative cooling equipment, or in the case of the PlayPlace evaporative cooler, as compared to a 7.5-ton DX unit installed in a McDonald's PlayPlace located in San Ramon. Short-term testing (2-3 weeks in each mode of operation) was conducted to obtain a range of operating conditions. The results were then extrapolated out to predict cooling season performance using TMY2 (typical metereological year) data [ref. PG&E TEEM Evaporative Cooling Analysis Report].

The PlayPlace evaporative cooler, when operated with the factory adjusted water flow control, operated at a relatively low effectiveness, which resulted in occasional comfort complaints in the store. After the water flow control was adjusted, the effectiveness increased significantly, improving comfort and reducing the energy consumption, since the fan didn't have to operate at high speed during relatively mild days. However, the water consumption increased dramatically. Fine tuning the water flow should reduce the water consumption while having minimal effect on the energy consumption. Additional testing using a different wet section and controller will take place in the summer of 1998. The evaporative cooler operating costs for both the factory and modified control are less than half of the cost of operating a DX unit.

For a portion of the monitoring period the kitchen unit control was modified to shut off the water flow when the ambient temperature was below 75°F. This had the effect of reducing the water consumption by approximately 50 percent, but the resultant increase in energy consumption increased the operating costs by approximately $300/year. The evaporative precooler resulted in a 13 to 25 percent reduction in operating costs.

The evaporative condensers on the dining units resulted in relatively small savings, from 2 to 6 percent. Further study will determine if the units could have been downsized without the precoolers. The original design calculations indicated that the high performance glazing allowed the tonnage reduction without considering the precooler impacts at high ambient conditions.

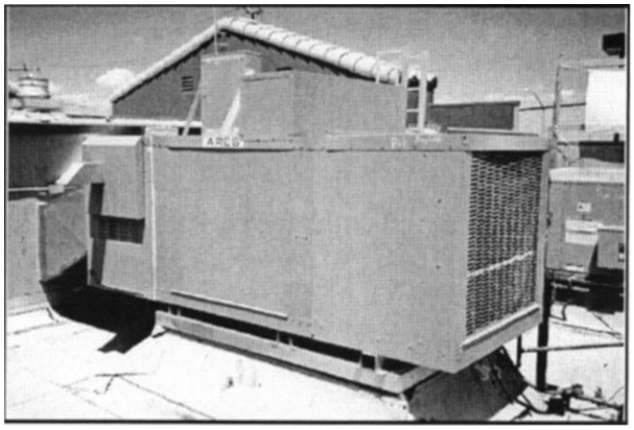


Fig. 10. Direct Evaporative Cooler

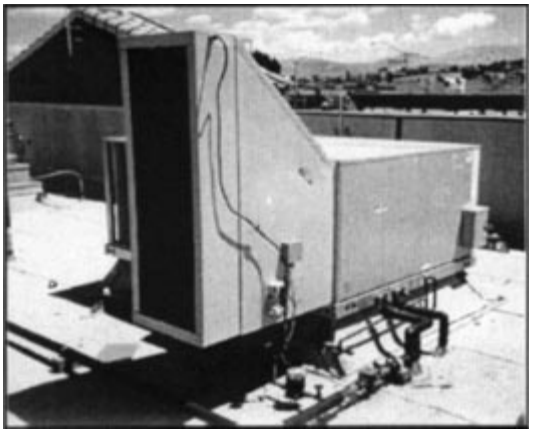


Fig. 11. Outside Air Evaporative PreCooler

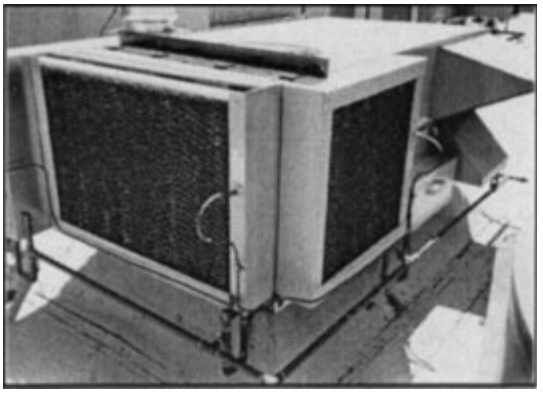


Fig. 12. Evaporative Condenser PreCoolers

Table 1. Summary of Evaporative Cooler Measured Performance & Cost Savings

	PlayPlace Factory Control*	PlayPlace Modified Control*	Kitchen Factory Control	Kitchen Modified Control	Dining Unit 1	Dining Unit 2
Evap Cooling Energy Consumption (kWh)	7560	2930	16522	20090	5006	4376
non-evap reference (kWh)	14334	14334	23613	23613	5507	4797
Evap Cooling Peak Demand (kW)	4.5	4.5	12	12	4.9	5.3
non-evap reference (kW)	9.8	9.8	13.2	13.2	5.8	5.9
Water Consumption (gallons)	6361	98998	11955	5669	22304	5969
Evap. Seasonal Operating Costs ($)	$727	$675	$1902	$2207	$664	$575
non-evap seasonal operating costs ($)	$1611	$1611	$2550	$2550	$677	$613
Cooling Season Savings due to Evaporative Cooling ($)**	**$884**	**$936**	**$648**	**$343**	**$13**	**$38**

* Based on performance of 7.5 ton DX unit installed in San Ramon PlayPlace

** includes both the cost of water and energy

Rates: Energy: $0.09/kWh; Demand: $6.70/kW; Water: $0.002634/gallon

Conclusions

The Bay Point TEEM project has provided a wealth of real world experience that McDonalds is already sharing with other store owners in an effort to help improve their operations. Monitoring the store since it's opening in June of 1996 has allowed the opportunity to learn about the operation of a variety of promising technologies as they are used in the field. At the recent Worldwide Owner/Operator McDonald's Convention, the dimming ballasts, low-temperature occupancy sensor, and spectrally-selective glazing garnered the most interest from owner/operators passing through the TEEM technology booth. These technologies are easily applied to both new and existing restaurants (window film, for glazing retrofits). Paybacks are short (< 1year) for these measures and offer immediate impact in the form of energy savings and improved comfort.

Additional study of the other measures will continue at Bay Point TEEM and other demonstration stores. Testing of a new wet section and controller for the direct evaporative cooler will be conducted in the summer of 1998 in order to optimize system performance. A study indicating where, geographically, the 3 different evaporative cooling technologies would work best, will be conducted in the summer of 1998. The TEEM project will also continue to evaluate other promising technologies at additional test stores across the country.

Acknowledgements

Individuals participating in various aspects of the project include: John Goodin, Dave Casentini, Don Fisher, and Grant Brohard from Pacific Gas & Electric; Mark Arney, and Stuart Waterbury of Architectural Energy Corporation; Rick Basden, Bay Point Store Manager; and Brad & Jason Goldblatt, the store owner/operators. Special thanks to companies providing product for evaluation: SunPipe, Electronic Lighting Inc., The WattStopper, York, Honeywell, Etta, International Energy Saver, ARES, Southwall Technologies, Greenheck, Sloan, and World Dryer.

References

"McDonald's TEEM Project, Bay Point, California: Computer Simulations", Pacific Gas & Electric Research & Development Report #008.1-97.1, January 1997.

"TEEM - Orientation and Climatic Sensitivity Analysis", Pacific Gas & Electric Research & Development Report # 008-97.2, February 1997.

"TEEM Monthly Status & Data Reports", Pacific Gas & Electric Research & Development.

"TEEM BayPoint, California: Computer Model Validation and Calibration" , Pacific Gas & Electric. FSTC report , 5/98.

"McDonald's TEEM Restaurant Baypoint, California - Evaporative Cooling Analysis", Pacific Gas & Electric. FSTC report , 3/98.

"McDonald's TEEM Restaurant Baypoint, California - Energy Management System Evaluation", Pacific Gas & Electric. FSTC report , 3/98.