Assessment of Energy Efficiency Solutions in a Commissary

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ABSTRACT

An integrated approach was used to evaluate the cost effectiveness of various combinations of energy efficient end-use technologies for the Twentynine Palms Marine Corps Base Commissary. The commissary's functional characteristics were similar to a large commercial supermarket. A detailed monitoring plan was developed and implemented to collect electrical end-use load data and other critical parameters such as indoor and outdoor temperature and relative humidity, and refrigeration systems' pressures. Sixty-two measurement points were recorded on five minute intervals for ten months. Additionally, a detailed on-site energy audit was conducted to develop appropriate inputs for the energy simulation model. The Department of Energy's hourly simulation program DOE-2.1E was utilized to analyze the building's energy systems. The DOE-2 model was calibrated with the end-use monitored data and used to evaluate the energy use and economics of a set of 28 Energy Efficiency Measures (EEMs). The most energy efficient package meeting governmental savings to investment ratio guidelines was comprised of 21 EEMs which produced a 58% reduction in the annual energy use of the site. This energy efficiency package saved 1,200,200 kWh/yr. and included the use of energy efficient lighting, daylighting controls, advanced refrigeration controls, multiplex refrigeration system, energy efficient condensers, liquid-to-suction heat exchangers, high efficiency display cases equipped with aluminum shields, and energy efficient air conditioning .

The results obtained from this study were intended to assist the Defense Commissary in developing the most energy efficient and cost-effective platform for future designs.

Introduction

The purpose of this paper is to evaluate a group of energy efficient measures in various combinations that can be implemented cost-effectively in a commissary (which has similar characteristics to a commercial supermarket). The selected site was within Southern California Edison's (SCE) service territory and located on the Twentynine Palms Marine Corps Base in Twentynine Palms, CA.

This paper provides documentation of the methodologies used to determine the energy use of various systems in the commissary and analyze a variety of energy efficient measures (EEM's) for cost effectiveness. A detailed on-site energy audit of the facility was conducted to establish a thorough understanding of the facility and its operational characteristics. Furthermore, the audit results were used to generate a building energy model. Building energy simulations were conducted using a modified version of the U.S. Department of Energy's DOE-2.1E software to predict EEM energy savings impacts. A ten months detailed end-use monitoring plan was initiated to provide the grounds for calibration of the DOE-2 base case model.

The results showed refrigeration, lighting and HVAC to be the major energy uses at the commissary. According to the simulation results, the annual energy consumption of the commissary is 2,072,943 kWh. **Figure 1** shows the annual distribution for each end use as a percent of the total electrical energy consumption.

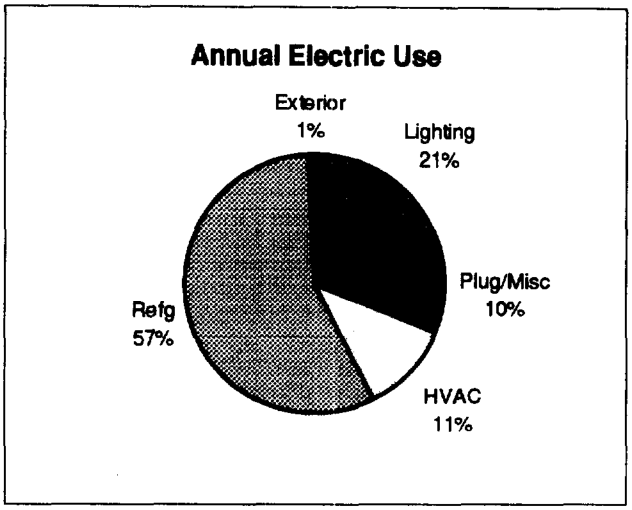


Figure 1. End Use Distribution from Simulation Results

The combined energy efficiency recommendations were made based on the best discounted Saving to Investment Ratio (SIR) and simple payback, as well as strategic design-to-planning inputs received from the Defense Commissary Agency (DeCA), and its consultants.

Factors such as DeCA's equipment replacement schedules played a significant role in the omission of some of the packages, and in advancing others to the top of the list. For instance: the DeCA plan to replace the main refrigeration system condensers and display cases in 1998 made improvements to these components more attractive, since the marginal cost increase could be used instead of replacement cost. The best combination of energy efficient measures was selected based on simulation of the commissary model with a variety of energy efficient measures.

Base Case Building

The commissary is located at Twentynine Palms, which is a desert region of California located 75 miles east of San Bernardino at approximately 2,000 feet above sea level. The site has an average of 1973 heating degree days and 1600 cooling degree days.

In 1988, the original building was converted to a warehouse area, and a new retail area was added. The building exterior walls are comprised of masonry block. The roof is a built-up composition roof over the retail area and corrugated metal roof over the warehouse, with fiberglass batt insulation over dropped tile ceiling. The building has a gross floor area of 42,080 square feet with 34,918 ft^2 conditioned. The retail section of the commissary is 23,078 ft^2. The conditioned space of the warehouse is 11,840 ft^2. **Figure 2** shows a floor plan of the entire building.

The commissary is open to customers six days a week. Vendors may stock shelves anytime from 3 p.m. to 7:30 a.m. There are 34 employees; 10 work during off-hours.

Base Case Indoor Lighting

The existing equipment in the Commissary Building includes fluorescent fixtures with magnetic ballasts and T-12 lamps, downlights with incandescent lamps, and downlights with mercury vapor lamps. The areas evaluated include the retail area, the warehouse area, the display case area, the produce area, and the deli service counter area. Most of the lighting in the retail area of the commissary is served by 8 ft. T-12 fluorescent lamps, with a few mercury vapor lamps. Most of the lighting in the warehouse area is served by

4 ft. T-12 fluorescent lamps. The offices are served by a mix of 4 and 8 ft. T-12 fluorescent lamps. The walk-in boxes (coolers, meat prep, produce prep, and freezers) are served by a mix of 8 ft. fluorescent and incandescent lamps. The total connected lighting load for the building is 83.16 kW, as shown in **Table 1**.

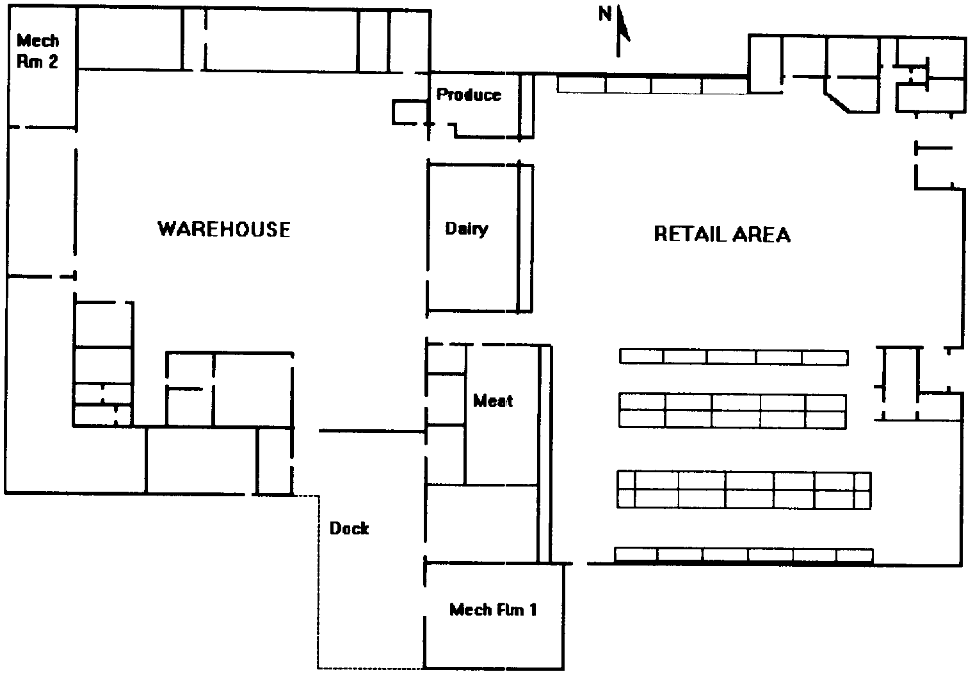


Figure 2. Commissary Floor Plan

Most lighting in the building is operated continuously. Office lighting is off after business hours. Some case lighting is turned off after stocking is completed.

Table 1. Lighting Power by Area

Area	Lighting, kW
Retail	38.04
Warehouse	26.27
Office	2.24
Coolers	10.12
Misc.	2.24
Exterior	4.25
Total	**83.16**

Base Case HVAC Systems

The primary HVAC system serving the retail area is a rooftop constant-volume multi-zone unit, providing cooling to three zones within the sales area. The system was designed to operate with a 7 day programmable time clock, but it is uncertain if the time clock is in operation. A thermostat is used to control the temperature of each of the three zones. The zone which serves the majority of the sales floor also has a humidity sensor. The multi-zone unit uses a hot and cold deck system. Modulating dampers in the supply air ductwork mix air from the hot and cold deck to satisfy the space thermostats. The hot deck temperature setpoint resets to the lowest temperature that will satisfy the zone(s) calling for heat. Similarly, the cold deck temperature setpoint resets to the warmest zone requiring cooling. Heating for the sales area has four stages. Stages one and two use heat rejected (reclaimed) from the refrigeration system, and stages three and four use natural gas duct furnaces to augment the first two stages.

Sales area cooling is supported by two Copeland 25 HP semi-hermetic compressors, which operate individually or simultaneously, depending on the cooling load requirements. The unit has 2 stage dehumidification control capability. During moderate weather, the unit was observed to provide heating and cooling at the same time.

Base Case Refrigeration System

The existing main compressor room includes four parallel compressor systems with two evaporatively-cooled condensers. The systems are equipped with mechanical subcooling. Most or all of the systems utilize the thermostat and solenoid method of temperature control. The compressor systems operate at a fixed head pressure at 90°F saturated condensing temperature. R-502 refrigerant (a CFC) is used for all compressor systems.

The two evaporatively-cooled condensers are piped with 2 circuits each. The fans operate continuously. Any decrease in discharge pressure below the setpoint causes a damper to modulate toward the closed position, reducing the air flow through the condenser. Each parallel compressor system is connected to a heat reclaim coil to provide heating for the main sales area. Each system contains a 3-way valve which, when energized, diverts the discharge gas from the compressor to the heat reclaim coil located in the air handler. Compressor system 4 is also connected to a hot water heat reclaim system. The discharge gas from the compressor is routed through a thermal recovery unit (heat exchanger) that is connected to an insulated storage tank. The setpoint for the water temperature is 120°F.

A smaller compressor room serves a large walk-in freezer box and a large walk-in cooler box. There are four single compressor systems which use R-22 and cycle on and off continuously. Small evaporatively-cooled condensers reject the heat of this refrigeration system. Temperature is controlled with thermostats and solenoids.

Base Case Refrigerated Display Cases

The commissary is currently using Tyler display cases. Existing display case and walk-in cooler fans were assumed to use standard shaded pole motors. Standard existing display case lighting was also assumed for simulation purposes. Display cases do not have anti-sweat heater control. Case temperature is controlled through the use of thermostats and solenoids.

Base Case Miscellaneous Loads

Miscellaneous loads include all outlet receptacles including office equipment and stand alone soda machines or coolers, check-stand equipment and battery chargers. The total power usage of this equipment was obtained from the monitored data.

End-Use Monitoring

The monitoring plan was developed based on the knowledge that energy efficient measures may occur in the lighting, refrigeration and HVAC systems. It was not known during the initial stages of the monitoring task what specific measures were to be considered. The monitoring plan implemented in the project uses seven meter recorders and 62 measurements. The primary type of data monitoring points are electric load measurements. Other monitoring points included temperature, relative humidity, refrigerant discharge and suction pressure and valve opening/closing status. **Table 2** shows the number of monitored points. The plan was developed to be as generic as possible to identify energy use of as many systems as feasible. Data were collected in five minute intervals so both demand and energy use can be evaluated. Southern California Edison did not have a billing meter attached to the commissary to provide a history of the building's energy use. Therefore, the total building electric load was also monitored. The measurement of the electric load has an accuracy of +/- 1.5%. The measurement of the total building load is also supported by the individual end use electric load measurements.

Table 2. Types and Quantity of Monitored Points

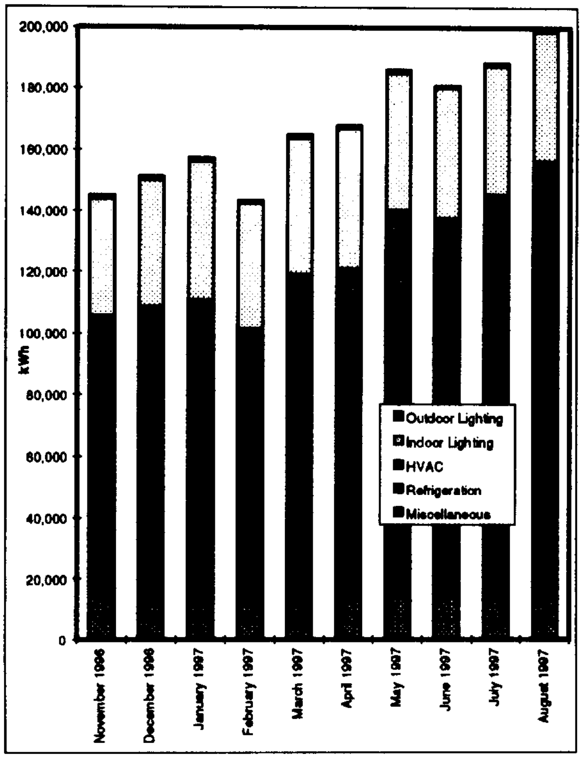
Number of Points	Units	General Description
1	kWh	Total Building
7	kWh	Lighting
7	kWh	HVAC
25	kWh	Refrigeration
5	deg F	Air Temperatures
2	%RH	Relative Humidity
12	psi	Suction & Discharge Pressures
3	open/close	Status

Monitoring Instruments Description

This project uses Synergistic Control Systems Meter/Recorders as the central monitoring equipment devices. There are seven loggers installed at this site. Two of the units are model C-180 and the other five are model C-140. The C-180 has 16 Current Transformers (CT), 15 analog and 16 digital input channels, and two sets of Potential Transformer (PT) inputs. The C-140 has 8 current transformer channels, 8 digital input channels, and two sets of potential transformer inputs. The C-140 and C-180 models calculate true power from the CT and PT channels as defined by the parameter set. The CTs used for this project are split-core to minimize power interruptions during installation of the monitoring equipment. They also are low voltage (0.333 Volts AC full scale) which reduces electrical hazards when wiring is routed outside the electrical panels. Primary ratings of CTs used at this site include 25, 50, 100, 200 and 600 Amps. These CTs are accurate to within two percent of the rating and can be used in conjunction with the recorders for up to 125% of full scale. Temperature measurements are made using 1000 ohm platinum Resistance Temp Devices (RTD). Relative humidity measurements are made using Hy-Cal sensors that have a 4-20 mA output signal. Ashcroft pressure sensors (0-500 psi) are used for the refrigerant lines and have a 1-5 V dc output signal.

Sample Monitored Results of the Base Case Building

The data were prepared as monthly electric loads by end use. **Figure 3** shows the ten months of base case data collection, November 1996 through August 1997. Most of the loads at the commissary are fairly uniform. The HVAC load is the only load that displays large month-to-month changes. August was the hottest month and has the largest air conditioning load. February only has 28 days and thus shows less energy use than other months.



End Use	Outdoor Lighting kWh	Indoor Lighting kWh	HVAC kWh	Refrig-eration kWh	Miscell-aneous kWh	Total kWh
November 1996	1,181	38,079	10,308	80,517	14,883	144,967
December 1996	1,342	41,154	9,575	83,677	15,626	151,374
January 1997	1,274	45,328	10,646	85,428	14,919	157,593
February 1997	1,084	40,839	10,920	77,745	12,891	143,478
March 1997	1,174	44,563	17,405	87,097	14,744	164,983
April 1997	1,028	45,546	18,859	87,003	15,337	167,773
May 1997	978	44,635	35,329	90,558	14,556	186,056
June 1997	806	42,563	35,543	88,103	13,909	180,917
July 1997	853	41,861	37,920	93,031	14,622	188,286
August 1997	859	42,390	45,830	95,933	14,658	199,670
Average	1,058	42,695	23,234	86,909	14,614	168,510

Figure 3. Graph and Table of Total Site Electrical Energy Consumption by End Use for Ten Months

Base Case Energy Simulation

The commissary was modeled using a special version of the DOE-2.1e Building Energy Simulation Program. This version, release 119r from J. J. Hirsch and Associates, includes extended capabilities for modeling supermarket refrigeration systems and runs on a standard personal computer. A detailed model of the building was created describing the building shell, internal power use, building operation, and HVAC systems and refrigeration systems. Information gathered from the on-site audit, building plans and monitored data was used to develop the base case model.

Based on the monitored data, the peak lighting load was determined to be 1.4 Watts per ft^2 in the warehouse section of the store and 1.93 Watts per ft^2 in the retail section of the store. Connected lighting loads may be higher than these values. Lighting schedules for each day of the week were derived from the interviews with commissary personnel, as well as monitored data. The store average miscellaneous equipment power use was determined to be 0.78 watts per ft^2. A DOE-2 weather file was created for the simulation based on the actual site weather data collected at SCE's weather station in Yucca Valley 22 miles west of the commissary. The weather data collected cover a one-year period from March 1996 through February 1997.

Refrigeration system performance characteristic curves were generated for use with the DOE-2 energy simulation program based on individual components and monitored data. These curves were developed as a function of ambient temperature, part-load, condensing temperature, etc. and were incorporated into DOE-2 simulation models. Development of various system characteristics was based on refrigerant properties and compressor mass flow pumping performance. Energy for mechanical subcooling was allocated to the three suction temperatures (if subcooled), based on the fraction of design load of each suction group to the total. Condenser energy was calculated within DOE-2. Separate curves were developed with and without heat reclaim holdback valve operation to allow for the appropriate difference in compressor energy (e.g. effective EER with elevated discharge pressure, but floating condensing temperature).

Calibration

The base case building model was calibrated to monitored energy use for a four month period from November 1996 through February 1997. To calibrate the model, average hourly profiles for indoor lighting, outdoor lighting, and plugload electric use were developed for each day type (Monday, Tuesday, etc.) based on the monitored data. These profiles were then used in the building simulation along with the measured peak values for each category. This approach guarantees that the non-weather related electric uses are accurately simulated. The overall building plug loads were determined as the difference between the whole building electric kW and the sum of all other monitored electric uses. **Figure 4** shows comparison between monitored and simulated energy use.

The HVAC systems were simulated using measured values for supply and exhaust fans. Other HVAC controls were adjusted to closely match the simulated and monitored performance of the systems. A detailed model of the refrigeration system was developed and compared with the monitored data. Some adjustments were made to the refrigeration parameters to more closely match the monitored data. This calibration was a critical step in developing confidence in predicting the impact of various technologies on the building energy use.

Base Case Energy Simulation Results

The DOE-2 energy simulation model output results of the annual energy use for the base case and packaged EEM's are presented in this section. For the base case commissary, 57% of the electric energy use is associated with the refrigeration systems in the store. The refrigeration systems' primary function is to keep perishable merchandise at its required temperature, while the waste heat of refrigeration is reclaimed by the HVAC system to provide space heating. Additionally, the cooling effect from the refrigerated display cases creates indirect space cooling, which reduces the HVAC system energy use. **Table 3** shows the annual electric loads and distribution results of the DOE-2 simulation for the base case building.

Table 3. Simulation Results of Base Case Annual Energy by End Use

End-Use	Annual kWh
Lighting	432,431
Plug/Misc.	213,355
Heat	6,218
Cool	106,337
HVAC misc.	1,767
Fans	110,408
Refrigeration	1,187,584
Exterior	14,843
Total	2,072,942

From the simulation results, 5,421 therms of gas are used annually; 88.9% is used for heating hot water and the remainder is used for space heating.

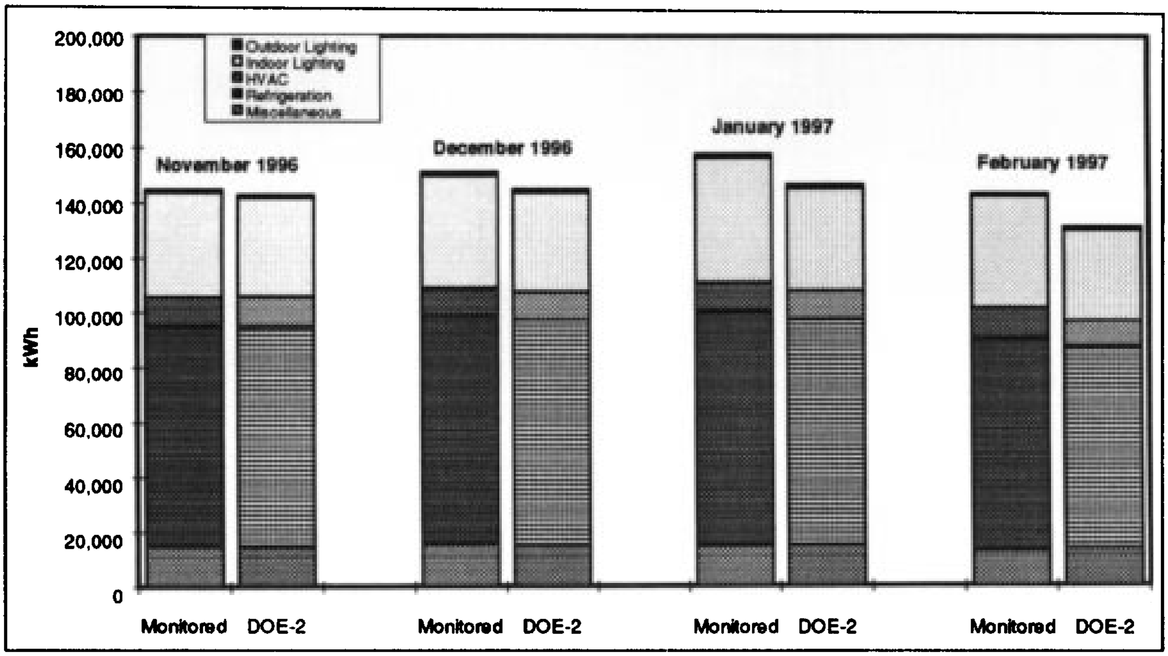


Figure 4. Comparison of Monitored Vs. Simulated Energy Use.

Energy Efficiency Measures

The following lists, by classification, the EEMs that were evaluated.

Energy Management System (E)

The Energy Management System (EMS) controlled three main end-uses.

Indoor Lighting EMS Control (E1). This measure reduces the indoor ambient lighting to approximately 50% of the peak lighting power density and turns off the accent lighting during non-business hours. The monitored data show that existing indoor lighting is rarely turned off, even when the store is completely unoccupied. They also show that the lighting was typically off (reduced to approximately 17% of peak) on Saturday and Sunday nights; these values were used for the simulation of the base case.

Daylighting EMS Control (E-2). Daylighting controls were associated with the installation of new skylights in the sales and warehouse areas. The EMS system allows continuous dimming of the ambient lighting in the sales area, down to 10% of peak power, and controls the lighting in the warehouse section of the store using 2-step switching, based upon the available daylighting resource.

Refrigeration EMS Control (E-3). This measure added the following features to the refrigeration system serving the main sales area:

- Floating head pressure down to 65° F
- Variable setpoint control for the condenser fan motors
- Controls for anti-sweat heaters. The control for the anti-sweat heaters is changed from "always on" to "proportional". With proportional control, the anti-sweat heaters are fully on when the space relative humidity is above 55% and fully off when the space relative humidity is below 30%. Between these relative humidity set-points the heaters are controlled proportionately.

- Turn off display case lights during closing hours. Case lighting is turned off at night between the hours of 8:00 p.m. and 7:00 a.m. in all of the refrigeration casework.

Indoor Lighting (L1)

The lighting measure re-designed the lighting system, utilizing new T-8 lamps with dimmable electronic ballasts and LED exit signs. Lighting kW in the sales area of the store was reduced by 41.7% and lighting in the warehouse section was reduced by 30.4%.

Daylighting (D)

Two daylighting designs are considered (D1 and D2). Each involved re-design of the lighting systems and single-pane skylights within an optimized roof opening of 6.5% of the daylit-controlled area.

Addition of Skylights with Removal of the Drop Ceiling (D1). This measure re-designs the lighting system while removing the existing drop-ceiling and adding skylights. This design allows more effective use of the available daylighting resource.

Addition of Skylights by Creating Light Wells (D2). This measure re-designs the lighting system while retaining the existing ceiling. Light wells are created between the skylights and the ceiling.

Refrigeration Compressors (Rk)

All of the following refrigeration measures feature multiplex systems and controls, and HFC Refrigerant R-404A or R-507. R-507 was used for simulation since it showed somewhat better efficiency in testing by SCE.

Regrouping of Display Cases (RK-1). Re-combine loads so that reach-in cases can be separated from the low temperature open case line-ups and assigned to a higher suction temperature group. [NOTE: RK1 is always implemented in combination with RK2.]

Un-evenly Sized Compressors and VSD (RK-2). Replace existing compressors with un-evenly sized high efficiency reciprocating discus compressors and add Variable Speed Drive (VSD) to control the compressor capacity.

Liquid-to-Suction Heat Exchanger (RK-3). High efficiency Liquid to Suction Heat Exchanger (LSHX) on low temperature groups. Simulation was done with separate compressor system curves reflecting the effect of lower mass flow, rather than of changing load. The compressor curves were generated outside of the DOE-2 program, and later inserted into the DOE-2 compressor curve-fit feature.

Refrigeration Condensers (RC-3)

Replace the existing units with (one or two) new high efficiency *Evaporatively Cooled* unit(s) with 1) Efficient heat exchanger (14 °F to 16 °F TD); 2) Low horsepower motors and 3) High efficiency motors.

Display Cases (F)

Four EEM sub-categories were developed concerning the display cases.

ECM Fan Motors (F-1). The evaporator fan motors in all the display cases are replaced with Electronically

Commutated Motors (ECM) fan motors, reducing the energy requirements of the fans themselves and reducing the heat gain to the casework. ECMs are the most efficient motors produced, and only available in small size motors.

Improved Case Lighting (F-2). The lighting fixtures in all the casework are replaced with more efficacious T-8 lamps and electronic ballasts. As with the ECM fan motors, this reduces the energy requirements of the fixtures themselves and reduces the heat gain to the casework.

Air Curtain Aluminum Shields (F-3). Air curtain low emissivity shields (night covers) are installed on all open cases. This reduces the refrigeration load when the curtains are in place and also reduces the heating load to the space. This measure effects the low and medium temperature open casework and reduces the casework cooling load when in place between the hours of 8:00 p.m. and 7:00 a.m.

New Case Fixtures (F-4). Replace existing cases with new high efficiency fixtures and add hot gas defrost (for selected medium and all low temperature fixtures).

Walk-in Coolers/Freezers

Three EEM sub-categories were studied for walk-in cooler/freezer. These measures effect the walk-in coolers in both the sales area and the warehouse area.

ECM Fan Motors in Walk-Ins (W-1). All of the evaporator fan motors are replaced with ECM fan motors. As with the casework ECM fan motors, this reduces the energy requirements of the fan motors themselves and reduces the heat gain to the walk-in cooler.

Double Acting Plastic Doors (W-2). These solid transparent doors replace the strip curtains used at the entrance of the walk-ins. It was roughly estimated that the addition of double-acting plastic doors reduces the walk-in's cooling load by approximately 3%.

Occupancy Sensors (W-3). The average lighting load in the walk-in coolers is monitored to be 2.2 kW. Occupancy sensors are assumed to lower the average load by 50%, to 1.1 kW. The reduction in lighting energy also reduces the load on the walk-in coolers.

HVAC

The HVAC EEMs were grouped into the following sub-categories:

Improved Economizer (H-1). The economizer control in the Sales area is adjusted to assure proper operation. Monitored data shows occasional use of the economizer when outdoor temperatures are above 78°F. This improvements reflects not allowing economizer operation above 70°F.

VSD Supply Fan (H-2). A Variable Speed Drive (VSD) is added to the supply fan for the main sales area. A parasitic of 5% is added to the full-load energy use. The VSD controller receives signals from the retail thermostat. It then adjusts the fan speed according to the difference between space temp. and the thermostatic set point.

Rerouting Duct Work in Warehouse Office (H-3). The office area in the warehouse suffers from under-cooling during many hours of the summer. This measure, in conjunction with measure H6, provides a dedicated heating / cooling system to the office, administration and lounge areas in the warehouse. It will include removing the existing duct work connected to one of the warehouse HVAC units and the thermostat from the office to the warehouse. New duct work will be added to connect to the new heat pump (H6).

Thermostat Adjustments (H-4). Thermostat set points are adjusted based upon review of current set points, to comply with DeCA's guidelines. Currently, the thermostat setpoints require more conditioning than DeCA's setpoint specifications.

CO_2 Outside Air Controller (H-5). Outside air is controlled by a sensor that measures CO_2 hourly concentrations in the return air path. For the simulation, the design outside air schedule followed the occupancy profile in the sales area.

Warehouse Office HP (H-6). Add a new energy efficient heat pump to the warehouse office. This is part of measure H3 (also see H3). This measure actually increases the building energy use, while providing better human comfort for the served zones.

High Efficiency Fan Motors (H-7). Efficiency of the 20 HP supply air fan motor for the main sales area is improved from 89% to 91%.

Improved Heat Reclaim (H-8). This measure extends the amount of heat reclaim that is available to the sales area HVAC system from a maximum amount of 20% of the available heat reclaim to 100% of the available heat reclaim.

High Efficiency Sales Area System w/ Evaporative Cooled Condenser (H-9). Replace the existing sales area's air cooled HVAC system with a new system with the following features (this unit will serve the entire retail area):

- high efficiency DX system
- evaporatively cooled condenser
- Variable speed drive on supply fan

Note: This measure is mutually exclusive with measure H2.

Indirect/Direct Evaporative Cooler for Warehouse (H-12). The four 10-ton DX rooftop units that serve the warehouse area are replaced with 2 Indirect/Direct evaporative coolers. The evaporative coolers have a direct efficiency of 90%, and an indirect efficiency of 63%.

High Efficiency Sales Area System w/ Air Cooled Condenser (H-13). Similar to measure H9, this new system for the sales area has an air cooled condenser.

Discussion of Results

The applicable electric and gas rate structures were included in the DOE-2 building model. Therefore, simulation outputs included energy costs (no demand rate structure for this site). Life cycle cost analyses were conducted using discount factors from the National Institute for Standards Technology. Based on bids received, the cost data for all measures were provided by DeCA's consultants. The analyses used 15 year life for all of the EEMs (excluding maintenance costs which were unavailable). The energy costs were determined based on $0.104/kWh for electricity and $0.58/therm for natural gas. The uniform present value (UPV) for electricity was 12.29, assuming a 15 year life and a 3.4% discount rate in the commercial sector. The UPV for natural gas was assumed at 11.85 under the same conditions.

Table 4 shows the annual peak demand savings, energy savings and installed measure costs for various packages including their ascending Savings to Investment Ratios (SIR) and paybacks. The commissary follows the federal requirements to determine the project's cost-effectiveness. According to the federal guidelines, a project should have a SIR of 1.25 or greater to qualify for investment. Package S provided the most energy savings, 1,200,200 kWh/yr., while meeting governmental SIR guidelines. This integrated package of EEMs promised a 58% reduction in the annual energy use of the site and included the use of energy efficient lighting, daylighting controls, advanced refrigeration controls, multiplex refrigeration system, energy efficient condensers, liquid-to-suction heat exchangers, high efficiency display cases equipped with aluminum shields, and energy efficient air conditioning.

Table 4. Savings, Cost and Payback by Package

Package	Included Energy Efficiency Measures	Savings (per year)				Measure Cost	Simple Payback (yrs)	Discounted SIR
		kWh/yr.	ave peak kW	gas therms	cost ($/yr.)			
A	E1, E2, E3, F1, F2, W1, H1, H2, H4, H7, H8	569,600	53	321	$59,400	$86,000	1.4	8.5
B	A, + L1	729,500	80	54	$75,900	$236,000	3.1	4.0
K	D, + H5	868,500	101	-571	$90,000	$430,000	4.8	2.6
C	B, + D1	859,600	101	-605	$89,000	$428,000	4.8	2.6
D	B, + D2	855,500	100	-589	$88,600	$428,000	4.8	2.5
L	K, + H3, H6	867,800	101	-510	$90,000	$435,000	4.8	2.5
J	I, +F4 (not applicable: F1, F2, F3)	1,084,400	131	-591	$112,400	$571,000	5.1	2.4
Q	J, + RC3	1,109,800	134	-591	$115,100	$586,000	5.1	2.4
F	D, + RK1, RK2	862,200	101	-589	$89,300	$463,000	5.2	2.4
I	F, +RK3, F3, W2, W3	974,500	118	-589	$101,000	$546,000	5.4	2.3
R	D, + H13 (not applicable: H1, H2, H7)	904,300	105	-631	$93,700	$544,000	5.8	2.1
S	Q, +H3, H5, H9	1,200,200	142	-527	$124,500	$751,000	6.0	2.0
P	D, + H12	906,800	108	-418	$94,000	$579,000	6.2	2.0
N	D, + H9 (not applicable: H1, H2, H7)	861,400	103	-589	$89,200	$573,000	6.4	1.9

Conclusions

An integrated energy efficiency approach in a commissary can yield significant energy savings and yet comply with federal cost effectiveness guidelines. Many commissaries here and abroad have similar existing equipment and energy needs. Computer simulations in conjunction with engineered end-use monitoring can provide a cost-effective method for evaluating numerous energy efficient technologies. With reliable computer models calibrated to actual end-use monitored data the effects of numerous technologies and their economics can be determined prior to field installation. The recommended EEMs in this study were not implemented by DeCA in this project due to budget constraints. These recommendations however, have provided effective energy efficiency guidelines for DeCA's remodeling and new construction projects.

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