Codes and Standards Enhancement Initiative
For PY2004: Title 20 Standards Development

Analysis of Standards Options For Refrigerated Beverage Vending Machines

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May 5, 2004

This report was prepared by Pacific Gas and Electric Company and funded by California utility customers under the auspices of the California Public Utilities Commission

Table of Contents

1 Introduction

The Pacific Gas and Electric Company (PG&E) Codes and Standards Enhancement (CASE) Initiative Project seeks to address energy efficiency opportunities through development of new and updated Title 20 standards. Individual reports document information and data helpful to the California Energy Commission (CEC) and other stakeholders in the development of these new and updated standards. The objective of this project is to develop CASE Reports that provide comprehensive technical, economic, market, and infrastructure information on each of the potential appliance standards. This CASE report covers standards and options for refrigerated beverage vending machines.

2 Product Description

Refrigerated beverage vending machines (vending machines) refer to standalone appliances selling refrigerated canned or bottled beverages. Other beverage merchandisers, such as reach-in refrigerators, fountain serve, or vending machines dispensing beverages in cups, are not covered in this analysis. Vending machines typically consist of a refrigerated compartment that holds from 500 to 800 or more canned or bottled drinks, accept dollar bills or coins, and dispense the drink product. Vending machines are comprised of two primary energy-consuming systems: a refrigeration system that keeps drinks cold and a lighting system that illuminates the front display panel.[1] The refrigeration system, including a compressor, evaporator and condenser fans, accounts for approximately 65% of the energy use, while the lighting system accounts for the remaining 35% (Kubo, 2000). New vending machines use an estimated 8.43 kilowatt-hours (kWh) per day.

Low power mode controls are now manufactured into virtually all new vending machines entering the market (Royal Vendors, 2002). These controls work very much like a programmable thermostat, allowing the machine to automatically adjust the lighting and temperature at defined times each day. For instance, the machine could be programmed to turn-off lighting and increase the temperature setting at midnight, and turn-on lighting and decrease the temperature setting at 7:00 am, Monday through Friday, and turn-off lighting and increase the temperature setting all day Saturday and Sunday. Refrigeration can be set to go into "storage mode", in which temperature rises to 50 degrees F, or another selected set point. Initial default settings when the machine leaves the manufacturer are lights on and a temperature of 37 degrees F, 24 hours per day, seven days per week (Royal Vendors, 2002).

[1] California Appliance Efficiency Regulations recently established prescriptive standards for lighting systems for vending machines that require T-8 fluorescent lamps with electronic ballasts or equivalent performance systems.

Figure 1: Example of a Refrigerated Vending Machine

3 Market Status

3.1 Market Penetration

An estimated 3 million refrigerated vending machines are in service in the U.S. (Horowitz, 2002). Since California accounts for about 9% of U.S. commercial sector electricity use (EIA, 2001), and about 12% of U.S. population, we assume California accounts for about 10% of the U.S. refrigerated vending machine stock, or 300,000. Three manufacturers, Royal Vendors Incorporated, Dixie-Narco, and the Vendo Company, control 85% of the market. Royal Vendors and Dixie-Narco enjoy approximately 35% of the market apiece, and Vendo has approximately 15%.

3.2 Sales Volume

According to the U.S. Census Bureau, 477,102 canned and bottled soft drink vending machines were shipped in 1999, and 337,796 were shipped in 2000 (U.S. Census Bureau, 2001). Since California accounts for about 9% of U.S. commercial sector electricity use (EIA, 2001), and about 12% of U.S. population, we assume California accounts for about 10% of the U.S. refrigerated vending machine sales, or 41,000 units per year.

3.3 Market Penetration of High Efficiency Options

Until very recently, only one manufacturer, Royal Vendors, was identified as having an energy-efficient product line already in the market. According to one industry representative, these Econo-cool-equipped vending machines account for 10 to 20% of Royal Vendors' sales (Royal Vendors, 2002). As of 2003, however, manufacturers appeared to be transitioning to substantially more efficient products relative to the average fleet now in service.

4 Savings Potential

4.1 Baseline Energy Use

As suggested above, the energy consumption baseline has fallen substantially from baselines of just three to five years ago. Using the most recent performance data provided to the California Energy Commission (CEC) for products certified to the CEC in the last year, we estimate that the annual per unit energy consumption of a new refrigerated vending machine is approximately 3,077 kWh. This number is based on daily energy consumption data averaged from all products from six different manufacturers certifying data with the CEC[2]. We estimate that if the stock of refrigerated vending machines in California, 300,000 units[3], were fully replaced, future baseline energy use would be 923 GWh, annually. Additionally, those units would represent an annual average demand of 105 MW and a coincident peak demand of 121 MW[4].

As previously noted, we estimate that annual sales of refrigerated vending machines in California are approximately 41,000 units. The aggregate energy consumption of the units sold in a year amounts to 126 GWh, and a corresponding energy demand of 14 MW and a peak demand of 13 MW.

In addition to the current baseline energy use derived from recent certifications to the CEC, our research uncovered five sources of energy use data that provide interesting insight into the energy consumption for the current stock of vending machines:

Table 1: Energy Use of Vending Machines Currently Installed

Source	Capacity (12 oz. cans)	Annual UEC (kWh)	Average Power Consumption (Watts)
US EPA (1996)	N/a	4,380	500
Arthur D. Little Report (1996)	400	2,961	338
Canadian Electricity Association (1996)	N/a	4,047	462
E-Source (1996)	450	3,644	416
Two national laboratories[5] (1997)	N/a	3,600	411
Average Consumption		3,726	425

Drawing upon daily and annual energy consumption data from these five sources, we estimate the average annual energy use of a vending machines in service to be 3,726 kWh/yr. Beginning in 2003, all refrigerated vending machines sold in California were required to be equipped with T8 fluorescent lamps and electronic ballasts, or a lighting system with no fewer lumens per Watt than a system using only T8 fluorescent lamps with electronic ballasts, as set forth in the California Appliance Efficiency Regulations. This helps explain the significant difference in annual energy use of vending machines already in the field versus those now being sold.

[2] The data is weighted to reflect the fact that three manufacturers represent approximately 85% of market share; but is not shipment weighted by individual model.

[3] Assuming that 10% of the 3.0 million units in the U.S. are in California.

[4] Assuming a load factor of 0.87.

[5] The source, ACEEE, does not identify the specific labs.

Based on the energy consumption data above, we estimate that the stock of California's 300,000 units uses a collective 1,118 GWh, annually. Additionally, those 300,000 units represent an annual average energy demand of 128 MW and a coincident peak demand of 146 MW.

4.2 Proposed Test Method

Two test methods currently exist for testing the energy consumption of refrigerated vending machines. In 1996, the Canadian Standards Agency (CSA) developed CAN/CSA-C804-96 "Energy Performance of Vending Machines", a daily energy consumption standard and test method. Based on the CSA standard, the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) developed a test method (but no standard), ANSI/ASHRAE 32.1-1997 "Methods of Testing for Rating Bottled and Canned Beverage Vending Machines".

Under the CSA test method, the daily rated energy consumption of a refrigerated vending machine is determined using the following calculation:

$E_D = (E_T / t_T) \times (24/1000)$

Where

E_D	= rated energy consumption per day, kWh
E_T	= energy consumed during the test, Wh
t_T	= duration of the test, hours
24	= hours per day
1000	= factor to convert from Watts to kilowatts

The CSA test procedure requires that the temperature control of the machine be adjusted to achieve a product temperature of 34± 1 degree Fahrenheit (F) and that the machine be allowed to stabilize for a period of at least 24 hours. (The 24-hour period may be reduced as long as temperature stabilization is achieved). The vending machine should be fully loaded to the minimum rated capacity, as specified by the manufacturer, and operated for a period of at least 24 consecutive hours under standard rating conditions. The test procedure specifies the following rating conditions and, where appropriate, the required accuracy of measuring each: ambient air temperature, voltage and frequency, installation, circulation of air at the rear of the machine, and product temperature. During the 24 hour period, the following data is continually recorded: ambient temperature, relative humidity, product temperature at compressor cut-in and cut-out, energy consumption in Watt-hours, and input voltage.

The ASHRAE Standard 32.1 is intended to specify methods of testing for rating the capacity and efficiency of refrigerated vending machines. The calculation for daily rated energy consumption of a refrigerated vending machine is similar to CSA's. The test procedure is also similar except that ASHRAE specifies that the temperature control be adjusted to achieve an average beverage temperature of 36± 1 degree F. Like CSA, ASHRAE requires a 24-hour period for temperature stabilization (no exceptions noted); however ASHRAE specifies a more abbreviated list of test conditions, including air temperature, voltage and frequency, relative humidity, and beverage temperature. The ASHRAE test procedure also differs from the CSA test procedure in that ASHRAE requires a test period of only six hours. In addition to the five types of data that CSA requires be recorded during the test procedure, ASHRAE requires that the duration of the test and the number and duration of cycles be recorded. The ASHRAE test method does not allow testing to be done with controls deployed.

In addition to the Energy Consumption Test described above, ASHRAE Standard 32.1 includes a Vend Test and Recovery Test. The purpose of the Vend Test is to determine how much cold product a machine will deliver when bottles or cans are vended at a rate of two per minute, three hours after a half-full machine is refilled with hot product. The purpose of the Recovery Test is to determine the product temperature recovery time of a vending machine when loaded with 90± 1 degree F product.

The U.S. Environmental Protection Agency (EPA) has established the Energy Star Program Requirements for Refrigerated Beverage Vending Machines- Eligibility Criteria. EPA specifies ASHRAE Standard 32.1-1997R *Methods of Testing for Rating Vending Machines for Bottled, Canned, and Other Sealed Beverages.* Energy Star's energy-efficiency specifications for qualifying products are discussed in the Standards Options section below.

We recommend that the ASHRAE test method also be used for the Title 20 standard for refrigerated vending machines.

4.3 Efficiency Measures

Lighting and refrigeration are the two primary energy-using systems in a refrigerated vending machine. All of the three largest vending machine manufacturers, Royal Vendors, Incorporated, Dixie-Narco, and the Vendo Company, are producing machines with T8 lamps and electronic ballasts, or a lighting system with no fewer lumens per Watt than a system using only T8 fluorescent lamps with electronic ballasts, as set forth in the current State Appliance Efficiency Regulations. Additional energy efficiency measures are also already being incorporated into or planned for refrigerated vending machines manufactured by the biggest market players. Vendo planned to introduce a new product line with a more efficient refrigeration system at the end of 2003, and Dixie-Narco's engineers are currently in the design phase of such a system. Royal Vendors developed a package of efficiency measures, Econo-cool, which has been marketed in recent years. Econo-cool includes three basic components:

- Standard T8 lamps with electronic ballast (14% savings over T-12 lamps with magnetic ballasts)
- Energy efficient evaporator fan and motor (21% savings)
- Energy-efficient cooling system with high efficiency compressor (15% savings)

Econo-cool is currently being incorporated into newly manufactured Royal Vendors machines. Royal Vendors has found Econo-cool to reduce energy use by 50%. As an aftermarket retrofit, any of the three Econo-cool components can be installed separately. Econo-cool can be used on any Royal Vendors machine manufactured since 1996.

Bayview Technology Group LLC (Bayview Tech) is the manufacturer of the retrofit efficiency measure known as VendingMiser. VendingMiser is a user-installable motion-sensor control device that uses a passive infrared sensor to power down a vending machine when the area surrounding it is unoccupied. VendingMiser then monitors the room's temperature and automatically re-powers the vending machine at one to three hour intervals, regardless of occupancy, to ensure that the products stay cold. Although this technology has been marketed as an aftermarket device, Bayview Tech has developed a similar device that can be incorporated into the machine at the time of manufacture. However, it has not been incorporated into any manufacturer's machines for sale at this time. The three largest manufactures already include internal controls in their machines that allow the owner to automatically shut down the entire machine, turn off the lights and/or set a higher refrigeration temperature during non-business hours. However, one manufacturer representative stated that it was his belief that almost no one is actually utilizing these controls (Dixie-Narco, 2002).

Although some of the data is several years old, the energy-efficiency measures and savings outlined in Table 2 provide additional guidance for determining appropriate standards options. We recognize that some savings estimates may overstate savings possible from more recent models due to the recent advances in refrigerated vending machine energy efficiency.

Table 2: Energy-Efficiency Measures and Associated Savings

Measure	Savings
High efficiency evaporator fan/ motor system	21%†
Evaporator fan ECM motor	14%#
Condenser fan/ ECM motor	3%#
ECM/ Variable speed compressor	15%#
High efficiency compressor	9%#, 15%†
Improved insulation	5.4%#
Motion-sensor activated controls[6]	47%*

Note: Savings not additive due to interactions between measures.
Sources:
† Royal Vendors Web site (2002)
# Arthur D. Little (1996)
*Bayview Technology Web site (2002)

[6] Given the test procedure we propose, this measure is irrelevant as a means to meet the proposed standards options; however, under other test procedures, motion-sensor controls could be relevant.

4.4 Standards Options

In developing standards options, we looked at US EPA's Final Draft of the Energy Star Program Requirements for Refrigerated Vending Machines as a point-of-reference:

A. Energy Consumption:

i. Tier I: Y= 0.55 [8.66 + (0.009 x C)], or 45% below CSA baseline.
Effective date: April 1, 2004 – December 31, 2006.

ii. Tier II: Y= 0.45 [8.66 + (0.009 x C)], or 55% below CSA baseline.
Effective date: January 1, 2007

B. Low Power Mode: Qualifying models shall come equipped with hard-wired controls and/or software capable of automatically placing the machine into a low power use mode during periods of extended inactivity while still connected to its power source. The machine shall be capable of operating in a lighting low power state, refrigeration low power state, and whole machine low power state, each of which is described in greater detail in the EPA final specification. In addition, the machine shall be capable of automatically returning itself back to its normal operating conditions at the conclusion of the inactivity period. The low power mode-related controls/software shall be capable of on-site adjustments by the vending operator or machine owner.

As stated earlier in the report, we assume 3,077 kWh to be the average annual energy use of a refrigerated vending machine manufactured in 2003. CSA has established a maximum daily energy consumption standard of 8.66 kWh, plus 0.009 kWh per can/bottle of capacity. The difference between CSA's standard (for a 500 can machine), 4,803 kWh per year, and the current baseline 3,077 kWh per year, is 35%. Therefore, the CSA standard provides a useful template for a California standard, but the standard itself is not aggressive enough to result in any savings. Vending machines currently sold in the US significantly exceed the CSA baseline, which is based on machine performance data almost 10 years old.

Based on the range of technology improvements and potential savings outlined in Section 4.3, we analyzed the standards options presented in Table 3, which can be met through a variety of combined measures. The standards options represent 5%, 10%, and 15% reductions from the average energy consumption of the products recently certified with the CEC. Option 1 savings are based on improved insulation; Option 2 savings assume the machine is retrofitted with a new evaporator fan ECM motor; and, Option 3 savings are based on the use of Econo-Cool or a similar package of efficiency measures.

Table 3: Savings and Daily Energy Use for Range of Standards Options

Option	Reduction from Baseline Energy Use (current products on the market)	Reduction from CSA Standard	Daily Energy Use Calculation (kWh)
Option 1	5%	40%	5.20 + 0.0054*C[7]
Option 2	10%	45%	4.76 + 0.0050*C
Option 3	15%	50%	4.33 + 0.0045*C

Beginning in 2003, all refrigerated vending machines sold in California were required to be equipped with T8 fluorescent lamps and electronic ballasts, or a lighting system with no fewer lumens per Watt than a system using only T8 fluorescent lamps with electronic ballasts. The standard proposed here should supercede this existing lighting standard as it affects refrigerated vending machines.

4.5 Energy Savings

As outlined in the earlier section, the current baseline annual UEC is assumed to be 3,077 kWh. The three standards options would result in the savings summarized in Table 4.

Table 4: Estimated Savings for Proposed Standards Options

Standard	Projected Savings (%)	Per Unit Annual Savings (kWh)	First Year Statewide Savings (GWh)	Full Replacement Projected Statewide Annual Savings (GWh)	Full Replacement Peak Demand Savings (MW)
Option 1	5%	154	6.3	46	6.1
Option 2	10%	308	12.6	92	12.1
Option 3	15%	462	18.9	138	18.2

Refrigerated vending machines are assumed to operate seven days a week, 24 hours per day and have a load factor of 0.87 (Brown, et. al., 2003).

[7] C = rated capacity of vending machine for standard product (12 ounce cans)

5 Economic Analysis

5.1 Incremental Cost

The following table lists the incremental costs for various energy efficiency measures applicable to refrigerated vending machines. As in the case of Table 2, some of the dollar amounts presented in Table 5 are based on efficiency upgrades to baseline products manufactured seven or more years ago, and may be somewhat inflated in light of the recent advances in the development of more energy-efficient machines. For example, we expect that the retail incremental cost of the motion sensor measure will cost substantially less than the $70 shown in Table 5, below.

Table 5: Incremental Cost for Various Energy Efficiency Measures

Measure	Incremental Retail Cost
Econo-cool[8]	$60#
Evap. Fan ECM motor	$56†
Condenser fan/ ECM motor	$56†
ECM/ Var speed compressor	$150†
High efficiency compressor	$16†
Improved insulation	$54†
Motion-sensor activated controls[9]	$70*

Sources:
Royal Vendors Website
† Arthur D. Little, "Energy Savings Potential for Commercial Refrigeration Equipment", report to the US Department of Energy, June 1996
*Based on Wattstopper Isole unit (www.Wattstopper.com), which has a retail price of $90. The Isole unit is an aftermarket product that includes a motion sensor controlled power strip. Subtracting out the cost of a power strip ($20), the retail price for motion-sensing controls would be $70. This price is likely overstated, but better data has not been provided.

5.2 Design Life

The design life of a refrigerated vending machine is estimated to be 10 years (Horowitz, 2002; Kubo, 2000).

5.3 Life Cycle Cost

Using the assumptions outlined above, we calculated the life cycle cost of a single refrigerated vending machine under each of the proposed standards scenarios. Option 1 savings are based on improved insulation; Option 2 savings assume the machine is

[8] Econo-cool includes a lighting retrofit to T 8 lamps with electronic ballast.
[9] Given the test procedure we propose, this measure is irrelevant as a means to meet the proposed standards options; however, under other test procedures, motion-sensor controls could be relevant.

retrofitted with a new evaporator fan ECM motor; and, Option 3 savings are based on the use of Econo-Cool or a similar package of efficiency measures.

Based on the ten-year design life and a present value of electricity of $0.709/kWh, we estimate an NPV ranging from $55 to $267, depending on the standards option.

Table 6: Analysis of Customer Net Benefit

Proposed Standard	Design Life (years)	Annual Energy Savings (kWh)	Present Value of Energy Savings* ($)	Incremental Cost, Retail ($)	Customer Net Present Value** ($)
Option 1	10	154	$109	$54	$55
Option 2	10	308	$218	$56	$162
Option 3	10	462	$327	$60	$267

* Present value of energy savings calculated using a life cycle cost of $0.709/kWh (CEC, 2001)
** Positive value indicates a reduced total cost of ownership over the life of the appliance.

6 Acceptance Issues

6.1 Infrastructure Issues

The marketplace has made great strides towards more efficient refrigerated vending machines in the last several years, lowering the incremental costs of described efficiency measures. Three of the largest manufacturers together represent approximately 85% of the market. In part, as a result of new efficiency requirements established by their clients--bottlers such as Coke—these three manufacturers plan to meet EPA Energy Star Tier 1 program requirements with much of their product line. Thus, a large proportion of the products sold next year may already meet or exceed standards options one and two.

6.2 Existing Standards

In 1996, the Canadian Standards Agency (CSA) developed CAN/CSA-C804-96 "Energy Performance of Vending Machines", a daily energy consumption standard and test method.

The CSA standard requires that the maximum daily energy consumption of a refrigerated vending machine at standard rating conditions not exceed the sum of 8.66 kWh and 0.009 kWh per can of capacity. CSA also requires that each vending machine have a permanent, easily readable, accessible marking indicating the daily rated energy consumption.

7 Recommended Standard

It is recommended that the CEC establish a standard using Option 2 described above, effective in January of 2006. While it is acknowledged that the largest manufacturers of refrigerated vending machines appear to be well on their way to manufacturing and selling primarily products meeting or exceeding the proposed standards level, a CEC standard would prevent delays in making this transition or back sliding in future years, as well as forcing the smaller manufacturers to also improve the efficiency of their products. By the time the CEC prepares to finalize its proposed standards, if significant progress is not noted in terms of the transition to more efficient models, it should proceed with establishing this standard. If indications are that most products will be in compliance and the CEC elects not to establish a standard, it should continue to monitor the efficiencies of products certified by the manufacturers to the CEC over time to ensure that there is no backsliding or increasing market share by under performing models.

We also recommend that any standard require that vending machines include low power mode controls and that they are set to the following factory settings: Lights on, temperature set at 37 degrees F from Monday through Sunday, 7:00 am to 11:59 pm; and, lights off, temperature set at 50 degrees F from Monday through Sunday, 12:00 am (midnight) to 6:59 am. In addition, anytime power is lost and recovered to the machine, the machine should default to the factory settings or be equipped with a backup system allowing the machine to revert to the customized program settings).

The following standards language is recommended for section 1605.3

*The daily energy consumption of refrigerated vending machines manufactured at least 12 months after adoption by the Commission, shall not exceed 4.76 + 0.0050*C kWh, where C is rated capacity for standard product, expressed in number of 12-ounce cans.*

8 References

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