Portable Classroom Controller Study

Final Report

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1.0 Introduction

As part of the administration of ecoEnergy Retrofit Program for Small and Medium Organizations, delivered by the Office of Energy Efficiency, the Program is required to develop recognized savings values and limits for certain types of energy measures.

Recently the Program has received an application for the installation of Log-One Controllers in school portables.

This study estimated the energy consumption of typical portable classrooms and the potential energy savings of installing a smart controller (such as Log-One) for a typical school portable with both unit ventilators and baseboard heating in the Toronto region.

2.0 Literature Search

2.1 Studies from Greater Toronto Area (GTA) School Boards

Two studies from GTA school boards were provided by Log-One (via NRCan staff). These studies compared existing portables with those controlled by the Log-One smart controller. Unfortunately, these studies consisted of only a one-page summary of results and described very little about the portables or how the comparison was done. Contact was made with the school boards to attempt to fill in missing information.

In the case of School Board No. 1, data were provided for 21 portables at one school. The first year of monthly data had electricity consumption for existing portables. The second year gave monthly electricity consumption (September to March) after portables had been retrofitted with Log-One controllers. Over this seven-month period, the smart controllers reduced electricity consumption by 27.4 percent.

Based on contacts with the school board, 16 of these portables had unit ventilators (probably meant 17, since results page indicates 17 portables had cooling and there were 21 schools in study) and four were heated with baseboards. Before the retrofit, the HVAC was controlled by manual thermostats and the board contact felt that there was inconsistent setback (if any setback at all) by school staff. After the retrofit, the smart controllers set back the temperature to 12°C from 4 p.m. to 8 a.m. the next day (the space would be at occupied temperature by 8 a.m.) and controlled lighting by the occupancy sensors. There was no independent outside air control and ventilation was introduced to the space when the unit ventilator's fans came on (even during unoccupied periods).

The board contact could not explain the suspicious monthly energy savings. Much of the savings occurred in shoulder seasons and there were very little electricity savings during the December to February period when you would expect much of the benefit of temperature setback to occur. He suggested that it was due to different weather (before and after done in separate years). But a comparison of monthly heating degree days (HDD) indicated little difference between the two test periods (9%).

In a letter (dated May 2006) attached to the results of this study, Log-One President Hugues de Milleville indicated installed costs were between $900 and $1,100 per portable. This letter is attached at the end of Appendix A.

The study related to School Board No. 2 was done in 1995. In this study, three portables were retrofitted with Log-One controllers and compared to five existing portables with manual thermostats during the same period. The heating in all portables was done by baseboard heaters (10 kW). They found the base (manual thermostats) consumed 11,706 kWh and the Log-One controller energy savings were 36%.

Based on discussions with a board representative, there was no ventilation in these portables and he did not believe there was any temperature setback with the manual thermostats. In addition, there was no lighting savings in this study (kept lighting consumption the same in both cases). He was not certain, but thought the Log-One setback was to 15°C.

See Appendix A for detailed questions and answers.

2.2 Contacts with Other Boards, Portable Manufacturer and Smart Controller Manufacturer

Additional contacts were made with School Board No. 3 which provided the portable design for the simulation analysis provided in Section 3.0. This recent design was equipped with smart controller/occupancy sensors (not Log-One) which set back the temperature to 10°C, but lighting was on manual control. The unit ventilator does not have independent control of the outside air (ventilation provided whenever fan is on).

Existing portables are controlled by programmable thermostats. Most are equipped with unit ventilators, but there are some with baseboards and no ventilation. The heating is set back to minimal temperatures and lights are off during summer break.

The manufacturer of the portable modelled in the simulation study indicated that occupancy sensor/smart controllers are not standard design in their portables. They are an option (at additional cost) and only included in approximately 25% of portables they sell. He also indicated that outside air is not independently controlled from fan operation. So, ventilation is introduced whenever the fans are operating.

The Log-One manufacturer was also contacted. He indicated that it is standard practice for Log-One controls to also control lighting. This is different from School Board No. 3, where the smart controller does not controller lighting. The Log-One contact was the only person contacted that indicated that ventilation was typically independent of the unit ventilator fan operation.

He indicated the typical setback temperature is 10°C and that the Log-One controller monitors both the indoor and outdoor temperature and can alter the warm-up period depending on the conditions.

See Appendix A for detailed questions and answers.

2.3 Literature Search

A literature search was performed to identify any studies evaluating the performance of automatic controls, more generally energy efficiency retrofits, in portable classrooms. The National Research Council's Canada Institute for Scientific and Technical Information library, U.S. Department of Environment (DOE) Information Bridge, American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE), U.S. Oak Ridge National Laboratory and a general Internet search yielded a small number of U.S studies. These reports are summarized below. No Canadian studies were identified.

Source: Florida Solar Energy Center (FSEC), Evaluation of Energy Efficiency Improvements to Portable Classrooms in Florida

Description:
Two-year study. 720 ft^2 (20' x 36', long axis oriented north-to-south).
Improvements made to existing typical portable classroom include T12 lamp-magnetic ballast lighting system replaced by a more efficient T8 lamp-electronic ballast lighting system and an occupancy-based control system for lighting and air conditioning. Within a year-long period of baseline monitoring, it was verified that a typical Florida portable classroom used about 30 kWh/day.

Some 17.6 kWh per day or 56% was used for space conditioning. Of this, 14.0 kWh/day (44%) was consumed by space cooling and 3.6 kWh (13%) was used for heating. Mean lighting energy use was 13.1 kWh/day or 41% of total consumption. Plug loads for projectors, computers and an outdoor night light averaged 0.7 kWh/day or just 2% of total use.

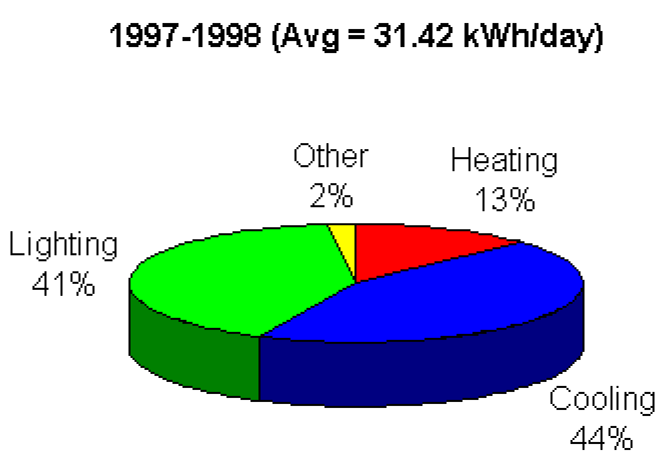


Figure 3. Energy end-use in Portable 035 in baseline data collection period (October 1997 - May 1998).

Results:

Figure 32 shows how the T8 lighting system and occupancy control reduced lighting energy use by an average of 53% (7 kWh/day) from one year to the next. The automated controls were found to be responsible for about 2.4 kWh of the savings (19% [of overall pre-retrofit energy consumption]). Total annual savings were estimated at 2,550 kWh, worth about $200 at current electricity prices. Lighting energy savings were fairly consistent year round.

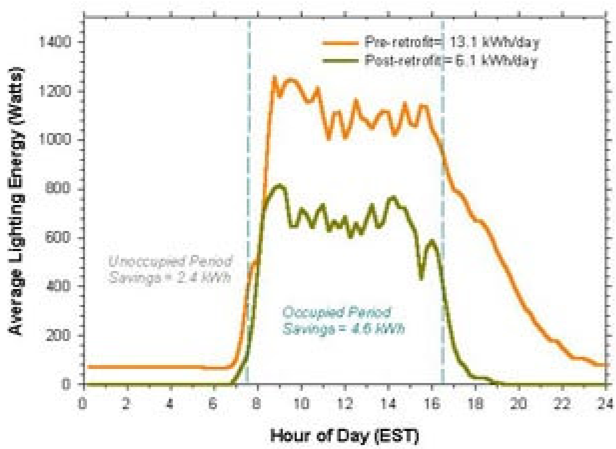


Figure 32. Time-of-day lighting energy demand in the year before (orange) and after (green) retrofit.

Along with automated HVAC controls, a more efficient HVAC system was installed with energy recovery ventilators (ERV) and the typical savings were 45% on similarly occupied school days. There was also a reduced sensible cooling load from lighting and the roof/ceiling (reflective white metal roof installed). However, as shown in Figure 18, much of the savings in Portable 035 are due to the automated control of the HVAC unit.

After the retrofit, the majority of the energy savings come during the unoccupied periods when the HVAC is off, while during the pre-retrofit period the HVAC was cycling on and off 24 hours a day. However, this figure also points out that during peak time the new unit used about 5% less energy (~180 W) than the old unit. Also, much of the overall reduction is due to the roofing change and lower internal heat from the lighting although the individual impact is difficult to separate in this analysis.

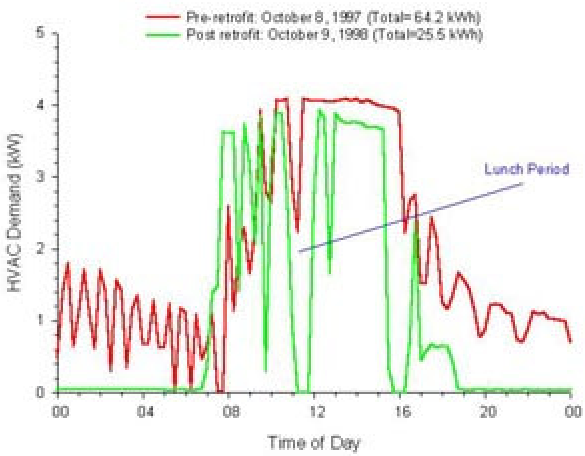


Figure 18. HVAC power use for Portable 035. The red trace is pre-retrofit energy use (64.2 kWh) and the green trace is post-retrofit energy use (25.5 kWh).

Figure 20 depicts the air conditioner use on the two portable classrooms on a teacher work day where the classroom is only occupied for a few hours. Note the difference in energy use during unoccupied periods before 7 a.m. and after noon. The occupancy sensor control on the system in Portable 035 turns off the HVAC when the classroom is unoccupied while the unit on Portable 096 cycles on and off during these periods because there is no automated control. During these periods Portable 035 used 7% less energy than Portable 096. **During the occupied periods, the energy use of the portables is similar.**

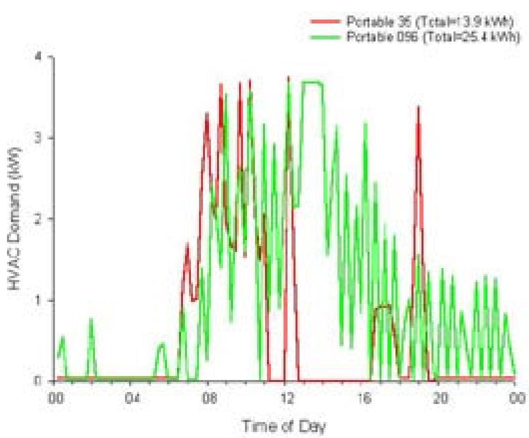


Figure 20. HVAC energy use comparison for both portables on August 14, 1999, showing the lower use at Portable 035 with the automated controls.

Figure 33 shows how the improved heat pump, white roof and reduced internal heat from the more efficient lighting was able to cut daytime space conditioning electrical demand while providing five times the ventilation air (13 cfm/student) found in the base situation. This cut internal CO_2 levels, with potentially beneficial impact on indoor air quality. Savings in space conditioning during the occupied period was 2.4 kWh/day or about a 14% reduction in daily energy use. The value of the occupancy controls was demonstrated in the large level of savings produced during unoccupied hours. This represented 4.5 kWh/day or a reduction in [energy use] of about 25%. Total reduction in space conditioning energy needs was 39% or about 6.9 kWh/day. Annually, the 2520 kWh savings is worth about $200 in reduced operating costs.

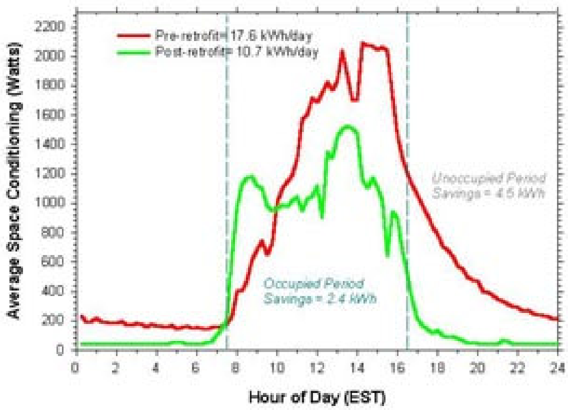


Figure 33. Average space conditioning energy demand before (red) and after (green) retrofit. Savings come from a package of measures.

Description of Occupancy Controls:

The occupancy sensors function to turn the HVAC and lighting on when the portable is in use and consistently turned off during unoccupied periods. The setup uses two occupancy sensors (DT-100L and DT-200; Figure 19) manufactured by WattStopper Inc. The controls use passive infrared and ultrasonic sensing to control the lights and HVAC operation. One control is located at the front of the classroom and another at the rear to ensure complete coverage of the space.

Figure 19. DT-200 occupancy sensor.

Source: Washington State University Extension Energy Program, Northwest Portable Classroom Project

Description:

The goal of the Northwest Portable Classroom Project was to promote the adoption of energy-efficient portable classrooms in the Pacific Northwest that provide an enhanced learning environment, high indoor air quality and energy savings that are both substantial and cost-effective.

Energy-efficient portable classrooms were built in Oregon and Washington; an existing portable classroom in Washington served as a control. In Idaho, an existing classroom was retrofitted to energy-efficient specifications. All of the classrooms were monitored for space heating energy use and overall energy use.

Major Findings:

- Most of the heat loss in portable classrooms manufactured after 1985 is by air leakage through T-Bar dropped ceilings (in place of more expensive sheet rock) that do not use a sealed air/vapour barrier. Blower door tests revealed air changes two to three times the amount in older portables with sheet-rocked ceilings.
- Air leakage is further aided by the use of an unsealed marriage line which is used as a low-cost method of meeting the state ventilation requirements in attics.
- Thermostats currently installed in all portables are either non-programmable or incorrectly programmed. Data analysis indicated that heating and air conditioning systems operate at night, weekends, holidays and vacations.
- Ventilation systems are controlled by CO_2 sensors that are not calibrated correctly, resulting in excessive operation of the systems during unoccupied periods. It also results in some ventilation systems not operating at optimal levels, causing a build up of CO_2 in the classrooms.
- The study found that in most new portables, the windows (usually two) are installed on the same wall which decreases passive ventilation
- In some of the newer classrooms, the ventilation exhaust fan is located on the same side of the room as the fresh air supply, causing a short-circuiting of the fresh air.
- The study found that it is possible to retrofit older portables and bring them up to current specifications at a cost considerably less that the cost of a new classroom. The Idaho portable was retrofitted with the recommended energy measures at a cost of $9,850.

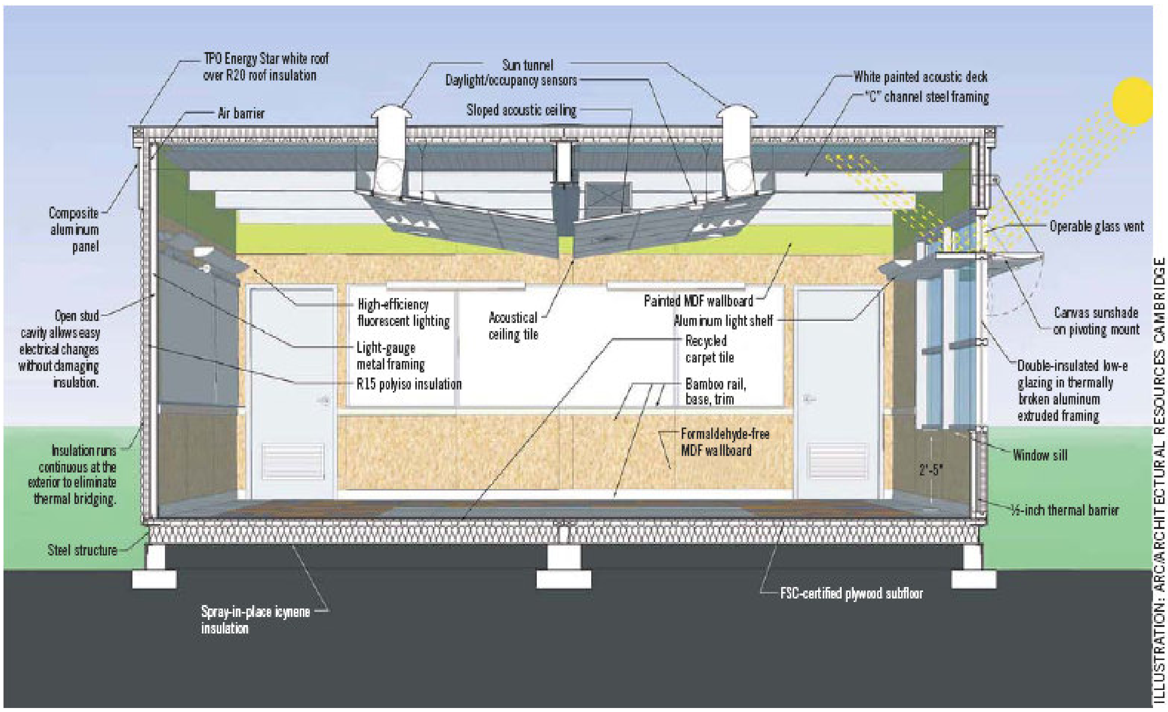
<u>Results/Recommendations:</u>

- Install 365-day programmable thermostats in all existing portables and specify them for new construction. These types of units are available and have been designed for small buildings such as portable classrooms.
- In portable classrooms constructed with T-Bar dropped ceilings, install an air/vapour barrier above the T-Bar ceiling and on the warm side of the insulation. Completely seal all edges and overlaps.
- If roof rafter insulation is used, seal the marriage line at the roof rafter joint with approved sealant such as silicon caulk or foam.
- Conduct an audit of the older portables that are being scrapped to see if retrofitting them will be cost effective. Retrofit measures included T-8 lighting, vinyl framed low-e windows at U-0.37, a new HVAC system with a heat recovery wheel and a heat pump, new R-10 doors, blown-in insulation in the attic above the sheet-rocked ceiling, installing crawl space vents, and caulking around base plates and other penetrations.
- Install occupancy sensors to operate the ventilation system.

- Specify new units be ordered with windows on opposite walls.
- Specify new units with the exhaust fans be placed on opposite side of classroom than the fresh air supply.

<u>Source:</u> Building Design + Construction, Green Modular Classrooms Hit the Market

<u>Description:</u> At Carroll School in Lincoln, Mass., a 950-sf re-locatable classroom, named SmartSpace, is one of a number of high-performance modular classrooms to emerge on the market during the last few years and it is the first LEED-level unit to be installed in the U.S.



- Double-door entry vestibule
- Sun-tunnel skylights
- Double-insulated low-e glazing
- Cool roof
- Light shelves
- Daylight and occupancy sensors

2.4 Portable Classroom Incentive Programs

An Internet search was also done to identify any utility or government rebate programs directly related to portable classrooms, particularly regarding programmable/smart thermostats and occupancy controls. Only one incentive program could be identified which provided a straight incentive per controller.

Puget Sound Energy, Washington State, offers a portable classroom control rebate program that offers rebates to schools which upgrade their portable classroom controls from 7-day programmable thermostats to 365-day programmable thermostats: $250 is available for 365-day programmable thermostats with an additional $50 each for occupancy sensor damper controls and occupancy sensor lighting controls. See Appendix B for more details on this program.

The Re-locatable Classroom Retrofit Pilot run by PG&E of California is a demonstration and direct installation pilot program to retrofit portable re-locatable classrooms with higher efficiency lighting, HVAC systems, day-lighting systems, controls and envelope improvements to significantly reduce electricity and gas consumption and utility bills. This work will also contribute to student and teacher safety, health, and productivity. It appears that this program offers feasibility studies and energy efficiency advice to boards, and no direct incentive is provided.

The City of Toronto Better Buildings Partnership (BBP) retrofit program offers incentives to multi-residential, institutional and municipal (including schools) [building owners] for electricity savings. The program provides $400/kW of demand or $0.05/kWh of electricity savings. The program does not have a prescriptive component, and energy or demand savings are evaluated on a case-by-case basis. Portable classroom controllers would fall under the Building Automation System category. Calculated savings would automatically be reduced by 25% to account for uncertainties in the calculation.

3.0 Energy Simulation Results

An energy analysis was done on a portable design from a GTA school board to evaluate the energy savings of installing smart controllers in portable classrooms conditioned with both unit ventilators and electric baseboards.

3.1 Development of Portable Model

The base model was developed from a recent portable design provided by School Board No. 3 Architectural, mechanical and electrical drawings were provided. The design details are summarized below:

Area	65 m² (700 ft²)
Occupancy	30 people (based on drawings)
Envelope	Walls: gross area = 86 m², RSI = 2.6 m² °C/W (based on drawings) Roof: gross area = 65 m², RSI = 3.7 m² °C/W (based on drawings) Windows: Area = 3.6 m² (% fenestration = 4%). Assumed wall with windows was north facing. Also assumed windows are double glazed, 13mm air-space, e=0.1, alum. w/ thermal break, operable (Uvalue = 2.77 W/m² °C) Floor above ground: gross area = 65 m², RSI = 4.0 m² °C/W (based on drawings) Doors: area = 4.2 m², RSI = 1.2 m² °C/W (based on drawings)
Lighting	2-tube 1'x8' fluorescent from drawings. Assumed to be T8 with electronic ballast.
HVAC	Unit Ventilator with 15 kW of heating and 7.3 kW (24.9 MBH) of DX cooling. 400 L/s supply air with 212 L/s design OA (based on drawings). Fan power not given – assumed ½" (125 Pa) total pressure drop at 40% combined efficiency.

Based on discussions with school boards, portable manufacturer and the Log-One contact, it appears that most unit ventilators are not equipped with separate outside air dampers to control when outside air introduced by the system. Under such a strategy, outside air is brought in when the unit ventilator is cycled on to maintain the set-point temperature.

This was modelled in DOE by changing the outside air schedule generated by EE4 from 0.0 during periods when the fan is off to the actual outside air fraction. However, this was complicated by another DOE [software] bug. When fans are cycled on to maintain the unoccupied set-point temperature, DOE assumes they are on for the entire 1-hour period. With this portable design, the outside air represents >50% of the supply flow rate, adding a significant energy load to the building. A work-around was implemented to estimate the monthly unoccupied run fraction and the outside air rate during unoccupied periods was adjusted accordingly.

One of the difficulties in developing the base model was determining the schedules that dictate how the portable is to be operated. This is the most important factor in determining the energy saving potential of smart controllers. How the heating and lighting is controlled by the occupants will have a significant impact on the savings.

Schedules were based on a before and after study of occupancy sensor controls (Florida Solar Energy Center discussed in Section 2.3) and feedback from school board contacts. In reality, it is impossible to define a single set of schedules to represent all-possible manually controlled scenarios. But the schedules developed are considered to be a reasonable schedule based on our contacts with local school boards and measured data provided in the Florida Solar Energy Center study.

The base (manual thermostat) portable schedules are defined as follows.

- Occupants: Filled to 90% capacity during the day (9 a.m.—4 p.m.) with nobody in the room at lunch (noon—1 p.m.). No occupancy during weekends and holidays.
- Lighting: Turned on at 9 a.m. when class is assumed to start. Turned off at 6 p.m. by caretaker. No lighting is used on weekends and holidays.
- Receptacle and Process: On during class time 9 a.m.—3 p.m.
- Fans: On from 6 a.m.—4 p.m. on weekdays only, cycles to maintain room temperature during unoccupied hours.
- Cooling: Set point of 24°C used. No setback assumed. No cooling during summer and holidays.
- Heating: Set point of 22°C used. No setback assumed during school week. A setback of 15°C is assumed for holiday periods. This assumes teachers and maintenance staff will not set back the thermostat manually at the end of each day. Manual thermostats would likely not have any connection to the school's building automation system (BAS), even if the school is equipped with one.

An intermediate simulation was performed where the portable's HVAC unit was controlled by a programmable thermostat. Many portables have been retrofitted with programmable thermostats and it is expected that most new portables are equipped with at least programmable thermostats. All parameters except for operation schedules are the same as the base model.

Programmable thermostat schedules

- Occupants: same as base model.
- Lighting: same as base model.
- Receptacle and Process: same as base model.
- Fans: same as base model.
- Cooling: Set point of 24°C used from 6 a.m.—4 p.m. No cooling during non-occupied hours. No cooling during summer and holidays.
- Heating: Set point of 18°C is used at 6 a.m. (morning start-up) and 22°C is used from 7 a.m.—4 p.m. A setback of 10°C is used during non-occupied hours and holidays (same as smart controllers).

The smart controller case was modelled by assuming tighter HVAC and lighting controls to building occupancy. It was assumed that in the case of the programmable thermostat it would require longer buffer to account for the odd time when staff or students were in class earlier or later than the expected schedule.

All parameters except for operation schedules are the same as the base model. A shorter fan schedule and occupied set-point temperature schedule is used to simulate the occupancy-based control of the smart controller compared to the programmable thermostat model. A shorter morning warm-up cycle is simulated by turning the fan on at 7 a.m. compared to 6 a.m. for the other two models.

Smart Controller/Occupancy Sensor Schedules

- Occupants: same as base model.
- Lighting: Turned on at 9 a.m. when class is assumed to start. Turned off at 4 p.m. by controller. No lighting used on weekends and holidays.
- Receptacle and Process: same as base model.
- Fans: On from 7 a.m.—3 p.m. on weekdays and is off at lunch (noon-1 p.m.), cycles to maintain room setback temperature during unoccupied hours.
- Cooling: Set point of 24°C used from 7 a.m.—3 p.m. with no cooling at lunch (noon-1 p.m.). No cooling during non-occupied hours. No cooling during summer and holidays.
- Heating: Set point of 22°C used from 7 a.m.—3 p.m. with a setback of 10°C during non-occupied hours and holidays.

Finally, a smart controller with outside air damper was modelled. This model simulates the controller ability to close the outdoor air damper of an HVAC system during unoccupied hours. There is no outdoor air introduced into the space when the unit cycles on/off to maintain setback temperature. All previous simulations introduce outdoor air anytime the fan is on, even in setback mode. All other parameters are the same as the smart controller simulation described above.

Simulations were also done for portable classrooms with electric baseboard heating. Three simulations were run; one with an ordinary thermostat, a second with a programmable thermostat and a third with the smart controller. Baseboard simulations did not include cooling or outdoor air supply since there is no presence of an HVAC system. Other than cooling, outdoor air and fan power, all parameters including operation schedules are the same as their unit ventilator counterparts.

3.2 Simulation Results

The tables below are a summary of the simulations performed in order to determine potential energy savings after installing smart controllers in portable classrooms. Simulations were done with classrooms conditioned by a unit ventilator as well as electric baseboard.

w/ Unit Ventilator

Model	Mbtu	kWh	% savings
Ordinary Thermostat	69.7	20420	
Program. Thermostat	53.7	15746	22.9%
Smart Controller	47.8	14009	31.4%
Smart Controller (no OA during cycle)	46.4	13581	33.5%

w/ Baseboards

Model	Mbtu	kWh	% savings
Ordinary Thermostat	41.2	12083	
Program. Thermostat	29.8	8729	27.8%
Smart Controller	28.4	8324	31.1%

As can be seen from the results, the unit ventilator consumes substantially more energy than the baseboard case. This is due to the large amount of outside air introduced by the unit ventilator system and to a lesser degree fan power and cooling done by the unit ventilator.

Based on the School Board No. 3 portable design, 212 l/s of outside air is supplied by the unit ventilator. This is 7.1 l/s/person (15 cfm/person). Assuming 2.6 metres inside height (8.5 ft), the volume of the classroom is 168 m^3 (5,950 ft^3); 212 l/s of outside air is equivalent to 4.5 air changes per hour (ACH) which represents a substantial load on the heating system.

As described in Section 2.1, School Board #3 reported the energy use of three portables with baseboard heaters and manual thermostats as 11,706 kWh/year and energy savings from the smart thermostat of 36%. The energy model predicted base energy use of 12,083 kWh (baseboards with manual thermostat) and 31.1% savings.

The model results compared less favourably with the School Board No. 1 study of 21 portables at one school. That monitoring study suggested average electricity use of 34,670 kWh per portable (17 with unit ventilators and four with baseboards) for only seven months of the year (September to March). This is much higher than the model predictions of 20,420 kWh for a manual thermostat with unit ventilator. The monitored percent savings were 27.4% versus 31.4%-33.5% predicted by the model. It is possible that the monitored portable electricity includes other school services (e.g., exterior lighting). This was not confirmed with the school board.

If the existing portable is controlled by a manual thermostat, savings in the 31% range can be expected by the implementation of a smart controller. This is consistent with the School Board No. 2 and No. 3 studies which report 27%-36% electricity savings with a manual thermostat base case. The analysis also shows that if the portables are already controlled by a programmable thermostat (with the same setback temperature as the smart controller), the savings are significantly smaller: 11%-14% for a unit ventilator and 5% for baseboard heating. The programmable thermostat captures most of the savings of a smart controller if temperatures are also set back to the 10 °C range during unoccupied periods.

A further 3% savings is possible in the unit ventilator case, if the occupancy sensors can provide independent control of the outside air using a damper.

3.3 Regional Impacts on Energy Savings

The model was also run in Vancouver, Calgary and Montreal to evaluate how much the energy savings varied regionally. The results of this comparison are described below.

Unit Ventilator c/w control of Outside Air Damper

City	Ordinary Thermostat		Smart Controller		Savings	
Area	Mbtu	kWh	Mbtu	kWh	kWh	%
Toronto	69.7	20,420	46.4	13,581	6,839	33.5%
Montreal	82.1	24,058	53.4	15,639	8,419	35.0%
Calgary	79.0	23,149	52.5	15,375	7,774	33.6%
Vancouver	50.0	14,661	34.4	10,072	4,589	31.3%

Baseboards

City	Ordinary Thermostat		Smart Controller		Savings	
Area	Mbtu	kWh	Mbtu	kWh	kWh	%
Toronto	41.2	12,083	28.4	8,324	3,759	31.1%
Montreal	47.1	13,809	32.9	9,629	4,180	30.3%
Calgary	47.6	13,932	33.3	9,756	4,176	30.0%
Vancouver	30.4	8,893	19.1	5,602	3,291	37.0%

As expected the kWh savings are highest in locations with the largest heating requirements (Montreal) and lowest in locations with the lowest heating requirements (Vancouver).

4.0 Other Energy Efficient Measure Applicable to Portable Classrooms

Through the literature search, contacts with local boards and the energy analysis, a number of other potential measures were identified that could be applied to portable classrooms. Although there are a large number of measures that could be implemented in portables (e.g. insulating, replacing windows), only those with the largest impact on energy savings and appearing to be the most cost-effective are summarized below.

Retrofit older T12/magnetic ballast lighting technology with T8/electronic ballasts: Two of the school boards contacted indicated that some portable lighting retrofits have taken place, but that there were still schools using T12/magetic ballast lighting. Lighting savings will be partially offset by an increase in heating energy during heating season, since waste heat from lighting reduces the heating load.

Control outside air intake separately from unit ventilator fan: All but one of the persons contacted indicated that the outside air intake did not have a separate damper to shut off the outside air during unoccupied periods (when the fans would cycle on to maintain the thermostat set point). Based on the energy analysis done during this study, the savings of this measure would be approximately 1,400 kWh per year in the base case unit ventilator model with a manual thermostat (Note: this was an intermediate step in preparing the final simulation result and not reported elsewhere in this study). In the same portable controlled by a smart thermostat/occupancy sensor, the savings would be 430 kWh as reported in Section 3.2. Although this control strategy is common in larger commercial equipment, it is not clear what the difficulties would be in implementing this measure in an existing portable. It may be more cost-effective to simply replace the unit ventilator with one that is equipped with an outside air damper. At the very least, this should be a minimum requirement for new portables and is worth further investigation in existing portables.

Install an HRV to preheat outside air: Given the extremely large quantities of outside air in classroom portables and the large portion of heating load that it represents, this is a worthwhile measure. A quick analysis on the portable examined in this study indicate an HRV with an effectiveness of 60% would save 6,800 kWh in the manual thermostat portable and 4,400 kWh in the smart thermostat/occupancy sensor portable (both values are for the case with the unit ventilator). This has been implemented on some portables at School Board No. 2. This measure is also worthy of further investigation.

Reduce air leakage: In the Washington State University Extension Energy Program, it was found that air leakage was a major component of heat loss in portable classrooms, particularly more recent models manufactured with T-Bar dropped ceilings. Installing an air barrier above the T-Bar ceiling and performing a blower door test to identify other leakage paths would be worth implementing. This would likely be limited to portables with unit ventilators, since a certain amount of infiltration would be necessary in the unventilated baseboard portables.

5.0 Summary

This study estimated the energy consumption of typical portable classrooms and the potential energy savings of installing a smart controller (such as Log-One) for a typical school portable with both unit ventilators and baseboard heating in the Toronto region.

A literature search was done to identify any published studies that evaluated the potential of smart controllers. Only one published study was identified, which found that a smart controller equipped with an occupancy sensor at portable classrooms in Florida resulted in approximately 22% lighting and HVAC savings. Unfortunately, this will have little relevancy for Canadian portables.

Two school boards in the Greater Toronto Area (GTA) compared portables controlled by manual thermostats with those controlled by Log-One smart controllers. Unfortunately, there was very little background information reported on these comparisons. The school boards were contacted to find out additional information about the comparisons (e.g. thermostats used in base portables, setback temperature of smart thermostats, type of heating system, was lighting controlled). This information made the results of these studies more useful. The reported energy savings from these studies were 27%-36% compared to a portable controlled with a manual thermostat where the temperature was not set back during unoccupied periods.

An energy model was created, based on a portable design from a GTA school board, to evaluate the energy savings of installing smart controllers in portable classrooms conditioned with [either] unit ventilators or electric baseboards. The savings of the smart controller/occupancy sensor over a manual thermostat with no setback during unoccupied periods was 31% for both unit ventilator and baseboard electric heating. If the unit ventilator is equipped with an outside air damper controlled by the smart controller/occupancy sensor, the savings would be 33.5%.

Energy consumption of portables varies based on location, use, occupancy, HVAC systems (unit ventilators or baseboards), lighting and existing controls (programmable thermostats). Modelled results for Toronto show annual energy consumption before retrofit ranging from 12,100 kWh (baseboard) to 20,400 kWh (unit ventilator) and energy savings ranging from 5% (base case of a baseboard unit with programmable thermostat) to 33.5% (unit ventilator with no setback controls and the smart thermostat controls the outside air damper).

The analysis also shows that if the portables are already controlled by a programmable thermostat (with the same setback temperature as the smart controller), the savings are significantly smaller: 11%-14% for a unit ventilator and 5% for baseboard heating. The programmable thermostat captures most of the savings of a smart controller due to temperature setback during unoccupied periods.

Through the literature search, contacts with local boards and the energy analysis, a number of other potential measures were identified that could be applied to portable classrooms. These measures include preheating outside air with an HRV, controlling outside air intake separately from unit ventilator fan, reducing air leakage and replacing T12/magnetic ballast lighting with T8/electronic ballasts.

Only one program was identified that provided a fixed incentive per smart controller. Puget Sound Energy in Washington State offers $250 incentive for a 365-day programmable thermostat installed in a portable classroom, with an additional $50 each for occupancy sensor damper controls and occupancy sensor lighting controls.

A 2006 letter from the President of Log-One (Hugues de Milleville) indicated that the installed cost of the Log-One EMS (including lighting control) was $900-$1,100 per portable.

Appendix A

Contacts with GTA School Boards, Portable Manufacturers and Smart Controller Manufacturer

Contacts for Portable Controller Study

Log-One Ltd.
Hugues de Milleville
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Relevancy: Manufacturer of controller in question

Questions:

1) Are Log-One controllers always set to control lighting and HVAC systems?

For portable classrooms: yes, almost always.

2) How do they control ventilation? From the HVAC designs we've investigated, the ventilation is hard-wired to the HVAC fan operation. So, during unoccupied hours, the ventilation still comes on if the heating comes on to maintain the unoccupied set point temperature (e.g. 10 °C).

[It} depends on customer needs but, for portable classrooms, most of the time ventilation is controlled and turned off during unoccupied hours even though heating or air-conditioning may be working.

3) How does the Log-One system control the temperatures during unoccupied periods? What is the setback temperature?

Setback is normally 10°C.

4) Do they use smart controllers? In other words, are they capable of learning how long it takes to warm up a portable and adjust the start-up time accordingly? Or are they standard programmable thermostats?

The controllers are very intelligent and unlike anything else on the market. Outdoor and indoor temperature is constantly monitored in real time. During unoccupied hours the controller's setback temperature is 10°C. Temperature is then slowly cranked up so that by 8:00 a.m. or 8:30 a.m. the temperature is 21°C.

If by 9:30 am the system does not detect any occupants, the system shuts off for the day. If this happens two days in a row, the system recognizes that the school is in an extended period of vacation and shuts off the system for one week and re-starts normal operation the following week.

Because indoor and outdoor temperature is monitored in real time, it can change the time that the morning heating starts in order to have the room ready for 8 a.m. at 21°C. This is unlike programmable thermostats which have a set time to start heating in the morning. It also starts heating by using half of the installed heating capacity to save on peak demand. Every operation is done to maximize energy savings.

5) Why were there so many saving in shoulder seasons September, October and March, but almost no savings in January for [one of the GTA schools]?

Most likely because they didn't adjust the billing for [heating] degree days.

School Board No. 1

Relevancy: Oversaw 21 portable classrooms at [one school] which were each outfitted with a Log-One controller.

Questions

1) Why was there so many savings in shoulder seasons—September, October and March—but almost no savings in January?

Not sure; it may have to do with the school calendar—students may have come back later from Christmas vacation in January in 2005/06. [Also] possibly there was temperature variation between years.

2) What were the heating systems of these portables (baseboard or forced air)? Was there ventilation to the portables?

16 [portables] had forced air with ventilation; and 4 had electric baseboards with manually controlled exhaust fans.

3) How was pre-retrofit heating/cooling controlled (i.e. was the thermostat programmable)? If heating was set back at night, to what temperature?

[Pre-retrofit heating cooling was] done with a manual thermostat. [There is] no guarantee that the temperature was ever set back [at night], although teachers and caretakers [may have been told] to set back the temperature on holidays and evenings.

4) After Log-One controllers were installed, to what temperature was the heating set back (e.g. 10 °C)?

At 4 p.m., the system shuts down and the temperature setback is maintained at 12°C overnight. Temperature is then slowly cranked up so that by 8 a.m. the temperature is 21°C. There is a manual switch on the thermostat that allows occupants to increase the temperature by 1°C to 2°C.

5) Did Log-One controllers also control lighting in portables?

Yes, by motion detector and door sensor.

6) Are the portables shut off during summer vacation?

Yes. Summer, March break and Christmas break periods are programmed so that the system is shut off / set back during those periods. Also, if by 9:30 a.m. the door has not been opened the system shuts off for the day. If this happens two days in a row, the system recognizes that the school is in an extended period of vacation and shuts off the system for one week and re-starts normal operation the following week. If [non-occupancy] continues, the system shuts off for a month.

7) Do all your new portables come equipped with these smart controllers?
Yes.

8) On new designs, does the ventilation intake have an on/off damper? Or is it just an intake and when the HVAC fans are running there is always ventilation. Specifically, when the HVAC unit is cycled on in the evening to maintain the temperature set point, is fresh air introduced to the space? Or does a damper shut off the ventilation and only return air is re-circulated?
[The board contact is] not sure, but even though he believes there is a damper, outside air is still always introduced into the space.

9) Have they implemented other energy-saving features in their existing portables?
They have converted some from T12 to T8 lighting. However, the ones in question are still T12.

School Board No. 2.
Relevancy: The board installed three Log-One EMS S2-95 controllers (equivalent to newer EMS S2-96 models) in portable classrooms at [one school] during October 1995 for evaluation. There was a reduction in energy use of 36% compared to standard line voltage thermostats.

Questions
1) The portables in question had 5 kW of baseboard heating. Was there any ventilation? If yes, how was it supplied?
No.

2) Does the school board have any more substantial reports on this study?
No

3) How were the baseline portables run? Was there a setback [practice]? Were lights shut off when the portable was unoccupied?
The [school board contact] is not sure, but does not believe there was a setback. However, [there was an effort] to keep lighting consumption the same between the controlled and non-controlled portables: lighting was turned off at night by caretakers.

4) To what temperature did the Log-One controller set back the unoccupied temperature?
The [school board contact] is not sure, but thinks it is around 15°C because that is close to the average setback used in their schools.

5) Have they implemented other energy-saving features in their existing portables?
[The school has] removed electric baseboards and now has Venmar ventilation units where outside air is introduced only during occupied hours. There is a setback of 13°C -15°C with a warm-up cycle the same [as the subject school in School Board No. 1], i.e. warming up so that by 8 a.m. the temperature is 21°C.

School Board No. 3

Relevancy: [The board contact] provided us with a portable design and has given us some feedback on how their portables are controlled.

Questions

1) Does the smart thermostat/occupancy sensor in the design you provided shut the heating/ventilating unit off or set back the temperature? If it sets back, to what temperatures? Are lights also controlled by the occupancy sensor?

The thermostat can be set back to a minimal temperature (10 °C).The lights are on manual switches.

2) This question would apply if the controls set back the temperature and heating is still provided in unoccupied mode. [It is] assumed there is no damper on the outside air intake, so when the heating unit is on, ventilation is provided.

Yes.

3) Do you know how lighting, heating and ventilation are controlled in existing portables at your board? [It is] assumed lighting is controlled by a switch and shut off at the end of the day. Is heating set back or turned off at night (manually or automatically)?

Yes, automatically.

4) Do you have portables with basic electric baseboards for heating? If so, is there any ventilation in these units?

Some older type portables have baseboard heaters with no vents.

5) [It is] assumed all portables (new and older units) are shut down in the summer (i.e. June 20--September 7). Is this a reasonable assumption?

Yes, temperatures are minimal but fire alarm and security still activated.

6) In existing portables, what type of lighting do you have (T8/electronic ballasts, T12/magnetic)?

All newer portables have electronic ballasts.

7) Have you implemented any other energy-efficient measures to existing portables (e.g. lighting retrofit)?

Some older portable lighting has been upgraded on an as-needed basis.

Follow-up question

1) [The contact] responded that older portables have the temperature set back automatically. Confirm that this is using programmable thermostats. Do they set back to the same temperature as the smart controllers (i.e.10 °C)?

Yes, programmable thermostats. Not sure what they were set back to before smart controllers.

NRB Portable Building Specialists (Portable Manufacturer)

Canadian Office - Grimsby, Ontario

Questions:

1) Are occupancy sensor/programmable thermostat controls standard design in new portables being sold?

No, they are an extra cost and it is a choice for the school board.

2) If not, what percentage of new designs are being sold with them?

Roughly 25%.

3) On new designs, does the ventilation intake have an on/off damper? Or is it just an intake and when the HVAC fans are running there is always ventilation. Specifically, when the HVAC unit is cycled on in the evening to maintain the temperature set point, is fresh air introduced to the space? Or does the damper shut off ventilation and only return air is re-circulated?

Outside air is always introduced into the space.

Letter from Hugues de Milleville (Log-One).

May 19, 2006

Please find above preliminary savings results for Log-One's energy management systems installed in classrooms at [a school in the Greater Toronto Area.]

These savings of close to $900 per classroom are only partial as the heating season is still far from being finished. Additionally, 17 out of 21 classrooms have air conditioning controlled by the Log-One which will bring further energy savings in the warmer months. (These savings are exclusively attributed to the Log-One EMS as there was no other energy management retrofit performed).

We do not know exactly how much the board paid for the installation; Log-One supplied just the EMS + peripherals. Usually in similar classrooms or portables, we budget between $900 to $1,100 for the EMS installation and for control of the lighting (as they did), which would represent a payback of one year or less.

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Appendix B

Puget Sound Energy
Portable Classroom Energy-Efficient Controls Rebate Program

Puget Sound Energy: Portable Classroom Energy Efficient Controls Rebate Program

Last DSIRE Review: 01/12/2009
Incentive Type: Utility Rebate Program
Eligible Efficiency Technologies: Programmable Thermostats
Applicable Sectors: Schools
Incentive Amount: 365-day programmable thermostat—up to $250
occupancy sensor damper control—additional $50
occupancy sensor lighting control—additional $50
Maximum Incentive: Payable only up to the cost of the project including labour.
Equipment Requirements: Thermostats must be 365-day programmable and have automatic daylight savings time correction and have battery backup in case of electricity interruption. Customers should see website for eligible models.
Project Review/Certification: Incentives are paid contingent that the equipment is properly installed and tested, and staff has been trained to program it.
Website:
http://www.pse.com/solutions/forbusiness/pages/comRebates.aspx?tab=5&chapter=3

Summary:
Puget Sound Energy's (PSE) Portable Classroom Controls Rebate program offers rebates to school customers who upgrade their portable classroom controls from 7-day programmable thermostats to 365-day programmable thermostats. Up to $250 is available for 365-day programmable thermostats, with an additional $50 each for occupancy sensor damper controls and occupancy sensor lighting controls. The amount of the rebate is payable only up to the cost of the project including labour. To be eligible a thermostat must be 365-day programmable and have automatic daylight savings time correction and battery backup in case of electricity interruption. More information on potential savings and rebate requirements is available on the portable classroom rebate information sheet.

Contact:
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