Northwest Portable Classroom Project

Final Report

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WSUCEEP03_060

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Executive Summary

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. To meet this goal, the Project had three objectives:

- Offer technical assistance to portable classroom manufacturers, school districts and related organizations. Through field assessment, monitoring and analysis, investigate innovative building technologies to determine the value of specific energy saving features and building techniques.
- Serve as facilitators to help build support and develop collaborative agreements among regional utilities, Northwestern portable classroom manufacturers and materials and equipment suppliers, as well as school districts, state departments of education and their affiliates.
- Present workshops and other educational resources to further advance the widespread adoption of energy efficient portable classrooms in school districts nationwide.

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/vapor 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.

Recommendations

- 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/vapor 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 systems 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.

For additional information on the study please contact:

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Northwest Portable Classroom Project

Final Report

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 substantial and cost-effective. The Project had three objectives:

- Offer technical assistance to portable classroom manufacturers, school districts and related organizations. Through field assessment, monitoring and analysis, look at innovative building technologies to determine the value of specific energy saving features and building techniques.
- Serve as facilitators to help build support and develop collaborative agreements among regional utilities, Northwestern portable classroom manufacturers and materials and equipment suppliers, as well as school districts, state departments of education and their affiliates.
- Present workshops and other educational resources to further advance the widespread adoption of energy efficient portable classrooms in school districts nationwide.

The Project was implemented by the WSU Energy Program, in conjunction with the Oregon Office of Energy and the Idaho Division of Energy Resources. Other partners include the Florida Solar Energy Center (FSEC), Pacific Northwest National Laboratory (PNNL), school districts in Portland, Oregon; Boise, Idaho; and Marysville, Washington, regional utilities, portable classroom manufacturers and other stakeholders in the Pacific Northwest.

The Project was part of the US Department of Energy's Building America Industrialized Housing Partnership (BAIHP), which seeks to increase the energy efficiency of industrialized housing, while enhancing indoor air quality, durability, and productivity.

School Partnerships

Pinewood Elementary

Figure 1: Energy Efficient Portable Classroom – Pinewood Elementary School, Marysville, Washington

An 895 ft^2 portable classroom (P5) was sited at the Pinewood Elementary School in Marysville Washington, in August 2000. This unit exceeds current Washington State Energy Code standards, with upgraded insulation in the floor, roof and walls, low E windows, and a sensor-driven ventilation system that detects volatile organic compounds (VOC). A second portable, built in 1985, and also located at Pinewood Elementary (P2), served as the control unit.

Energy use comparisons of the two classrooms show that the energy efficient portable used considerably more energy than the control portable. This was attributable to several factors:

1. Originally, the exhaust fan was hard-wired to the ventilation system that was controlled by a VOC sensor School district maintenance staff disconnected the exhaust fan from the ventilation control during the first year of the study and hard-wired it into the breaker box. The upshot of this is that the exhaust fan ran 24 hours a day, non-stop, until BAIHP staff turned it off at the breaker box (in the summer, when school was out.) The exhaust fan was subsequently re-connected to the ventilation system control, and energy use declined as a result.

   To remedy this situation, BAIHP staff proposed that Marysville school district staff remove the current ventilation controls, and replace them with an occupancy sensor driven control for the ventilation system, and a programmable thermostat for the heating system. The heating system should also be equipped with a simple on/off switch to turn off the system during the summer and other school vacations.

2. The programmable thermostat was not programmed for holidays and vacations resulting in high energy consumption.

3. Blower door testing found twice the air leakage in the energy efficient classroom - 19 ACH @ 50 PA than the control classroom - 9 ACH @ 50PA. Additional blower door, smoke stick and APT pressure tests indicated that the predominant leakage path was from the classroom through the T-bar ceiling and into the vented attic. The leakage was a result of an ineffective air leakage barrier. The P2 portable uses a taped ceiling drywall, greatly reducing air leakage through the ceiling.
   BAIHP staff proposed design changes to the local portable classroom manufacturer, including the possible use of SIPs, elimination of the vented attic, tightening the existing ceiling air barrier and sheetrocking the ceiling.

4. The HVAC supplier and the school district did not initially commission the HVAC control in the energy efficient portable classroom. This led to comfort problems resulting in the teacher using plug-in electric heaters during the winter of Year 2. This problem was identified from conversations with teachers and in a review of energy use monitoring data. The monitoring data indicated significant temperature variations and high plug-load energy usage.

   In Year 3, alterations were made to the HVAC system (including re-wiring, replacement of the ventilation system's VOC sensor with a CO_2 sensor, and modifications to other aspects of the HVAC control system) by school maintenance staff, district maintenance staff, and the HVAC system supplier. Calibration testing done by scientists at the Florida Solar Energy Center on CO_2 sensors showed significant drift in output results. Staff from WSU, OOE and IDWR are recommending that occupancy sensors be used in place of CO2 sensors.

5. Another problem with the energy efficient portable, related to indoor air quality, is that the fresh air intake and exhaust fan are positioned in such a way that they create a "short circuit" of fresh air, bypassing the students and teacher. BAIHP staff have proposed locating the exhaust

fan for future portables on the wall opposite the supply air vent.

The experiences working on the energy efficient portable were instructive, particularly in the identification of flaws in portable classroom design. The difficulties that BAIHP staff encountered demonstrate the importance of well-defined commissioning protocols, documentation, and coordination among all personnel that service and install HVAC equipment.

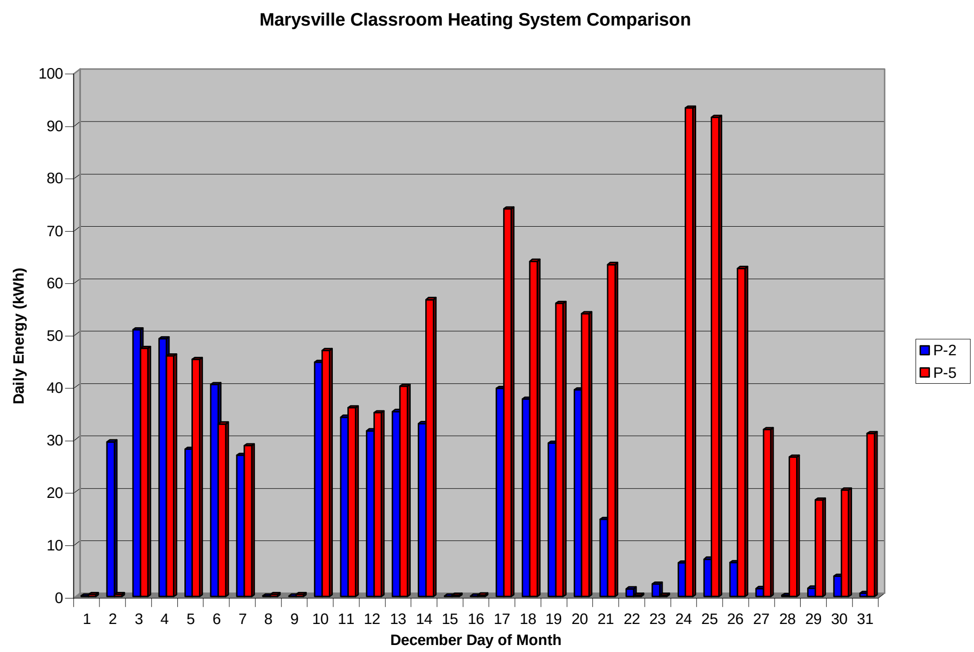

Figure 2: Comparison of heating system use between Pinewood control portable classroom (P-2) with energy efficient portable (P-5). Note efficient portable's high energy use during the Christmas holidays due to incorrectly configured heating system controls.

<u>Boise School District Retrofit</u>

Figure 3: Weather monitoring system installation – Boise portable classroom

BAIHP staff located a portable classroom at the West Boise Junior High School in the Boise Idaho School District, occupied by a teacher who was interested in having the classroom monitored and retrofitted. The teacher is also an Idaho State legislator active in education issues, so the chance of the project results having impact was increased.

BAIHP staff performed a field testing, and installed data logger monitoring equipment to track the classroom's energy use during Year 1. In Year 2, the classroom was retrofitted with an efficient HVAC system (controlled by CO_2 sensors), lighting and envelope measures. The classroom was then retested, and monitored for the rest of the year.

BAIHP staff worked with Pacific Northwest National Laboratories (PNNL) on the pre- and post-retrofit audits, and installation of the monitoring equipment. In their capacity of providing energy management services to the school district, the local utility, Avista Corp., collected lighting and occupancy data.

The classroom was retrofitted in the summer of 2001. Monitoring data indicates a reduction of 58% in energy usage post-retrofit. Blower door tests indicate a reduction in air leakage from 9 ACH at 50 PA to 5 ACH at 50 PA.

The cost of the retrofit was $9,892.

Monitored CO_2 data suggests that the CO_2 sensor that controls the HVAC system is not correctly configured. The system does seem to react to an increase in CO_2 levels early in the day, but does not remain on; CO_2 levels only begin to significantly dissipate after 1 p.m. BAIHP staff have noted the difficulty of correctly configuring these sensors in other monitored classrooms.

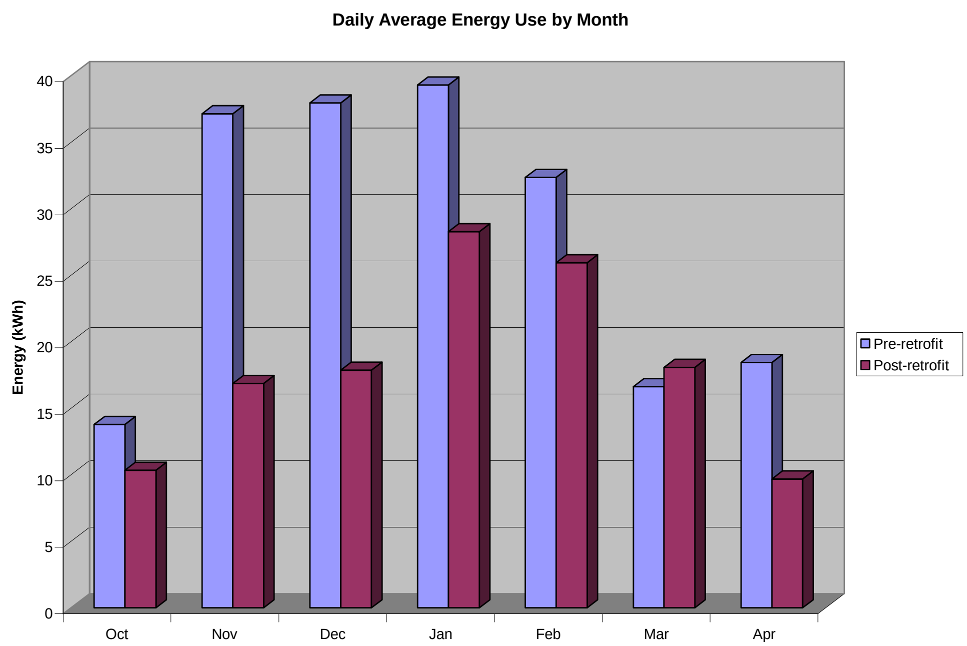

Figure 4: Average daily energy use in Boise portable, pre- and post-retrofit.
Note that energy use dropped by 31% post-retrofit. Data revealed that heating use actually increased on weekends and holidays because of lack of internal heat gains and because the HVAC control systems are not programmed to shut off on weekends and holidays.

Oregon Schools

Oregon BAIHP staff worked with the Portland Public School District to procure two energy efficient classrooms. The classrooms were constructed to specifications determined by BAIHP staff. The specifications include increased insulation levels in the envelope, high efficiency windows, transom windows designed to increase daylighting. BAIHP staff videotaped the construction process for one of the classrooms.

The classrooms were delivered and sited in September 2001. During set-up, BAIHP staff noted inadequate sealing at the marriage line.

Monitoring equipment was installed by PNNL staff. Estimates using the software Energy-10 indicate a total energy consumption of 9200 kWh, or $583 per year at Portland energy rates. Measured results showed the Oregon portable used about 6600 kWh for the monitored period.

Incremental costs for the energy efficiency measures were $6,705 over Oregon commercial code, including approximately $2,500 for the HVAC system. This suggests a simple payback of 10-12 years.

Initial blower door tests indicate air leakage rates of 11.3 ACH at 50PA. BAIHP staff also identified significant leakage in the attic at the marriage line, like due to inadequate sealing during set-up.

Monitoring results indicate the same HVAC control problems exist with the Oregon classroom as with the others studied in this project.

A survey sent to teachers and maintenance staff indicates a high degree of satisfaction with the efficient portables; the teachers were most impressed with the improved indoor air quality and increased light levels due to the daylighting windows.

Outreach to other school districts included involvement in numerous meetings, including the Oregon School Facilities Managers annual meeting, and the Oregon Association of School Business Officials annual meeting.

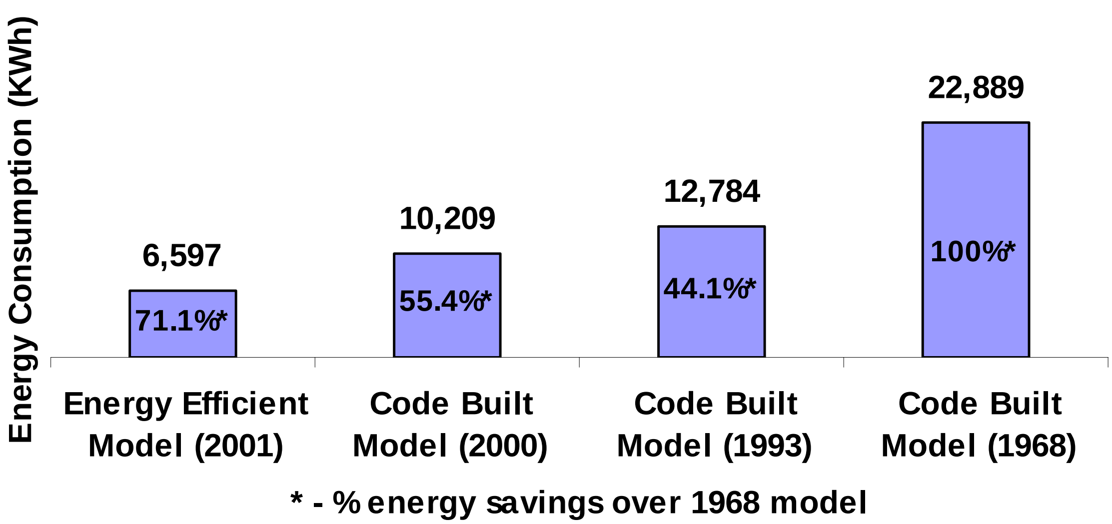

Figure 5: Measured Energy use in Oregon efficient portable classroom, compared to existing classrooms.

The Energy Efficient model outperformed code level models in the Portland area. The older the classroom, the more energy consumed. Even compared with new code level models in the same year, the Energy Efficient model used 35% less energy. Conventional code level classrooms do not include energy efficient measures, greatly increasing operating costs. Classrooms built more than 10 years ago use twice as much energy compared to the efficient model, and those older than 20 years consume more than 3 times the amount of energy. High performance classrooms can save anywhere from $200 to $1000 dollars a year in energy costs when compared to less efficient models.

Additional Outreach

BAIHP staff authored and submitted an article on the portable classroom project for publication in the Rebuild America/Building America Partner Update newsletter.

BAIHP staff also worked with the North Thurston School District to troubleshoot a portable classroom in Lacey, Washington. The classroom was experiencing high energy use and poor indoor air quality. BAIHP staff tested the classroom, made recommendations (including marriage line sealing and opening the supply dampers), and discussed the specification development process with district staff.

Workshops

In Year 2, BAIHP staff hosted the Smart Portable Classroom Collaborative Workshop in Portland, Oregon. This was the first opportunity for national experts in portable classroom design, construction, siting, and end use to come together and discuss energy-related issues.

No additional workshops were held in Year 3, as the specifications were still being developed. In Year 4, BAIHP staff will meet with district procurement staff, maintenance personnel, administrators, manufacturers, suppliers, and other interested parties to disseminate the specifications once they are finalized.

Findings

Comparative Energy Usage in Portable Classroom Study

School Year 2000-2001

Location	Total Electric Use (kWh)	Space Heating Use (kWh)	Heating Degree Days (HDD)	kWh (Space Heating)/HDD	Period
Boise	5911	3861	5670	0.68	October - April
Marysville P2 (Control)	7468	6255[2]	4246	1.47	October - April
Marysville P5 (Efficient Model)[1]	7975	4688	4246	1.10	October - April

	Total Electric Use (kWh)	Heat Pump East (kWh)	Heat Pump West (kWh)	Heating Degree Days (HDD)	kWh (Space Heating)/HDD	Period
Portland	5363	1849	1804	4257	0.43[3]	November - April

School Year 2001-2002

Location	Total Electric Use (kWh)	Space Heating Use (kWh)	Heating Degree Days (HDD)	kWh (Space Heating)/HDD	Period
Boise	3833	2480[4]	5287	0.47	October - April
Marysville P2 (Control)	5624	4092[2]	4475	0.91	October - April
Marysville P5 (Efficient Model)	9367	6751	4475	1.51	October - April

Figure 6: Comparative Energy Usage in Portable Classroom study. .

Notes

1. In the 2000-2001 school year, the teacher in P5 (efficient classroom) brought in small portable heaters; this offset space heating, and made for excessive plug loads. The portable heaters were not in use during the 2001-2002 school year.
2. The significant difference in space heating use in P2 between the two school years can be explained by the fact that the thermostat was set-back manually at the end of the day during the 2001/2002 school year.
3. The Portland portable had the lowest energy use of all the portables monitored during this project, adjusted for climate (0.43 kWh/HDD ratio).
4. The Boise Portable data shows a 58% reduction in space heating use due to the retrofit measures.

- Portable classrooms in the NW are occupied about 1225 hours per year, or about 14% of the total hours in a year.
- Most portable classrooms are constructed of standard materials at a construction facility that comprises low mass in classrooms (chairs, desks, wallboard, carpeted flooring).
- The average number of occupants in the standard 28' X 32' portable classroom provide internal heat of about 480 kWh/yr, or 8 – 10 % of space heating requirements.
- Even though most portable classrooms are not constructed to maximize energy loss they still have relatively low energy consumption due the items listed about. The energy use ranges from 4000kWh/yr to 9700 kWh/year.
- Most of the heat loss in portable classrooms manufactured after 1985 is by air leakage through T-Bar dropped ceilings that do not use a sealed air/vapor barrier. This phenomenon is due to the utilization of a dropped T-Bar ceiling in place of the more expensive sheet rock used in older portables. 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.
- Because all portables tested in the project used a simple 7 day programmable thermostat, the HVAC systems are operating on weekends, vacations and holidays which greatly increases the electricity consumption.
- The energy codes in Washington, Oregon and Idaho are high enough to make beyond-code envelope measures non cost-effective.
- Older portable classrooms that are being considered for removal and disposal can be retrofitted with new energy efficiency measures at much less than the cost of a new portable classroom. Low e, vinyl framed windows; insulated doors; T-8 light fixtures; and caulking and sealing air leaks can all be cost-effective when refurbishing older portable classrooms. New HVAC systems being replaced in older portable classrooms will be the biggest single cost item and can cost anywhere from $4500 to $6500. A significant decrease in space heating can be attained by utilizing these measures.
- CO_2 sensors appear to be unreliable as a control strategy. CO_2 sensors installed by the field crews and monitored by data loggers did not match the readings being shown by the CO_2 sensors that controlled the ventilation systems in the portable classrooms. CO_2 sensors tested by staff at the Florida Solar Energy Center went out of calibration rather quickly after being installed.

Recommendations

Based on the data analysis the following measures are recommended:

- 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/vapor barrier above the T-Bar system 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. Make sure there is adequate ventilation between the insulation and the roof.
- Conduct an audit of the older portables scheduled for disposal to determine if retrofitting them will be cost effective.
- 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.

Guidelines

Based on the experiences of the project, BAIHP staff produced guidelines for procurement, set-up, and commissioning of new portable classrooms, as well as guidelines for the retrofit of existing classrooms. These guidelines are included in the Appendices of this report.

Appendices

- **Appendix A - New Construction Procurement Guidelines**
- **Appendix B - New Construction Set-up Guidelines**
- **Appendix C - New Construction Commissioning Guidelines**
- **Appendix D - New Construction Set-up/Commisioning Checklist**
- **Appendix E - Retrofit Guidelines**

APPENDIX A
BUILDING AMERICA EFFICIENT PORTABLE CLASSROOM PROGRAM

NEW CONSTRUCTION PROCUREMENT GUIDELINES FOR THE PACIFIC NORTHWEST

DESIGN QUALIFICATION AND CERTIFICATION:

General: Electrically-heated and combustion fuel heated portable classroom buildings shall be built to Building America's Energy-Efficient Portable Classroom Program specifications. Implementation of these in-plant specifications, set-up specifications commissioning, maintenance and operation specifications will help ensure lowest life cycle costs, maintain acceptable indoor air quality and comfort standards and provide a suitable learning environment.

These specifications have been developed with support from the US Department of Energy's Building America Program partners and the Oregon Office of Energy, the Idaho Energy Division of the Department of Water Resources and Washington State University Energy Program.

Additional information is available at: http://www.BAIHP.org

Technical assistance regarding these specifications is available from:

- Washington State University Energy Program - Michael McSorley: (360) 956-2008
- Idaho Department of Water Resources, Energy Division – Bob Minter: (208) 327-7970
- Oregon Office of Energy – Betty Merrill/Justin Klure: (503) 373–1581

APPENDIX A
BUILDING AMERICA EFFICIENT PORTABLE CLASSROOM PROGRAM

NEW CONSTRUCTION PROCUREMENT GUIDELINES FOR THE PACIFIC NORTHWEST

Table 1. Recommended Portable Classroom Specifications

Component	Description	Component U-factor	Nominal R-value
Ceilings	Flat	U-0.036	R38
	Sloped	U-0.033	R30
Walls	Above Grade	U-0.065	R19
Floors	Steady State	U-0.041	R30
Glazing		U-0.37[1]	n/a
Skylights		U-0.5[1]	n/a
Exterior Doors[2,3]		U-0.19	n/a
Building Tightness	Tested to achieve air tightness of less than 8.0 ACH @50PA.		
Ductwork Tightness	Tested to ensure total leakage rate of less than 30 CFM @ 50PA.		
Ductwork Design and Materials	All ductwork shall be located within the pressure envelope. Metal ductwork shall be sealed with water-based mastic. Duct-board shall use water based mastic and/or UL181AP tape. Tapes shall be installed per manufacturer listing instructions.		
Lighting	All interior ceiling lighting shall be rapid start T-8 fluorescents with electronic ballasts with a CRI of 75. The controls shall be an on-off switch for each bank of lights.		
Quality Control	The manufacturer's quality control inspector shall certify that each building meets or exceeds all requirements of these specifications. An authorized state plant inspector shall verify that each building has been inspected at least once during its construction and that the inspected measures meet or exceed the requirements of this specification. School district personnel are also encouraged to inspect these classrooms during site set up.		

[1]NFRC tested U-factor
[2]Door frame shall be of thermally improved material(s).
[3]Up to 1 ft^2 of security glass is allowed in doors.

THERMAL EFFICIENCY:

General Insulation: All insulating materials shall be installed according to the manufacturer's instructions to achieve proper densities, minimize voids and maintain uniform R-values.

Clearances: Where required by applicable codes, or where specified in the following sections, proper insulation clearances shall be maintained.

Insulation installed around exhaust vents shall comply with manufacturer's recommendations.

All ventilation baffles in attics/roofs shall be moisture-resistant.

Ceiling Insulation: Ceiling insulation shall be installed to meet the nominal R-values specified in Table 1 or as approved.

Ceilings insulated with fiberglass batt insulation shall use full-width batts which cover the truss members and extend the entire attic length without visible gaps.

Insulation with a vapor barrier shall be installed to minimize compression–face-stapling is preferred over stapling to the side of the joist.

Wall Insulation: Insulation shall be installed to minimize compression and voids as a result of plumbing or wiring wall cavities.

Where structural conditions allow, headers over windows and doors shall be insulated.

Where structural conditions allow, insulation shall fill the cavity between corner studs and other wall structure materials.

Spaces around window and door frames greater than ½ inch shall be filled with an insulating material.

Insulation with a vapor barrier shall be installed to minimize compression–face-stapling is preferred over stapling to the side of the stud.

Floor Insulation: Floor insulation shall fill floor joists to the manufacturer's insulation density or greater.

Insulation shall be installed to minimize compression and voids as a result of plumbing or wiring in floor cavities.

Set-Up Kit: Manufacturer shall include an approved marriage line sealer, and instructions on how and where to install it.

Door and Glazing u-factors: U-factors for doors and glazing shall be determined certified and labeled in accordance with the National Fenestration Rating Council (NFRC) Product Certification Program (PCP), as authorized by an independent certification and inspection agency licensed by the NFRC.

Glazing: To improve ambient lighting, all portable classrooms built to these specifications shall have operable transom windows installed on one wall. There shall be a minimum of 18 square feet of operable transom windows installed.

In addition to the transom windows two standard vinyl framed windows shall be installed; one window on each side wall. Each window shall have a minimum of 12 square feet of glazing area.

Window frames and sashes shall be constructed of vinyl, wood or other approved materials. Vinyl frames and sashes shall be joined with external and internal welds.

Window Location: Windows shall be located on opposite to ensure passive cross ventilation.

Skylights: Skylights with a maximum of 16 square feet of surface area may be installed in lieu of transom windows provided they are double glazed with a minimum U-factor of 0.50. Up to 10ft^2 of non-NFRC rated solar daylight tube may be installed if it is sealed from the conditioned space, and has a tube wall insulated to at least R-19.

AIR LEAKAGE CONTROL

All buildings shall be sealed using the following standard air-leakage control method and approved sealants. An average air change rate of 0.35 air changes/hour shall be used to calculate thermal losses.

All buildings shall comply with the following prescriptive requirements, or as approved to achieve the tightness levels specified in the prescriptive path.

Windows: Tested air-leakage rates shall not exceed 0.3 cfm/linear foot.

Doors: Tested air-leakage rates shall not exceed 0.2 cfm/linear foot of perimeter.

Caulking and Sealing: All penetrations through the building envelope shall be caulked or otherwise sealed to limit air leakage, including the following:

- *Ceiling* – ceiling and roof insulation shall be installed with a complete air/vapor barrier installed on the warm side of the insulation, with all corners and seams sealed. Sealing can be accomplished using sheetrock tape and texture, or 6 mil plastic sheeting.
- *The floor and wall marriage line* - sealed using using gasket and non-porous silicon caulking, foam or closed cell backer rod
- *All window and door frames* - sealed to the building envelope. If the seal is made on exterior grooved siding, then the groove lines shall be sealed at the door or window frame.
- *Exterior-wall sole plates and the structural floor* - caulked using silicon caulking or approved alternate.
- *All receptacles, switches or other electric boxes in exterior walls* - sealed or fitted with outlet plate gaskets.
- *HVAC ducts* - sealed at interior surfaces where ducts penetrate the building envelope.
- *Around openings in the building envelope for HVAC and ventilation ducts, and wiring.*
- *All other penetrations in the building envelope*.

HEATING, VENTILATION AND AIR CONDITIONING (HVAC) SYSTEMS:

Design: Complete operation protocols and maintenance procedures shall be provided for all HVAC equipment. Procedures shall be written to be easily understood and implemented by facilities managers and teachers. Teacher operable controls shall be affixed with a permanent label listing control instructions.

Sizing: Heating systems shall be sized according to standard engineering practice, using an interior design temperature of 70°F and the standard ASHRAE winter design temperature (WDT) for the building location, or as approved. Cooling systems shall be sized according to standard engineering practice using ASHRAE Total Cooling Load calculation procedures (ASHRAE Fundamentals, Chapter 29).

Heat Pump Systems: Heat pumps shall have a minimum HSPF of 7.5 and air conditioning systems shall have a minimum SEER of 12.0

HVAC Controls: HVAC setback shall occur whenever the classroom is not occupied (at night, weekends, summer vacations and holidays). The ventilation system shall be controlled by an occupancy sensor in conjunction with an on-off switch that can be accessed by occupants. The occupancy sensor will shut off the system off 15 minutes after occupancy. The heating and air conditioning system will be controlled by a 24/7/365 programmable thermostat with a minimum set back of 50 degrees for heating during unoccupied periods. Thermostats are required to ensure correct operation for at least three days in the event of power outages.

Air conditioning: If both air conditioning and electric heat are required, a heat pump shall be used as the primary heating/cooling system.

Economizer: If air conditioning is not provided, economizer cooling is required

Ventilation Rates: Minimum ventilation airflows shall meet the requirements of ASHRAE Standard 62-1989 and state codes: 15 cfm per person.

Heat Recovery Ventilation: Heat recovery ventilation is recommended.

Ventilation Duct Insulation: All ventilation exhaust ducts shall be insulated to at least R-4.

OutsideAir Source: The outside-air source shall be located at least ten feet from exhaust vents to minimize drawing outdoor pollutants and excessive outdoor noise.

HVAC Ducts: To minimize noise and to provide conditioned air evenly to all occupants, ventilation and air conditioning shall be provided through a series of ducts.

Ductwork for HVAC systems shall be installed to comply with the equipment manufacturer’s static pressure specifications.

Ductwork shall be sealed using approved sealant as appropriate. Metal ducts shall be sealed with approved mastic. Duct board shall be sealed with mastic or UL181 pressure sensitive tape applied per UL listing.

Moisture Vapor Transfer: A vapor retarder of not more than 1.0 perm dry cup rating shall be installed in exterior walls, exterior ceilings and exterior floors. It shall be installed according to the manufacturer’s specifications on the warm side (in winter) of all insulation.

Attic Ventilation: Adequate attic ventilation shall be maintained above all ceiling insulation by providing both high and low vents for roof rafter installed insulation, or gable end vents for insulation installed above a T-bar ceiling.

At least 1 square foot of net-free vent area shall be provided for every 300 ft^2 of ceiling area with 50 to 60 percent of the vent area located near the roof ridge and 40 to 50 percent located near the eaves. A minimum clearance of one inch shall be maintained between attic insulation and the roof sheathing when soffit vents are used.

Exception: Attic venting is not required when Structural Insulated Panels (SIP) are used to create an un-vented "hot roof," or an unvented attic design is used. In the case of the use of SIPs, all panels shall be effectively sealed together.

APPENDIX B
BUILDING AMERICA EFFICIENT PORTABLE CLASSROOM PROGRAM

NEW CONSTRUCTION SET-UP GUIDELINES FOR THE PACIFIC NORTHWEST

General: The classroom shall be inspected on site to determine compliance with these specifications and manufacturer's instructions and/or local codes. An on-site set up guideline checklist shall be used to meet the following specifications.

Damage Repair: Damage occurring to factory-installed energy measures during transportation and setup shall be corrected. Any disturbance of insulation due to wiring or other on-site work shall be corrected.

Marriage Line: The ceiling marriage line shall be sealed using gasket and non-porous silicon caulking, foam or closed cell backer rod.

Exception: The marriage line need not be sealed if the attic ventilation is provided through roof cap venting, using the rafter marriage line as the ventilation path. In such a situation, however, there must be a vapor barrier installed between the T-bar ceiling and the attic insulation.

The floor and wall marriage lines shall be inspected to insure integrity during shipping, and replaced or repaired as necessary.

Window and Door Frames: Window and door frames shall be installed and adjusted (if needed) according to the original equipment manufacturers instructions to minimize air leakage and water penetration. Windows and doors shall be tested to ensure that they open and close easily and seal tightly, and confirm weather-stripping is correctly installed.

Other Penetrations: All penetrations in the building envelope, such as for piping, wiring, recessed fixtures in walls and ceilings, and exhaust-fan housings shall be sealed.

Ground Cover: A vapor retarder, consisting of 6-mil black polyethylene or approved linear low-density poly, shall cover the ground throughout the entire crawl space. All joints shall be lapped at least 8 inches.

Crawl Space Ventilation: Crawl space ventilation shall meet all applicable state or local codes.

HVAC System:

- If mechanical dampers are installed, they shall be opened to the 100% open position, or set to design specifications.
- A complete maintenance and operation manual shall be provided to the school facilities manager. The manager shall use this manual and keep records of M&O for each unit.

Appendix C
Building America Efficient Portable Classroom Program

New Construction Commissioning Guidelines for the Pacific Northwest

Commissioning ensures the proper functioning of the classroom's mechanical systems and envelope. Prior to the commissioning process, all parties should agree on the required tasks. After the portable classroom is set up on site the commissioning shall include at least the following items:

- All mechanical equipment shall operate properly in accordance with the operation protocol provided by the HVAC manufacturer. The setback controls shall be set to ensure temperature setback and ventilation system shut down during nights, weekends, holidays and summer vacations. If provided, the 24/7/365 programmable thermostat shall be programmed for set back for nights, weekends, holidays and summer vacations.

- Outside fresh air supply flow measurements shall be taken to ensure that the correct mechanical ventilation rate is provided at the appropriate outside damper settings. Exhaust air flow measurements shall be taken to ensure correct ventilation system flow rates are achieved if exhaust ventilation is employed as part of the ventilation system.

- Supply air-flow measurements shall be conducted to ensure the correct ventilation air-flow rates of 15 cfm per designed occupancy.

- If provided, exhaust fan air flow rates shall be tested.

- During each classroom installation, the first representative classrooms shall be blower door and duct leakage tested to the values provided in the prescriptive path. Additional testing is required until prescriptive path values are achieved.

APPENDIX D
BUILDING AMERICA EFFICIENT PORTABLE CLASSROOM PROGRAM

NEW CONSTRUCTION SET-UP/COMMISIONING CHECKLIST FOR THE PACIFIC NORTHWEST

	Set-up	Commissioning.
1. Roof/ceiling marriage line sealed with approved backer rod, caulk or foam.	__________	
2. Floor marriage line inspected to insure integrity, and repaired if necessary.	__________	
3. Wall marriage line inspected to insure integrity, and repaired if necessary.	__________	
4. Wiring and duct penetrations are sealed.	__________	
5. 24/7/365 programmable thermostat is properly programmed.	__________	
6. Heating/Ventilation duct dampers are opened to the 100% open position or set to design specifications.	__________	
7. A complete maintenance and operation manual is provided to the school facilities manager.		__________
8. Outside fresh air supply is tested to insure a minimum of 15 cfm per designed number of occupants		__________
9. Ventilation exhaust system is tested to insure the designed flow rates are provided		__________
10. HVAC system air flows are tested to insure that all designed air flows are met		__________
11. Occupancy controls are installed and operating to manufacturer's specs		__________
12. Duct flow measurements are tested and the duct system is balanced to ensure even flows from each diffuser and grill.		__________

BUILDING AMERICA EFFICIENT PORTABLE CLASSROOM PROGRAM

RETROFIT GUIDELINES FOR THE PACIFIC NORTHWEST

Purpose: To ensure the most energy-efficient operation of existing portable classrooms by providing efficient and cost-effective envelope, air sealing and control measures. Implementation of these guidelines will help ensure lowest life cycle costs, maintain acceptable indoor air quality and comfort standards while providing a suitable learning environment.

These guidelines have been developed with support from the US Department of Energy's Building America Program partners and the Oregon Office of Energy, the Idaho Energy Division of the Department of Water Resources and Washington State University Energy Program.

Additional information is available at: http://www.BAIHP.org

Technical assistance regarding these guidelines is available from:

- Washington State University Energy Program - Michael McSorley: (360) 956-2008
- Idaho Department of Water Resources, Energy Division – Bob Minter: (208) 327-7970
- Oregon Office of Energy – Betty Merrill/Justin Klure: (503) 373–1581

RETROFIT GUIDELINES FOR THE PACIFIC NORTHWEST

Introduction: The decision to retrofit an existing portable classroom with energy-efficient measures is a complex one. While the lack of energy-efficient envelope measures may result in costly utility bills and comfort issues, the cost of installing most measures will likely not be cost-effective. There are specific instances where it makes sense to retrofit:

- In the event of a portable classroom that is scheduled for removal and demolition, retrofitting the classroom may be extremely cost-effective, in that the cost for retrofit is much less than the cost for disposal.
- In the event that building components are replaced, they should be replaced with the most energy-efficient possible.
- There are specific measures that are always cost-effective, or are cost effective in most situations.

Table 1 lists the potential retrofit measures for portable classrooms, and identifies instances where retrofitting the building component may be appropriate. Details for specific measures are listed below the table.

Table 1. Recommended Portable Classroom Retrofit Specifications

Component	Description	Component U-factor	Nominal R-value	Recommended
Envelope Measures				
Ceilings	T-Bar Ceiling	U-0.033	R30	When existing insulation is R-11 or less, or if insulation is replaced
	Rafter	U-0.033	R30	When existing insulation is R-11 or less, or if insulation is replaced
Walls	4 inch	U-0.077	R13	If siding is removed or insulation is replaced
	6 inch	U-0.053	R19	If siding is removed or insulation is replaced
Floors	Joists	U-0.041	R30	If insulation is replaced
Glazing		U-0.37[1]	n/a	If glazing is replaced
Skylights		U-0.5[1]	n/a	If skylight is replaced
Exterior Doors[2,3]		U-0.19	n/a	If door is replaced
Air Sealing				
Penetrations in building envelope	All penetrations caulked or otherwise sealed to limit air leakage (see detail below)			As appropriate (see detail below)

Ceiling Air Barrier	T-bar drop ceiling	A 4-6 mil polyethelene air barrier shall be installed on the warm side of the insulation and caulked at penetrations, overlaps and at the outside edges of the ceiling/roof junction.	For all drop T-bar ceilings
	Roof rafter ceiling	A 4-6 mil polyethelene air barrier shall be installed under the insulation, stapled to the roof rafters, and sealed with caulk at the edges.	For roof rafter ceilings, if drywall is removed.
Mechanical Systems			
HVAC control	The HVAC system shall be controlled by a 365-day programmable thermostat equipped with an occupancy sensor for ventilation system control.		In all cases
Lighting	All interior ceiling lighting shall be rapid start T-8 fluorescents with electronic ballasts with a CRI of 75. The controls shall be an on-off switch for each bank of lights.		If fixtures are replaced

[1]NFRC tested U-factor
[2]Door frame shall be of thermally improved material(s).
[3]Up to 1 ft^2 of security glass is allowed in doors.

Glazing and skylights
As the total square feet of windows is usually small in most portable classrooms (approximately 48 $ft.^2$), it is not cost-effective to replace old windows unless seals have failed, admitting moisture from the exterior.

Penetrations through building envelope
All penetrations shall be caulked or otherwise sealed to limit air leakage, including the following:

- *All window and door frames* - sealed to the building envelope. If the seal is made on exterior grooved siding, then the groove lines shall be sealed at the door or window frame.
- *Exterior-wall sole plates and the structural floor* - caulked using silicon caulking or approved alternate.
- *All receptacles, switches or other electric boxes in exterior walls* - sealed or fitted with outlet plate gaskets.
- *HVAC ducts* - sealed at interior surfaces where ducts penetrate the building envelope.
- *Around openings in the building envelope for HVAC and ventilation ducts, and wiring.*
- *All other penetrations in the building envelope.*

Ceiling air barrier

Most of the portable classrooms built after 1990 do not use sheetrock ceilings; rather, they incorporate a T-bar dropped ceiling with tiles. This type of ceiling typically has no air sealing to control air leakage, and represents a major source of heat loss in the classroom.

To combat this heat loss, a 4-6 mil polyethelene air barrier shall be installed above the ceiling tiles and below the insulation. All penetrations through this air barrier shall be sealed with silicone caulking; the same shall be done for any overlaps and the perimeter of the air barrier.

Portable classrooms that have the ceiling insulation installed in the roof rafters shall have the air barrier installed under the insulation, stapled to the roof rafters, and sealed with caulk at the edges.

HVAC Control

Most of the portable classrooms in the Northwest region are controlled by 7 day programmable thermostats. The result of this type of control is that the HVAC system operates throughout the year, even during holidays and vacations. Even new units that were installed during the study exhibited this behavior.

In addition, many portable classrooms are controlled by CO_2 sensors. The BAIHP study determined that CO_2 sensors can be unreliable as a control strategy, since they go out of calibration easily, and many HVAC installers and school maintenance personnel do not have the proper equipment to calibrate them.

New low-cost, 365-day programmable thermostats are available, with occupancy sensor control for the ventilation system; they are highly recommended for all portable classrooms, regardless of age. Estimated simple payback for these thermostats is 2-3 years.