CODE CHANGE PROPOSAL FOR

High Performance Relocatable Classrooms

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Overview

Relocatable classrooms (RC's), also referred to as "portable" or "modular" classrooms, represent a unique opportunity for improving the energy efficiency of non-residential buildings in California. About 3,000 Relocatable classrooms are built annually in California by a group of less than twenty manufacturers.[1] RC's are factory-built often with more attention to first cost than to energy efficiency (about ten percent of the RC's are built to specifications of the Office of Public School Construction which call for more significant energy efficiency measures). School buildings have always been covered by the California Building Energy Efficiency Standards (Title 24, Part 6, Section 100(a)). However, until adoption of the *2001 California Building Code*, there was a lack of clarity in the Division of the State Architect's administrative regulations regarding the responsibility of school boards to ensure thatRC's and other school buildings comply with the Energy Standards. Currently, it is not uncommon for RC's to have features that fail to comply with Title 24, Part 6, including windows that are single glazed, lighting that is mostly T12 fluorescent, and deficient insulation (DEG and Consol, 1997)[2]. Wall mount heat pumps that are standard equipment in RC's typically meet minimum standards (SEER 10). However, the factory construction setting is conducive to rapid improvement in the energy efficiency of new RC's. Costs for improved energy efficiency measures can be minimized through volume purchase of components and the opportunity to standardize installation labor practices, and verification of quality installation of energy efficiency features can be easily added to current in-plant inspections.

There are two opportunities to significantly improve RC efficiency. First, the current Standards can be upgraded to include additional cost effective energy efficiency measures and to establish a more standardized set of requirements that relate more effectively to the unique construction processes of Relocatables. Second, compliance with existing and new standards must be effectively communicated to the RC manufacturers and must be effectively enforced. A number of current RC construction details often do not meet Title 24 energy efficiency Standards. These include lack of insulation on metal roof beams, high lighting power density, and high window U-values and solar heat gain coefficients. Additional measures that are potentially cost-effective include lowered lighting power density, adding insulation, using high performance windows, cool roofs (white roof coating), and adding skylights. Also, federal standards for air conditioner efficiency which are adopted by reference in the Standards will be upgraded effective in 2006.

The current regulatory structure is not set up to effectively enforce the Title 24 standards. The Department of General Services, Division of the State Architect (DSA) currently enforces structural,life safety and accessibility code requirements. DSA clarified in the 2001 *California Building Code* (CBC) that schools must meet Title 24, Part 6 (the Energy Efficiency Standards). . RC manufacturers are required to submit standard plans for RC's to DSA for plan check and approval. These standard plans are required to be upgraded whenever the *CBC* is revised to comply with the changes that have been made in the *CBC*. The 2001 *CBC* will be going into effect in the next few months, bringing with it the clear obligation for RC's to meet the 2001 California Energy Efficiency Standards. Standard plans will have to be upgraded to comply with the Standards. A second State agency, the Office of Public School Construction (OPSC), also has a role in construction of energy efficient RC's . OPSC contracts with RC manufacturers to provide RC's for the state's lease fleet (about 300-500 lease RC's built per year). OPSC currently has specifications that RC's purchased under this contract must meet.

The RC market consists of 4 markets sectors:

1) The Office of Public School Construction (OPSC) market, which accounts for about 300-400 units/year. RC units that are purchased by OPSC must meet the fairly efficient specifications that are currently in place;

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[1] Source E.V. Garcia, California Energy Commission. Recent class size reduction mandates created an increased demand for relocatable classrooms, resulting in a short term manufacturing rate as high as 10,000 annually.

[2] Steel beams located above the walls and t-bar ceiling are typically not insulated.

2) RC’s that are sold directly to districts according to district specifications, which currently may or may not be Standards compliant;

3) RC’s that are rented/leased by districts from the manufacturers/dealers. This sector includes RC’s that are furnished to meet a district specification (which may/may not meet the Standards) and those that are speculatively built to no particular district specification; and

4) RC’s that are stick built by a district and may or may not comply with the Standards.

The RC approval process depends on which of the above markets are involved. Both OPSC and DSA are involved if the RC’s are leased by OPSC. Otherwise OPSC is not involved. Districts are required to hire an in-plant inspector to inspect the RC’s for compliance with the building code during the construction process. Typically, the manufacturer will have an in-plant inspector that they often work with who the manufacturer will recommend that the districts hire.

Sometimes RC’s are manufactured without the manufacturer knowing where they will be sold or ultimately located. Usually, the manufacturer has no knowledge of the orientation in which the RC’s will be installed. For these RC’s there is no way for manufacturers to take advantage of energy efficiency measures in the Standards that are climate zone specific or orientation specific. Such RC’s would be required to meet the most stringent of the climate zone and orientation specific requirements in the Standards. RC’s built to withstand snow loads are specially labeled. Its conceivable that climate zone specific Standards requirements could be associated with the RC’s that are labeled for snow load, but current requirements in the Standards that apply to very cold climates where snow load labeled RC’s are used also apply to climates without major snow loads. An advantage of building RC’s to comply with the most stringent of the climate zone and orientation specific Standards requirements is that some RC’s (definitely a minority) are actually subject to being relocated. Also, building to the most stringent of the Standards’ climate zone and orientation specific requirements also allows the manufacturer to cut production costs by standardizing the components that will be built into the units.

RC’s that do not incorporate cost-effective efficiency measures represent a substantial opportunity for increasing energy efficiency relative to the savings opportunity of other new non-residential buildings types in California. The major goal of this effort is to develop a package of measures for RC’s which cost effectively save more energy and electricity demand than the current Standards. Other goals are to identify barriers and opportunities to improve enforcement, and to address specific ventilation and moisture issues.

School districts purchase RCs to provide added class space to existing schools due to population growth or mandated class size reduction (California State Education Code Section 52120). The majority of RCs in California are either 24’ × 40’ or 30’ × 32’ modular structures consisting of two or three modules or “floors” respectively. The modules are factory-built and then trucked individually to the site where they are assembled together. The necessity of highway transportability imposes certain design constraints such as maximum height and width, and structural integrity.

RC's are constructed using either a rigid steel frame or wood framing, with an increasing majority being steel framed. They typically have a single metal frame window on each end and one door. The walls are framed in wood and covered with plywood siding on the outside and architectural fabric covered gypsum board on the inside. They have standing-seam metal roofs and a dropped T-bar ceiling. The floor is plywood and is typically covered with carpet. The walls, floor, and roof are insulated with fiberglass batts.

Budget-constrained school districts necessarily acquire RC’s on a low bid basis often as part of a multi-school district contract. School districts lack the resources to determine which efficiency measure choices are cost-effective and therefore result in the lowest cost to the district for owning and operating the Relocatables. In addition, facilities budgets are often separate from operating budgets so that the higher initial cost of energy efficiency measures are typically not considered in the same context as operating cost savings.

Description

Due to their unique situation, RC's are proposed to be treated as a special category of buildings with its own Standards requirements. Because RC's are factory-built in controlled conditions, the economics of many of the measures can be unique to buildings in this category. The proposed measure would make modifications to current RC Standards requirements for ceiling insulation, cool roofing and lighting, and develops a set of prescriptive envelope component measures that would apply to all relocatable classrooms built, sold, and leased in California, regardless of the climate zone where the RC would be located. In addition, RC's will continue to be subject to the mandatory lighting controls, HVAC controls and other mandatory requirements applicable to all nonresidential buildings. Improvements to these sections of the Standards will also apply to RC's. This report also discusses the current ability of the responsible parties in enforcing current and future Title 24 standards and recommends methods to ensure that RC's meet Title 24.

Benefits

Usually, RC manufacturer charges for energy efficient upgrade options are greater than if these options were standard equipment. Because RC's are production line items, most options require additional manufacturing coordination, which add cost to the measures that would not be present if they were standard equipment. These options are frequently ordered in small volumes or from non-standard distributors, which add cost to the measures. Development of cost effective energy efficient standard measures for RC construction will provide long-term benefits to California and will have the added benefit to school districts that the costs of these upgraded RC's will be provided at lower first cost than if the school districts special ordered RC's with energy efficient options.

Added ceiling insulation, cool roofs and high performance windows will improve teacher and student comfort in both cold and hot days. Positive productivity and improved health impacts can result from improved comfort and indoor air quality, complementing the energy savings.

Environmental Impact

The proposed measure has no adverse environmental impacts, and indirectly reduces atmospheric emissions through the reduction of demand on fossil fuel power plants because of increased energy efficiency. Added insulation will slightly impact material extraction.

Ventilation, noise levels and moisture control are related issues can potentially be improved concurrent with the energy improvements. Ventilation in RC's is frequently below the required design specification of 15 CFM per person (Davis Energy Group, 2000). Wall-mounted heat pumps commonly used with RC's provide a fixed percentage of outside air whenever the fan operates. Smaller capacity heat pumps (3 to 3.5 tons) are not capable of providing adequate air quantities for most RC's. OPSC RC's are typically specified with 5 ton heat pumps to provide adequate outside air, and equipped with economizers and demand control ventilation. However, fans often are not run continuously because of noise issues. Noise levels in portable classrooms have as much to do with location and baffling of the return air and forced air duct systems as with heat pump design. Wall-mount heat pump installations are noisy because they typically use a direct through-the-wall return with no ducting. Commercially available HVAC sound enclosures add baffling to the return air side and can significantly reduce noise levels. Supply duct and diffuser design modifications can also reduce noise levels. It also appears that in some cases thermostats are installed in RC's which fail to meet Standards requirements for being capable of operating the heating and cooling system to continuously meet ventilation requirements. In-plant inspectors can insure that proper thermostats are installed to enable adequate ventilation to be provided.

RC's are built with metal roofs that are insulated on the underside with fiberglass. The addition of roof insulation decreases roof surface temperatures in winter, which can result in increased condensation at the underside of the roof unless a vapor barrier is applied. While it is currently not within the scope of the Standards, installing a vapor barrier is recommended to prevent condensation damage, which can occur with R19 insulation and may be a greater risk when R30 insulation is used. Assuring compliance with ventilation requirements to remove indoor moisture accumulation can also mitigate this problem.

Type of Change

The proposed change would develop a prescriptive package of envelope component measures, which are the same regardless of climate zone and are specific to RC's.

Establishing a single prescriptive envelope component package could dramatically simplify enforcement. Standards requirements would be uniform across all climate zones, and inspectors could apply the same compliance checklist to most RC units. However, tradeoffs between the prescriptive measures and other high potential measures such as skylights and lighting controls would remain available through the performance approach if a manufacturer wished to incorporate those measures instead.

The current Standards enable a tradeoff to be taken in one of the prescriptive approaches, the Overall Envelope Approach, for buildings with glazing area less than 10% of the wall area. For RC's which commonly have less than half of that glazing area, this creates a perverse tradeoff that allows the energy efficiency of the RC to be degraded, such as substantially lower performing windows to be installed. This tradeoff also creates an inappropriate incentive for window area to be kept at very low levels, even though there is growing support for improving the teacher and student environment by increasing window area and greater use of natural daylighting. This proposal would eliminate the 10% glazing area tradeoff in the prescriptive Overall Envelope Approach. This also will lead to a more standardized package since these tradeoffs would not have to be determined separately for each RC model and checked by the inspector.

This change would require modifications to the Standards, the Nonresidential Alternative Calculation Method and compliance documents. The Standards would include a table listing the prescriptive envelope component measures that are unique to RC's, and references to other Nonresidential Standards requirements that also apply to RC's. Specific forms should be added to compliance documentation to facilitate verification by DSA plan checkers and in-plant inspectors.

Technology Measures

Most of the envelope measures that are proposed for application to RC's are substantially similar to the prescriptive envelope component requirements in the current Standards that would apply to RC's if the climate zone and orientation of where the RC will be located is unknown. The exception is for R-30 ceiling insulation, which currently is widely applied to low-rise and high-rise residential buildings. Other measures that would be applied to RC's, including cool roofs for low-sloped roofs, a lower lighting power allowance and the new federal air conditioner efficiency standards will be the same as are proposed to apply to other school buildings and nonresidential buildings. There are no problems with the availability or practicality of these measures.

Measure cost is addressed in Methodology. Useful life, persistence, and maintenance for all technology elements proposed for this measure are identical to the baseline assumptions.

Performance Verification

In-plant Standards compliance inspections can be completed visually to verify window labeling, installed lighting, and insulation thickness and coverage and other compliance requirements. Verifying proper ventilation for RC's should be done at the same time as the other visual inspections at the factory.

Cost Effectiveness

When evaluated individually, each of the proposed measures in the package are cost effective, and with the exception of R19 floor insulation in Climate Zone 6, all measures are cost-effective in all climate zones. The complete package of measures is cost-effective in all five climate zones evaluated, including Zone 6. Results of cost-effectiveness calculations are provided in the Results section. This proposal's cost effectiveness has been evaluated using an average annual energy cost forecast. This analysis showed the proposed measures to be cost effective in almost all climate zones. There are several reasons that are identified later in the report that this analysis was very conservative, especially for evaluating the cost effectiveness of cool roofs. The project was not budgeted to evaluate the cost effectiveness using the Time Dependent Valuation (TDV) methodology. The TDV methodology substantially increases the valuation of measures that reduce on-peak energy. If the TDV methodology had been used, the cost effectiveness of cool roofs would have been even more strongly demonstrated.

Analysis Tools

The current Standards reference method can be used to quantify energy savings and peak demand reduction for the proposed package of measures. No enhancements to the reference method are necessary. EnergyPro and DOE-2 were used to develop the energy savings data for the analysis.

Relationship to Other Measures

The proposed mandatory measures package includes envelope, and lighting, measures, all of which are interactive. Since the proposed measures were evaluated as a package, the analysis accounts for these interactions. Other measures that are being evaluated for 2005 Standards changes for nonresidential buildings are also applicable to RC's. These include lighting improvements, cool roofs for low-sloped roofs, and acceptance requirements (particularly related to inspections for ventilation requirements).

Acknowledgments

This code change proposal was sponsored by PG&E and managed by Douglas Mahone and Lynn Benningfield of the Heschong Mahone Group on their behalf. PG&E program managers include Steve Blanc, Gary Fernstrom, and Pat Eilert.

PG&E has a historical contribution to the development of this proposal. In 1997 PG&E initiated a project, managed by Pat Eilert, to attempt to transform the relocatable classroom market towards more efficient designs. An initial report by Davis Energy Group and Consol developed two energy efficiency packages based on computer simulations of over 20 energy efficiency measures. In 1998, the PG&E Premium Efficient Relocatable Classroom (PERC) project, managed by Pat Eilert and subsequently Larry Stevens, worked with three modular manufacturers to facilitate the construction and installation of efficient RC's. At the same time Gregg Ander, at Southern California Edison, initiated a project called Rethinking the Portable Classroom to look at ways of improving the design and performance of portable classroom buildings in Southern California. A second 1998 PG&E project managed by Larry Stevens monitored three RC's that were built to PERC package 1 specifications and installed in Auburn, Redding, and Ophir.

Lawrence Berkeley Laboratory (Mike Apte) and Florida Solar Energy Center (Danny Parker) have also been supporting research relating to RC's. Element 6 of the LBNL PIER High Performance Commercial Building Systems project is currently monitoring four RC's located in Cupertino and Modesto that were built to PERC package 1 specifications with the addition of low VOC materials, and two HVAC systems. They will be run alternately with a standard 10 SEER wall mount and an Indirect Direct Evaporative Cooler (IDEC). The goal of the project is to demonstrate both increased indoor air quality and reduced energy usage. The Florida Solar Energy Center (FSEC) has just initiated a DOE funded project to monitor RC's with skylights, lighting controls, and other efficiency measures in four areas of the country. One will be located in the Sacramento valley and is expected to be placed this fall.

RC manufacturers are both primary stakeholders and contributors to the information provided in this report. Gary Doupnik Manufacturing, Inc. built the three RC's that were monitored, and DMSI built another demonstration unit. American Modular Systems, Inc. (AMS) built the RC's for the current LBNL project and is contributing to the FSEC project. Bob Scott of AMS and Kirtus Doupnik of Doupnik Manufacturing have been most helpful with providing cost and other data. A listing of California manufacturers is provided in the appendix.

DSA plays a regulatory role in the construction and siting of RC's. Chip Smith of DSA contributed valuable information about the approval process, enforcement, and other issues. E.V. (Al) Garcia, Bill Pennington, Daryl Mills, and Bryan Alcorn, all of the CEC, also participated in the review of this report.

Methodology

Development of a Baseline RC

Before it was possible to begin developing an energy-efficient package of measures it was necessary to define a base case RC. The baseline building evaluated had floor plan dimensions of 24' x 40' and a 10' exterior wall height. Windows were located in front and back walls, and the building was oriented with the front facing west.[3] School schedules for lighting, occupancy, and fans were obtained from ASHRAE 90.1 recommended schedules as supplied with EnergyPlus.[4]

Currently, steel-frame RC's include a 20" steel roof beam, running the entire perimeter, supporting the roof. This roof beam is typically left uninsulated. Figure 1 shows a detail of the roof and wall assembly for a typical steel framed RC. Because the roof is insulated, the plenum above the lay-in ceiling tiles is considered conditioned space and this roof beam should be insulated. The metal purlins supporting the roof deck also represent a thermal bypass in the roof assembly and diminish the effectiveness of the roof insulation. Where metal framing is used, U-factors must be calculated using the Commission's EZFRAME computer program to account for actual assembly performance. It is necessary to provide a thermal break in this assembly or additional batt insulation for steel framed roofs to meet the assembly-factors specified in the performance approach and Overall Envelope Approach by the current Standards.

Typical RC's do not meet the 2001 Title 24, Part 6 requirements. Analysis was completed to develop a Basecase package of measures that complies with the performance standards [5] in each of five representative climate zones. Table 1 lists these measures, and compares them to measures commonly used in RC's built presently. A ventilation rate of 450 CFM[6] was assumed in both the baseline and current construction cases as required for compliance modeling, though this level may not commonly be attained. The baseline package of insulating the roof beam and changing from T12 to T8 lighting was selected as the measures that were easiest and most cost-effective for RC manufacturers to implement using the performance method. While the window properties do not comply with the 2001 Standards Envelope Component Approach, the building complies with the performance approach, because the Basecase building has a substantially lower lighting density than the performance standards reference design. The window properties also comply through the prescriptive Overall Envelope Approach because a tradeoff currently can be taken when the window area is less than 10% of the gross exterior wall area. This tradeoff is not available in either the performance approach or the basic prescriptive method.

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[3] It should be noted that under the current Standards, the orientation of the building must be specified if the performance approach is to be used. If the orientation is not known then either the performance approach can not be used or the energy consultant doing the modeling would have to complete a parametric analysis to determine the worst case orientation and compliance would have to be demonstrated for that orientation. It is very likely that the worst case orientation would perform significantly worse than the west orientation used in this analysis to determine the basecase. Therefore, the cost effective analysis conclusions in this report should be viewed as conservative.

[4] It was necessary to use the non-compliance version of EnergyPro to implement these schedules. Appendix D contains the schedules used for the analysis.

[5] It should be noted that this Basecase would not comply with the current Standards prescriptive envelope criteria for RC's for which the climate zone where the RC is to be located or the orientation of the RC on the school grounds is not known at the time of construction of the RC. For such RC's compliance with the current prescriptive envelope criteria would require that the most stringent criteria for all climate zones and orientations be met.

[6] 15 CFM per person, 30 people typical occupancy.

Table 1: Typical Steel Framed Roof and Wall Section

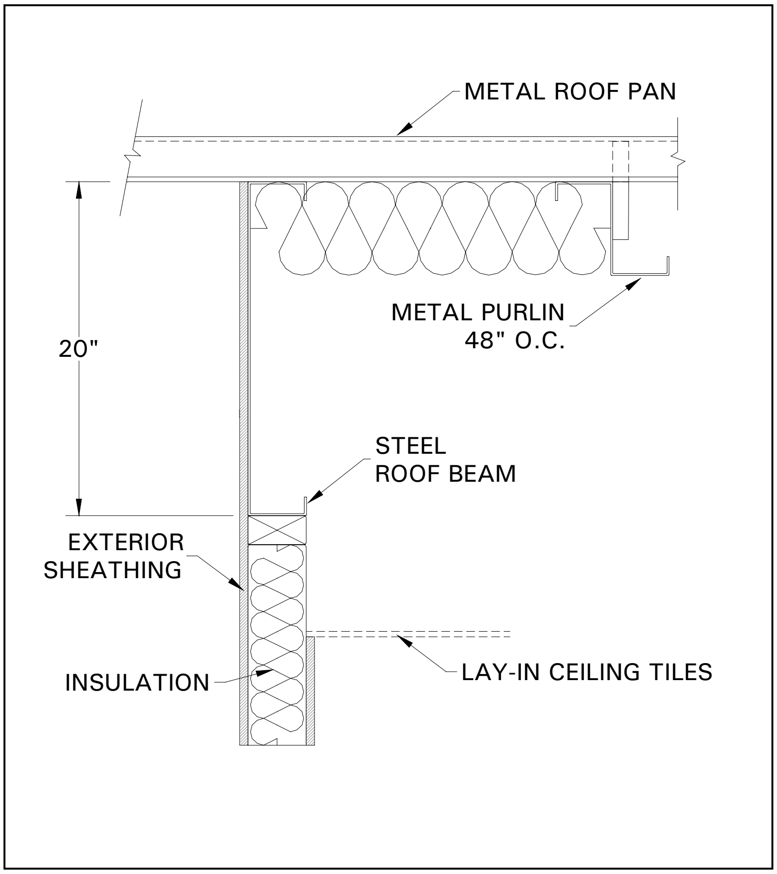

Table 1: Comparison of Baseline Design to Current Construction Practice and Current Standards Prescriptive Measures

Feature	Baseline	Current Construction[7]	Current Prescriptive Requirements[8]
Wall insulation	R-11, beam insulated[9]	R-11, beam not insulated	R-13, including beam
Floor insulation	R-11	R-11	R-19
Roof insulation	R-19 (R-30 in CZ 16 only)	R-19 (R-30 if engineered for a snow load)	R-19
Lighting	1.31 W/ft² power density[10] (10 – 4 lamp T8)	1.71 W/ft² power density (10 – 4 lamp T12 F34)	1.6 W/ ft² power density
Heat pump	10 SEER	10 SEER	9.7 SEER
Windows	Double pane, alum. frame, gray tint (U=0.87, SHGC=0.59)	Double pane windows, alum. frame, gray tint (U=0.87, SHGC=0.59)	Double pane, alum. frame, spectrally selective (U=0.49, SHGC=0.46)

Table 2 compares the source energy use of an RC using the Baseline group of measures to the current Title 24 performance standard (the reported energy use for the Baseline Design assumes that the RC is in an orientation that uses no more energy than facing the windows west and east), and to the source energy consumption for RC's as currently built. The baseline design provides an ample compliance margin in each climate zone driven primarily by the lighting assumption of 1.31 W/ft^2 compared to the 1.6 W/ft^2 Standards requirement. Because of this difference the cost effectiveness analysis in this report is quite conservative relative to the Title 24 performance standards for RCs where the climate zones and orientation of the RC is known.

Table 2: Comparison of Baseline Source Energy Use to Title 24 Standard and Current Construction

Source Energy Use, MMBtu/yr			
Climate Zone	Title 24 Standard[11]	Baseline Design[12]	Current Construction
4	139.5	117.9	150.9
6	130.2	103.2	138.0
12	147.3	127.8	165.0
14	161.4	140.7	186.6
16	161.7	152.1	195.9

[7] Current construction of RC's was based on the finding in the 1997 Davis Energy Group and ConSol report, "Energy Analysis and Review of Modular Classrooms".

[8] Envelope measures are for the Prescriptive Envelope Component Approach when climate zone and building orientation are not known.

[9] Refers to the steel beam above the walls around the perimeter of the building that supports the roof purlins in steel-framed RC's.

[10] Current Title 24 prescriptive standards Area Category Method require a maximum power density of 1.6 W/ft². The 1.31 W/ft^2 used in the Basecase would significantly reduce the base case cooling energy, and therefore make cooling measures, such as spectrally selective glazing and cool roofs appear substantially less cost effective, making the cost effectiveness conclusions conservative. 1.2 W/ft^2 has been proposed for all school occupancies in another code change proposal (Benya).

[11] Values determined using EnergyPro as the Standard values for minimum compliance.

[12] Values determined using EnergyPro for the Baseline measures.

Package Development

A list of energy efficiency measures with promising cost-effectiveness[13] to be implemented in the prescriptive component package were individually analyzed using the baseline model to determine their performance with Title 24 economic assumptions applied. Daylighting using skylights and T8 lighting with dimmable ballasts were included in the PERC package 2 (Davis Energy Group 1998), and a demonstration RC with these measures was built. However, school districts were very reluctant to include skylights and no RC with skylights has yet been commercially built in California. Daylighting using skylights and T8 lighting with dimmable ballasts was therefore not included as a measure until there is a viable RC skylight system available. Florida Solar Energy Center is currently working with manufacturers to develop approaches for integrating skylights in RC's.

Improved efficiency (12 SEER) heat pumps were not separately evaluated for cost effectiveness, because states are pre-empted from adopting minimum efficiency levels different than federal standards. New federal air conditioner and heatpump standards (12 SEER or 13 SEER) will go into effect in 2006, and will be adopted by reference into the Standards.

Table 3 lists the measures evaluated, the incremental costs obtained from manufacturers through previous research, and the economic life used to evaluate the net present value. Net present value energy costs of $2.10 per kWh/yr and $1.37 per kWh/yr were applied to the annual energy savings values to determine the net present value of savings for the 30 year and 15 year measures, respectively. Measures were considered cost-effective if their NPV savings were greater than their incremental cost.

The lighting in the Baseline package (10 4-lamp fixtures) results in overlit classrooms. Reducing lighting levels to 1.2 W/ft^2 can be achieved with twelve 3-lamp T8 fixtures and provide the proper lighting levels and distribution.

Although the OPSC specifications call for economizers and demand control ventilation, these measures were not evaluated for cost effectiveness. The current Nonresidential prescriptive Standards require economizers for air conditioners and heatpumps larger than 75,000 Btu/hr. The heatpumps installed in RC's typically are smaller than this. Demand controlled ventilation (DCV) is being addressed by another code change proposal (Hydeman-Eley). Under the Hydeman-Eley proposal, DCV would be required only for classrooms that are conditioned by systems with economizers. The current Standards lighting controls requirements, which were upgraded in the 2001 Standards, apply to RC's. Another code change proposal sponsored by PG&E will be looking at additional lighting control requirements that if adopted would also be applicable to RC's. No separate lighting controls applicable only to RC's were evaluated by this project.

Table 3: Measures Evaluated, Incremental Cost, and Economic Life

Measure	Incremental Installed Cost[14]	Economic Life
R-13 wall insulation	$38	30 years
R-19 floor insulation	$100	30 years
R-30 roof insulation	$130	30 years
Selective surface alum. frame windows (U=.47, SHGF=.46)	$80	30 years
Cool Roof (white coated steel)[15]	$192	30 years
1.2 W/ft^2 Lighting (12 3-lamp T8 fixtures)	$40	15 years

[13] Refer to the two PG&E reports cited in the Bibliography on page 14 of this report (DEG, ConSol, 1995 and DEG, 2000).

[14] Includes 25% overhead & profit. All incremental costs are for materials only, since no additional labor is required for materials/equipment substitutions.

[15] Base case is bare galvanized roof pans. Incremental cost is for coated stock. Based on concurrent studies on cool roofs, incremental costs for coated stock range from $0 – $0.20 per square foot.

Table 4 summarizes results of the analysis of the individual measures compared to the Basecase using average annual energy costs[16]. All measures have positive net present values except cool roof (white-coated metal roof)[17], using a high incremental cost ($0.20/ft^2). A separate code change proposal sponsored by PG&E proposes to prescriptively require cool roofs on all low-sloped roofs on nonresidential buildings. This study found that the cost of cool roofs do not exceed $0.20/ft^2. Using this cost estimate cool roofs were shown to be cost effective in all climate zones except 12 and 16. It should be noted that the lighting assumption in the Basecase causes the cooling load to be understated relative to the current performance standards level (the difference between the Baseline design and the Title 24 Standards level in Table 2 is 9.6 MMBtu/yr). This makes cool roofs appear less cost effective compared to the current standards. It also should be pointed out that field research has indicated that DOE 2.1 computer analysis underestimates the cooling energy savings of cool roofs by about 30% (Akbari, 1993). Also, cool roofs would allow the heat pump to be downsized resulting in a reduction in initial cost. Cool roofs should also result in an increase in the life of the roof, reducing maintenance costs by postponing the need to repair or replace the roof. As mentioned earlier, TDV analysis was not budgeted as part of this report. It is likely that cool roofs would be more favorable under the TDV analysis. Taking these factors into consideration, cool roofs were included as part of the prescriptive package. R-19 floor insulation did not prove to be cost-effective in Climate Zone 6, but in the interest of establishing one prescriptive envelope component package for RC's, this measure was preserved in all climate zones.

All measures were combined to form the proposed prescriptive package, which was analyzed using the same methods as used for the individual measures to determine overall cost-effectiveness.

Table 4: Net Present Value of Individual Measures Assuming Average Annual Energy Costs

Measure	Incremental Installed Cost	Net Present Value				
		CZ 4	CZ 6	CZ 12	CZ 14	CZ 16
R-13 wall insulation	$38	$148	$24	$85	$270	$394
R-19 floor insulation	$100	$85	($37)	$146	$329	$699
R-30 roof insulation	$130	$608	$362	$671	$1039	n/a
Select. surface windows	$80	$227	$105	$227	$410	$536
Cool roof	$192	$159	$219	($16)	$40	($192)
1.2 W/ft^2 lighting	$40	$321	$322	$240	$321	$241

Results

Results of DOE-2 simulations completed for the comprehensive RC prescriptive measure package are listed in Table 5 assuming average annual energy costs. Baseline energy use was determined by applying the package described in Table 1; RC Package energy use includes all measures from Table 4. Site energy savings across all climate zones averages 1,043 kWh/yr, or 8%. The average net present value across all climate zones is $1,549. Applying these data, at an annual construction volume of 3000 units per year, annual energy savings would be approximately 2,919 MWh and school districts statewide would accumulate savings of $4.6 million (present value $) each year of production. Actual savings may be less as a result of the increased energy used to achieve the required ventilation rates, but this will be offset by health and productivity improvements.

[16] See Appendix for detailed results.

[17] The Cool Roof check box in EnergyPro was used to determine energy savings because the construction absorptivity value is not used in the compliance model.

Table 5: RC High Performance Package Energy Savings and Net Present Value Assuming Average Annual Energy Costs

Climate Zone	Site Energy Use, kWh/yr			NPV Savings $	Installed Costs	Net Present Value
	Baseline	RC Package	Savings			
4	11,514	10,548	967	$1,848	$580	$1,268
6	10,079	9,317	762	$1,409	$580	$830
12	12.481	11,427	1,054	$2,046	$580	$1,466
14	13,740	12,393	1,347	$2,648	$580	$2,069
16	14,854	13,770	1,084	$2,126	$450[18]	$1,677

On the basis of these results, the RC prescriptive package is recommended for adoption into the standards.

Recommendations

It is recommended that the standards be changed to include a specific prescriptive envelope component package for Relocatable Classrooms manufactured for installation in California with the following measures if they are built to be installed in California. Establishment of this specific package regardless of climate zone and orientation will simplify implementation and enforcement.

- R-13 wall insulation (including roof beam)
- R-19 floor insulation
- R-30 ceiling insulation
- Selective surface windows (U=0.49, RSHG=0.46 or lower for glazing areas above 10%)

Relocatables also will be subject to the other mandatory and prescriptive requirements applicable to all Nonresidential buildings, including a lighting power density of 1.2 W/ft^2, federal air conditioner efficiency standards (12 SEER or 13 SEER) effective in 2006, and HVAC and lighting control requirements.

In order for the implementation of these standards change to be successful, several barriers to compliance must be overcome. Before a manufacturer can build a new RC, they must obtain DSA approval for a set of plans and specifications. This allows the manufacturer to build a number of units under a single approval. DSA has clarified that all RC's must comply with Part 6 of the Title 24 standards (Standards). Manufacturers are required to update previously DSA-approved plans to comply with the 2001 Title 24 Standards. Due to the DSA's experience with building code enforcement and its role as the plan check agency for California's public schools, it is the proper entity to verify school facilities compliance with Title 24 Energy Efficiency Standards.

During construction, school districts are required to provide an in-plant inspector who verifies compliance with all building code requirements, now including compliance with the 2001 Standards. However, at present, these inspectors are not properly trained on the requirements for energy Standards compliance.

As an extension of the very successful training efforts conducted for site constructed residential and nonresidential buildings, Public Goods Charge-funded training is recommended to train persons involved in plan review and RC inspectors responsible for enforcement of the 2001 Standards. A similar training effort should be conducted to help the industry transition to the proposed new Standards once they are adopted by the Commission in 2003.

[18] The installed cost for Climate Zone 16 is lower because R-30 roof insulation is included in the baseline case.

Work underway by the Florida Solar Energy Center to develop methods for incorporating skylights into RC's should be monitored. If FSEC is successful this measure should be evaluated for a future standards change.

Proposed Standards Language

Suggested standards language changes are included as Appendix A. These changes are drafted as a package of prescriptive envelope measures.

Proposed ACM Language

Suggested ACM language changes are included as Appendix B.

Bibliography and Other Research

Two studies completed for PG&E on relocatable classrooms provided valuable information that was referenced for the development of the proposed standards changes. These include:

Davis Energy Group and ConSol, 1997. "Energy Analysis and Review of Modular Classrooms."
This project included visits to manufacturers and RC sites, a review of the market, analysis of energy efficiency measures, and development of energy efficient RC packages. Measures analyzed include T8 lighting, low-E glazing, R13 and R19 wall and floor insulation respectively, daylighting using skylights/T8 lamps/dimmable ballasts, gaskets at the heat pump/wall interface, and two-stage evaporative cooling. Annual energy savings from implementation of cost-effective measures were projected to be 27%.

Davis Energy Group, 2000. "Premium Efficiency Relocatable Classroom Performance Assessment in PG&E Territory." Three premium efficiency modular classrooms were constructed and monitored, and computer models were calibrated to the monitoring data and used to predict annual energy savings of 28-29% in three climate zones. Lighting power density was lowered by more than 50% from the base case, while an acceptable 50 foot-candles of lighting was provided.

A large body of information on school energy efficiency, and relocatable classrooms in particular, is available. Key documents, listed below, contain citations for this work.

Akbari, H., SE Bretz, J.W. Hanford, D.M. Kurn, B.L. Fishman, H.G. Taha, and W. Bos. 1993. "Monitoring Peak Power and Cooling Energy Savings of Shade Trees and White Surfaces in the Sacramento Municipal Utility District (SMUD) Service Area: Data Analysis, Simulations and Results". Lawrence Berkeley National Laboratory Report No. LBL-34411.

Callahan, Michael P.; D.S. Parker et al, 1999. "Evaluation of Energy Efficiency Improvements to Portable Classrooms in Florida". University of Central Florida, Cocoa, FL.
This paper presents findings from a 2-year experiment exploring ways to reduce energy costs and improve the learning environment in Florida's 25,000 portable classrooms. Measures included T8 lighting, high efficiency heat pump with energy recovery ventilator, white roof, and occupancy control of HVAC and lighting systems.

Eley & Associates, 2001. *High Performance Schools Best Practices Manual.* Prepared for the California Collaborative for High Performance Schools (CHPS). Addresses the needs of school districts, and provides design guidelines and specific criteria for a high performance school.

Sustainable Buildings Industry Council, 2001. *High Performance School Buildings*. A resource and strategy guide developed as course material for SBIC's education campaign.

EdSource, Inc., 1998. "Portable School Buildings: Scourge, Saving Grace, or Just Part of the Solution?" A report exploring the current role of portable classrooms in California schools and the options available for their use.

CA, 1999, Public Schools Accountability Act of 1999, California State Education Code Section 52120, http://www.leginfo.ca.gov/calaw.html

The National Clearinghouse for Educational Facilities (www.edfacilities.org/portable.cfm) also provides an extensive resource list on the subject of RC improvements, selection, and other topics.

School schedules for occupancy, lighting and fans were obtained from ASHRAE 90.1 recommended schedules as provided with the EnergyPlus software .

Appendices

Appendix A: Recommended Modifications to Energy Standards Language

Appendix B: List of Relocatable Classroom Manufacturers

Appendix C: Detailed Measure Analysis Results

Appendix D: School Schedules Used for Analysis

Appendix A: Recommended Modifications to Energy Standards Language

Section 10-102 Changes:

SECTION 10-102 – DEFINITIONS

RELOCATABLE CLASSROOM (RC) is a factory-built individual classroom designed for relocation.

Section 143 Changes:

The following table is proposed to be added after Table 1-I:

TABLE 1-J – PRESCRIPTIVE ENVELOPE CRITERIA FOR RELOCATABLE CLASSROOMS

	ALL CLIMATE ZONES
Roof/Ceiling R-value or U-factor	 30
Wall R-value or U-factor Wood frame Metal frame	 13 0.084 0.182
Floor R-Value or U-factor	 19 0.050
Windows U-factor Relative solar heat gain 0-10% WWR 11-20% WWR 21-30% WWR 31-40% WWR	 0.49 0.46 0.36 0.36 0.31
Skylights U-factor Glass w/ Curb Glass w/o Curb Plastic w/ Curb SHGC 0-2% Glass 2.1-5% SHGC 0-2% Plastic 2.1-5%	 0.99 0.57 0.87 0.46 0.36 0.71 0.58

(b) Overall Envelope Approach

EQUATION (1-C) – STANDARD BUILDING HEAT LOSS EQUATION

…

WHERE:

…

A_{Gi} = Window (glazing) area of each type on the north, east, south, and west orientations of the standard building (in $ft.^2$) …

If the total window area of the proposed building **(excluding relocatable classrooms)** is less than 10 percent of the gross exterior wall area, the window area of each type and on each orientation of the standard design shall be increased in proportion to the area in the proposed design according to the following formula: …

Section 146 Changes:

TABLE 1-N—AREA CATEGORY METHOD - LIGHTING POWER DENSITY VALUES (Watts/ft.²)

PRIMARY FUNCTION	ALLOWED LIGHTING POWER
Auditorium	2.0*
Auto repair	1.2
Bank/financial institution	1.4
Classrooms, lecture, training, vocational room	~~1.6~~ 1.2
Commercial and industrial storage	0.6
Convention, conference, multipurpose and meeting centers	1.5*
Corridors, restrooms, stairs and support areas	0.6
Dining	1.1*
Electrical, mechanical rooms	0.7
Exercise center, gymnasium	1.0
Exhibit, museum	2.0
General commercial and industrial work	
High bay	1.2
Low bay	1.0
Grocery store	1.6
Hotel function area	2.2*
Kitchen, food preparation	1.7
Laundry	0.9
Library	
Reading areas	1.2
Stacks	1.5
Lobbies:	
Hotel lobby	1.7*
Main entry lobby	1.5*
Reception/waiting	1.1*
Locker/dressing room	0.8
Lounge/recreation	1.1
Malls, arcades and atria	1.2*
Medical and clinical care	1.4
Office	1.3
Precision commercial or industrial work	1.5
Religious worship	2.1*
Retail sales, wholesale showrooms	2.0
Theaters	
Motion picture	0.9
Performance	1.4*
All other	0.6

Appendix B: List of Relocatable Classroom Manufacturers Contacted During the Study

David Smith
DMSI
P.O. Box 367
800 South Highway 33
Patterson, CA 95363
TEL 209-892-6298
FAX 209-892-5018

Bob Scott
American Modular Systems, Inc.
333 East Carnegie Court
Manteca, CA 95337
TEL 209-825-1921
FAX 209-825-7018

Joe Sublett
Enviroplex, Inc.
4777 East Carpenter Road
Stockton, CA 95215
TEL 209-466-8000
FAX 209-461-6555

Bill Meehleis
Meehleis Modular Buildings, Inc.
1303 East Lodi Avenue
Lodi, CA 95240
TEL 209-334-4637
FAX 209-334-4726

Jerry Gonzales
Aurora Modular Industries
16833 Krameria Avenue
Riverside, CA 92504
TEL 909-789-7196
FAX 909-789-2521

Steve Scharry
Modtech, Inc.
P.O. Box 1240
2830 Barrett Avenue
Perris, CA 92572
TEL 909-943-4014
FAX 909-940-0427

Kirtus Doupnik
Gary Doupnik Manufacturing, Inc.
P.O. Box 527
3237 Rippey Road
Loomis, CA 95650
TEL 916-652-9291
FAX 916-652-9021

Appendix C: Detailed Measure Analysis Results

INCREMENTAL INSTALLED COSTS FOR PROPOSED MEASURES

Measure	Incremental Installed Costs	Class
R13 Walls	$37.50	30-year
Low E2 Windows	$80.00	30-year
R19 Floor	$100.00	30-year
R30 Roof	$130.00	30-year
Cool Roof	$192.00	15-year
3-lamp T8	$40.00	15-year

R-13 Wall Insulation Installed Costs = $37.50

	Site Energy Use kWh/yr				
CZ	Compliance Design	Package Design	Savings	NPV Savings ($) (1)	Net Present Value ($)
04	11,514	11,426	88	$185	$148
06	10,079	10,050	29	$61	$24
12	12,481	12,423	58	$122	$85
14	13,740	13,594	146	$307	$270
16	14,854	14,648	205	$431	$394

R-19 Floor Insulation Installed Costs = $100.00

	Site Energy Use kWh/yr				
CZ	Compliance Design	Package Design	Savings	NPV Savings ($) (1)	Net Present Value ($)
04	11,514	11,426	88	$185	$85
06	10,079	10,049	30	$63	($37)
12	12,481	12,364	117	$246	$146
14	13,740	13,536	204	$429	$329
16	14,854	14,473	381	$799	$699

R-30 Roof Insulation Installed Costs = $130.00

	Site Energy Use kWh/yr				
CZ	Compliance Design	Package Design	Savings	NPV Savings ($) (1)	Net Present Value ($)
04	11,514	11,163	352	$738	$608
06	10,079	9,845	234	$492	$362
12	12,481	12,099	382	$801	$671
14	13,740	13,183	557	$1,169	$1,039
16	14,854	n/a	n/a	n/a	n/a

Low-E2 Windows Installed Costs = $80.00

CZ	Site Energy Use kWh/yr Compliance Design	Package Design	Savings	NPV Savings ($) (1)	Net Present Value ($)
04	11,514	11,368	146	$307	$227
06	10,079	9,991	88	$185	$105
12	12,481	12,335	146	$307	$227
14	13,740	13,507	233	$490	$410
16	14,854	14,560	293	$616	$536

Cool Roof Installed Costs = $192.00

CZ	Site Energy Use kWh/yr Compliance Design	Package Design	Savings	NPV Savings ($) (1)	Net Present Value ($)
04	11,514	11,339	175	$351	$159
06	10,079	9,874	205	$411	$219
12	12,481	12,393	88	$176	($16)
14	13,740	13,624	116	$232	$40
16	14,854	14,854	0	$0	($192)

(12) 3-lamp T8 Installed Costs = $40.00

CZ	Site Energy Use kWh/yr Compliance Design	Package Design	Savings	NPV Savings ($) (1)	Net Present Value ($)
04	11,514	11,251	263	$361	$321
06	10,079	9,815	264	$362	$322
12	12,481	12,277	204	$280	$240
14	13,740	13,477	263	$361	$321
16	14,854	14,648	205	$281	$241

Appendix D: School Schedules Used for Analysis

	Lighting		People		Fans	
Hour	Weekday	Sat	Weekday	Sat	Weekday	Sat
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8	0.30	0	0.05	0	1.0	1.0
9	0.85	0.15	0.70	0.10	1.0	1.0
10	0.95	0.15	0.90	0.10	1.0	1.0
11	0.95	0.15	0.90	0.10	1.0	1.0
12	0.95	0.15	0.80	0.10	1.0	1.0
13	0.80	0.15	0.80	0.10	1.0	1.0
14	0.80	0.15	0.80	0.10	1.0	1.0
15	0.80	0	0.80	0	1.0	0
16	0.70	0	0.45	0	1.0	0
17	0.50	0	0.15	0	1.0	0
18	0.50	0	0.05	0	1.0	0
19	0	0	0	0	0	0
20	0	0	0	0	0	0
21	0	0	0	0	0	0
22	0	0	0	0	0	0
23	0	0	0	0	0	0