# Overview and Summary of Design Ideas From The High Performance Green Relocatable Classroom Charrette

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# Overview and Summary of Design Ideas From The High Performance Green Relocatable Classroom Charette

## Charette Description

On June 2-3, 2008 a design charrette was held in Palm Beach Gardens with the goal of developing qualities that should be considered for a High-Performance Green Relocatable Classroom (HPGRC) standard for Florida. This charrette is just one of many steps involved in development and acceptance of a HPGRC standard. It is hoped that the results of this can be shared with others and used to build on the development of improved relocatables.

School districts and other building professionals involved with school building construction were invited from around Florida. The charrette included architects, engineers, and facility managers familiar with school building construction in south and central Florida districts. Representatives from Broward, Palm Beach, and Hillsborough county school districts attended. Also participating in the charrette were presenters Kristin Heinen, John Michael, and Charles Withers.

## Presentations

The charrette was led by Charles Withers, a Senior Research Analyst with the Florida Solar Energy Center (FSEC) for over 18 years. His presentation was on the potential for savings from improving relocatable classrooms in Florida based on a control study conducted by FSEC. The project showed how overall reductions in energy use of 80% were achieved in a control study. The improvements involved tightening the building envelope and air ducts, locating the ducts within primary air and thermal barriers, using daylighting, using improved electric lighting design and control, and improved HVAC efficiency and control. More information on this or other buildings energy research can be found through free publications on FSEC's website at www.fsec.ucf.edu . FSEC publication FSEC-PF-382-04 reports results of the controlled study of portable classrooms in three different U.S. climate zones.

Another presentation introduced the Collaborative for High Performance Schools (CHPS) program and was given by Kristin Heinen, who is a manager of this program. CHPS primarily serves California, but school districts in states such as Colorado, Texas and Virginia are beginning to become involved. CHPS has developed a six-volume Best Practices Manual on designing, construction and operating high performance, healthy, green K-12 schools. You can find more information about CHPS or access other school related resources (for example, you can download a list of low emitting materials or a scorecard that helps promote sustainable building practices) at www.chps.net .

The last presentation was given by John Michael who is an HVAC engineering expert with ATEX AC. He has years of engineering experience with wall mounted and floor model HVAC equipment used in relocatable classrooms. He presented information on the latest technology developments and shared information about how noise standards such as American National Standards Institute (ANSI) create challenges particularly for wall mount AC systems used in classrooms.

## Resources to Review

There has been a substantial amount of work already done in improving sustainability in school building construction. The following resources on this page are good resources to review when considering the qualities that HPGRC should have.

Those interested in improved portable classrooms should review CHPS manuals since they have already developed extensive recommendations and specifications. The manuals can be downloaded from their website at http://www.chps.net/manual/index.htm . Manual VI was written specifically for relocatable classrooms.

***It is imperative that Florida's hot and humid climate be considered before accepting any building construction designed originally for buildings in California or anywhere else, which do not have to take hot and humid weather into account as a dominate environment. Florida is represented by zones 1and 2 in Figure 1of the DOE climate map.***

A design guide titled *Advanced Energy Design Guide For K-12 School Buildings- Achieving 30% Energy Savings Toward a Net Zero Energy Building* published by ASHRAE can be a helpful resource that offers climate-specific recommendations according to the DOE climate map. The Advanced Energy Design Guides (AEDG) can be downloaded for free through http://www.ashrae.org/freeaedg . Pages 34-38 of this guide show a summary table of recommendations specific to Florida that exceed ASHRAE 90.1 1999 by 30%. Exceeding 90.1 by 30% would mean you could expect building energy use to be about 30% lower under a specific set of circumstances. Currently Florida code uses ASHRAE 90.1 2004 which requires more stringent measures such as minimum efficiency SEER of 13 for system capacities of 65kbtu/hr or less. Evaluations are currently underway to determine what type of measures are required to exceed ASHRAE 90.1 2004 by 30% and 50%.

One place to review building envelope designs for hot and humid climates can be found on the Building Science Corporation website at http://www.buildingscience.com The body of knowledge found at BSC's website is largely from Dr. Joseph Lstiburek, a nationally recognized buildings expert. One document that should be read and understood is "*BSD-106: Understanding Vapor Barriers*" This includes discussion about the difference between permeable, semi-permeable and non-permeable materials and how these should be used in hot and humid climates. This resource contains many illustrations of different wall systems.

A simple caution is offered in *BSD-106* that warns if you build where it rains, sooner or later, water can find its way into the envelope, so the envelope should be designed to manage the moisture by allowing it to drain back out and to allow wet materials to dry to inside and outside. Walls with higher moisture storage capacity, for example concrete, can manage unplanned water intrusion better than those with lower storage capacity.

Other sources to consider for reviewing documents on relocatable classrooms can be found by searching under relocatable classrooms on National Clearinghouse for Educational Facilities website at http://www.edfacilities.org/

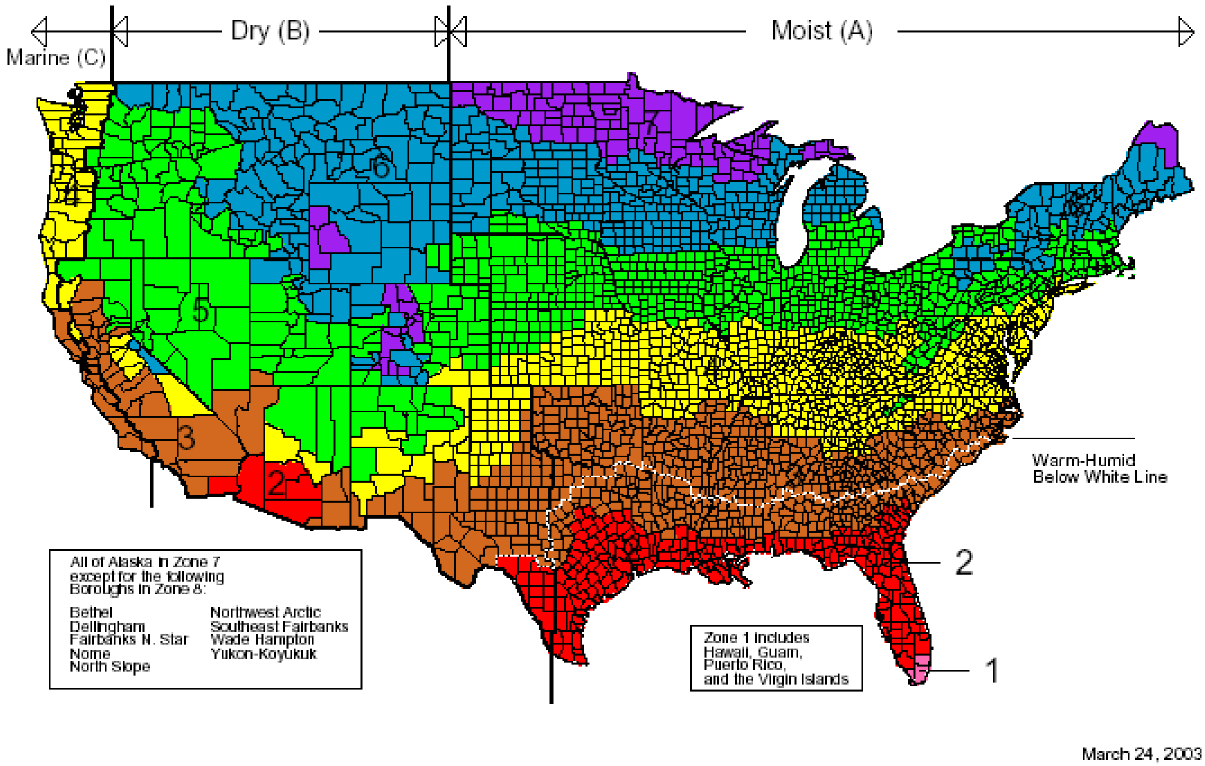


**Figure 1 DOE climate zone map**

## COMMENTS FROM CHARRETTE PARTICIPANTS

In essence it is expected that a HPGRC should:

- Protect health
- Promote learning productivity
- Be comfortable
- Be durable
- Have minimum impact on environment and resources
- Have simple O&M
- Allow flexible usage
- Be interesting & Educational

Design ideas were presented by small groups and discussed. The ideas generated by the groups are summarized here. Listed ideas do not necessarily indicate a group consensus on all things listed. The ideas fall into the categories of site layout, envelope construction, HVAC, daylighting, electric lighting, and indoor environmental quality (IEQ). Comments about concerns regarding specific ideas are also noted. The intent of including comments here is to allow others to consider them and develop solutions or recommendations.

**Site Layout**

- Land should be sloped in such a way to move rain water away from all building structures. There will be no pooling of water allowed to occur below units elevated above ground.
- One consideration discussed was to place two units together into pods shown in Figure 2. Several units could be arranged together into groups of 4 (quads) if construction is such that it would satisfy fire and other life and safety codes. This would minimize exterior surface exposure thereby lowering space conditioning loads. It would also minimize the land footprint needed to accommodate units (Figure 3). This design or stacked units (multiple floors) could be considered as a preferred way to minimize site footprint.

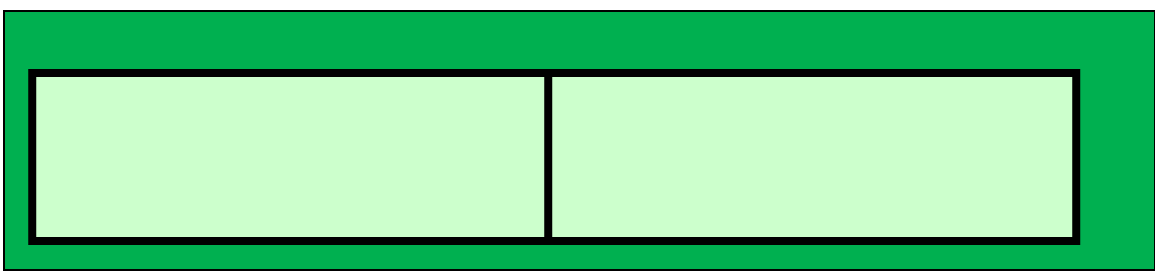

**Figure 2. One proposed idea was to place two units together**

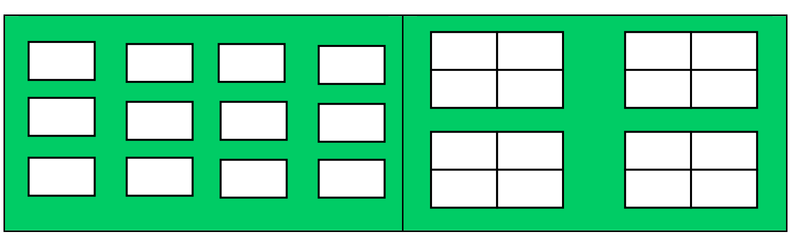

**Figure 3. Example shows two equal site areas. The space on left can fit 12 units while the space on the right can fit 16 units.**

Grouping units into quads requires even less ground space and reduces exposed exterior wall surfaces by one fourth (this reduces heating and cooling loads). Consider 24 ft. x 40 ft. units with 128 linear feet of wall x 8 foot high wall exposure. Grouping units into groups of 4 would reduce exposed surface area by 1,024 $ft^2$ for every four units. Stacking units will significantly shade and reduce the cooling load of units on ground level.

**Orientation**

There are not likely to be many options on how relocatable classrooms (RC) can be oriented on well-established school sites. However, orientation should always be considered, when feasible, to allow maximum daylighting from northern exposures and utilize adequate shading of east, west, and southern glass exposures.

**Envelope**

- Ceiling space should have no air leakage to outdoors. There should be no vents. If a vented soffit is desired, ceiling space must be physically blocked and air sealed from soffit.
- RC must meet the most stringent Florida construction code wind load requirements.
- Standard should consider benefits of high mass construction such as concrete. Concrete system transfers heat more slowly, which helps keep surfaces exposed to direct sunlight cooler and occupants more comfortable. Properly designed concrete wall system is durable when it gets wet if it is allowed to dry to interior and exterior environments.
- Meet or exceed R13 insulation performance recommended for walls. A high mass wall system should also collectively provide R13.
- One charrette group wanted R19 insulation performance recommended for roof and floors (assumed for elevated floors). The ASHRAE Advanced Energy Design Guide for K-12 schools (AEDG K-12) recommends R25 continuous insulation if located above the roof deck.
- Windows double-pane with Low-e coating and approved impact resistant glass. This would have performance of about U=0.4 and SHGC =0.6. (AEDG K-12 recommends U=0.56, SHGC=0.25 for zone1 for all types of fenestration and orientations. Zone 2 is U=0.45 and SHGC=0.25)
- Some in the group would like operable windows to be an option. One comment about this is that there may be limited benefit in RC due to the close proximity of adjacent RC wall mount units or nearby outside physical activities creating noise that could be disruptive. Sensors should be used on operable windows that eliminate operation of HVAC while windows are open.
- AEDG K-12 recommends high-reflective roofing membrane or metal roof with solar reflectance index (SRI) of 0.78 or higher). See page 81 of AEDG K-12 for SRI details.
- There was one suggestion to not allow composite shingles to be part of HPGRC.
- There was another suggestion that green roofs (having live plants on top) should not be used on relocatable classrooms.
- It is recommended that much of the CHPS standards be considered, without using any vapor barriers in or on walls. Semi-vapor permeable finishes should be used on inside and outside surfaces. (Read and understand *BSD-106:Understanding Vapor Barriers previously mentioned)*

- Vapor impermeable materials should be NOT be used on the inside of the wall or on the interior wall surface. Vapor impermeable material would be rated as 1 perm or less dry cup and 2 perms or less wet cup.
- Tested airtightness of a finished relocatable classroom should be about 10 ACH50 (air changes per hour when pressurized to 50 pascals). 10 ACH50 is not very tight, but works for RC due to the relatively high amount of outside ventilation brought into a small building. This would result in space pressurization of about 7 Pascals (0.028 inWC) if 400 cfm of ventilation air is brought in without the assistance of an Energy Recovery Ventilator (ERV). Recommendations of tested airtightness less than 8 ACH50 should also address pressure relief method during periods of maximum outside air delivery.
- Pressurization of interior spaces is considered an important part of managing moisture. However, there is currently no scientific consensus that supports a specific amount of pressure to be maintained over a specific period of time. RCs built very tight may actually need pressure relief to ensure that the designed amount of ventilation air is delivered. Using an ERV would result in less space pressurization. Less positive pressure should not be considered to be a concern as long as some space pressurization occurs during several hours each day during hot and humid weather and there are no periods of depressurization.

**HVAC**

- Turn HVAC off during unoccupied periods. System should be controllable by occupancy sensor (*see cautions about occupancy sensor in Electric Lighting section*) and communicable with EMS if school has one.
- Use Energy Recovery Ventilators. They help transfer desirable thermal qualities of exfiltrated cool dry air to incoming unconditioned outside air.
- Do NOT operate the AHU fan to run continuously as a means of ensuring adequate ventilation. Fan operation when the coil is not cold re-evaporates water on the coil and increases humidity in the space. Often, facilities staff set thermostat settings very low to “create” more load and force the condenser to operate longer, thereby increasing the time the coil is cold and lowering indoor relative humidity. This poor operational strategy wastes a significant amount of energy and makes occupants uncomfortably cold.
- Setpoint temperature is very important in energy savings. For every degree the set point is below 80 F, the cooling energy usage will increase approximately 10% during hot and humid weather.
- Heating set points should not be greater than 70 F.
- System operation should be able to maintain space relative humidity below 65%.
- Another proposed idea is to use a dedicated outdoor air system with ERV controlled by CO2 sensor. This allows the air conditioner to be sized down to meet only the solar and internal loads and makes it easier to maintain comfort. One drawback is that it would require another penetration to be made into the building.
- Use ducted supply with 3- 4 diffusers overhead.
- Ducts shall be placed within air and thermal barrier of building. Ducts placed in ceiling space require a ceiling space with no air leakage to outside and roof insulation at roof deck, not on ceiling tiles.
- Duct shall be tested for total leakage (Q25,total). Duct system tested with AHU installed shall have leakage in cubic feet per minute (cfm) of no more than 5% of the conditioned

square footage when tested at 25 Pascals of pressure (0.10 in WC). This means a RC having 960 square feet would require tested leakage of no greater than 48 cfm.

- When wall mount units are chosen, specify a system with qualities equal to or better than Bard Quiet Climate 2 with ERV.
- 2 stage cooling with variable speed blower ARI rated 12 SEER or better
- Heat pump heat COP >= 3.2 at 47 F.
- Use CO2 control of OA damper.
- OA maximum and minimum set appropriate per code and ASHRAE 62.1-2007.
- OA Damper set to 100% closed during unoccupied, non-business hours.
- The charrette groups discussed ways to move equipment from wall to roof in effort to free valuable wall space for educational use. Travel clearance is an issue with standard height RC, and accessibility is more difficult for servicing. No solution was determined.
- Charrette groups also spent considerable time trying to think of alternatives to standard wall mount DX cool systems. Ways to use chilled water were discussed, but one issue is that a chiller has to be available to supply the chilled water, and this is difficult to size for units intended to be moved around. No recommendation is offered at this time, but assistance in determining a scalable option to use small portable chillers that can be transported to serve 2-3 RC could help overcome this barrier. Using chilled water makes it easier to have a dedicated coil for outside air to pass through which is an effective way to remove high water content of outside air during part of the school year. The latent load can represent 80% of the energy needed to condition hot and humid air. As space set points are met, a VAV AHU can slow down the rate of delivered cooling while the coil is kept cold to maintain good humidity control.

**Daylighting**

Daylighting is most often provided through side lighting. Relocatable classrooms make it more difficult to specify a cost-effective design that works well for all orientations since an RC could be placed in very different orientations during its lifetime when it is relocated. During the charrette, one of the groups proposed using clerestory windows. This design uses vertical glazing, but reflects indirect diffused light downward from the ceiling. Figure 4 shows a re-creation of a conceptual drawing created during the charrette. It shows a side elevation view of two RC each having two clerestory windows. One classroom could have as much as 120 square feet of window area from two clerestory assemblies that have a maximum of 2 feet elevation above top of roof (if this is within allowable transport height clearance). A substantial amount of light could still come through just a 1 foot high clerestory window that spanned 40 feet wide.

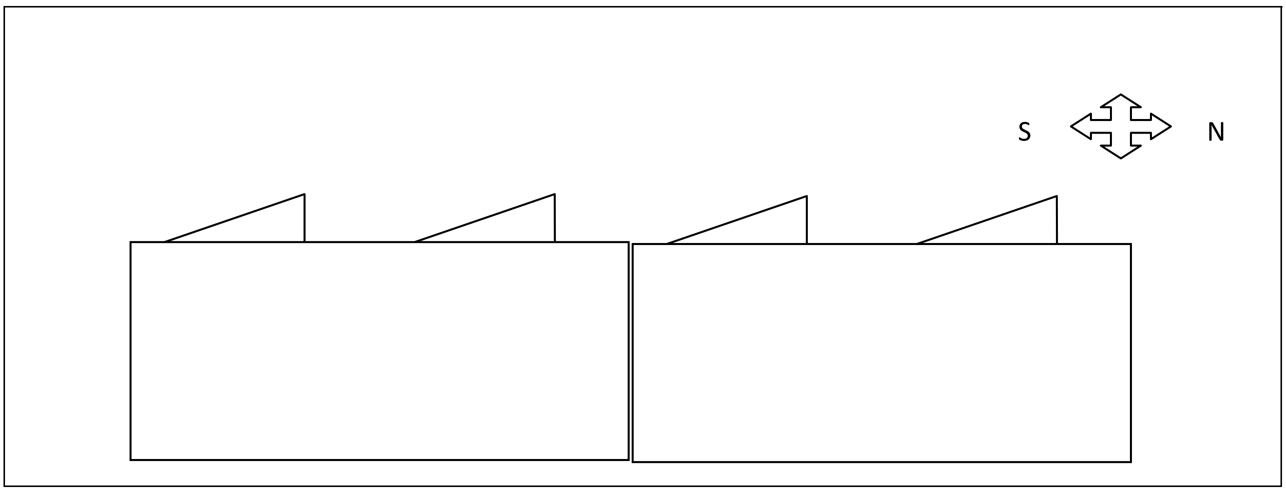


**Figure 4. This is a re-creation of a sketch proposing clerestory windows oriented towards a north exposure. The elevation of the clerestory assembly must be low enough to accommodate transportation height limitations or be able to be assembled and disassembled on site.**

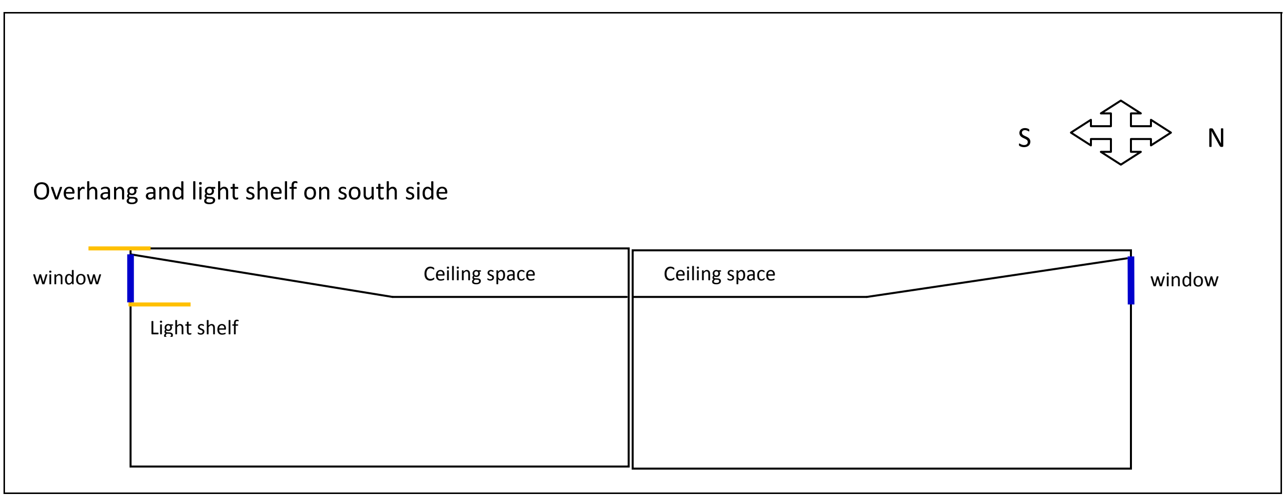


**Figure 5. Windows built into upper wall with tapered ceiling space. Windows in upper section reduce glare and open up wall area for other uses. South, East and West exposures need shading device and benefit from light shelves.**

Figure 5 shows high sidelighting with a sloped suspended ceiling. Page 126 of the Advanced Energy Design Guide for K-12 School Buildings shows a combination of the two ideas illustrated in Figures 4 and 5 of this document.

- A Florida RC has had daylighting performance evaluated and documented using tubular skylighting (see Thomas-Rees 2004 publication in the Resources section). Six 21” diameter tubular skylights were used in an experimental RC and performed well resulting in less lighting energy needed and more desktop illumination than a similar RC without skylighting. During the charrette, comments were made about the need to build in roof curbing and possible noise concerns during rain storms. It would be good to evaluate the effect rain has on interior noise levels. One advantage tube skylighting has over rectangular designs is that the top is covered by a dome which has less exposed area incident to rain. The dome skylights are not high enough to impose concern about height clearance during transport.
- Window/skylight areas must have illumination control such as operable blinds, or dampers.

**Electric Lighting**

- Manual on/Auto off occupancy control. Occupancy controls should be used to turn off lights when space is unoccupied.
- Photosensor controls should be used to dim electric lighting when adequate dayligting is provided. AEDG K-12 recommends dimming fixtures within 15 feet of sidelighting edges and within 10 feet of toplight edges. It is important that system controls be commissioned to verify proper performance. Past studies have found that occupancy sensors can be sensitive to art projects hung from ceilings causing “false” occupant indication resulting in lights and HVAC operation during unoccupied periods. School EMS or other timer based control could also be used to ensure lights and HVAC are turned off.
- Lighting control must be simple and easy to use allowing flexibility in controlling illumination particularly at desktop, chalkboard/whiteboard, and computer learning stations.
- Individuals in the charrette recognized how electronic projection media are being used more in instruction. This means it is important to have the ability to decrease illumination at whiteboards or projection surfaces.
- Two specific recommendations were made regarding lamping. The first was T5 fluorescent lamp utilized so that indirect illumination occurs at desktop. T5 lamps are more luminous thereby increasing luminance ratios and the likelihood of glare issues unless the light is directed more upward to a reflective ceiling. This usually requires ceiling heights of at least 10 feet to be able to implement effectively.
- The second recommendation was to use typical T8 lamps and fixtures. This would be less costly and make maintenance simpler since the same equipment is typically used in site built school buildings.
- Fluorescent lamps with CRI>80
- Ballasts used with fluorescent lights should be able to be continuously dimmable.
- Target designed electric power density should be equal to 0.9 W/ft$^2$.
- See CHPS manual for recommended reflected ceiling plans showing electric light fixtures and skylight locations.
- Outdoor entry lighting to be done by 15W CFL.
- Hillsborough County prefers a dark campus policy as they have found 40% less incidence of vandalism on dark campuses.

**Indoor Environmental Quality**

- Furnishings and components No/Low VOC and formaldehyde free.
- FSC certified wood
- Polished concrete walls and floors have a good appearance, are durable and can be wet-mopped. However, this hard floor surface will be noisier than a carpeted surface.
- Carpet, if used, should have no VOC and high recyclable content.
- Consider padded area carpet in area where instructor will most likely stand during instruction.
- Acoustical tile 5/8" min.
- Use CHPS noise standard of 45 dB (A) for RC. The Acoustical Society of America (ASA) and American National Standards Institute (ANSI) published a standard for classrooms of 35 dB (A). Relocatables were not being considered when development began on this standard.
- Merv 11 filter suggested by one group. Merv 6 should be adequate, but greater filtration efficiency should be considered particularly for schools in areas where there are more pollutants or allergens. Impact of static pressure increase on airflow rates should be considered if high efficiency filtration is planned to be used.

**Other Considerations**

- At least 5'x 5' covered entry areas.
- Covered walkways are an important part of shelter.
- Integrated pest control management method
    - Eliminate pest pathways into building
    - Eliminate food sources inside building
    - Only apply pesticides as needed and notify occupants when doing so
    - Apply pesticides to target pests in locations not accessible to occupant contact
    - Utilize least toxic pesticide appropriate for targeted pest
- Walk –off mats outside RC at entry and inside to collect dirt before being tracked into room could control as much as 86% of floor dirt.

**Resources**

Advanced Energy Design Guide For K-12 School Buildings- Achieving 30% Energy Savings Toward a Net Zero Energy Building
Published in 2008 by American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. Atlanta, GA.
Available for free through http://www.ashrae.org/freeaedg

Collaborative for High Performance Schools (CHPS) has information on best-practices and will partner with districts to assist in energy conservation efforts.
website at http://www.chps.net/

IESNA Handbook, 9th edition
Published 2000 by Illuminating Engineering Society of North America. New York

National Clearinghouse for Educational Facilities website at http://www.edfacilities.org/

Southeast Rebuild Collaborative is a joint effort of the energy offices of Alabama, Florida, Georgia, Mississippi and South Carolina to assist schools to save energy, save money, and reduce the emissions of greenhouse gases. Website has presentations and documents on how to save energy as well as educational material for teachers to use in the classroom.
Website at http://www.southeastrebuild.org/

"Preliminary Evaluation of Performance Enhanced Relocatable Classrooms in Three Climates" by Stephanie Thomas-Rees, Danny Parker, and John Sherwin published by the Florida Solar Energy Center, FSEC-PF-382-04, Aug. 10, 2004. Cocoa, FL.

US Department of Energy Building Technologies Program Website on Energy Smart Schools
Site contains information and links to publications on best-practices for design, O&M, and financing options for funding Energy Smart Schools projects.
http://www1.eere.energy.gov/buildings/energysmartschools/