



# *Energy Smart Schools*

**Relocatable Classrooms (Task 3) *and*  
Large Scale Study and Diagnostic Testing (Task 6)**

Chicago, IL

R. Vieira

Florida Solar Energy Center

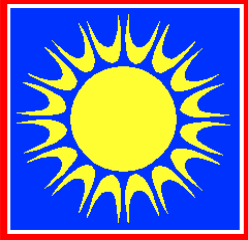
Sept 29, 2004



# *Task 3- P.E.R.C. ( Performance Enhanced Relocatable Classrooms )*

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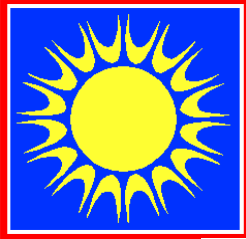


## *Task 3- P.E.R.C.*

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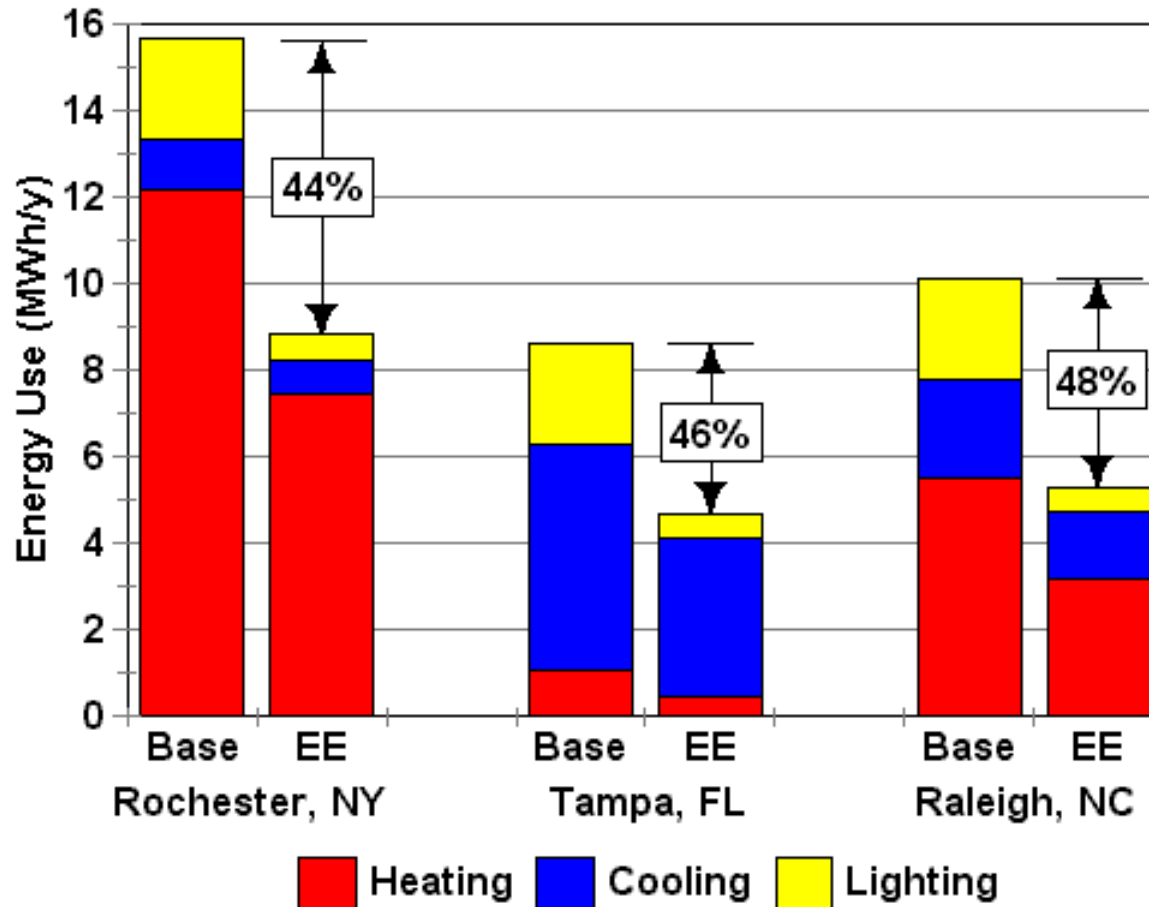
### *Issue:*

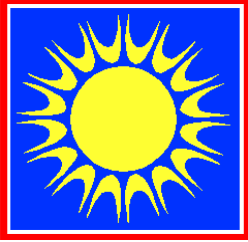
Many States have a large number of portable classrooms. Most are not energy efficient and are a suspected source of health problems.



# Energy Savings Potential

Annual Energy Savings Potential for Typical Modular Classrooms in Various Climates





# *Objectives*

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- ❖ Substantially improve energy performance of prototype designs in various climates
- ❖ Incorporated daylighting designs to improve classroom learning atmosphere
- ❖ Measure side-by-side energy performance
  - Standard classroom model
  - Energy-efficient classroom prototype
- ❖ Work with typical portable classroom industry partners.



# *PERC Prototypes*

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<b>Location</b>	<b>Contractor</b>	<b>Upgrade Price for one of a kind</b>
New York	William Scottsman	\$27,806
N. Carolina	Roger Carter Corporation	\$12,293
Florida	Resun Leasing	\$24,409



# *New York PERC*

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( Cold Climate Design )



NY PERC and Control Units



# *NY PERC Features*

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- ❖ Wall insulation: R-11 → R-19ff (w/ 1/2" PolyStyrene)
- ❖ Roof/ceiling insulation : R-19 → R-30
- ❖ Floor insulation: R-11 → R-13ff
- ❖ Building leakage: ACH50 16.4 → 16.7
- ❖ Mechanical Systems:
  - Strip heat → HSPF 7.5
  - 3 ton / SEER 10 → 3 ton / SEER 12 w/ERV
  - Duct air leakage: Standard → Sealed w/ mastic
  - Ventilation: Fixed CFM → CO<sub>2</sub> modulated



# *NY PERC Features*

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## ❖ Lighting

➤ T-12s, CLC=2,264W → T-8s, CLC=1,422W

## ❖ Windows

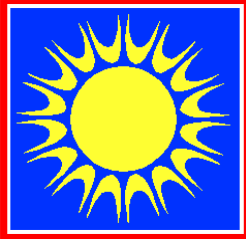
➤ U-Factor = 0.69 → 0.24

➤ SHGC = 0.64 → 0.38

➤ Tvis = 0.78 → 0.61

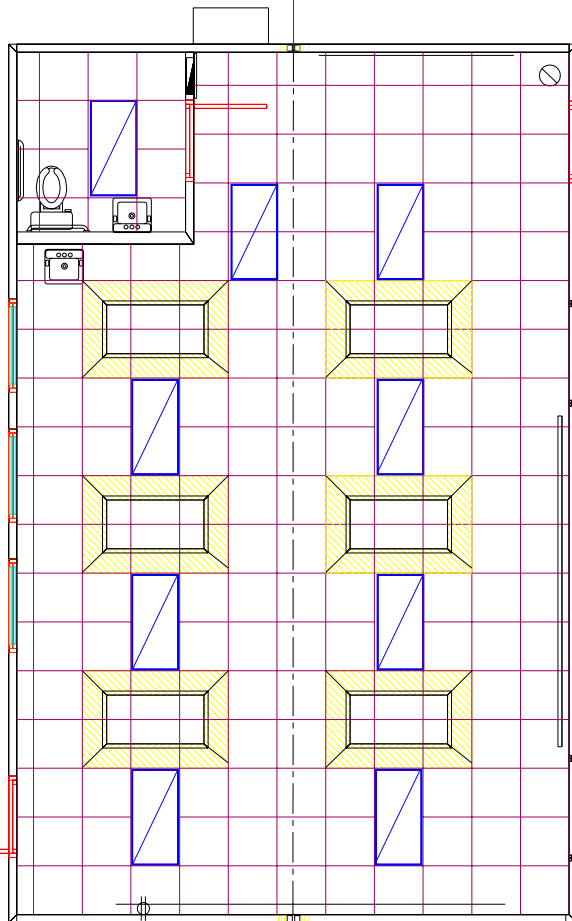
## ❖ Skylights:

➤ None → Prismatic with wells



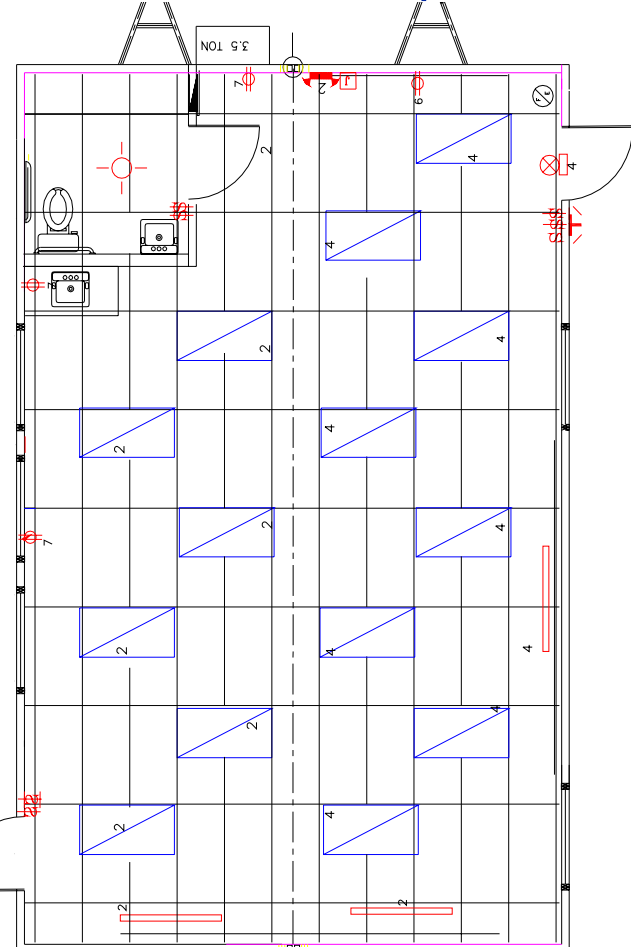
# Lighting Design

24 T-8 lamps



NY Energy Model

56 T-12 lamps



NY Standard Model

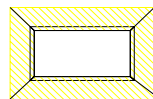
(3) lamp dim. fixture



(4) Lamp (2 step) fixture



2'x4' Skylight, w/ 4'x6' well a.f.c.





# *Lighting Levels*

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NY Energy model interior view (no electric lighting)

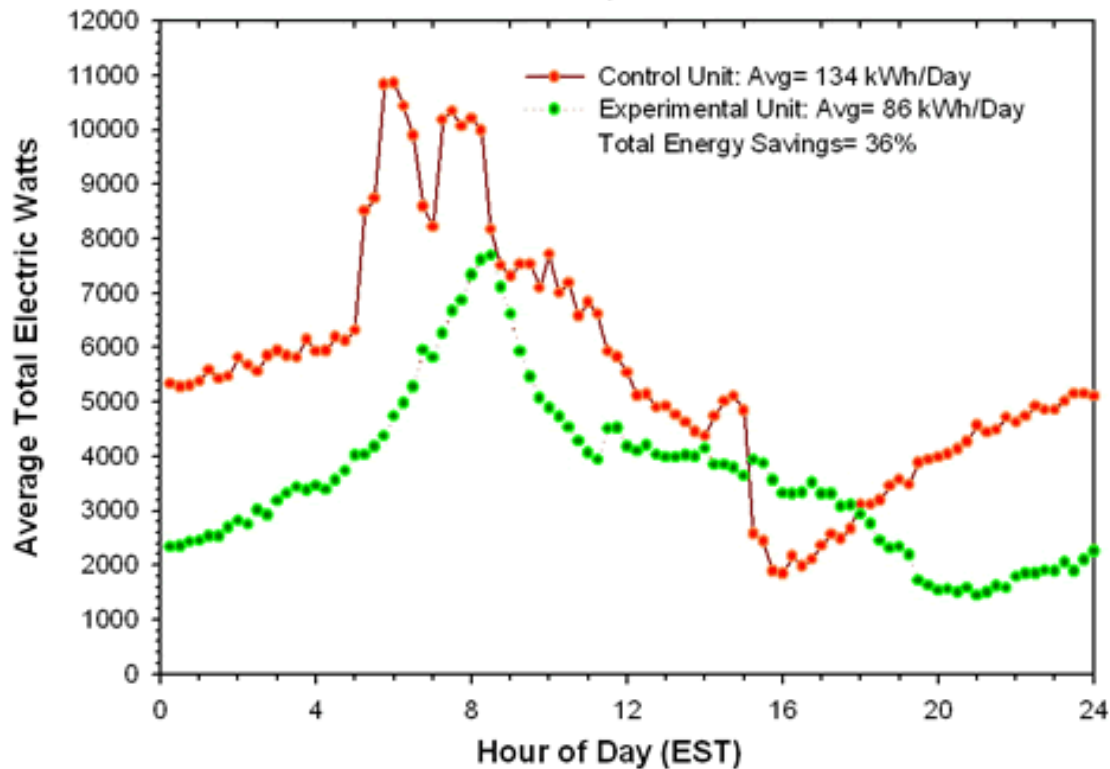


NY Standard model interior view (no electric lighting)



# *NY Measured Performance*

**Total Electric Energy Demand Profile  
November 2002- June 20, 2003  
Experimental vs. Control Portable Classrooms  
Cornwall, New York**





# *North Carolina PERC*

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( Mixed Climate Design )



NC PERC Unit



NC Control Unit



# *NC PERC Features*

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- ❖ Wall insulation: R-11 → R-15ff (w/ R-7 sheathing)
- ❖ Roof/ceiling insulation : R-19 → R-38
- ❖ Roof shingles: Dark → Light w/ RB
- ❖ Floor insulation: R-11 → R-15ff
- ❖ Building leakage: ACH50 9.1 → 4.8
- ❖ Mechanical Systems:
  - Strip resistance → HSPF 7.5
  - 3.5 ton / 10 SEER → 3 ton 12 SEER w/ERV
  - Ventilation: Fixed CFM → CO<sub>2</sub> modulated



# *NC PERC Features*

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## ❖ Lighting

- T-12s, CLC=1,268W → T-8s, CLC=1,065W
- Manual control → Photosensor / dimming

## ❖ Windows

- U-Factor = 1.10 → 0.35
- SHGC = 0.86 → 0.38
- T<sub>vis</sub> = 0.90 → 0.58

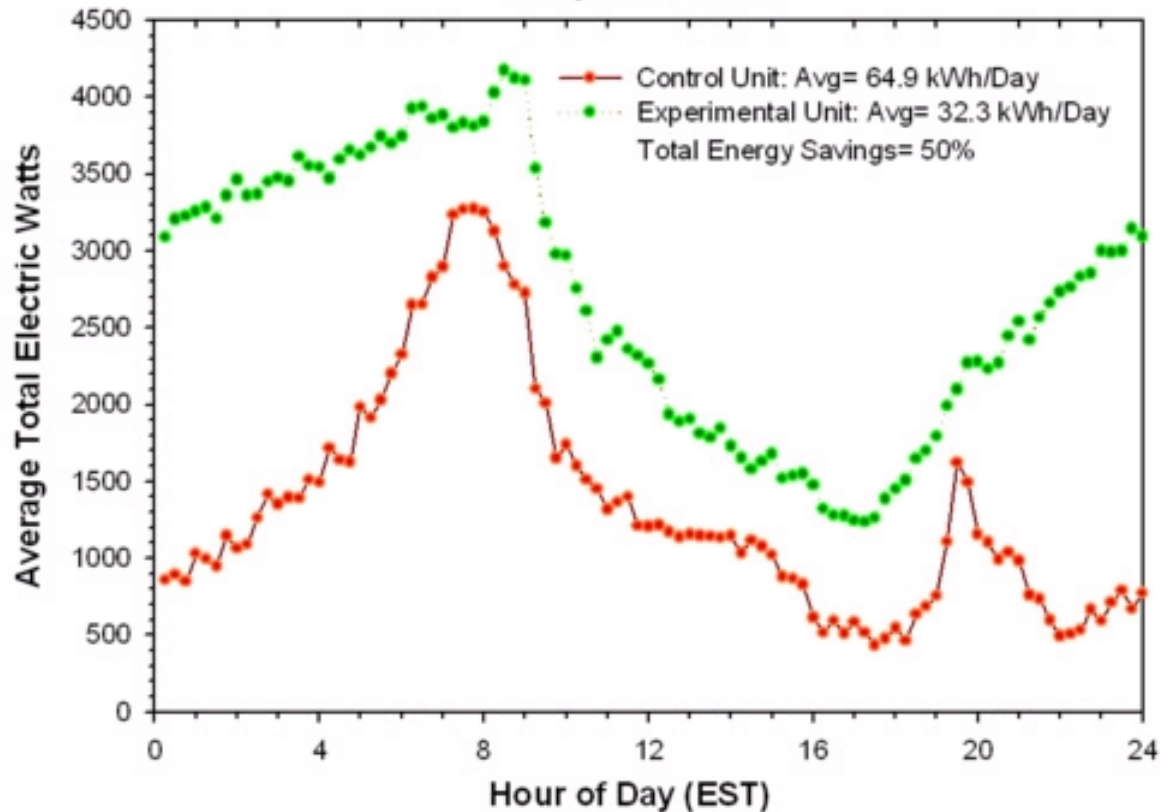
## ❖ Skylights:

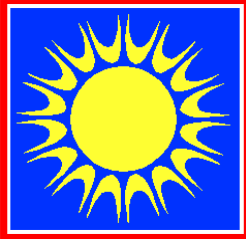
- None → Dbl. glazed prismatic, power louver



# NC Measured Performance

**Total Electric Energy Demand Profile**  
**November 1, 2003- March 8, 2004**  
**Experimental vs. Control Portable Classrooms**  
**Chapell Hill, NC**





# *Florida PERC*

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( Hot-Humid Climate Design )



FL PERC Unit



FL Control Unit



## *FL PERC Features*

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- ❖ Wall insulation: R-11 faced → R-14ff unfaced +
- ❖ Roof/ceiling insulation : R-19 → R-30 Icynene
- ❖ Roof surface: Standard dark → White reflective
- ❖ Floor insulation: R-14 unfaced → R-14ff unfaced
- ❖ Building leakage: ACH50 23.2 → 9.6
- ❖ Mechanical Systems:
  - Strip resistance → HSPF 7.5
  - 3.5 ton, SEER = 10 → 3 ton, SEER 12 w/ERV
  - Ventilation: Fixed → CO<sub>2</sub> modulated



# *FL PERC Features*

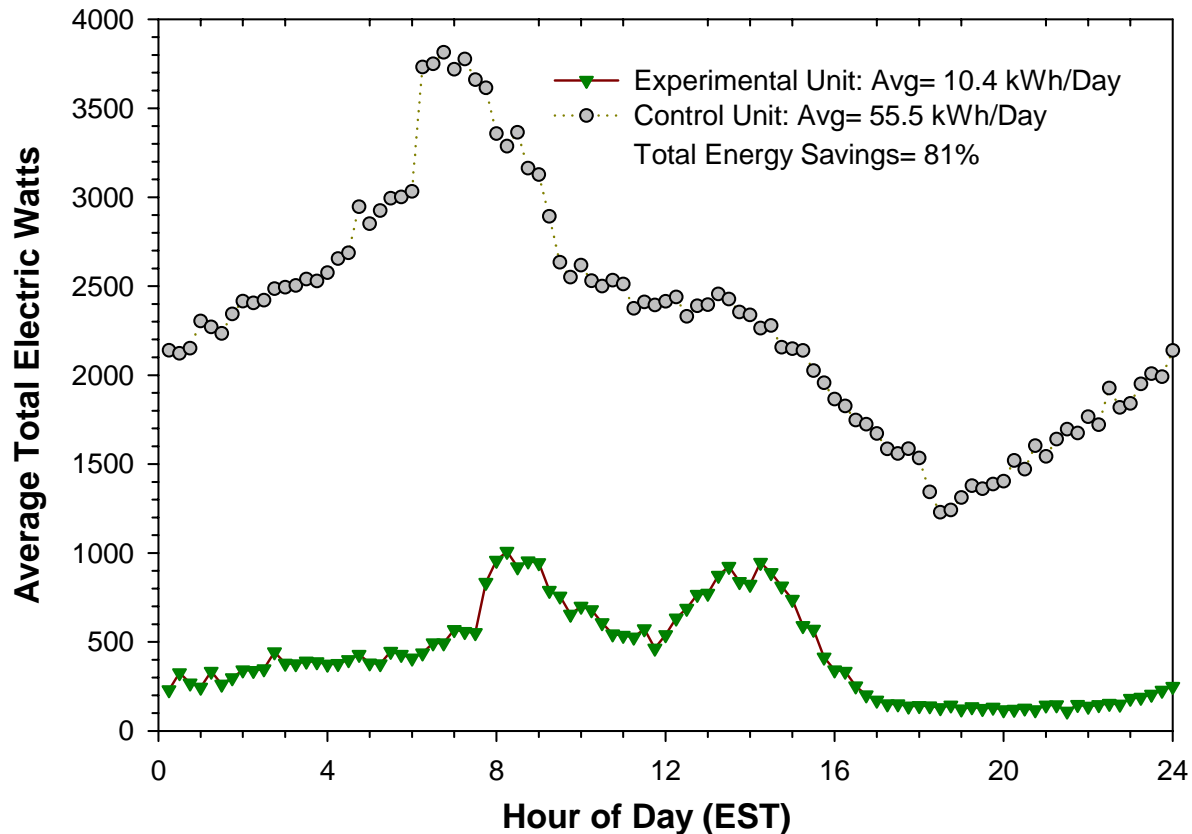
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- ❖ Exterior Doors: Steel, R-1.5 → Steel, R-4.8
- ❖ Lighting
  - T-12s, CLC=1,234W → T-8s, CLC=915W
- ❖ Windows
  - U-Factor = 1.03 → 0.28
  - SHGC = 0.84 → 0.39
  - Tvis = 0.77 → 0.71
- ❖ Skylights:
  - 21" diameter Solatubes

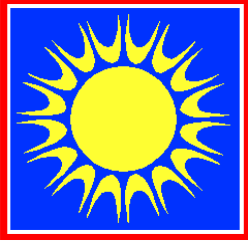


# *FL Measured Performance - 81% Savings*

**Total Electric Energy Demand Profile  
November 2003 – May 2004  
Experimental vs. Control Portable Classrooms  
Orlando, FL**

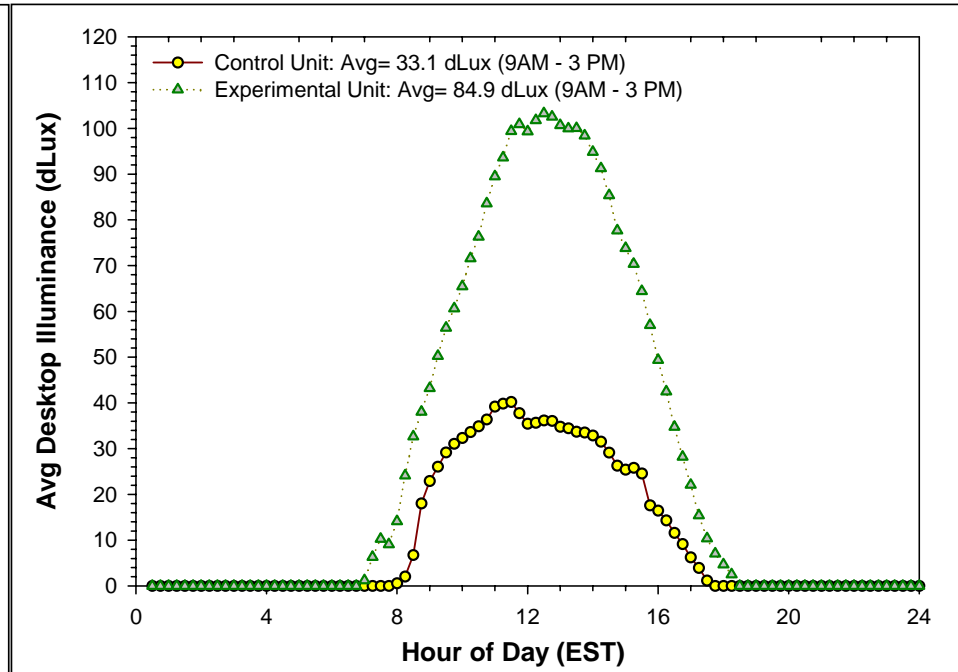
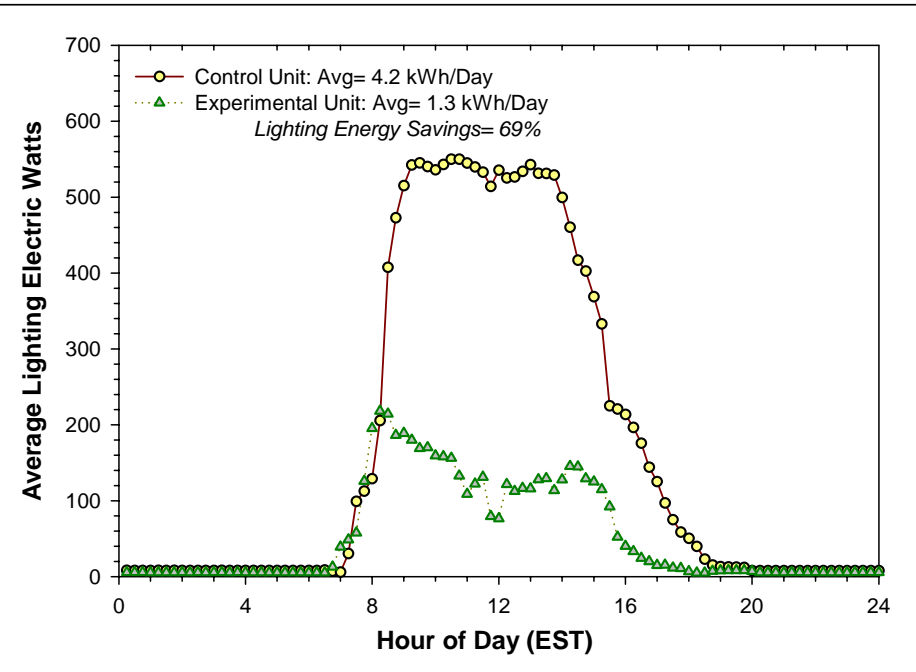


# Lighting Electric Energy Savings= 69%, Orlando



One third the energy use

For 2.5 times more light!





# *Visual impact of daylighting*

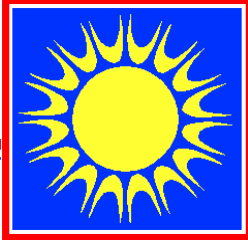
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*Control*



*Experiment*





# Measured Long-Term Performance of Portable Classrooms

Parameter	New York Control	New York Exp	North Carolina Control	North Carolina Exp	Florida Control	Florida Exp
<b>Total (kWh/Day)</b>	134.3	88.6	51.1	27.3	55.5	10.4
<b>HVAC (kWh/Day)</b>	118.8	71.9	45.0	19.9	49.6	8.5
<b>Lighting (kWh/Day)</b>	14.9	13.6	3.9	1.3	4.2	1.3
<b>DHW (kWh/Day)</b>	0.2	0.4	1.0	0.9	---	---
<b>Other (kWh/Day)</b>	0.4	2.7	1.2	5.2	1.7	0.6
<b>Savings (kWh/Day)</b>	---	45.7	---	23.8	---	45.1
<b>Interior CO<sub>2</sub> (ppm)*</b>	777	788	746	628	531	744
<b>Interior Temp. (°F)*</b>	71.3°	70.4°	68.9°	67.5°	70.7°	70.7°
<b>Interior R. Humidity (%)*</b>	32%	30%	42%	38%	50%	49%

\* Weekdays, 8AM-3PM

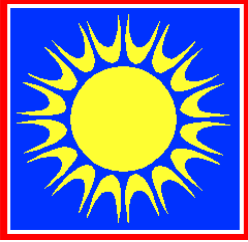


# Conclusions

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- ❖ HVAC was 80%+ in all location
- ❖ Lighting was 10-15% of total energy
- ❖ Savings
  - New York: 36%
  - North Carolina: 46%
  - Florida: 81%
- ❖ Superior daylighting demonstrated; teacher/student preferred
- ❖ Lighting savings require good controls
- ❖ Impact on CO<sub>2</sub> was mixed
- ❖ HVAC controls with heat pumps are an important issue...
- ❖ Acoustic tile ceilings with vented plenum produce leaky inefficient structures
- ❖ Sealed plenum with reflective roof= large cooling energy savings

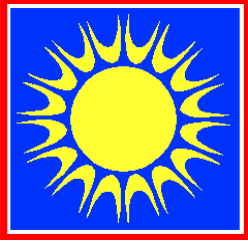




## *Some Lessons*

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- ❖ Control issues to overcome (general HVAC mainly plus e.g. automated sky lights)
- ❖ Skylights should have light wells – provided much better light distribution and result in 20% increase in measured illuminance
- ❖ **Insist** on reduced fixture and lamp count with integrated skylighting
- ❖ Field measurement/follow through is a must!



# *Summary*

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- ❖ PERCs show significant energy savings are possible (estimate 40 - 50% average for production)
- ❖ Able to work with industry, and industry claims to be interested
- ❖ **Large orders and/or Code changes will be needed for reasonable costs and real change**



# PERC Website

FSEC - PERC Comparison - Netscape

File Edit View Go Bookmarks Tools Window Help

http://www.fsec.ucf.edu/bldg/active/education/perc/index.htm Search

Mail AIM Home Radio My Netscape Search Bookmarks WebMail

 **PERC Comparison**

**NASEO** National Association of State Energy Officials  
ENERGY'S WASHINGTON VOICE

| [Education & Training](#) | [Environment](#) | [Homes & Buildings](#) | [Photovoltaics](#) | [Solar Energy](#) |

[Home](#) > [Homes & Buildings](#) > [Activities](#) > [Schools](#) > [PERC Comparison](#)

**Performance Enhanced Relocatable Classrooms** are improved modular built classrooms constructed in a factory and delivered to school sites. They are not only designed to use less energy than the typical modular classrooms built today, but have improved indoor air quality and enhanced levels of natural lighting, which has been shown to increase test scores and enhance attendance levels for school children.

This project is sponsored by [National Association of State Energy Officials \(NASEO\)](#) and the [Department of Energy \(DOE\)](#). The first PERC was located at Willow Avenue Middle School in Cornwall, New York, in September 2002, and is known as the NY PERC. Two more PERCs were located in Florida and North Carolina. Click the links to access these classrooms to view energy performance, photographs and construction details.



<http://www.fsec.ucf.edu/bldg/active/education/perc/index.htm>

# Task 6 – Large Scale Study and Diagnostic Testing



**WHAT'S MISSING IN THIS PICTURE?**

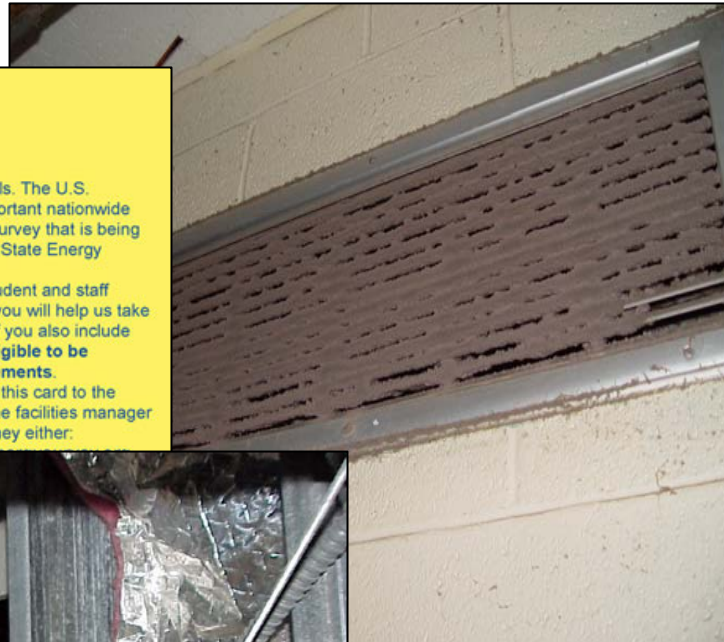


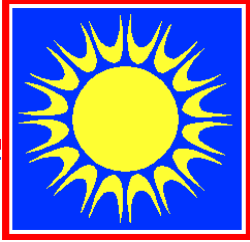
Dear School Principal:

You are! You can help us help our schools. The U.S. Department of Energy is conducting an important nationwide school comfort conditions and energy use survey that is being administered by the National Association of State Energy Officials (NASEO).

Comfort conditions significantly affect student and staff productivity. By participating in this survey, you will help us take an important step toward positive change. If you also include contact information, **your school will be eligible to be selected for one or more energy improvements.**

Here's what we're requesting — forward this card to the appropriate individual at your school (e.g. the facilities manager or head of maintenance) and request that they either:





# *Task 6 – Large Scale Study and Diagnostic Testing*

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## *Issue:*

There are significant Indoor  
Air Quality Problems in  
Schools throughout the U.S.



# Web-enabled Survey

[energysurvey.org](http://energysurvey.org)

**NASEO** National Association of State Energy Officials

school puzzle piece **Welcome to the K-12 School Conditions and Energy Use Survey website.**

**Thank you for your help in completing this important survey. Please take a moment to read excerpts from a letter from the Director of the National Association of State Energy Officials (NASEO).**

"Research shows that there are a number of benefits from positive environmental conditions in schools. Among them are improved comfort, healthier and more productive students and teachers, reduced absenteeism and greater learning . . .

. . . the first step in making improvements is to know where we stand right now and where the improvement opportunities are. By completing the following survey, you will help us do just that".


**You can read the [entire letter](#) or proceed directly to the [survey](#).**



# Web-enabled Survey

- ❖ Postcards Sent to over 90,000 schools
- ❖ Also solicited help from groups such as Schooldude.com

**WHAT'S MISSING IN THIS PICTURE?**



Dear School Principal:

You are! You can help us help our schools. The U.S. Department of Energy is conducting an important nationwide school comfort conditions and energy use survey that is being administered by the National Association of State Energy Officials (NASEO).

Comfort conditions significantly affect student and staff productivity. By participating in this survey, you will help us take an important step toward positive change. If you also include contact information, **your school will be eligible to be selected for one or more energy improvements.**

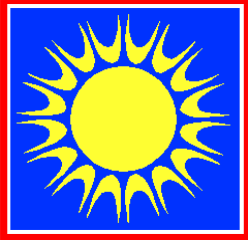
Here's what we're requesting — forward this card to the appropriate individual at your school (e.g. the facilities manager or head of maintenance) and request that they either:

- complete the survey on our website at [energysurvey.org](http://energysurvey.org)
- or
- call (866) 215-4035 toll free to complete the survey on the phone or to ask questions.

Thank you for your assistance!

*Frank Bishop*  
Frank Bishop, Executive Director, NASEO

- ❖ 247 total respondents (0.27% response rate)
- ❖ At least one response from each of 46 states.

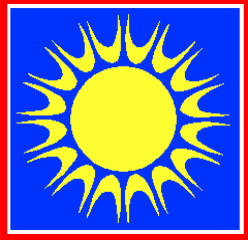


# *Classroom Comfort*

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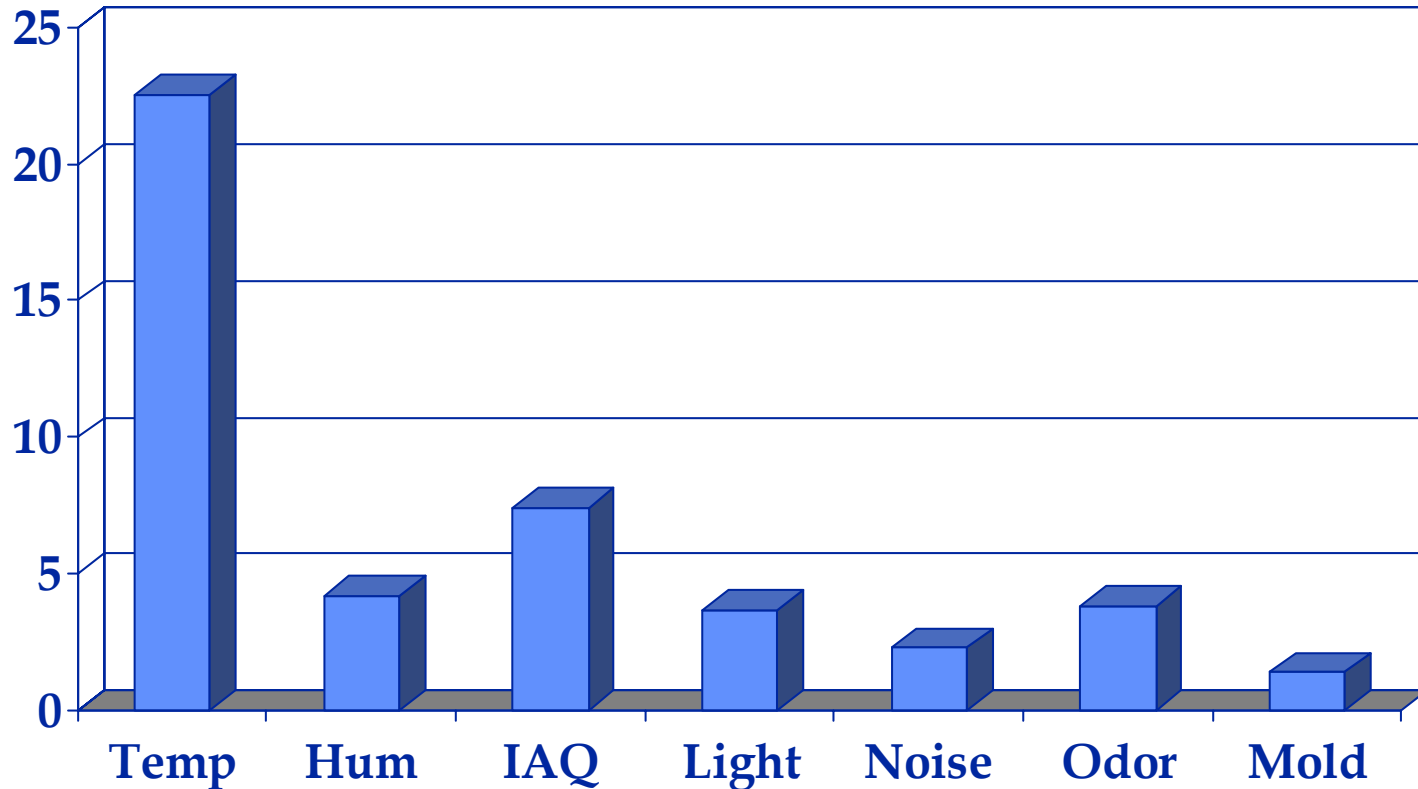
% of respondents

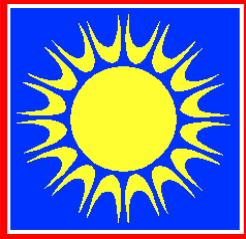
Complaint Level	Temp	Humidity	IAQ
None	3.2	48.6	34.4
A Few	46.3	37.4	44.2
Many	28	8.9	13.0
Chronic	22.5	4.2	7.4
N/A		0.9	0.9



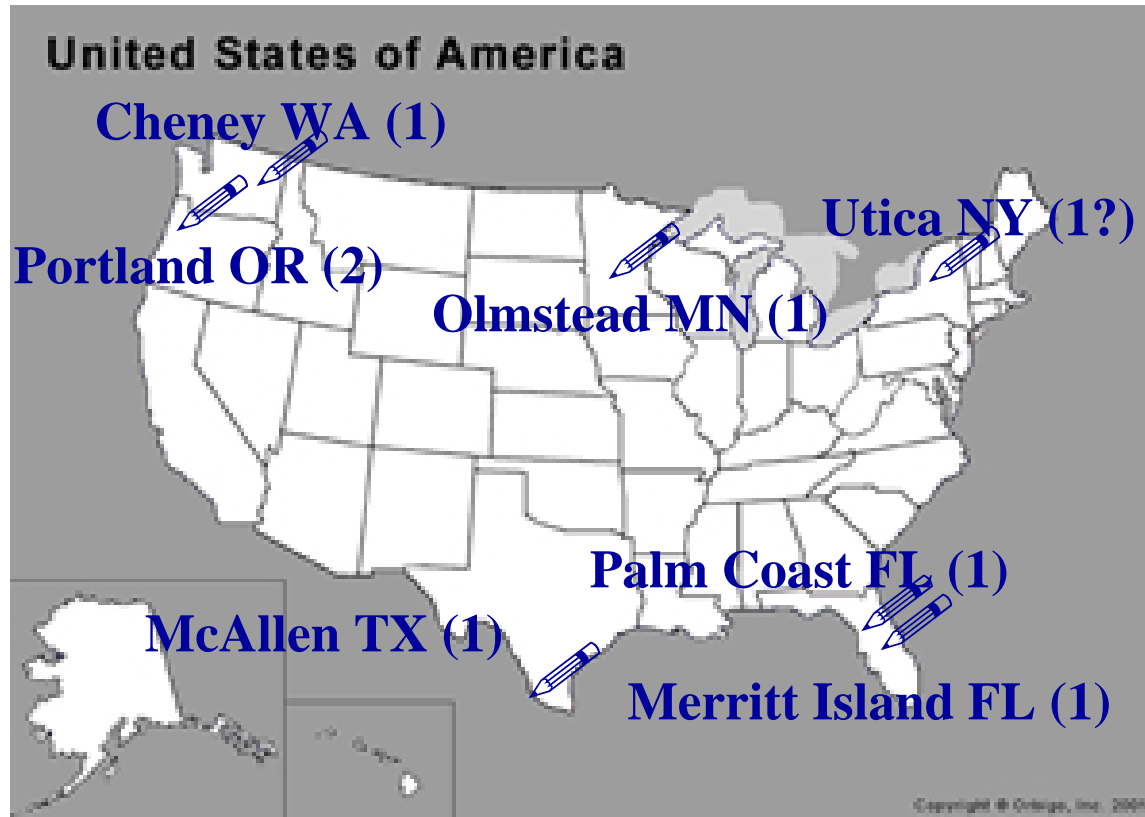
# *% Chronic Complaints*

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# *School Audit Locations*





# *School Audits Review*

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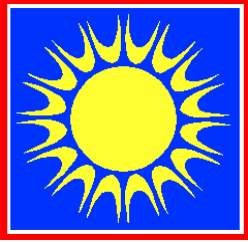
- ❖ Audit teams in South, Northeast, Midwest and Northwest
- ❖ 8 Audits conducted through March 2003.
- ❖ Significant effort to line up schools for all audits
- ❖ Only 2 of 8 school audits found from survey (including Minnesota audit)



# *School Audits*

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- ❖ Florida and Texas audits found:
  - Low classroom temperatures (68-70F)
  - High RH levels common (60-70%)
  - Ventilation and exhaust air problems
  - Operations and maintenance problems (e.g. not aware of return grilles)
  - “Band aids” (e.g. portable dehumidifiers)



# *School Audits*

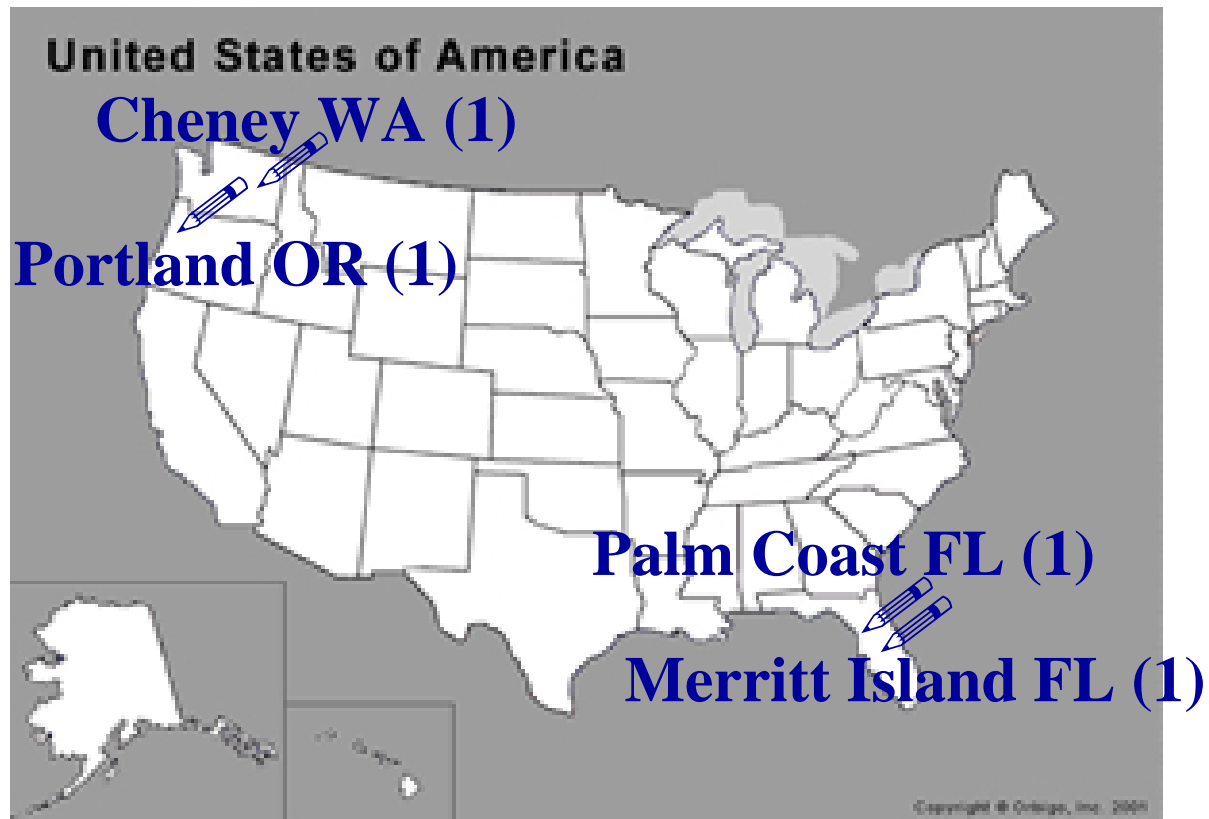
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- ❖ Northwest and Minnesota audits found:
  - Ventilation control problems
  - Exhaust fans inadequate (pollutants/odors)
  - Air mixing problems
  - Operations and maintenance issues (e.g. switching maintenance services)



# *Retrofit Locations*

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# *Palm Coast (FL) Retrofit*

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# *Palm Coast (FL) Retrofit*

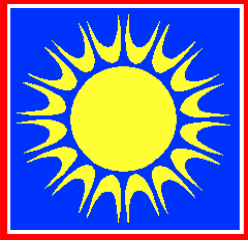
- ❖ Staff complaints of:
  - High humidity
  - Moldy smells
  - General IAQ dissatisfaction
- ❖ Testing and monitoring found:
  - Significantly leaky building (vented soffits)
  - High classroom humidity levels and some low classroom temperatures (~70F)



# *Palm Coast (FL) Retrofit*

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# *Palm Coast (FL) Retrofit*

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## ❖ Recommended:

- Building sealing
- Run AHs in Auto mode, reduce AH flow rates
- Adjust outdoor air intakes

## ❖ Implemented:

- Building sealing
- Building is now tighter but follow up on other recommendations required – some CO<sub>2</sub> levels high and RH still high in some locations



# *Palm Coast (FL) Retrofit*

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## What We Specified



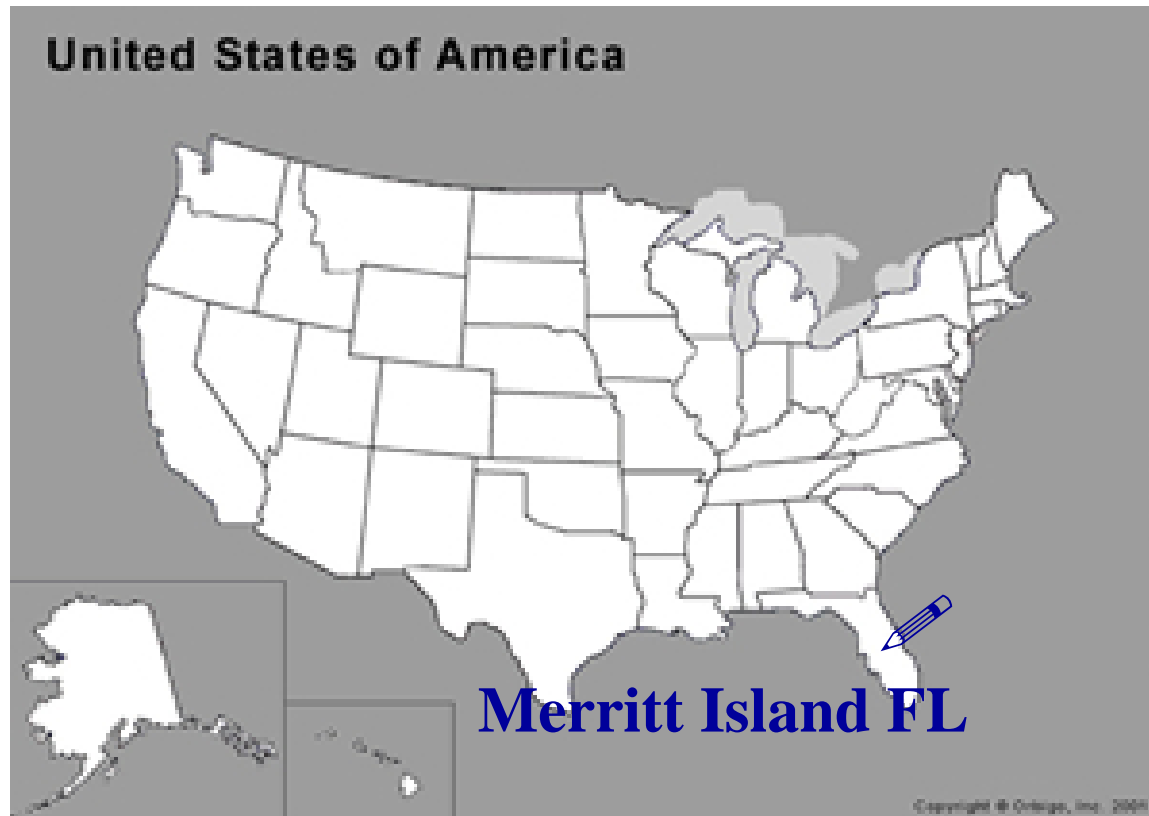
## What We (almost) Got (for ~ \$3,000 more)





# *Merritt Island (FL) Retrofit*

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# *Merritt Island (FL) Retrofit*

- ❖ Staff complaints of:
  - High humidity
  - Mold problem in several classrooms
  - Cold classrooms
- ❖ Testing and monitoring found:
  - Var. flow chilled water, fan coils manual on/off
  - OA partially from ceiling space (fan coil openings)
  - Building leaky (ACH50 11.1)
  - Several rooms < 70F and/or 60-65+% RH



# *Merrit Island (FL) Retrofit*

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# *Merritt Island (FL) Retrofit*

## ❖ Recommended:

- Dedicated outdoor air ventilation system
- Tighten building envelope/evaluate fan coil leak openings

## ❖ Implemented:

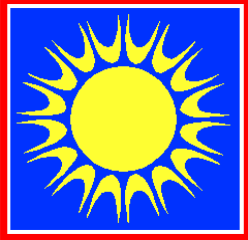
- Band aid dehumidification solution for two classrooms with mold problems
- Post data shows lower RH (generally 50% or lower) and no additional mold problems reported in the two classrooms



# *Cheney (WA) Retrofit*

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# *Cheney (WA) Retrofit*

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- ❖ Staff complaints of:
  - Odors in several areas
- ❖ Testing and monitoring found:
  - Over ventilation of gym and multipurpose room
  - Ventilation air mixing problem in gym (“short circuit”)



# *Cheney (WA) Retrofit*

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## ❖ Recommended:

- CO<sub>2</sub> sensor controls for gym and multipurpose room
- redirect gym supply diffusers

## ❖ Implemented:

- CO<sub>2</sub> sensor controls for gym and multipurpose room, redirect gym supply diffusers
- New controls not programmed at first, now post retrofit monitoring completed; data analysis underway



# *Portland (OR) Retrofit*

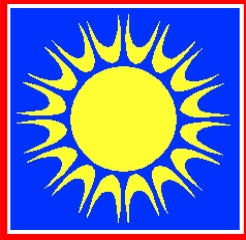
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# *Portland (OR) Retrofit*

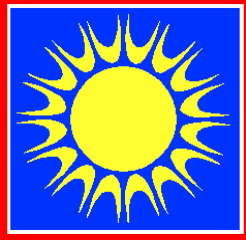
- ❖ Staff complaints of:
  - Periodically too hot or too cold
  - Stiffness and odors
- ❖ Testing and monitoring found:
  - Widespread inadequate ventilation
  - Low bathroom exhaust fan flows
  - Common areas (gym, cafeteria and auditorium) over ventilated



# *Portland (OR) Retrofit*

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# *Portland (OR) Retrofit*

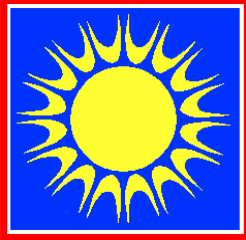
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## ❖ Recommended:

- Unit ventilator maintenance throughout
- CO<sub>2</sub> sensor controls for common areas

## ❖ Implemented:

- Unit ventilator maintenance and CO<sub>2</sub> controls
- Several implementation problems, post retrofit monitoring now completed; data analysis underway
- Initial reports from school administrator indicate the retrofits have been working well



# *Retrofit Observations*

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- ❖ Difficult to get initial school cooperation, even with clear problems present
- ❖ Recommendations modified by school and/or contractor
- ❖ Difficult to get follow-up cooperation after retrofit
- ❖ Some limited success indicated



# *Summary*

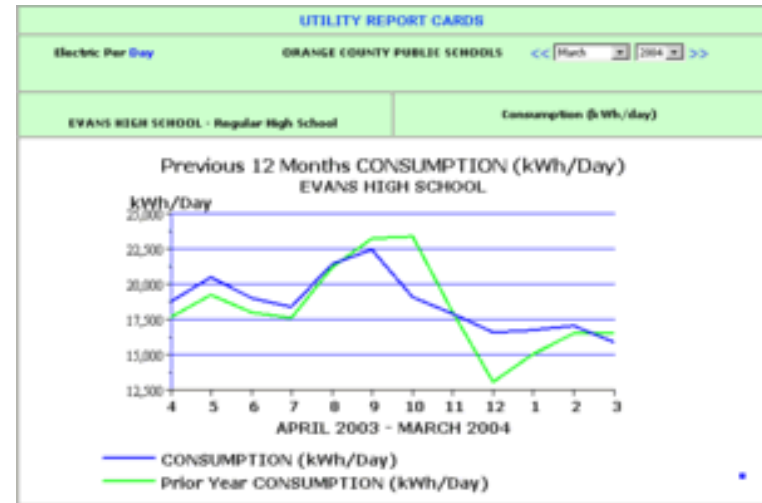
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- ❖ Comfort improvements are possible
- ❖ Schools must have real incentive(s) to participate
- ❖ Energy analyst must be paid to supervise all work
- ❖ Need to design schools with separate means of treating outside air in humid climates
- ❖ School officials need to be educated that IAQ problems are real and should not be ignored or covered up



# Other FSEC schools work

- ❖ *Utility Report Card* – automatic report on utility energy bill with newsletter and web site:  
*UtilityReportCard.com*



- ❖ *Building Performance Matters* - web based science unit for grades 9-12:  
*www.fsec.ucf.edu/ed/bpm/*



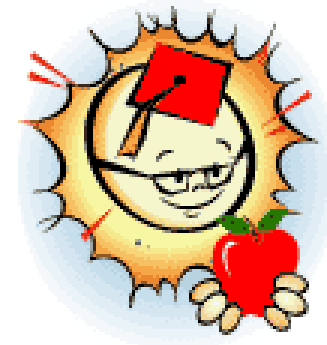


# *Other FSEC schools work*

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- ❖ *Energy Whiz* – information site for students and teachers:

*EnergyWhiz.com*



Professor Sunny

- ❖ *PV for Schools* – demonstrating solar power at Florida schools:  
*www.fsec.ucf.edu/pvt/Projects/pvforschools/index.htm*

