Energy Smart Schools

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

Chicago, IL

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Florida Solar Energy Center
Sept 29, 2004

Task 3– P.E.R.C. (Performance Enhanced Relocatable Classrooms)

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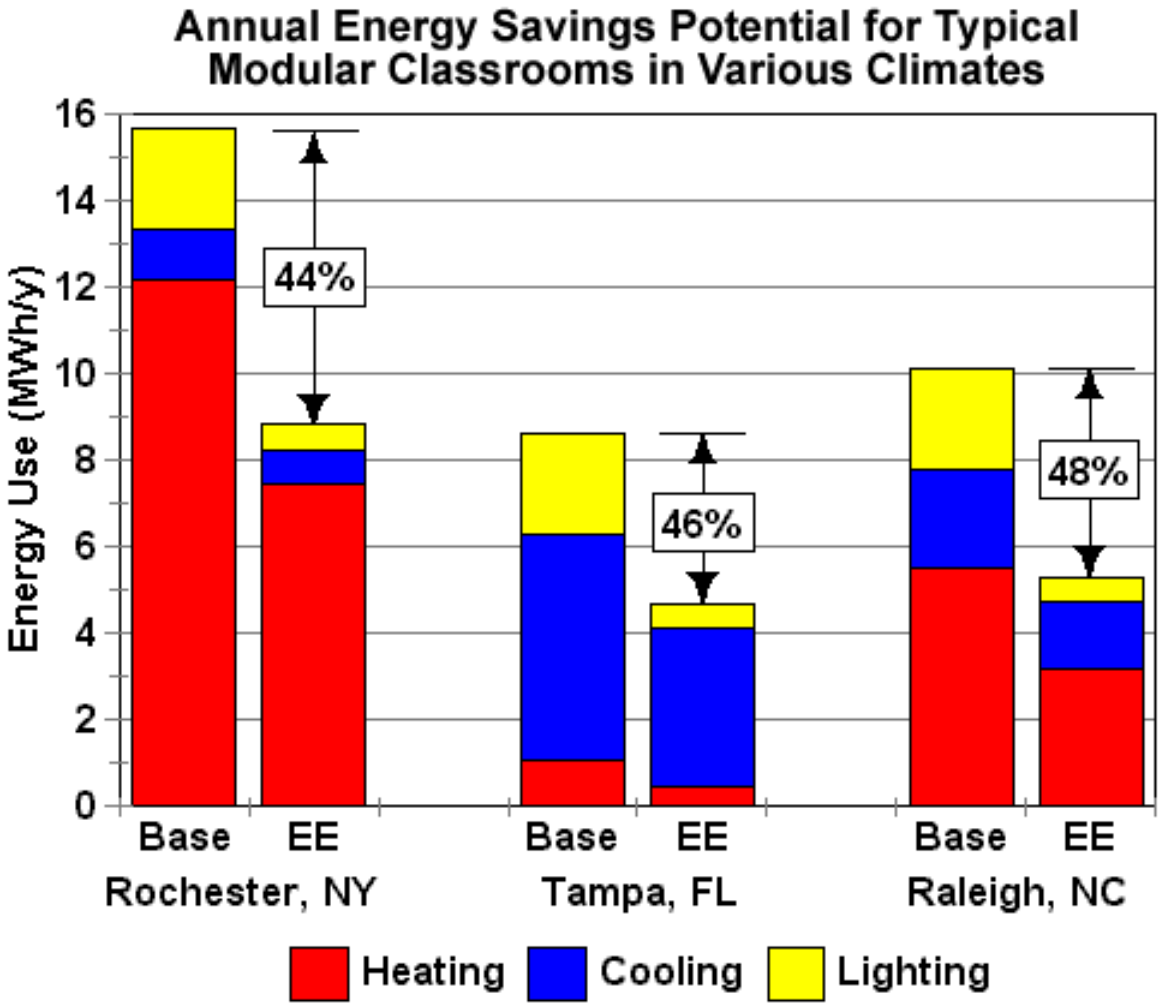
Issue:

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



Objectives

- 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

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

New York PERC

(Cold Climate Design)

NY PERC and Control Units

NY PERC Features

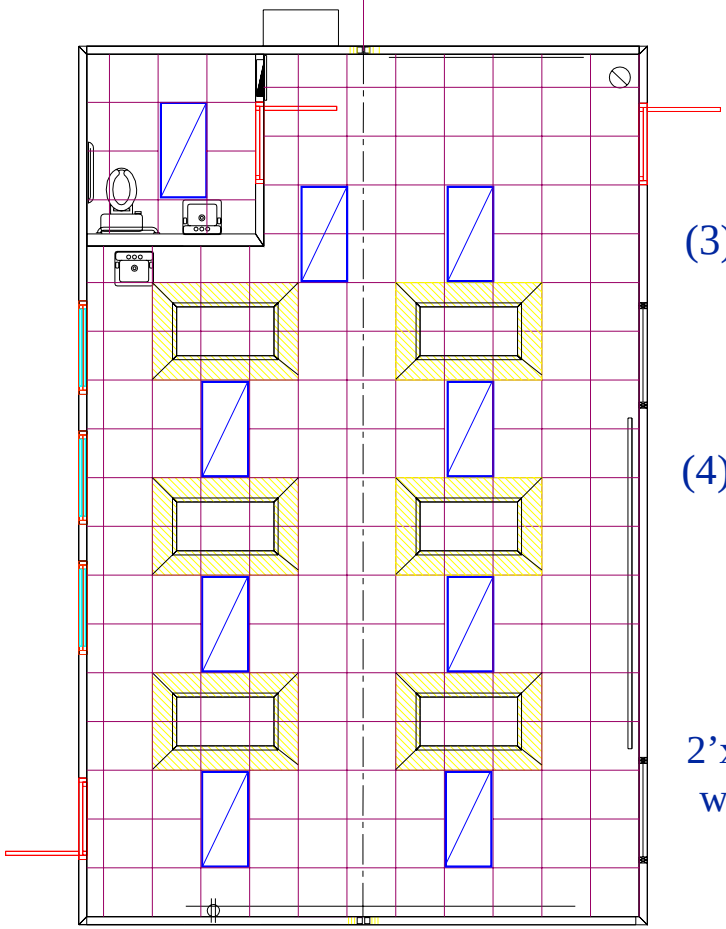
- Wall insulation: R-11 → R-19ff (w/ ½" PolyStyrene)
- Roof/ceiling insulation : R-19 → R-30
- Floor insulation: R-11 → R-13ff
- Building leakage: ACH50 16.4 → 16.7
- Mechanical Systems:
  - Strip heat → HSPF 7.5
  - 3 ton / SEER 10 → 3 ton / SEER 12 w/ERV
  - Duct air leakage: Standard → Sealed w/ mastic
  - Ventilation: Fixed CFM → CO_2 modulated

NY PERC Features

- 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



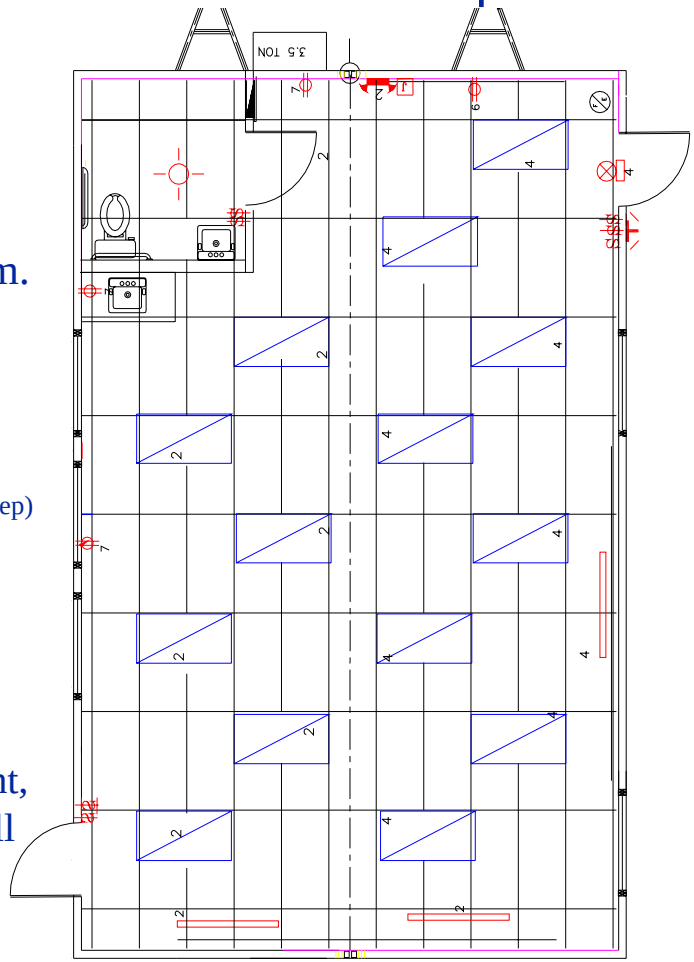
NY Energy Model

(3) lamp dim. fixture

(4) Lamp (2 step) fixture

2’x4’ Skylight, w/ 4’x6’ well a.f.c.

56 T-12 lamps



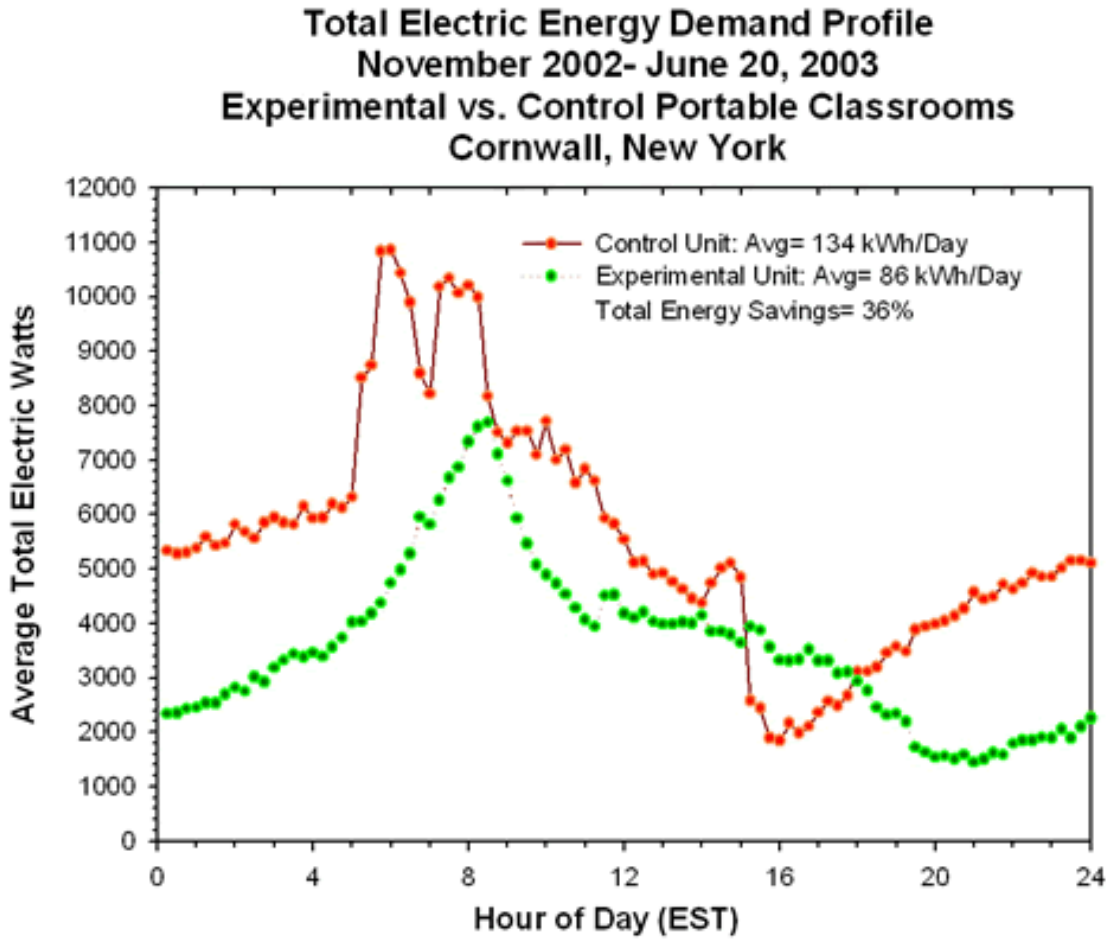
NY Standard Model

Lighting Levels

NY Energy model interior view (no electric lighting)

NY Standard model interior view (no electric lighting)

NY Measured Performance



North Carolina PERC

(Mixed Climate Design)

NC PERC Unit

NC Control Unit

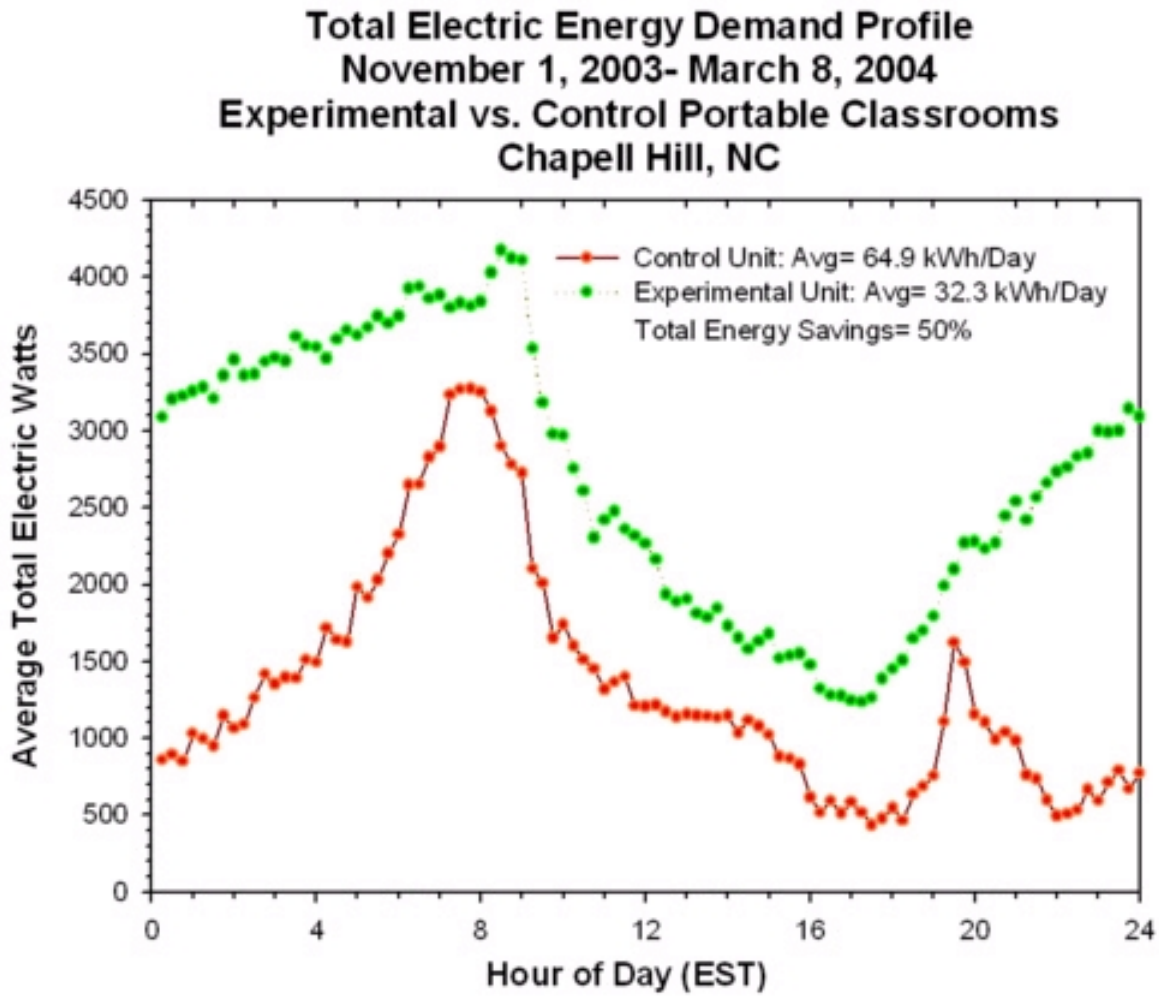
NC PERC Features

- 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_2 modulated

NC PERC Features

- 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
  - Tvis = 0.90 → 0.58
- Skylights:
  - None → Dbl. glazed prismatic, power louver

NC Measured Performance



Florida PERC

(Hot-Humid Climate Design)

FL PERC Unit

FL Control Unit

FL PERC Features

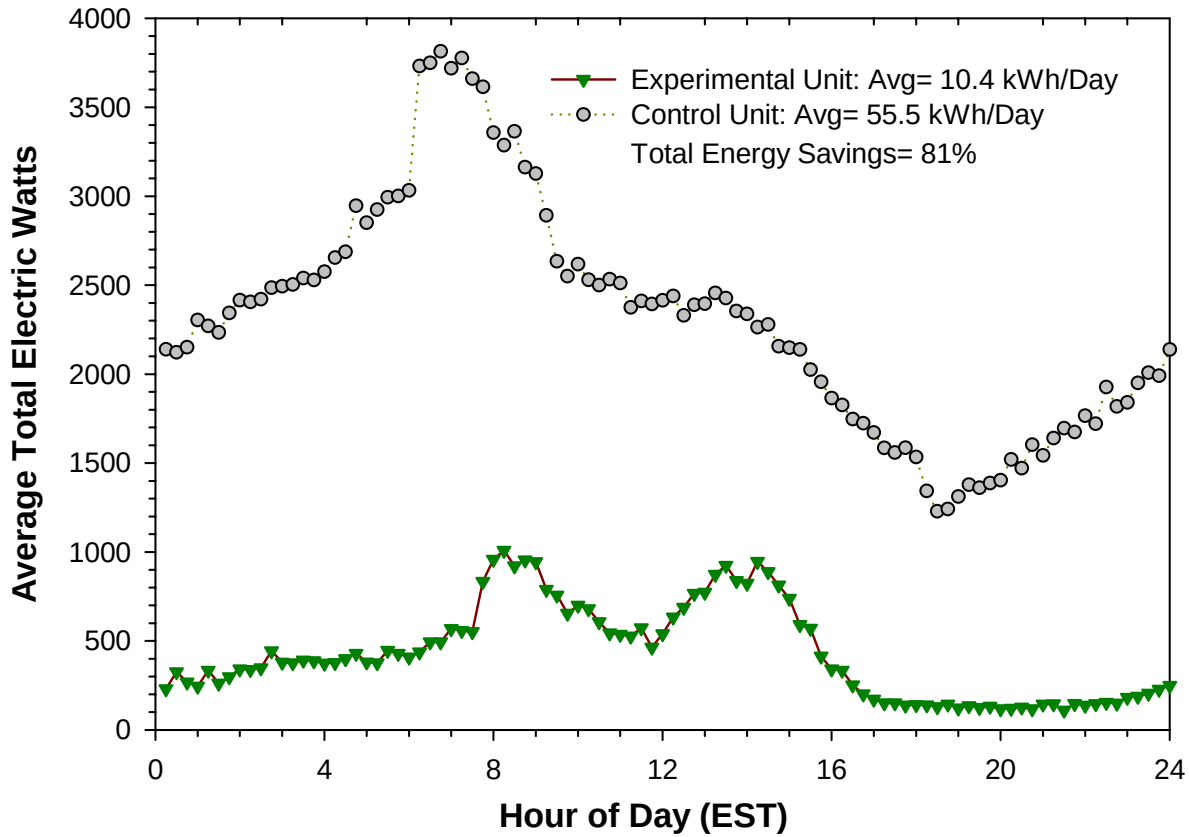
- Wall insulation: R-11 faced → R-14ff unfaced +
- Roof/ceiling insulation : R-19 → R-30 Icynene
- Roof surface: Standard dark → White reflective
- Floor insulation: R-14 unfaced → R-14ff unfaced
- Building leakage: ACH50 23.2 → 9.6
- Mechanical Systems:
  - Strip resistance → HSPF 7.5
  - 3.5 ton, SEER = 10 → 3 ton, SEER 12 w/ERV
  - Ventilation: Fixed → CO_2 modulated

FL PERC Features

- 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

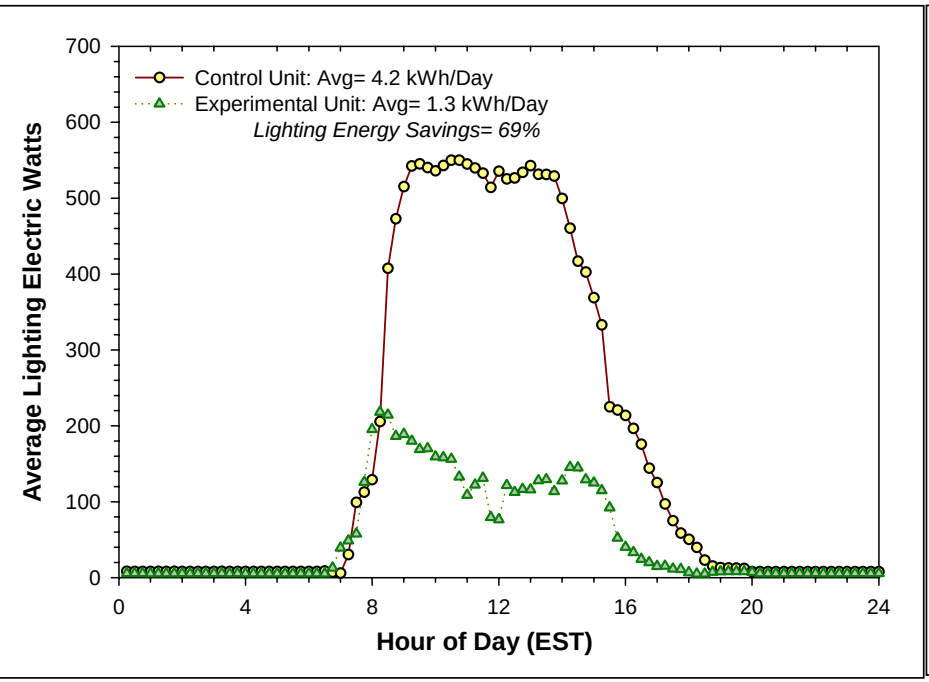
Total Electric Energy Demand Profile
November 2003 – May 2004
Experimental vs. Control Portable Classrooms
Orlando, FL

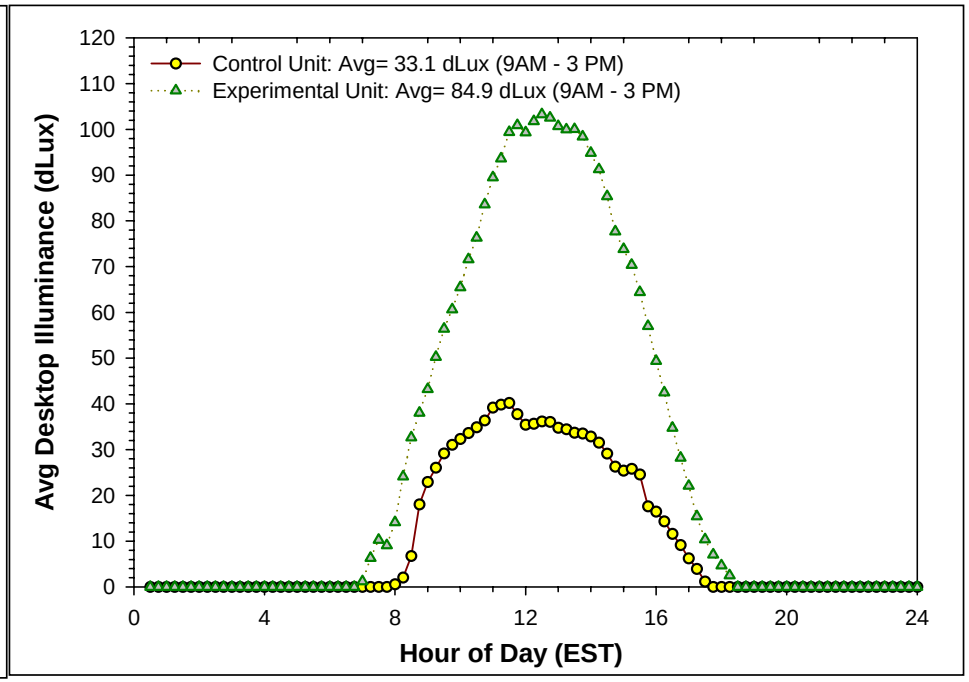


Lighting Electric Energy Savings= 69%, Orlando

One third the energy use

For 2.5 times more light!





Visual impact of daylighting

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
Total (kWh/Day)	134.3	88.6	51.1	27.3	55.5	10.4
HVAC (kWh/Day)	118.8	71.9	45.0	19.9	49.6	8.5
Lighting (kWh/Day)	14.9	13.6	3.9	1.3	4.2	1.3
DHW (kWh/Day)	0.2	0.4	1.0	0.9	---	---
Other (kWh/Day)	0.4	2.7	1.2	5.2	1.7	0.6
Savings (kWh/Day)	---	45.7	---	23.8	---	45.1
Interior CO_2 (ppm)*	777	788	746	628	531	744
Interior Temp. (ºF)*	71.3º	70.4º	68.9º	67.5º	70.7º	70.7º
Interior R. Humidity (%)*	32%	30%	42%	38%	50%	49%

*** Weekdays, 8AM-3PM**

Conclusions

- 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_2 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

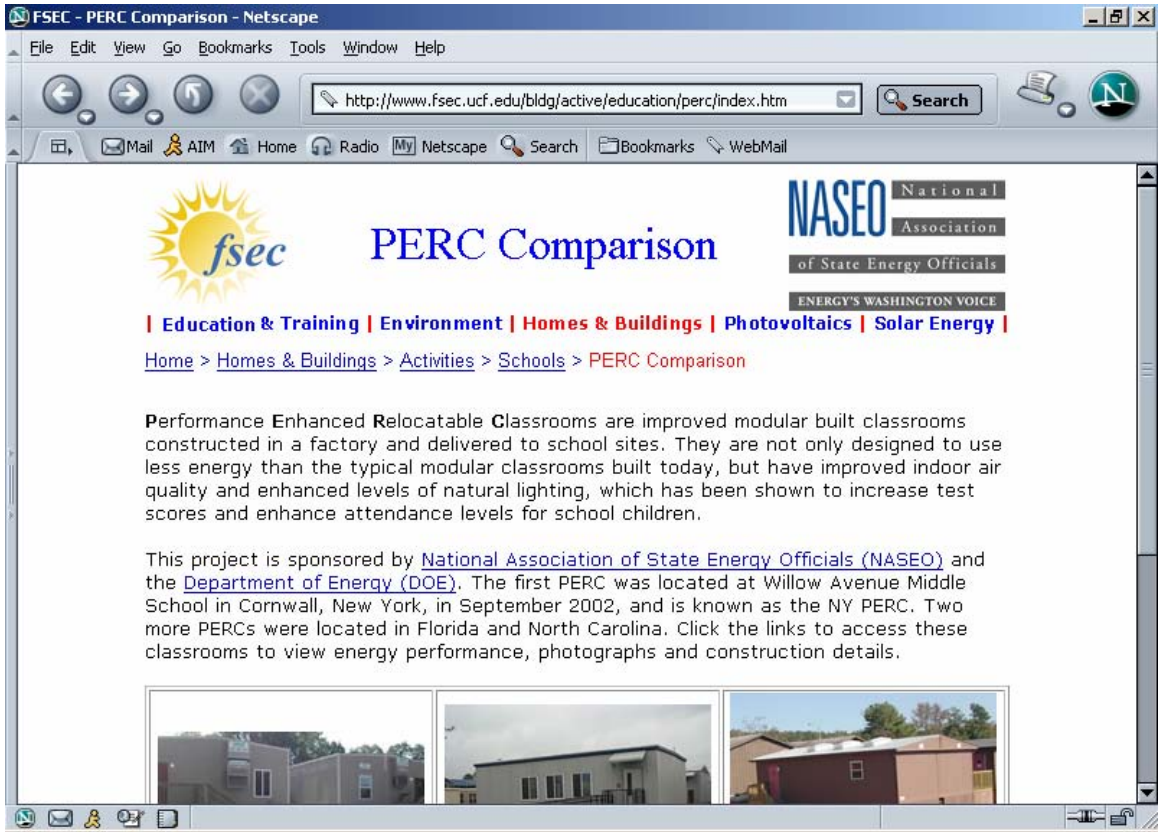
Some Lessons

- 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

- 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



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

Task 6—Large Scale Study and Diagnostic Testing

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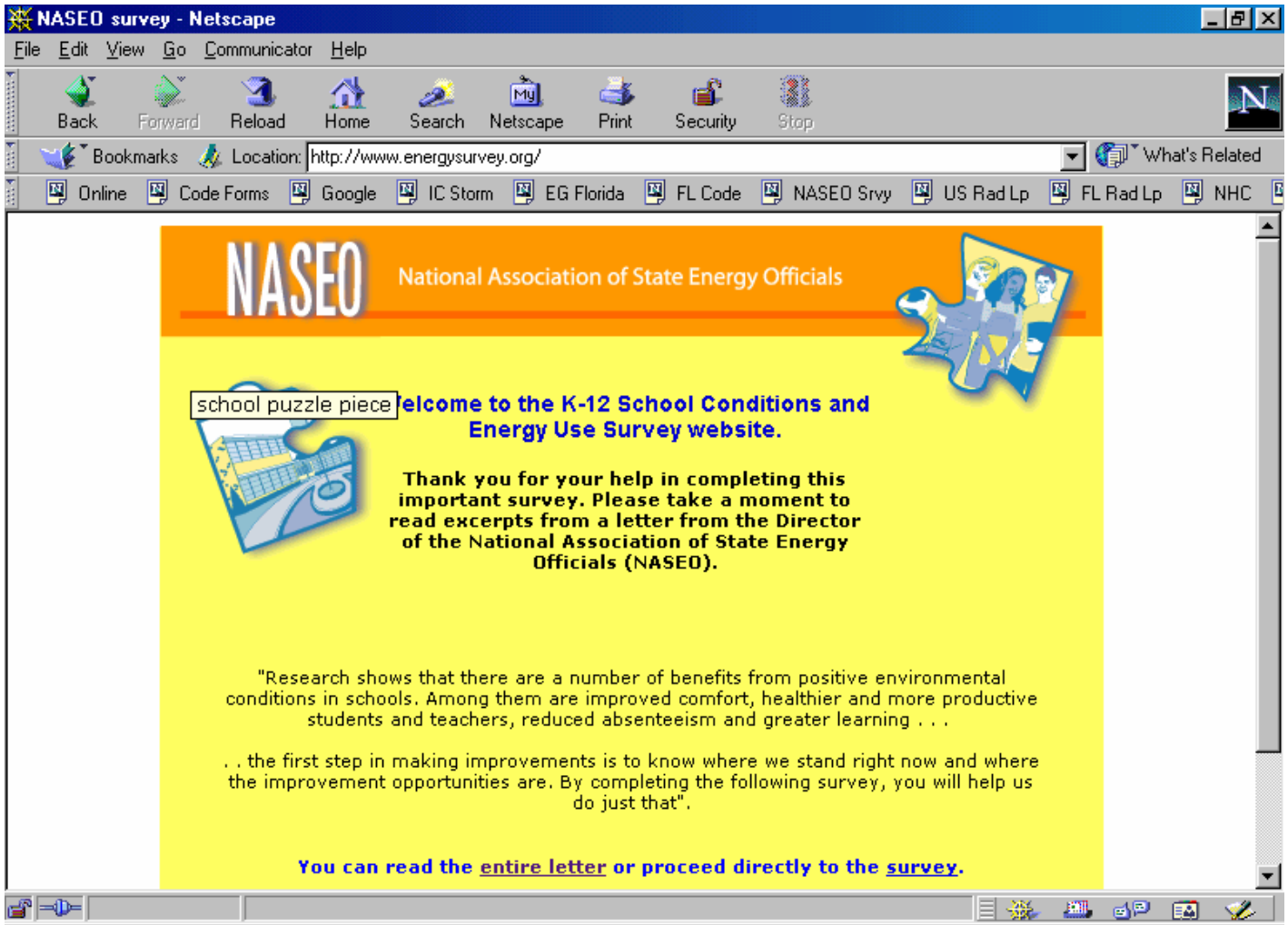
Issue:

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

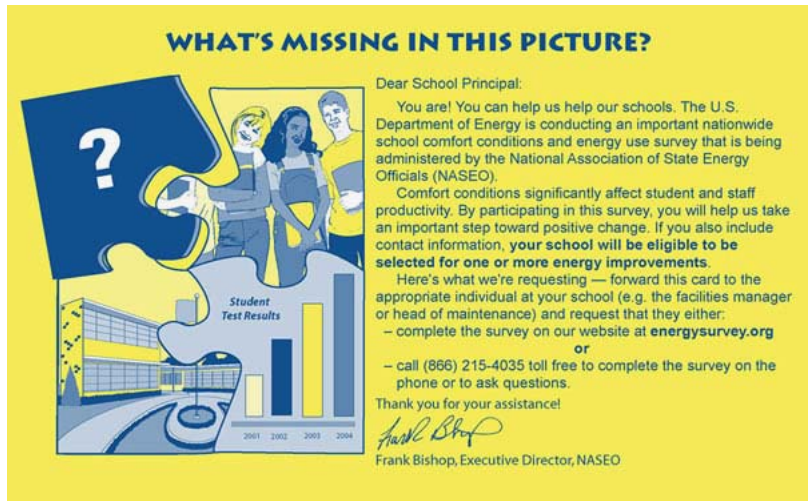
Web-enabled Survey

energysurvey.org



Web-enabled Survey

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



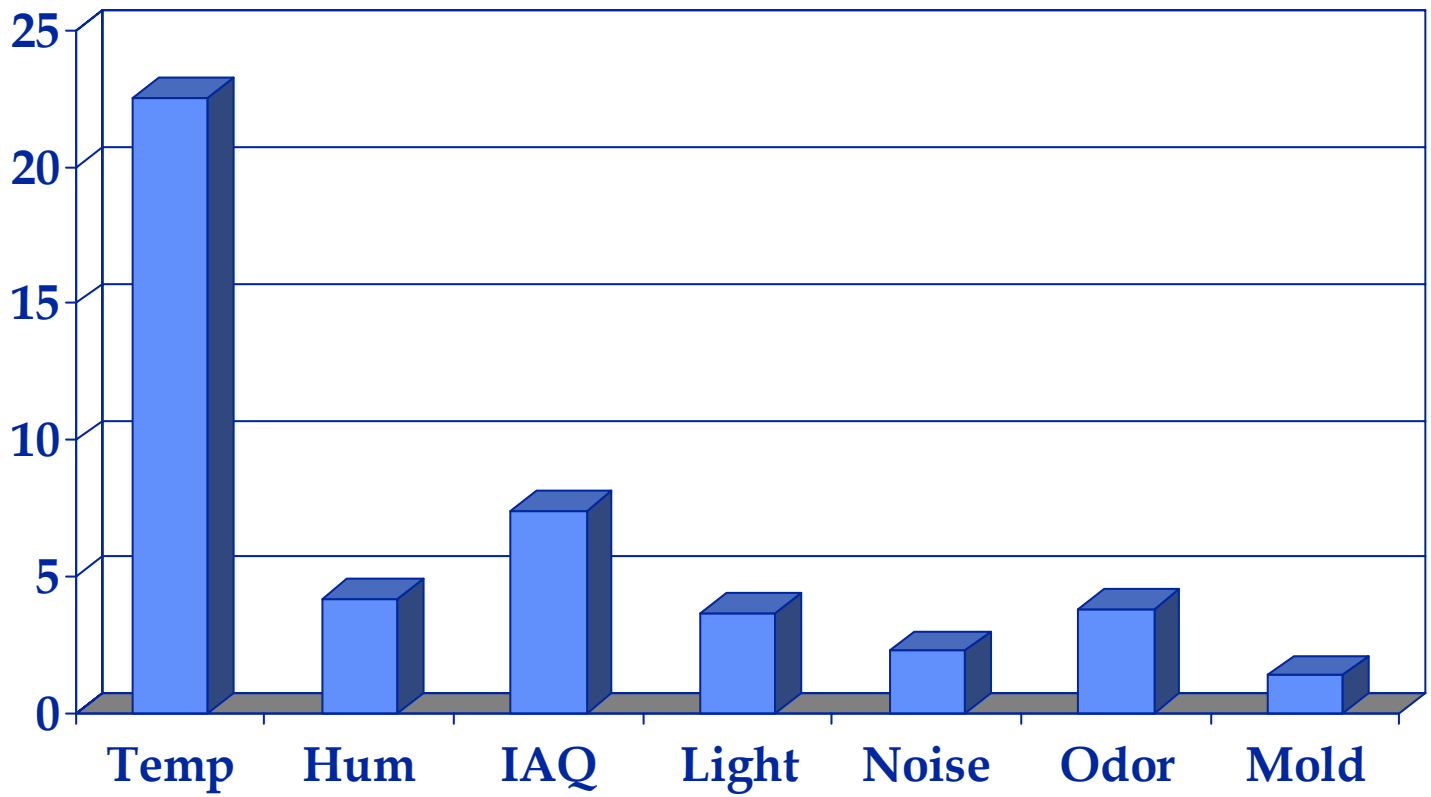
- 247 total respondents (0.27% response rate)
- At least one response from each of 46 states.

Classroom Comfort

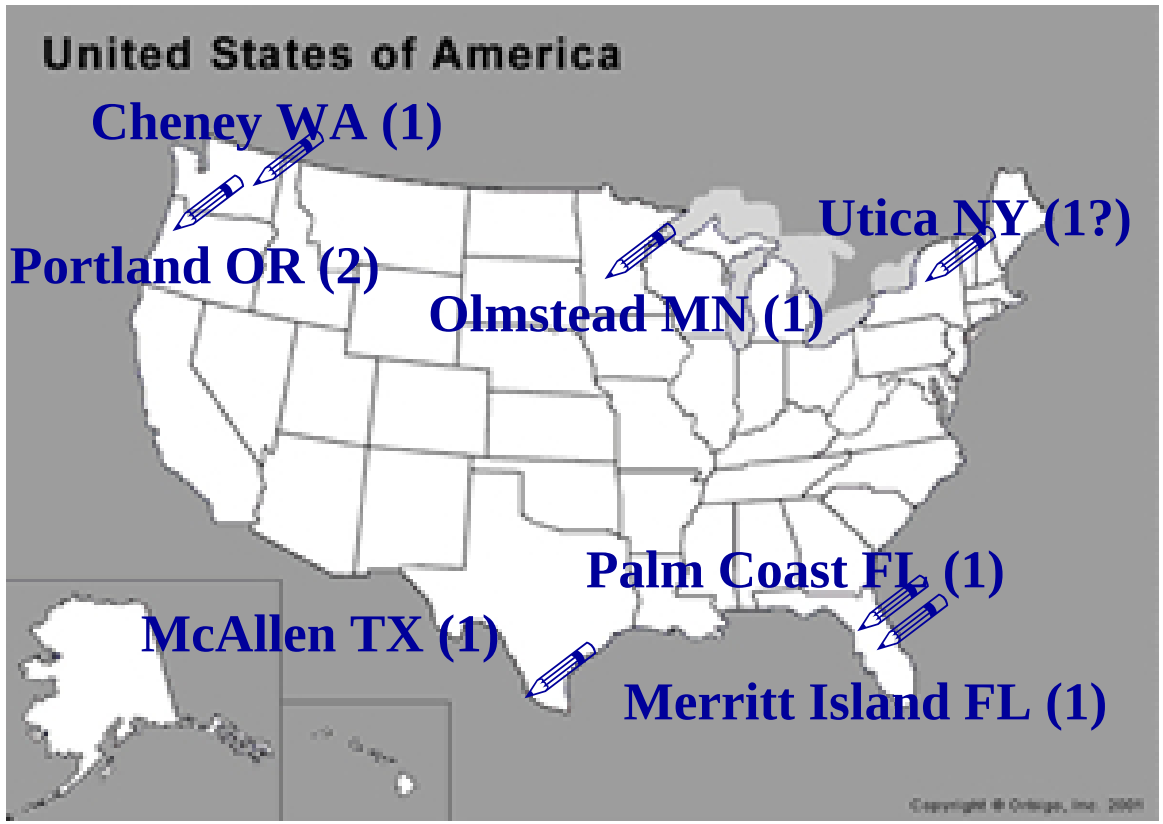
% of respondents

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



School Audit Locations



School Audits Review

- 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)

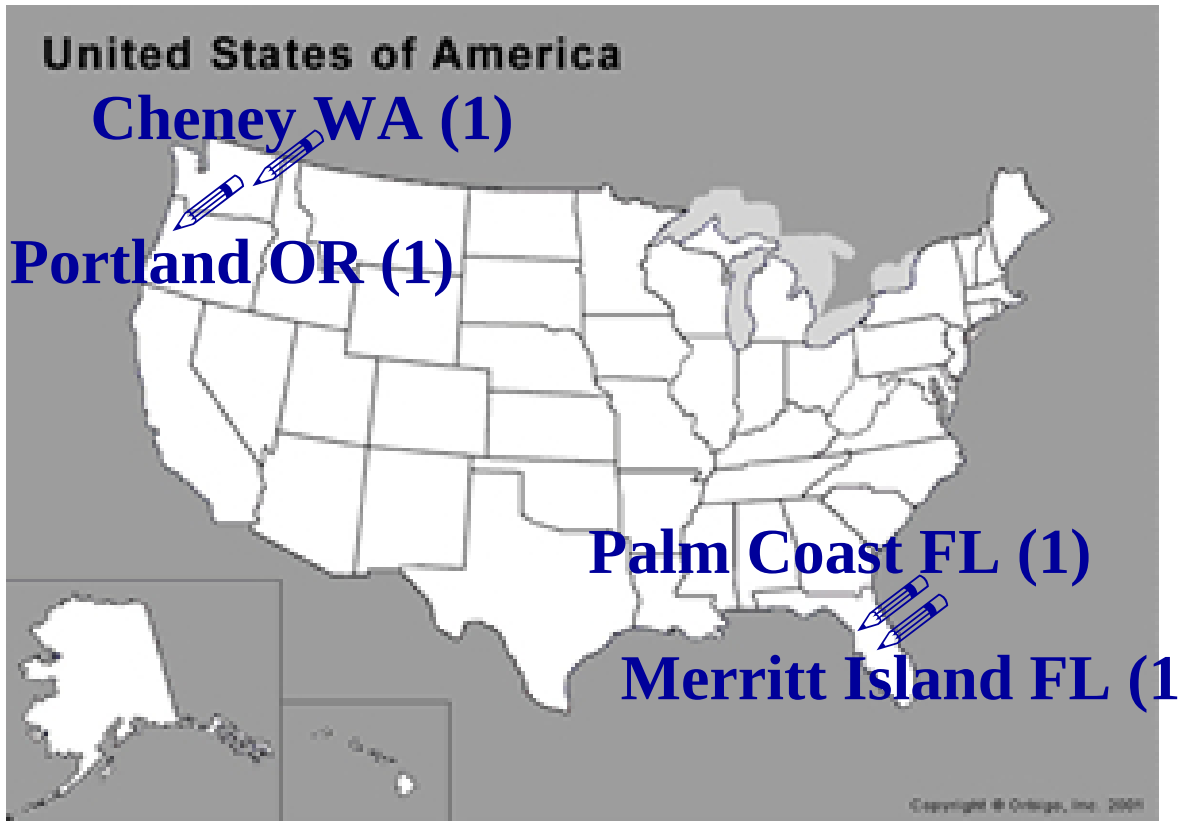
School Audits

- 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

- 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



Palm Coast (FL) Retrofit

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

Palm Coast (FL) Retrofit

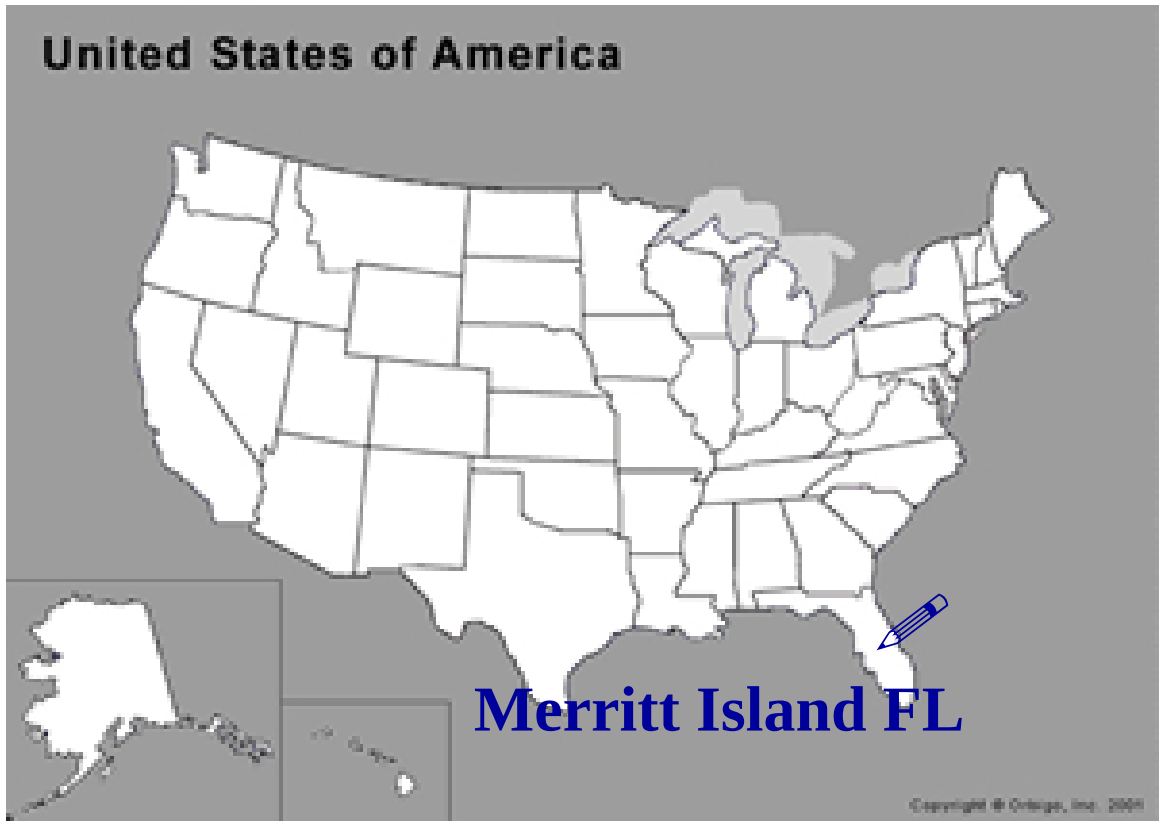
- Recommended:
  - Building sealing
  - Run AHs in Auto mode, reduce AH flow rates
  - Adjust outdoor air intakes
- Implemented:
  - Building sealing
  - Building is now tighter but follow up on other recommendations required – some CO_2 levels high and RH still high in some locations

Palm Coast (FL) Retrofit

What We Specified

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

Merritt Island (FL) Retrofit



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

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

Cheney (WA) Retrofit

- 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

- Recommended:
  - CO_2 sensor controls for gym and multipurpose room
  - redirect gym supply diffusers
- Implemented:
  - CO_2 sensor controls for gym and multi-purpose room, redirect gym supply diffusers
  - New controls not programmed at first, now post retrofit monitoring completed; data analysis underway

Portland (OR) Retrofit

Portland (OR) Retrofit

- Staff complaints of:
  - Periodically too hot or too cold
  - Stuffiness 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

Portland (OR) Retrofit

- Recommended:
  - Unit ventilator maintenance throughout
  - CO_2 sensor controls for common areas
- Implemented:
  - Unit ventilator maintenance and CO_2 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

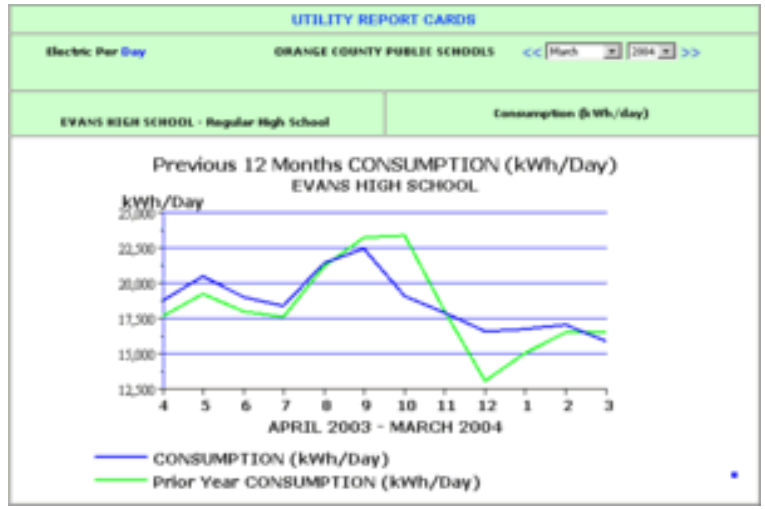
- Difficult to get initial school cooperation, even with clear problems present
- Recommendations modified by school and/or contractor
- Difficult to get follow-up cooperation after retrofit
- Some limited success indicated

Summary

- 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*



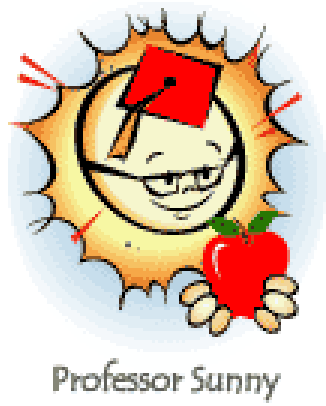
- ***Building Performance Matters*** - web based science unit for grades 9-12:

www.fsec.ucf.edu/ed/bpm/

Other FSEC schools work

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

  EnergyWhiz.com



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