Energy and Environment in Schools Technical Assistance Program

ASERTTI

U.S. Environmental Protection Agency

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Project Scope

- Highlight need for energy & environmental improvements in schools
- Document and disseminate results of four state-based schools demonstration projects
- Demonstrate energy, economic & health benefits

Why is this Project Important?

- Nation's schools have a energy bill of $6 billion annually
- Poor IAQ adversely affects teachers, administrators, students' performance
- DOE estimates that $1.5 billion could be saved through better design and use of widely available energy efficient and renewable technologies

Project Focus

- Daylighting
- Energy efficient integrated school buildings
- Improved indoor air quality
- Improved energy efficiency and comfort of portable classrooms

Participating ASERTTI Organizations

California Energy Commission

Florida Solar Energy Center

Energy Center of Wisconsin

California Energy Commission

- State's primary energy agency
- Major responsibility areas:
  - forecasting future energy needs and keeping historical energy data
  - siting and licensing power plants
  - promoting energy efficiency through appliance and building standards
  - developing energy technologies and supporting renewable energy

Technology Demonstration

- High performance design concepts in two public K-12 California schools that:
  - Provide good indoor and natural lighting
  - meet improved acoustical standards
  - use advanced HVAC technologies
  - monitor and control indoor air quality
  - reduce energy use

High Performance Schools

- Cesar Chavez Education Complex, Oakland, CA
  - 95,000 sq ft 2-story building
  - Construction cost: $240 per sq ft
  - Opened January 2004
  - Climate zone 3
  - 1st year energy use: 25% less than typical comparable school

High Performance Schools

- Alder Creek Middle School, Truckee, CA
  - 96,120 sq. ft 2-story building and 9.5 portable classrooms
  - Construction cost: $275 per sq ft
  - Opened Sept 2004
  - Climate zone 16
  - 1st year energy costs per sq ft: $1.06

Energy Efficient/Environmental Design Features

- Daylighting
- Natural ventilation
- High efficiency light fixtures
- Triple pane operable windows
- High efficiency ground source heat pump
- R-13 wall insulation
- Low-E building materials
- Recycled content products
- High efficiency boiler
- Energy Star-compliant roof

Design Benefits

- Lower operating costs (20-40% less for energy and water)
- Improved student and teacher health
- Higher attendance
- Better student performance
- Frees up scarce resources for books, supplies, equipment
- Onsite teaching opportunity in advanced technology and building design

Lessons Learned

- Building commissioning is extremely important to saving both time and money
- School districts and architects need more information and education on use of alternative materials
- Use a contractor familiar and receptive to CHPS criteria and insure clear communication to all involved parties
- With proper planning, CHPS schools can be designed and constructed for the same cost as typical public school

Energy Center of Wisconsin

- Private, non-profit 501(c)(3) organization dedicated to improving energy efficiency and renewable energy
- Mission: sponsor and conduct research in efficient use and management of energy and to transfer the results of that research to energy service consumers and providers

Technology Demonstration

- Monitor and evaluate daylighting at four diverse school sites in four states
  - Study the effects of daylighting on human factors and energy efficiency
- Daylighting and HVAC Impacts
  - Primary research on sidelighting and potential cooling savings

School Monitoring: School Demonstration Sites

- Congress Elementary School, Milwaukee, **WI** (urban setting)
- Georgina Blach Intermediate School, Los Altos, **CA** (suburban setting)
- Solon High School, Solon, **IA** (rural setting)
- Zach Elementary School, Fort Collins, **CO** (suburban setting)

Congress Elementary School

Original fenestration and new tinted glass

Photosensor built into luminaire

Congress Elementary School Results

- Pros
  - Automatic dimming not noticeable
  - Dimming override appreciated by teachers
  - Window tinting not noticeable
- Cons
  - Eastern exposure, too much sun in mornings
  - Numerous blinds must constantly be adjusted; inaccessible
  - Diminished space for posting teaching aids

Blach Intermediate School

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Typical pendant lights, white-board light (C), and clerestory windows (R)

Blach Intermediate School Results

- Pros
  - Windows, lighting well-accepted
  - Dimming works well, not noticeable
  - No major concerns about restricted view
  - Some teachers choose to work without electric lighting
- Cons
  - Some find the space too dark
  - Some teachers find the space not dark enough to audio/visual
  - Some blinds are inaccessible
  - May see premature lamp failure in future due to no lamp seasoning procedures

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Solon High School

Solon High School, South side

North side of classroom wing

Solon High School Results

- Pros
  - Window tinting not noticeable
  - No major concerns about restricted view
  - Use of blinds does not impact lighting energy savings
- Cons
  - Insufficient shading on South side, making blinds essential
  - Upper blinds are inaccessible yet are frequently needed and thus are left closed
  - Switching somewhat noticeable at first

Zach Elementary School

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Zach Elementary School Results

- Pros
  - Windows, blinds, lighting generally well-accepted
  - Window tinting not noticeable
  - Few complaints of switching being noticeable
  - No major concerns about restricted view
- Cons
  - Insufficient shading on South side making blinds essential
  - Overlighted in some spaces (Kindergarden rooms)

Human Factors Summary

- Tinted glass is considered visually comfortable
- Shading devices are necessary
- Teachers object to spaces where blinds require frequent adjustments and are difficult to access
- A limited number of view windows is acceptable
- All four schools find their classrooms visually comfortable, bright and cheerful
- All four school find their lighting comparable or superior to other schools

Cost and Energy Savings

- Daylighting recommended as a no or low-first-cost, simple approach for schools; low or no-first-cost is achieved through incorporation of a downsized HVAC system
- Potential savings of nearly 25% on operating costs
- Careful attention to glazing characteristics and lighting configuration can result in significant reduced lighting costs

Lessons Learned

- Light sensors must be properly located and maintained
- Dimming controls must be compatible with light sensors
- Daylighting controls must be user-friendly
- Teachers and administrators must be trained and support daylighting concept
- Various uses of the classroom such as darkening for audio-visual equipment must be considered

Energy Savings from Daylighting – A Controlled Experiment

Analyst: Scott Pigg, Senior Project Manager

Energy Resource Station
operated by the Iowa Energy Center

The theory

Daylighting controls + high performance glazing =

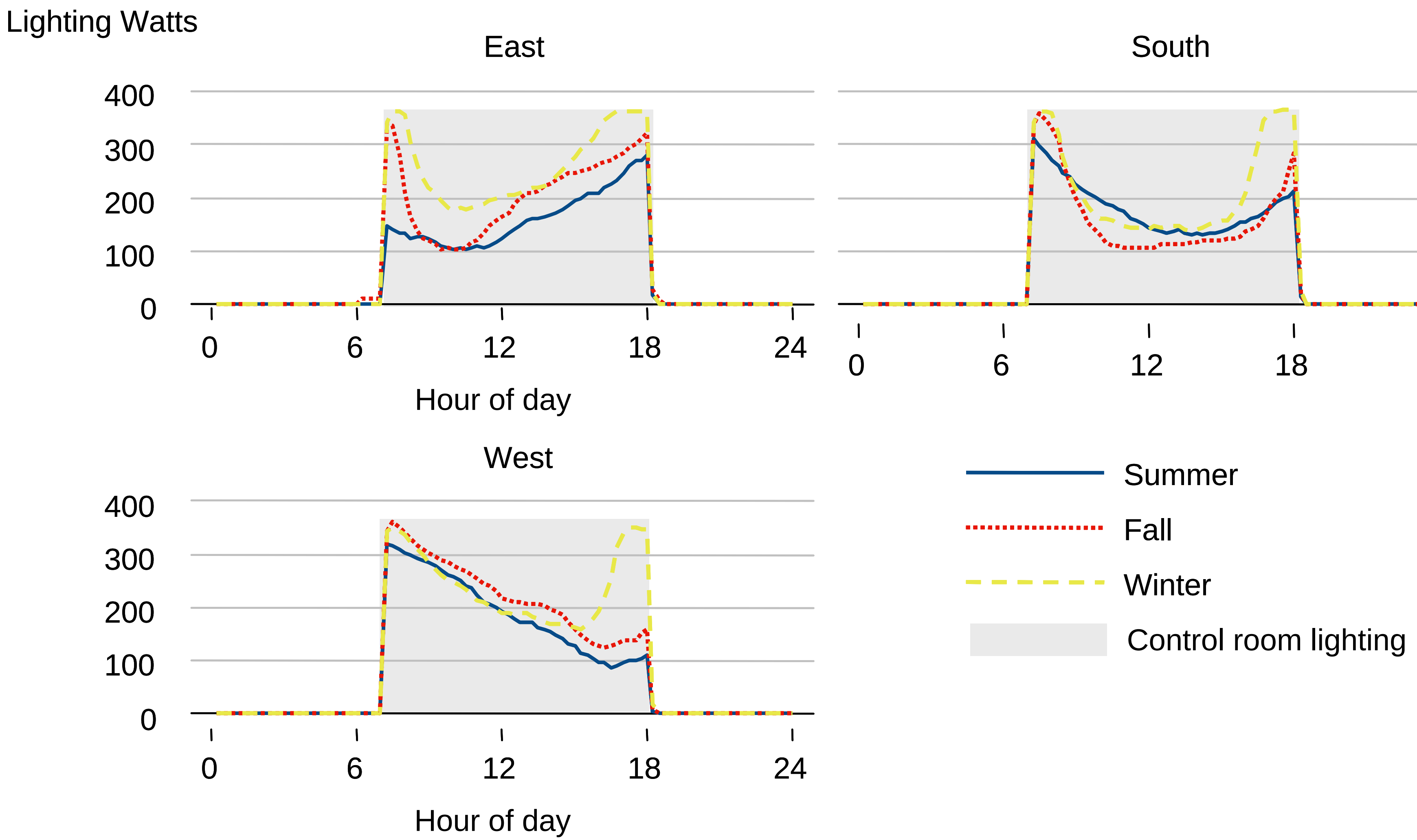
- reduced electricity for lighting
- reduced HVAC loads
- a more pleasant environment

dimmable ballasts + light sensors to automatically adjust the level electric lighting in response to the available daylight

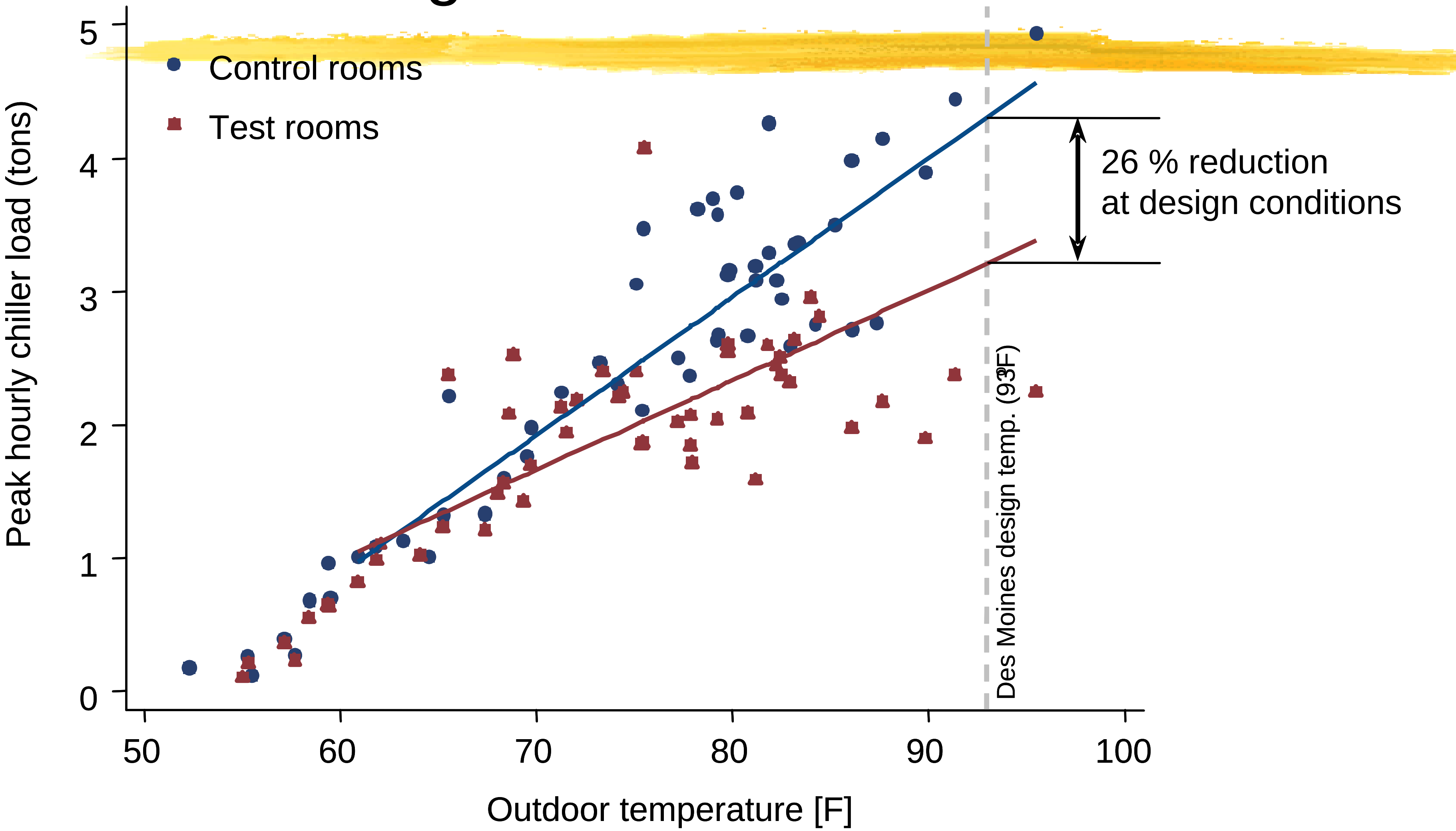
reduced visible transmittance (VT) to reduce glare, and reduced solar heat gain coefficient (SHGC) to reduce cooling load

Lighting savings

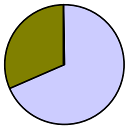
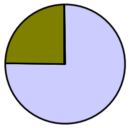
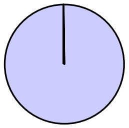
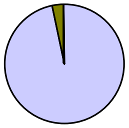
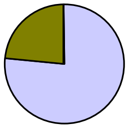
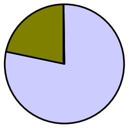
Overall: 41% savings (32% incl. interior rooms)



Peak cooling load



Putting it all together – annual operating costs

	Base (cents/ft^2)	Savings (cents/ft^2)	Savings Percent	
Lighting energy	22	7	32%	
Cooling energy	19	5	25%	
Heating energy	6	0	-1%	
Fan energy	13	<1	3%	
Demand charges	53	12	24%	
Total	**113**	**24**	**22%**	

Florida Solar Energy Center

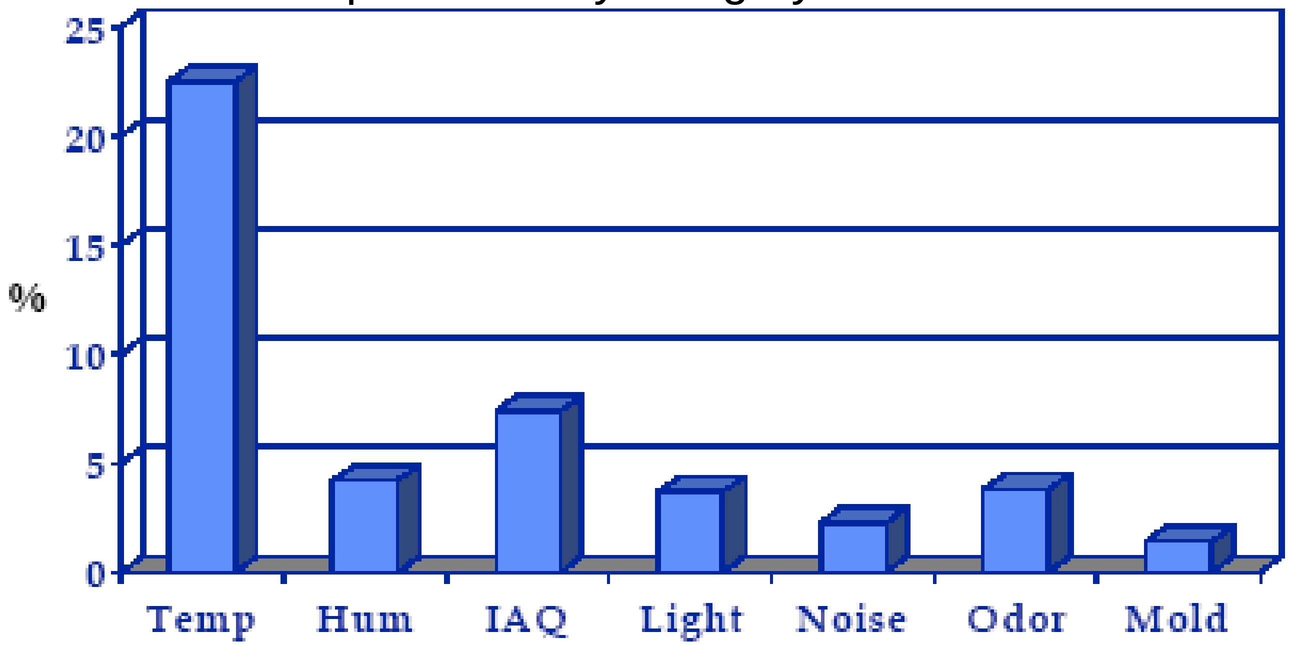
- State-supported renewable energy and energy efficiency research, training and certification institute
- Mission: research and development of energy technologies that enhance the nation’s economy and environment, and to educate the public, students and practitioners on the results of the research

Technology Demonstration

- Three-part project to investigate indoor air quality in eight schools
  - Nationwide web-based survey to obtain occupant feedback on indoor air quality, thermal, lighting and acoustical conditions in schools
  - Field audits and diagnostic tests and measurements at these eight schools
  - Recommend retrofits in problem schools to alleviate problems

Survey Results

Percent of respondents indicating chronic problems by category



Based on 239 total respondents

School Demonstration Locations

Based on the results of the web-based survey, eight schools were identified for comfort conditions audits.

Comfort Conditions Audits

- On-site comfort conditions audits conducted at each of the eight schools
- Findings
  - Significant ventilation problems in all eight schools
  - High relative humidity levels (60-70%) and low classroom temperatures conducive to mold problems in hot-humid climate schools

Retrofits Recommended and Implemented at Four Schools

- Sealing soffit vents
- Installing ceiling mounted dehumidifiers
- Cleaning and calibrating unit ventilators
- Reconfiguring multizone fan systems
- Reducing air handler flow rates
- Controlling ventilation based on occupancy
- Adjustment/replacement of dampers, controls and valves

Energy/Environmental Benefits after Retrofits

- Less energy loss from building envelope
- Relative humidity drop of 20-30%
- Decreased energy demand; energy cost savings
- Increase in average air flow of 207 cfm
- Increase in occupant comfort level

Lessons Learned

- School conditions problems can be successfully diagnosed and solved
- Schools in humid climates need to be designed with a separate means of treating outside air
- Relatively minor changes/improvements can offer big improvements in indoor air quality
- From initial testing to verification of retrofit effectiveness, a knowledgeable professionals needs to initiate, closely know and verify all project steps
- Schools must employ on-site experienced maintenance personnel knowledgeable in the buildings' diverse and unique systems

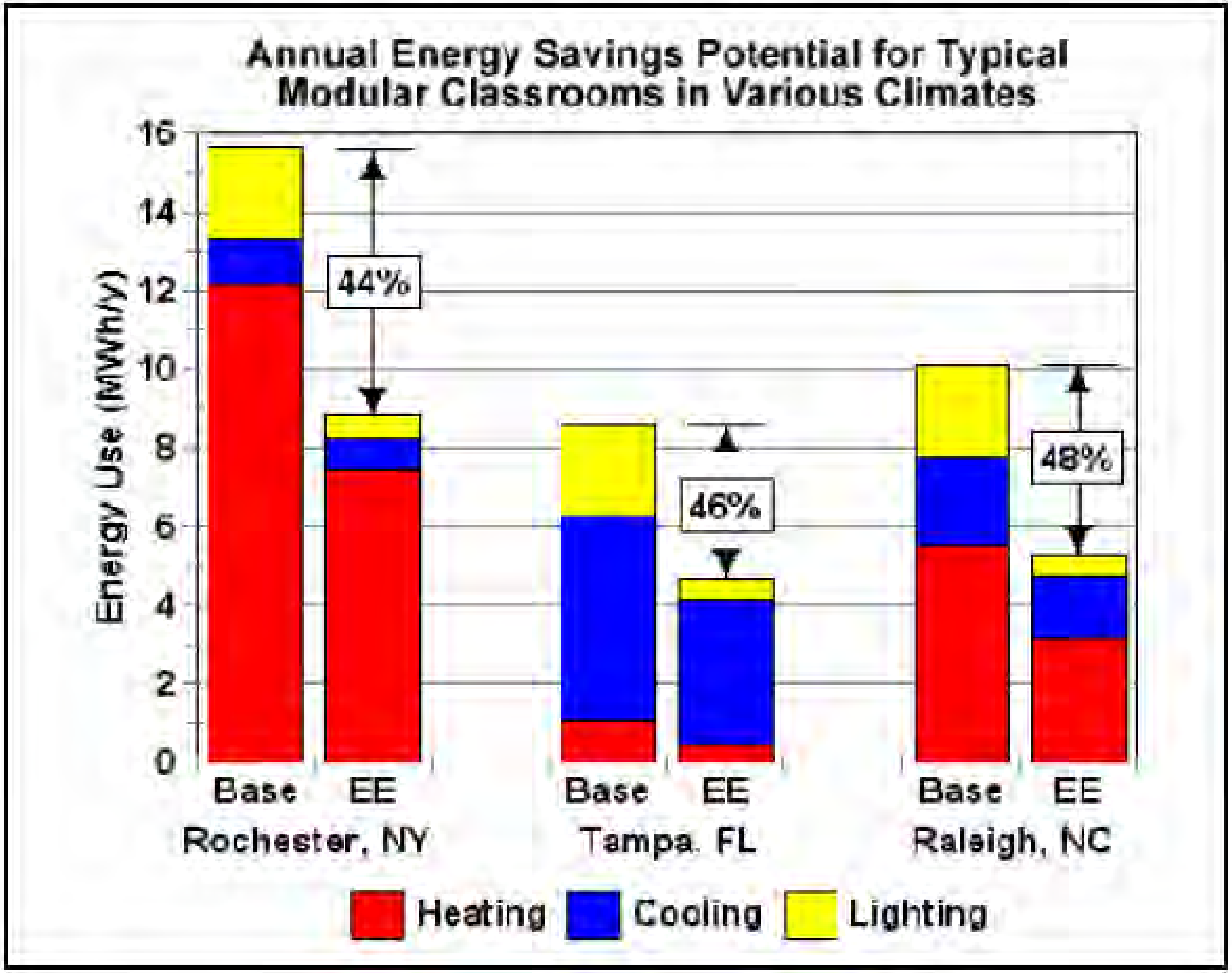
Florida Solar Energy Center

- Performance Enhanced Relocatable Classrooms (PERC) Project
  - Monitored and evaluated standard portable classrooms
  - Based on data gathered, designed energy efficient portable classrooms (PERC)
  - PERCs were located next to standard portable and tested in different climates to determine benefits

Technology Demonstration

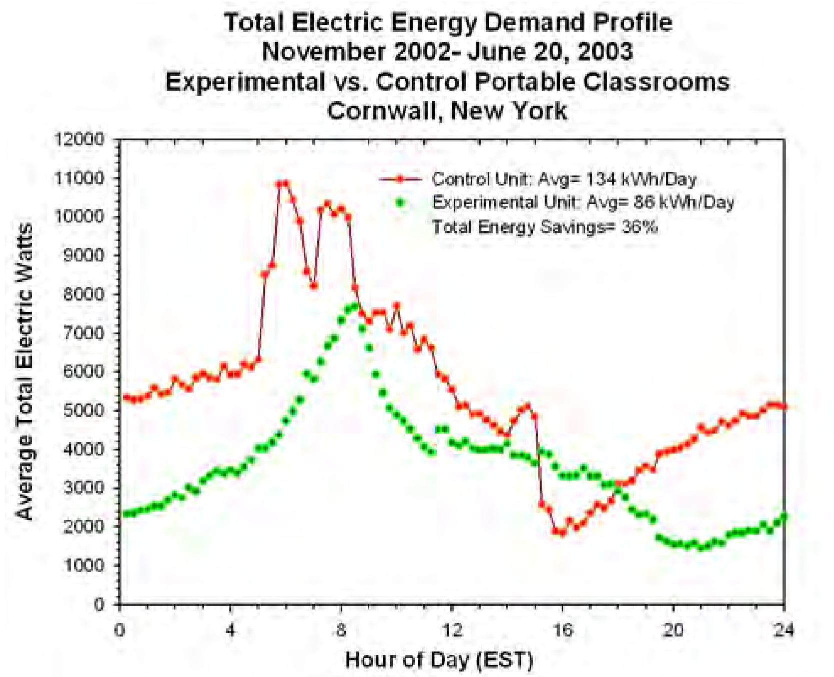
- Monitored and evaluated standard and energy efficient portable classrooms (PERCs) at three schools:
  - Cornwall Elementary School, Cornwall, NY (cold climate)
  - Chapel Hill Hill School, Chapel Hill, NC (mixed climate)
  - Shingle Creek Elementary School, Orlando, FL (hot-humid climate)

Estimated Energy Savings Potential for PERCs



Cornwall Elementary School

- Project Results
  - PERC was 36% more energy efficient than standard portable
  - PERC had 47% (79 kWh/day) HVAC savings
  - Enhanced natural lighting
  - Improved indoor air quality



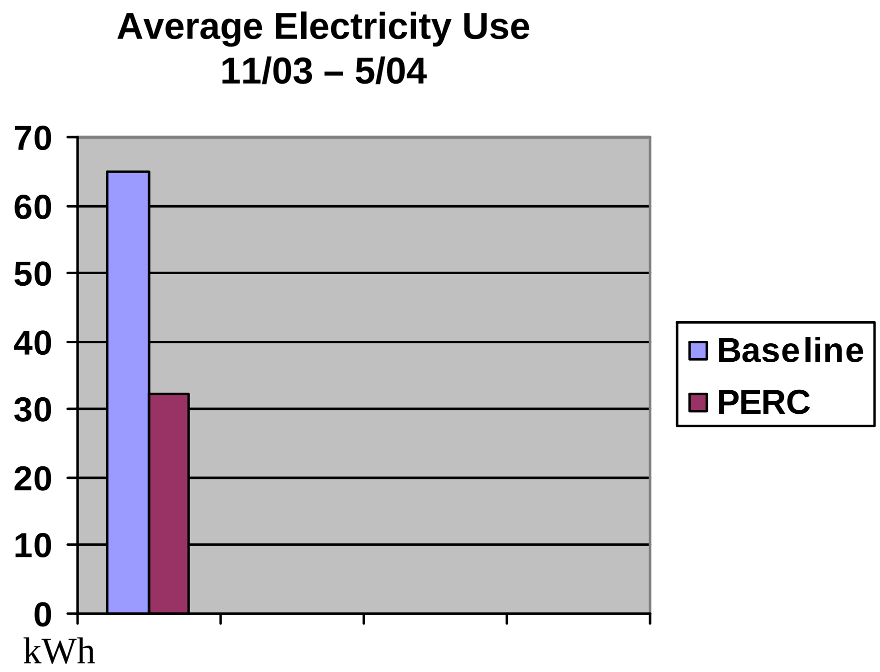
Cornwall Elementary School

Lessons Learned
Cold Climates

- In cold, heating dominated climates such as Rochester, New York, insulation measures and duct air leakage control measures look to be the most important.
- Results further suggest that ground source heat pumps or natural gas heating may be attractive alternatives to air-source heat pumps.
- Daylighting, while producing savings in lighting energy, tends to increase heating budgets and is not as attractive as insulation and heating system measures.
- Solar control glass is counterproductive.

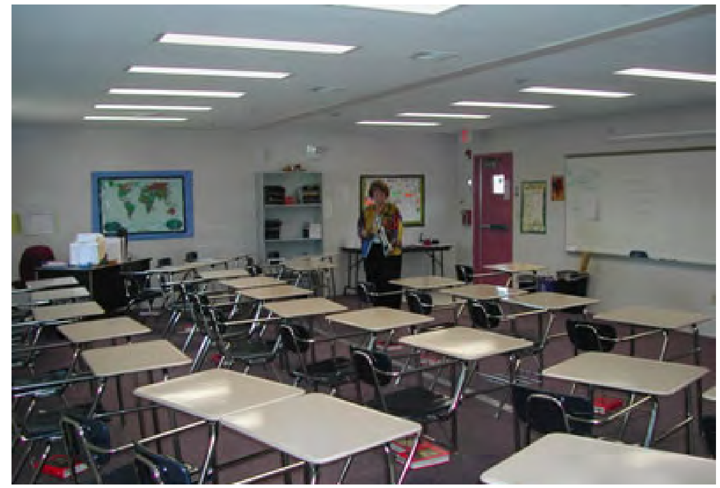
Chapel Hill High School

- Project Results
  - 50% overall energy savings
  - 32.3 kWh/day HVAC savings
  - Enhanced natural lighting
- Improved indoor air quality

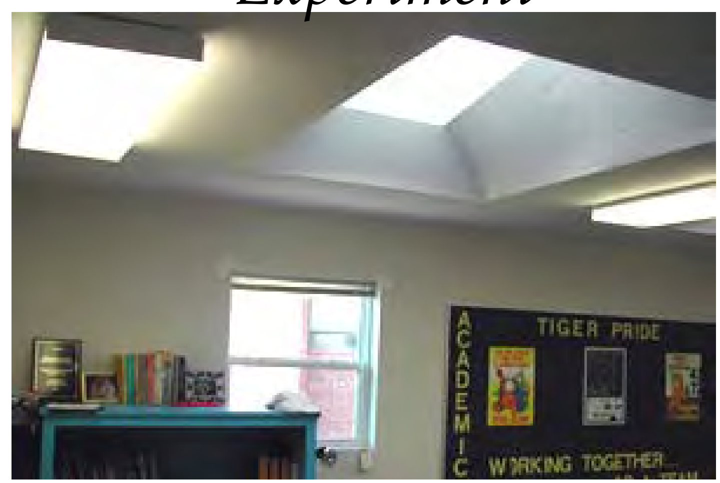


Chapel Hill High School

Control



Experiment

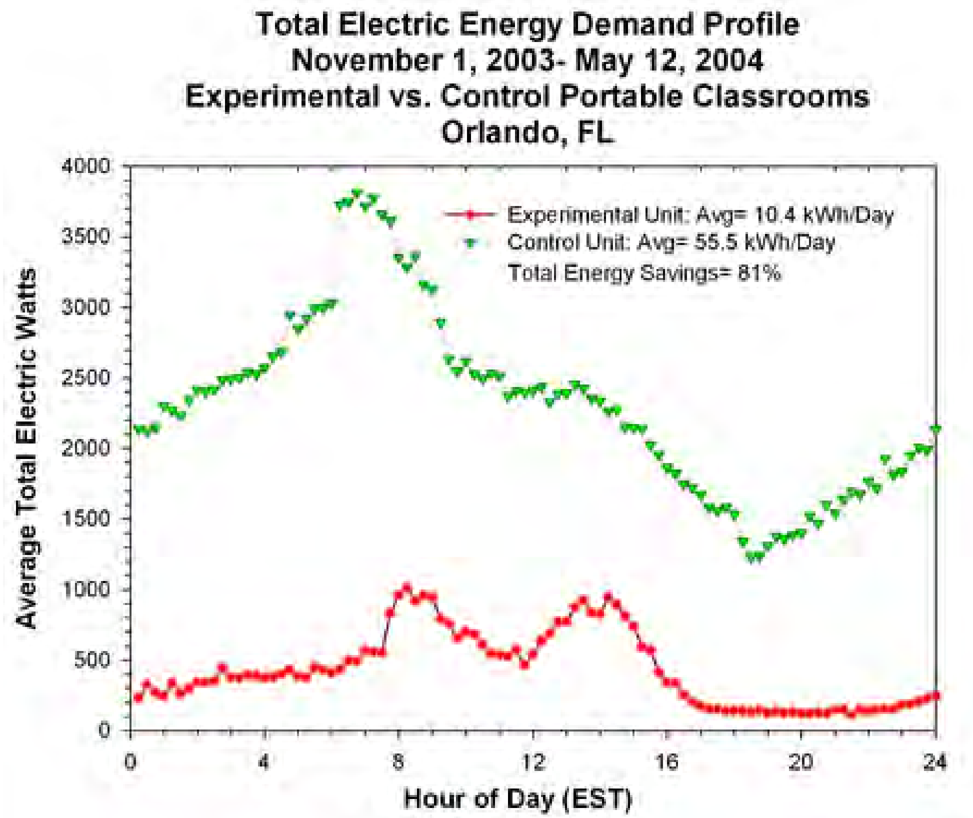


Lessons Learned
Mixed Climates

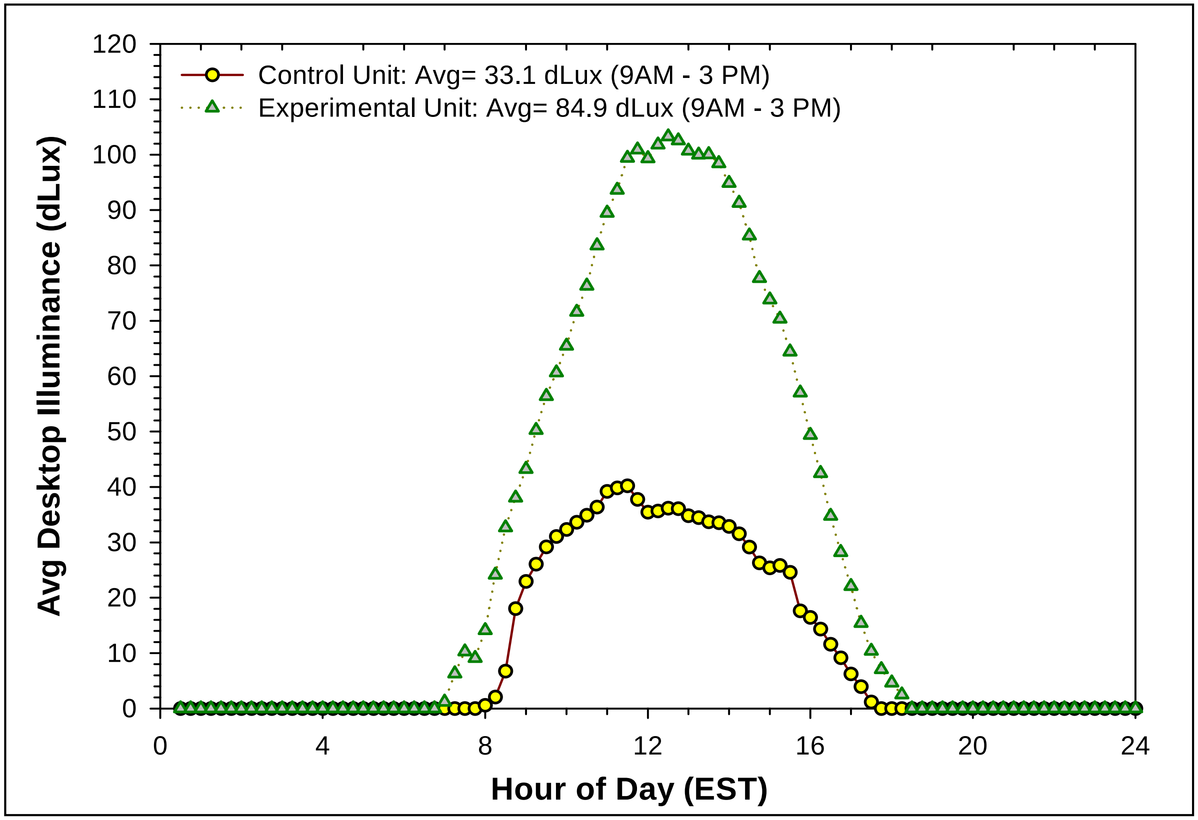
- Adjustments to the LCD lighting control module can significantly contribute to energy savings without compromising indoor light levels.
- Carefully designed and installed skylight wells are a must for natural light distribution in the classroom.
- In mixed climates, insulation with a radiant barrier looks to be the best strategy for the roofing system as it helps control both heating and cooling needs.
- Daylighting is quite attractive as it reduces lighting energy and substantially reduces space cooling. Insulation measures, duct leakage control and a more efficient heating system all look to be promising measures.
- Specification of a heat pump is important to controlling heating costs.

Shingle Creek Elementary School

- Project Results
  - 65% overall energy savings with PERC versus baseline portable
  - HVAC savings of 45.1 kWh/day
  - Improved indoor air quality
  - Enhanced natural lighting (69% savings lighting)



Interior Light Level Profile Orlando, Florida



Shingle Creek Elementary School

Experiment

Control

Lessons Learned
Hot-Humid Climate

- Use of the Solatube which included a tube that is standard with the skylight well required no extra fabrication for the skylight well area.
- In hot, cooling dominated climates, measures that reduce lighting and its internal heat generation show greatest promise to reduce building energy needs.
- Daylighting is particularly attractive although solar control glass is important to reduce the space cooling liability. Similarly, light colored surfaces and solar control glazing looks more important than insulation.
- Heating system type is not as critical as cooling efficiency.
- Floor insulation is counterproductive.

Additional Information on the ASERTTI Energy & Environment in Schools Project

- <u>Daylighting</u>

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Websites: www.aserti.org/schools

http://www.asertti.org/schools/resources.htm