ENERGY CENTER OF WISCONSIN

NASEO ENERGY SMART SCHOOLS
Applied Research, Field Testing & Technology Integration
Task 4 – Advanced Daylighting Research

YOUR PARTNERS IN ENERGY RESEARCH, EDUCATION & CONSULTING

Project Status

ENERGY CENTER OF WISCONSIN

- Project completed September 2004
- Total project budget is $811,762
  - $450,028 in Federal funding and $361,762 in Matching funds
- Tasks:
  - 1. Baseline energy use in schools
  - 2. Daylighting experts roundtable
  - 3. HVAC Performance research
  - 4. Daylighting demonstration evaluation
  - 5. Daylighting Design Guideline Reference for Schools

Team Members

- Energy Center of Wisconsin
- Lawrence Berkeley National Laboratory
- The Lighting Research Center
- Iowa Energy Center
- Local utilities, Schools and individuals

Task 1 - Baseline Data

ENERGY CENTER OF WISCONSIN

- **Scope**
  - **Obtain and analyze existing and emerging data in 4 states**
  - **Deliver a baseline database or recommendations for future database development**
- **Intent**
  - **Assist in establishing a database of school energy performance for assessing technology applications for window and daylighting design**
  - **Assist in identifying future R&D needs**

Baseline Data

- **Approaches**
  - **Conducted literature research and communications**
  - **Reviewed survey forms and existing data**
  - **Analyzed California Commercial End Use Survey (CEUS) database**
  - **Recommended key contents to be included in baseline databases**

Baseline Data

- **Accomplishments**
  - **Data Collection and Compilation**
    - **California CEUS databases 1992-99**
    - **Florida FSEC data & report (Callahan et al. 1997)**
    - **Wisconsin WEI-2 school survey data (1997-98)**
    - **New York NYSERDA – no data**
    - **National level: Commercial Buildings Energy Consumption Survey (CBECS)**

Baseline Data

- **Accomplishments**
  - **Review and Analyses of Databases**
    - **Identified strengths and weakness of existing databases**
    - **Recommended key information to be included in future databases**

Baseline Data

- **Accomplishments**
  - **Dataset Establishment and Content Recommendation**
    - **Produced datasets that contain design features, energy use, and factors impacting energy use in California K-12 schools**
    - **Suggested key features for windows, glazing, and daylighting for K-12 school buildings**

Baseline Data

- **Outcomes**
  - **Site energy usage of sampled school buildings in three states and on the national level - Electricity**

Energy Use and Floor Areas	Statistics	State				National
		CA	FL	NY	WI	CBECS (Education)
		electricity energy use per square foot of school building floor area	-	-	electricity energy use per square foot of school building floor area	electricity energy use per square foot of classroom floor area
Statistics of EUI ($kBtu/ft^2Yr$)	Median	**23.8**	-	-	18.8	22.5
	Mean	**37.6**	-	-	20.8	29.7
	Max	**190.5**	-	-	-	-
	Min	**2.6**	-	-	-	-
Floor Area (ft^2)	Median	**40,131**	-	-	57,904	-
	Mean	**63,210**	-	-	76,057	26,456
Schools	Total number	**106**	-	-	917	32,7000

ENERGY CENTER OF WISCONSIN

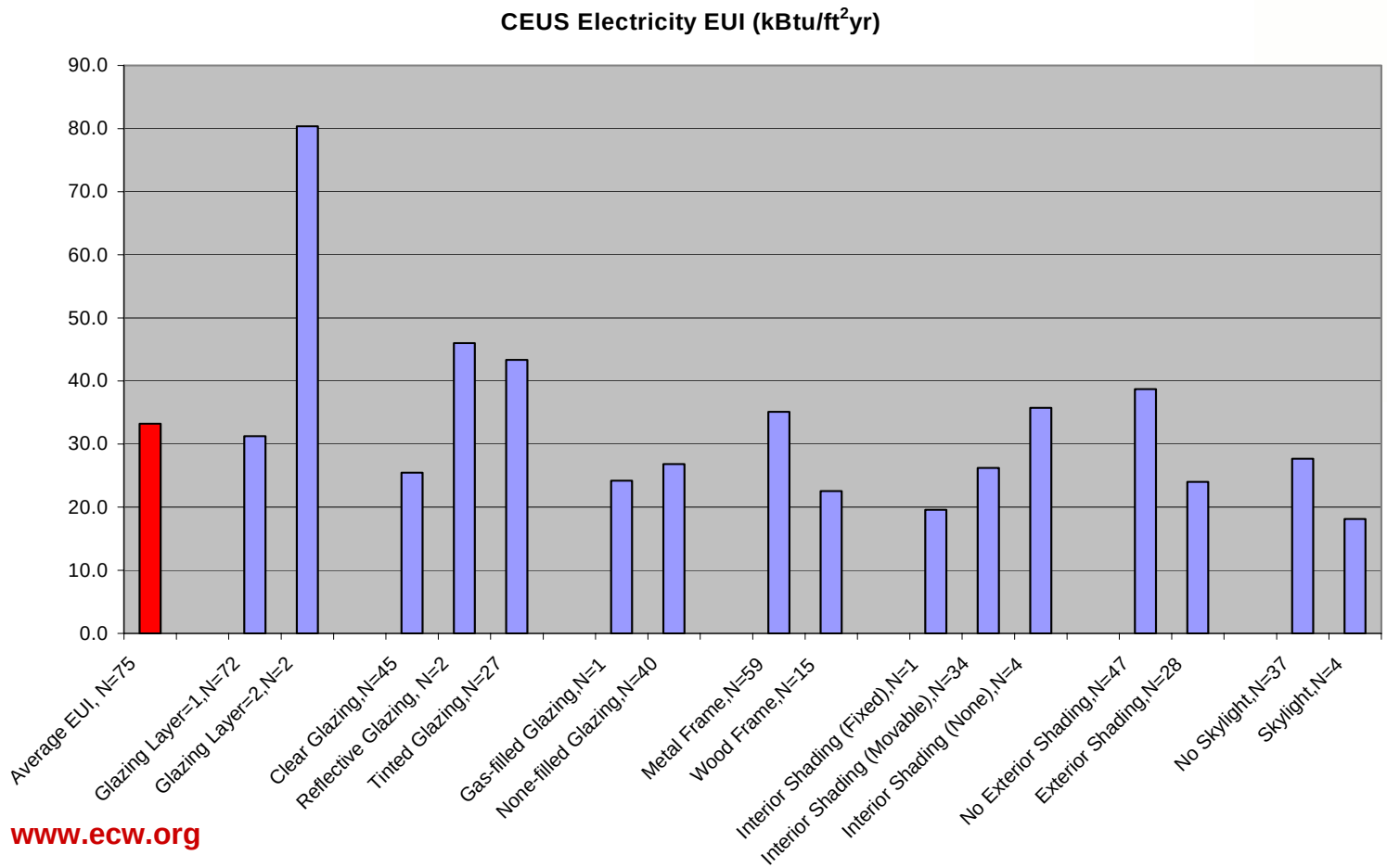
Baseline Data

- **Outcomes**
  - **Site energy usage of sampled school buildings in three states and on the national level - NG**

Energy Use and Floor Areas	Statistics	State				National
		CA	FL	NY	WI	CBECS (Education)
		Natural gas energy use per square foot of school building floor area	-	-	fossil fuel and wood energy use per square foot of school building floor area	Natural gas consumption (ft^3) per square foot of classroom floor area
Statistics of EUI ($kBtu/ft^2Yr$)	Median	**24.6**	-	-	52.2*	25.0**
	Mean	**30.7**	-	-	55.6*	33.5**
	Max	**108.7**	-	-	-	-
	Min	**6.2**	-	-	-	-
Floor Area (ft^2)	Median	**37,434**	-	-	57,904	-
	Mean	**54,546**	-	-	76,057	26,456
Schools	Total number	**37**	-	-	917	32,7000

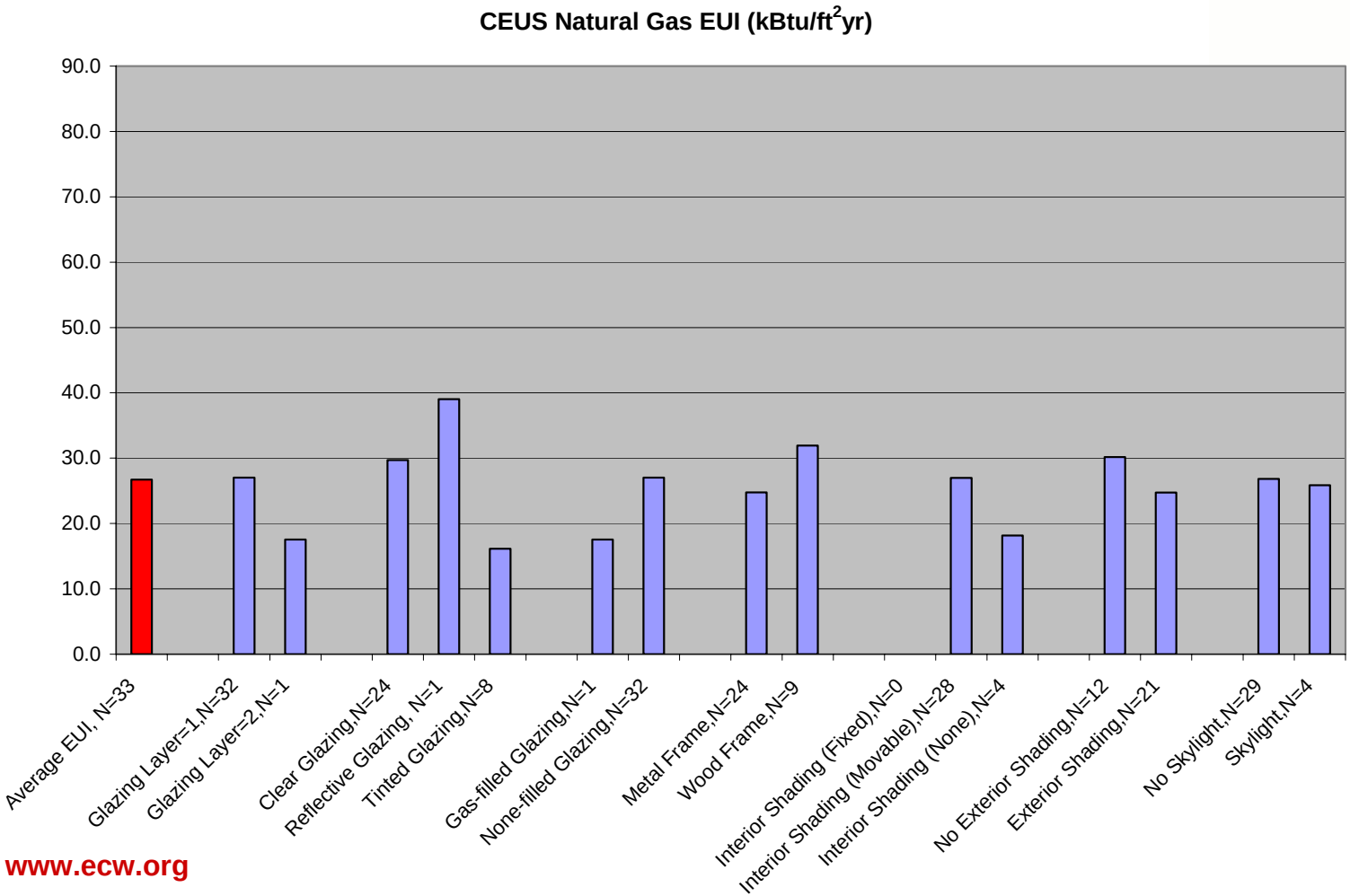
Baseline Data

- **Outcomes - EUI in CA K-12 schools (Electricity)**



Baseline Data

- **Outcomes - EUI in CA K-12 schools (NG)**



Baseline Data

- **Conclusions**
  - **Many compounding factors impact overall energy use in K-12 schools**
  - **Lighting energy use and lighting levels (due to artificial lighting or daylight) not readily quantifiable**
  - **Opportunities to develop more powerful CEUS databases in the future**

Baseline Data

- **Recommendations for future databases**
  - **Energy information**
    - **Annual energy use and costs**
    - **Climate zones**
    - **Services that may impact the on-site energy use**
  - **Features of window and daylighting**
    - **Design features of windows, glazing, shading and daylighting**
    - **Operational characteristics such as operable windows and their use**

Baseline Data

- **Recommendations to include in future databases - Continued**
  - **Building design and operation information**
    - **Building and school type**
    - **Square footage, months in use, PCs, number of students and faculty, operation schedule**
    - **Data on gymnasium, athletic facilities, swimming pool, auditoriums, media center and cafeteria**
    - **Vintage and retrofits**
    - **Lighting equipment types, control and operation**
    - **Mechanical systems, control and operation**

Task 2 - Roundtable

- Conducted a Roundtable and peer review of daylighting strategies with researchers and practitioners
- Recommendation:
  - include Daylighting in New York state classrooms

Roundtable

- **Roundtable findings:**
  - **Conduct a human factors evaluation of comfort and acceptability of low transmittance glazing and window layout**
  - **Emphasize one-time installation of glass to reduce maintenance costs compared to investment in HVAC equipment**
  - **Introduce glazing shading coefficient early in the design to downsize mechanical equipment**
  - **“Why do Daylighting” training session for school board members, “How to Daylight” session for architects and engineers**

Task 3 - HVAC Performance Research

ENERGY CENTER OF WISCONSIN

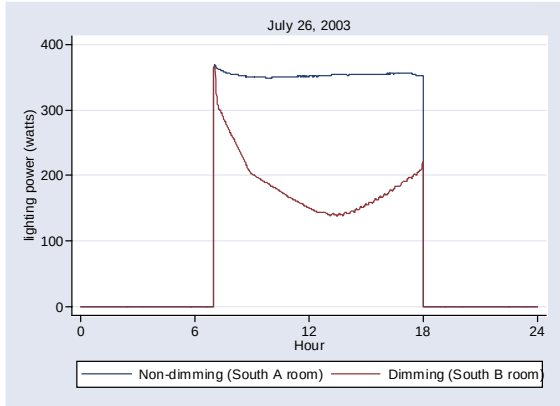
- Conducted experiments in classroom simulation at Iowa Resource Station
  - Glazing options
  - Lighting systems and controls
  - Window treatment
- Evaluate experimental data against actuals

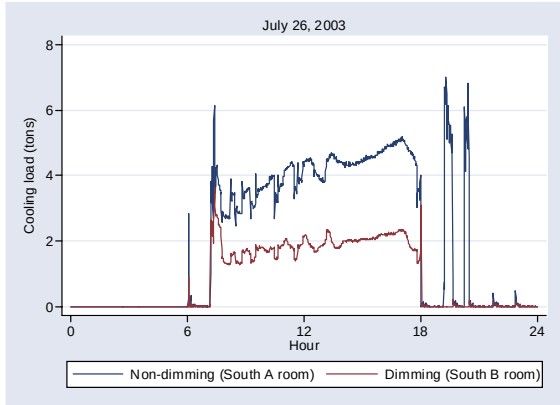
HVAC Performance Research

- **Objective:**
  - **Lighting and HVAC impacts from low VT glazing and dimming lighting (Cool daylighting)**
- **Comparison of rooms with and without daylighting**
  - **Controled approach**
  - **Three daylighting configurations**
- **Three rounds of data collection**
  - **Summer 2003**
  - **Fall 2003**
  - **Winter 2003/2004**

HVAC Performance Research

- Data collection completed in January 2004
- Analysis underway
- Final results posted www.daylighting.org





Task 4 - Demonstration Sites

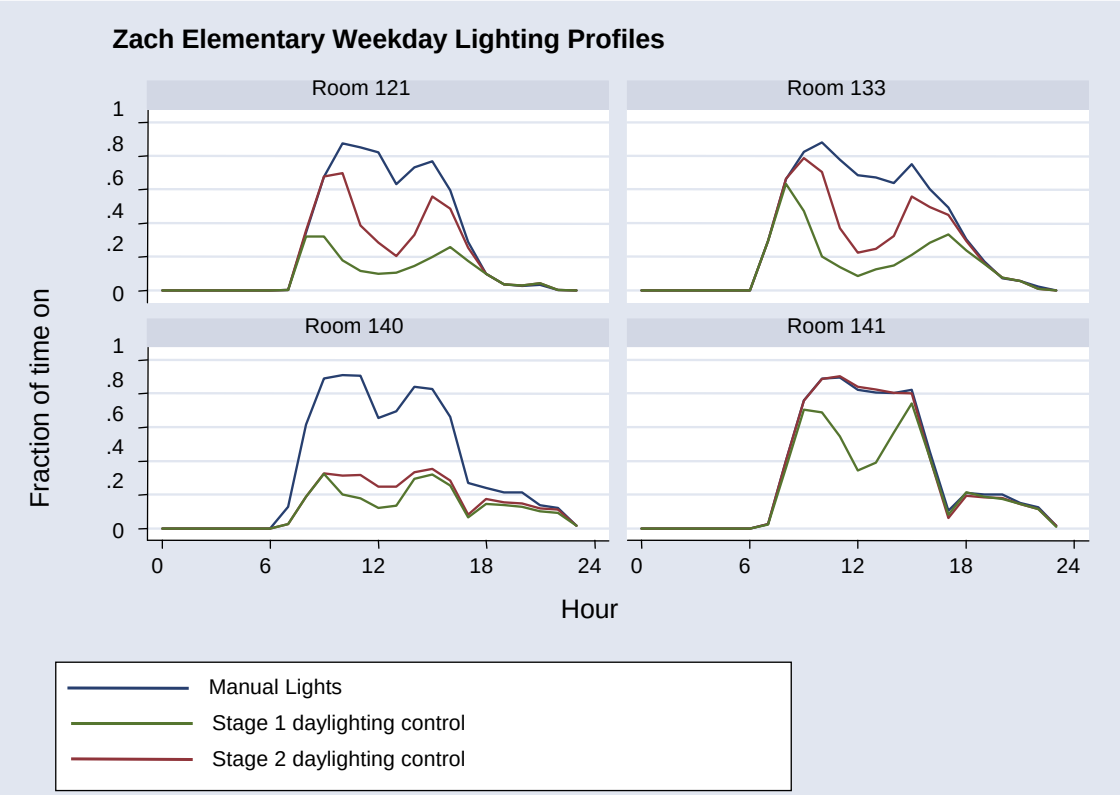
ENERGY CENTER OF WISCONSIN

- Monitor and evaluate daylighting at school sites
- Study the effects of daylighting on human factors and energy efficiency

School Demonstration Sites

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

School Demonstration Sites



Observations

ENERGY CENTER OF WISCONSIN

- Occupant behavior affects savings
- Savings from controls only apply when lights are on
- Light switches must be available to turn lights off
- Savings from daylighting occur when lights are off
- Savings from daylighting reduced when blinds are closed for audio-visual or glare

Congress Elementary School Milwaukee, Wisconsin

ENERGY CENTER OF WISCONSIN

- Grades K – 6
- School type Urban
- Demo size 2 classrooms (grades 1-2)
- Construction scope Small Retrofit
- Fenestration Window wall East-facing
- Blinds (upper) Venetian
- Blinds (lower) Black perforated roller shades
- Lighting Direct-indirect pendants
- Photosensor location On fixture
- Controls type Dimming (in one classroom)
- LRC visited September 2003

Original fenestration and new tinted glass

Photosensor built into luminaire

Congress School Results

Pros

- Automatic dimming not noticeable
- Dimming override appreciated by teacher
- 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

Zach Elementary School
Fort Collins, Colorado

ENERGY CENTER OF WISCONSIN

Grades	K – 6
School type	Suburban
Demo size	Whole school (24 classrooms)
Construction scope	New construction
Fenestration facing,	Punched window openings, mostly North- some South
Blinds (upper)	North, none; South, Venetian
Blinds (lower)	North, venetian; South, black perf. Shades
Lighting	Direct-indirect pendants
Photosensor location	Outside
Controls type	Switching (not dimming)
Controls results	Overlighting in Kindergartens, but maintaining overall (plan to recommission to reduce light levels
LRC visited	April 2004
Survey scope	140+ students, grades 4 - 6

ENERGY CENTER
OF WISCONSIN

Figure 1: Zach Elementary School

Zach Elementary 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 (kindergardens)**

Blach Intermediate School
Los Altos, California

ENERGY CENTER OF WISCONSIN

Grades	7 – 8
School type	Suburban
Demo size	Whole school (25+ classrooms)
Construction scope	New/substantial retrofit
Fenestration	Clerestory and roof monitors, North-facing
Blinds (upper)	Perforated roller shades
Blinds (lower)	Curtains (on sliding doors)
Lighting	Direct-Indirect pendants
Photosensor location	On fixture
Controls type	Dimming
LRC visited	March 2004
Survey scope	250+ students, grades 7 – 8

ENERGY CENTER
OF WISCONSIN

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

Blach 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 find the space not dark enough for audio/visual
- Some blinds inaccessible.
- May see premature lamp failure in future due to no lamp seasoning procedures.

Solon High School
Solon, Iowa

ENERGY CENTER OF WISCONSIN

Grades	9 – 12
School type	Rural
Demo size	Whole school (20 classrooms)
Construction scope	New construction
Fenestration	Punched window openings, North- and South-facing
Blinds (upper)	Venetian blinds
Blinds (lower)	Venetian blinds
Lighting	Pendants, indirect
Photosensor location	Outside
Controls type	Switching
Controls results	Maintaining luminances, when blinds used
LRC visited	September 2003
Survey scope	80+ students

ENERGY CENTER
OF WISCONSIN

Solon High School, South side

North side of classroom wing

Solon School Results

ENERGY CENTER OF WISCONSIN

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 (in defiance of school orders to try to keep them open)
- Switching somewhat noticeable at first, but became occupants became accustomed

ENERGY CENTER OF WISCONSIN

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 and find their lighting is comparable or superior to other schools

Task 5 - Daylighting Design Guidelines

ENERGY CENTER OF WISCONSIN

- Performance data of fenestration and lighting designs
- Includes training materials
- Coordinating efforts with:
  - National Daylighting Forum
  - New Jersey's School New Construction effort
- Information on www.daylighting.org

Conclusion

- More data to come – posted on:

  www.daylighting.org

- Many people worked on this project to make it successful

Thank you!