

Documentation and Modeling to Support 30% Energy Savings: Advanced Energy Design Guide for K-12 School Buildings

ASHRAE Summer Meeting – Seminar 60

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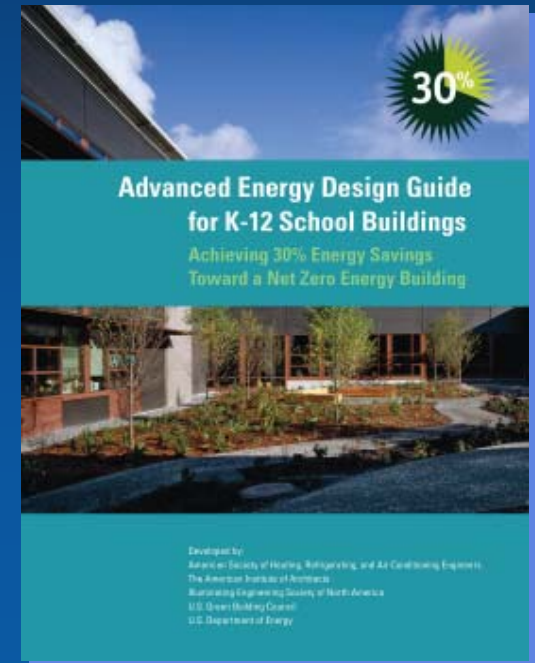
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www.nrel.gov

www.highperformancebuildings.gov

Material to be Covered

- Recommendation development process
- Modeling to show 30% savings
 - Concepts
 - Prototypes
 - Baseline model inputs
 - Low-energy model inputs
 - Model results
- Summary and Conclusions



Recommendation Development Process

- Collaboration of project committee members
- Focus on “good” design practices for
 - Envelope
 - Daylighting and lighting
 - HVAC
 - Service hot water
- Recommendations available from multiple manufactures
- At least as stringent as ASHRAE 90.1-2007
- Some life cycle analysis to determine optimal levels of insulation

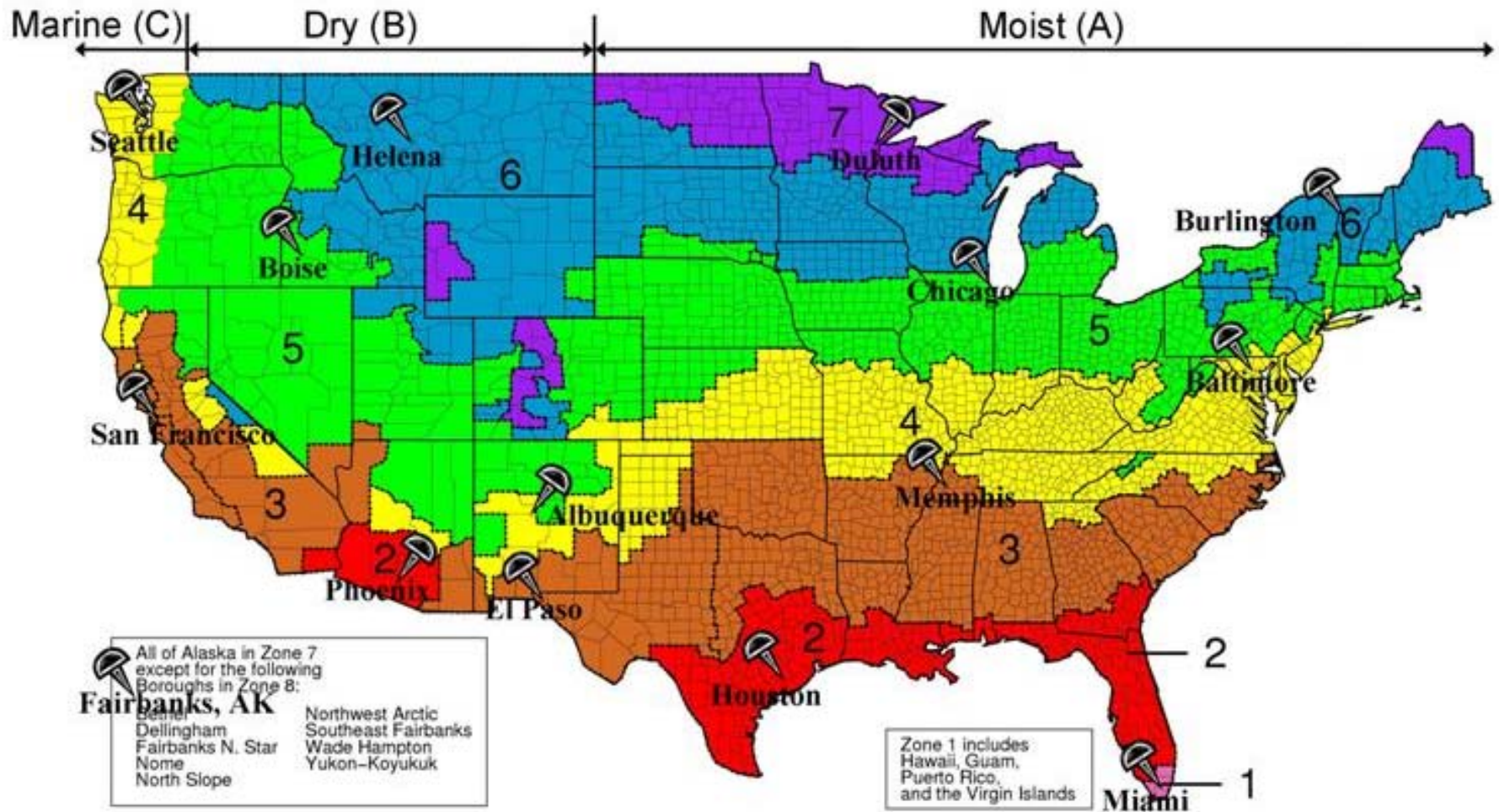
Modeling Analysis Concepts

- Modeling to verify 30% savings in all climate zones and sub-climate zones
- Develop hourly building energy models and auto-generation routines
 - combination of 90.1-2004 Appendix G modeling rules and previous AEDG modeling experiences

Modeling Analysis Concepts (cont.)

- Site Energy Use
- ASHRAE 90.1-1999 and 2004 Baseline
 - 30% savings over 1999 baseline for Guide recommendations
 - 30% savings over 2004 baseline for additional analysis purposes
- Include “typical” plug loads
 - Whole building energy savings analysis

Climate and Sub-climate Zones with Representative Cities



Lots of Possible Design Options

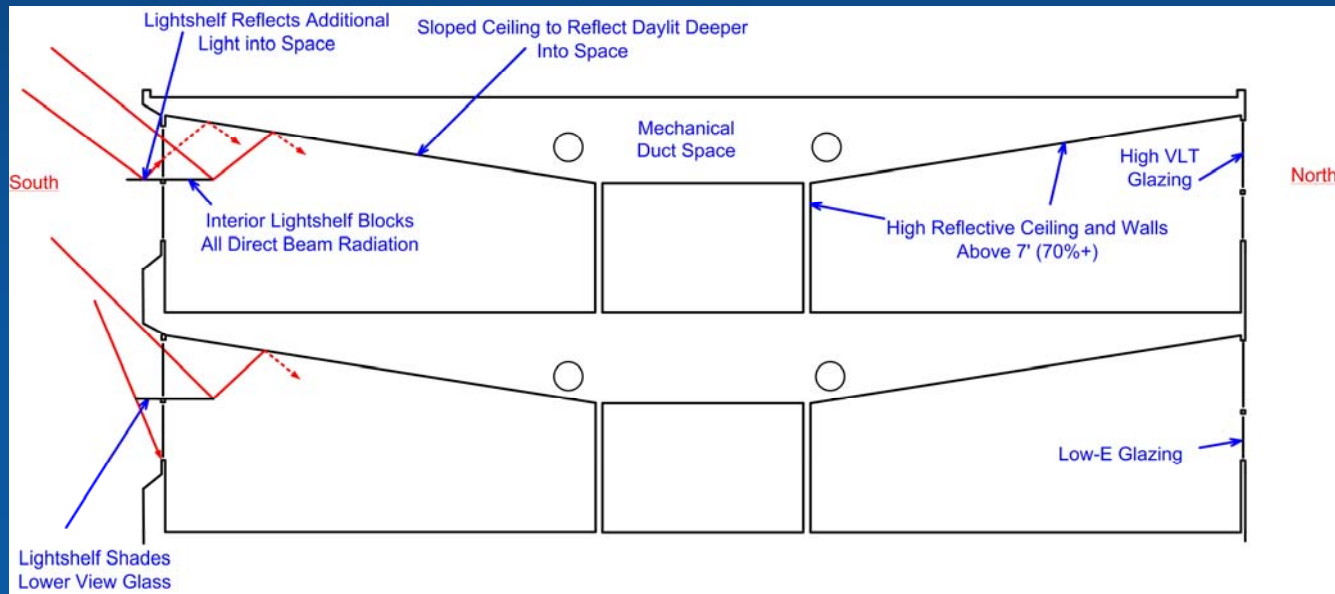
- Elementary, middle, and high schools
- 3 different roof types, 5 different wall types
- 3 Classroom daylighting options
- 3 Gym daylighting options
- 1 High performance electrical lighting option
- 6 HVAC types
- 3 Service hot water options

- Many ways to 30%

~5,000 unique combinations of options

Model Development Concepts

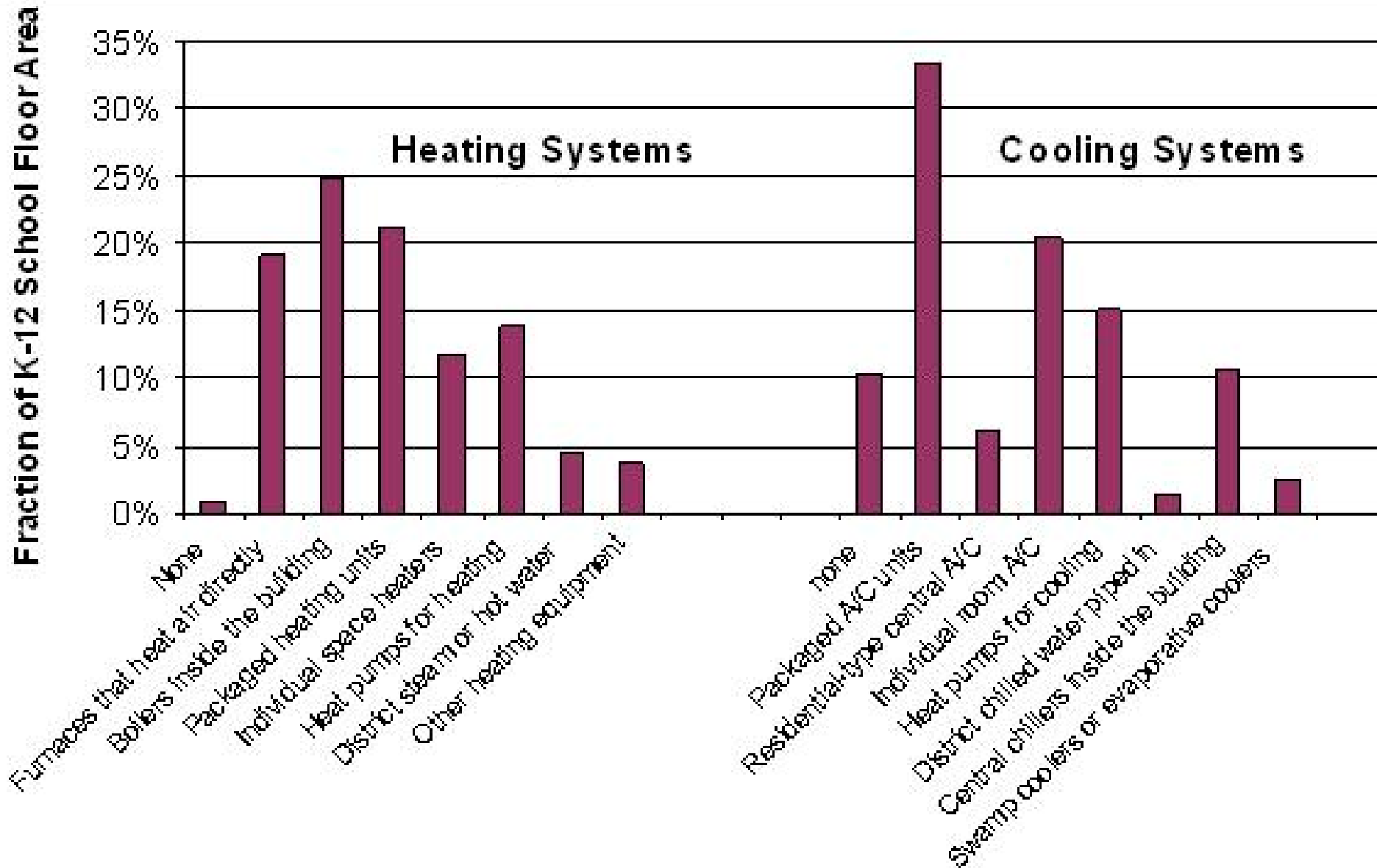
- Ensure recommendations will result in 30% savings
- To focus model development:
 - Typical school characteristics
 - Model recommendations that are estimated to be the least stringent
 - Input from project committee
 - Example: Sidelighting option modeled



Prototype Model Characteristics

School Characteristics	K-12 AEDG Prototype	Source
School types	Elementary, middle, and high school	Industry Publications, AEDG PC
Size	73,930 ft ² elementary, 116,080 ft ² middle, 210,810 ft ² high	Industry Publications, CBECS, AEDG PC
Number of floors	1 for elementary, 1 for middle, 2 for high schools	CBECS
Number of students	Elementary: 650, middle: 800, high: 1200	Industry Publications
Constructions	Mass walls, insulation entirely above deck	CBECS, AEDG PC
Floor plan	North- and south-facing classrooms similar to example floor plans	AEDG PC
Window area	35% fenestration to gross wall area, 3% gym skylight area	CBECS, AEDG PC
Occupancy	Fully occupied during school hours, partially occupied year round and into the evening	CBECS, AEDG PC
Peak plug loads	1.1 w/ft ² for elementary, 1.0 W/ft ² for middle and high	AEDG PC
Percent conditioned	Fully heated and cooled	CBECS
HVAC system types	Baseline: PSZ Low-energy: PSZ, PVAV, and VAV	CBECS, AEDG PC

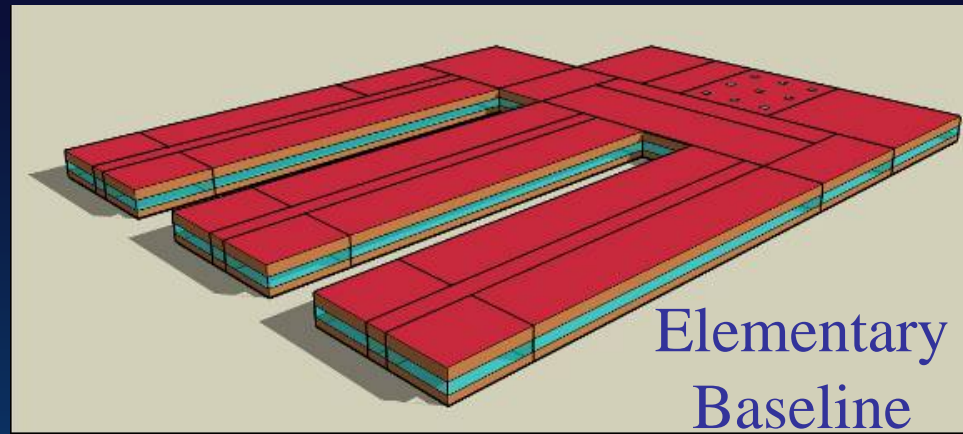
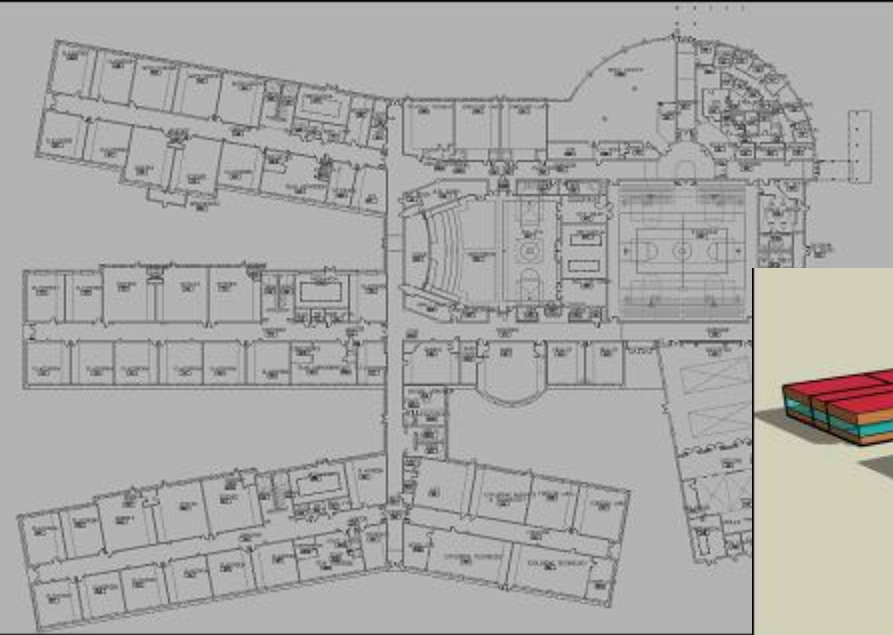
CBECS School HVAC Types



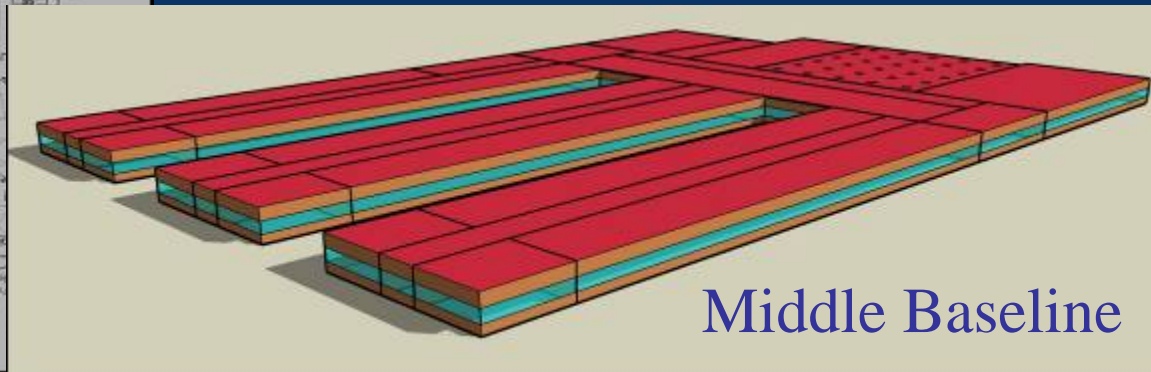
Prototype Model Space Types

	Elementary School		Middle School		High School	
Space Type	Total Size (ft ²)	% of total	Total Size (ft ²)	% of total	Total Size (ft ²)	% of total
Classrooms (all types except computer classrooms)	35,443	47.9%	47,161	40.6%	64,108	30.4%
Offices	4,745	6.4%	8,586	7.4%	11,449	5.4%
Multipurpose room/gym	3,841	5.2%	12,008	10.3%	34,690	16.5%
Computer classrooms	1,743	2.4%	2,227	1.9%	10,265	4.9%
Kitchen	1,808	2.4%	2,324	2.0%	2,324	1.1%
Cafeteria	3,389	4.6%	5,229	4.5%	6,714	3.2%
Media center	4,293	5.8%	5,810	5.0%	9,038	4.3%
Corridors/lobby	13,913	18.8%	25,351	21.8%	49,711	23.6%
Mechanical/restrooms	4,756	6.4%	7,381	6.4%	11,879	5.6%
Auditorium	0	0.0%	0	0.0%	10,631	5.0%
Total	73,932		116,079		210,810	

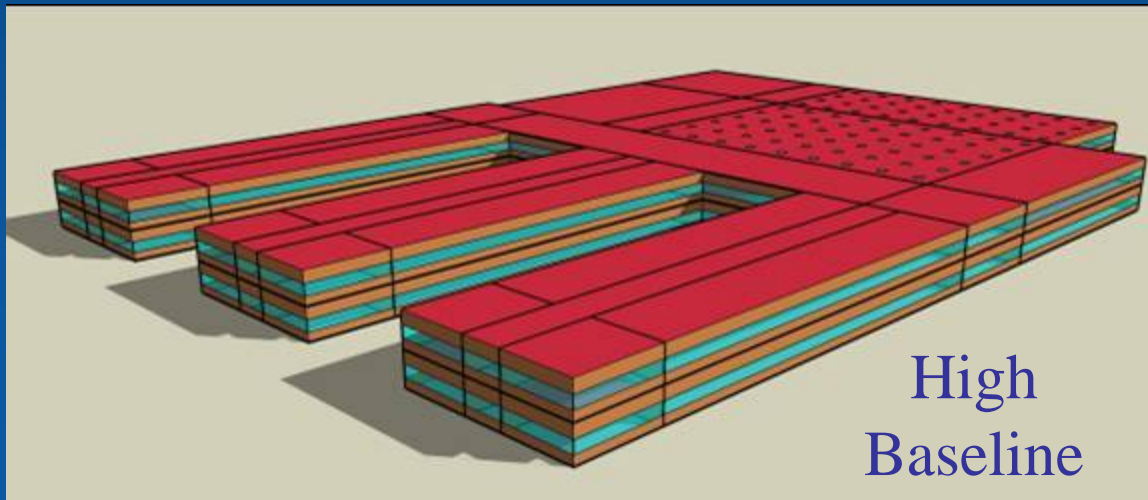
Baseline Models



Elementary
Baseline



Middle Baseline



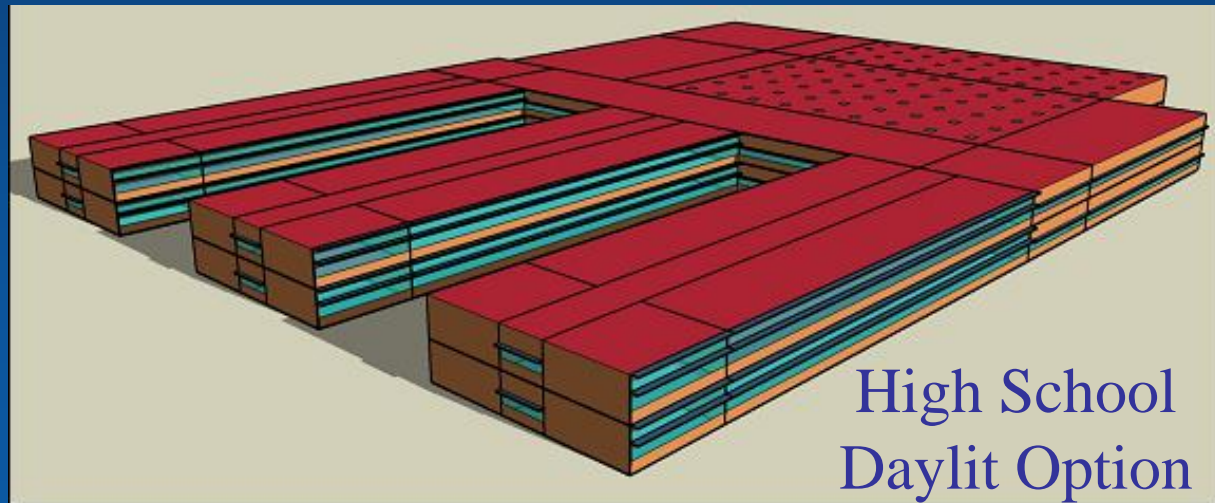
High
Baseline

Baseline Model Development

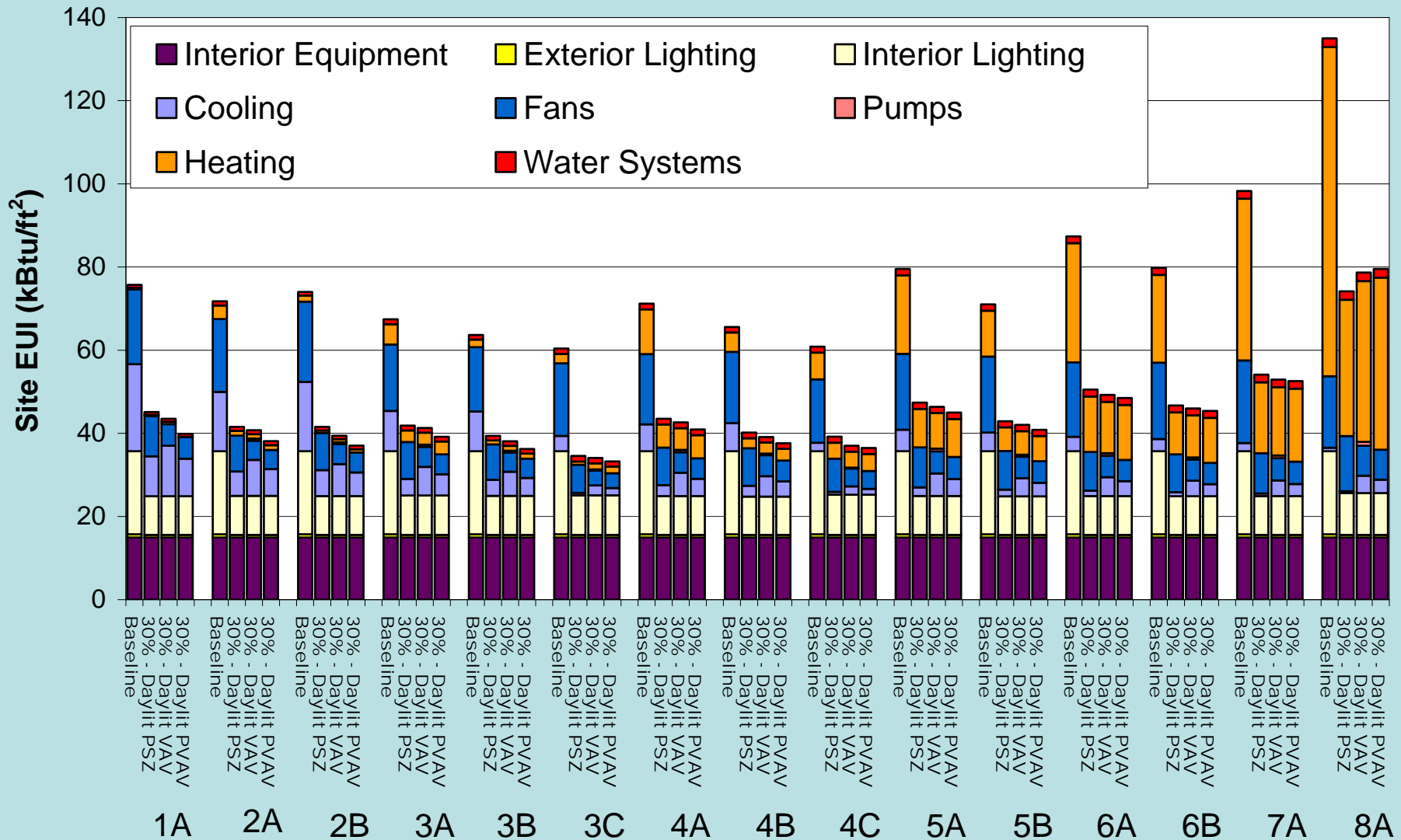
- Apply 90.1-1999 (and 2004) to prototype elementary, middle, and high schools
 - Envelope
 - Mass walls
 - Insulation above deck
 - 35% window to wall ratio, 3% gym skylights
 - LPD by space type
 - Typical 5-ton roof top
- ASHRAE 62- 2001 for outside air
- Schedules by space type based on 90.1-2004 User's Manual
 - Extended use classrooms, gym

Low-Energy Model Development

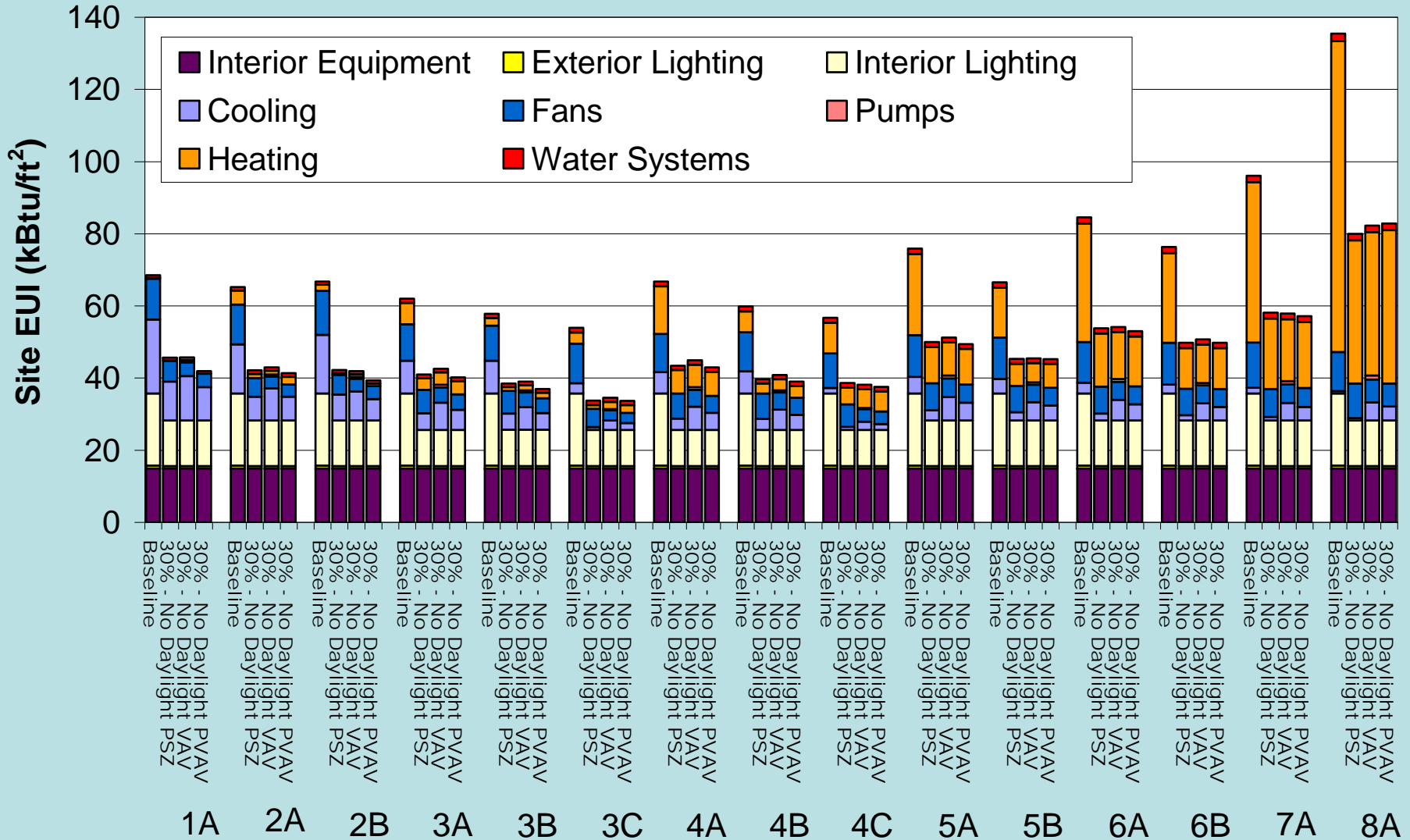
- Apply K-12 AEDG Recommendations to Elementary, Middle, and High School Baselines
 - Mass walls, Insulation above deck
 - Daylit option
 - Sidelit in classrooms
 - Skylights in gym
 - Non-daylit option
 - Package Single Zone
 - Package VAV
 - VAV with a Chiller and Boiler



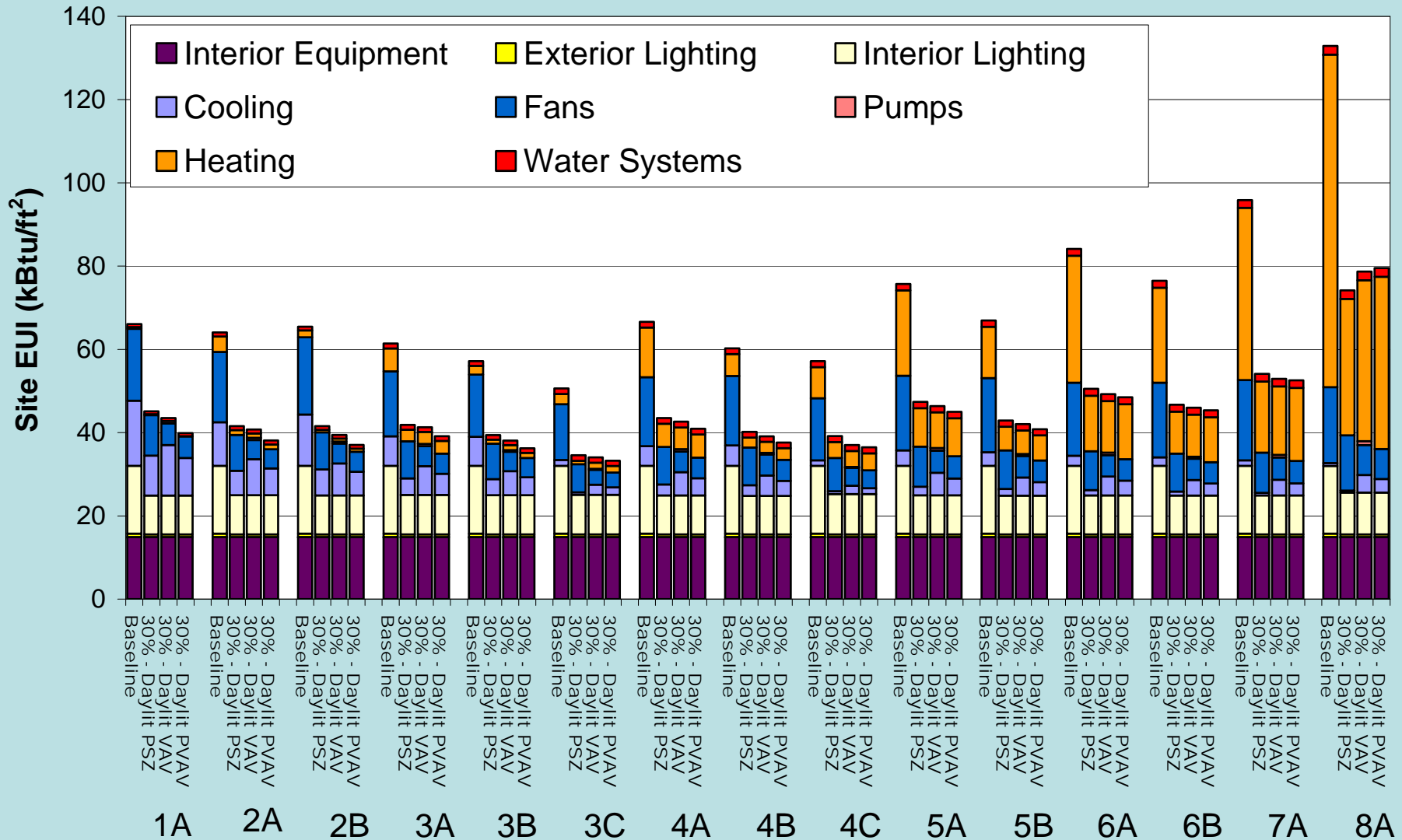
Elementary Daylit – 30% over 90.1-1999



Elementary No Daylighting – 30% over 90.1-1999



Elementary Daylit – 30% over 90.1-2004



Minimum Savings over all Options

Climate Zone	Minimum Savings over ASHRAE 90.1-1999- No Daylighting Option	Minimum Savings over ASHRAE 90.1-1999- Daylighting Option	Minimum Savings over ASHRAE 90.1-2004- Daylighting Option
1A	34%	40%	31%
2A	36%	42%	35%
2B	37%	44%	36%
3A	36%	38%	31%
3B	36%	38%	31%
3C	40%	43%	31%
4A	35%	38%	33%
4B	35%	38%	32%
4C	32%	34%	30%
5A	33%	38%	34%
5B	32%	38%	33%
6A	34%	39%	36%
6B	33%	39%	36%
7A	36%	41%	39%
8A	34%	37%	36%

Discussion

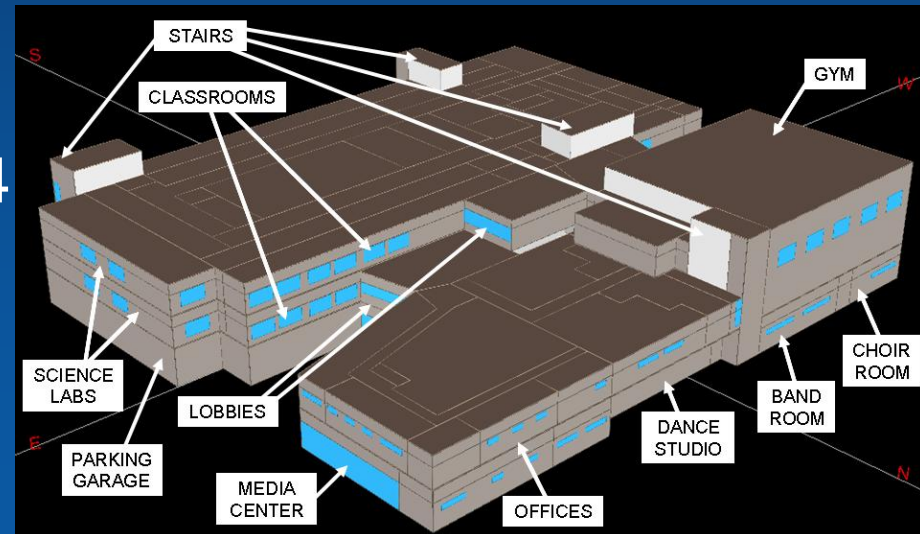
- Exceeded 30% frequently
- More savings with daylighting option (without lower LPD) than with high performance lighting option
 - For 90.1-2004 baseline, non-daylit option did not result in 30% savings in temperate climate zones
- 50% savings should be possible in most climates

Summary

- We have verified the K-12 AEDG recommendations result in *at least* 30% savings over ASHRAE 90.1-1999
 - Elementary, middle, and high schools
 - Typical space types
 - Typical size
 - Typical constructions
 - Sidelit and non-daylit options
 - PSZ, PVAV, and VAV
 - Suggests the more stringent recommendations in the Guide also result in at least 30% savings
 - For all climate and subclimate zones
- Daylighting options needed for 30% savings over ASHRAE 90.1-2004

Reality Check

- Quick Start New Orleans Schools
- Used 30% K-12 AEDG
- Exceeded some of the recommendations
 - High efficiency chiller
 - Dedicated dehumidification
- Used non-daylit option
- LEED Modeling
 - 23% savings over 90.1-2004
 - Corresponds to 4 EA Credit points



Questions?

- Full Report Available:

Pless, S.; Torcellini, P.; Long, N. (2007). Technical Support Document: Development of the Advanced Energy Design Guide for K-12 Schools--30% Energy Savings. 178 pp.; NREL Report No. TP-550-42114. Golden, CO.

<http://www.nrel.gov/docs/fy07osti/42114.pdf>

