ASHRAE Chapter
Dayton, OH

Advanced Energy Design Guides

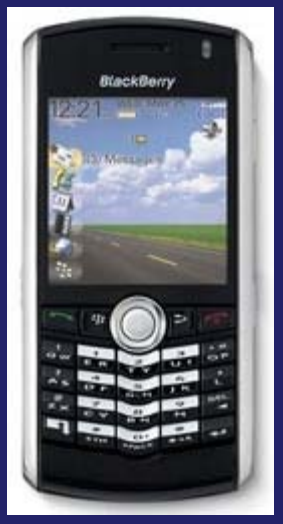
Merle McBride, Ph.D., P.E.

November 12, 2012

Welcome

ASHRAE Members
And
Guests

Silence is Golden



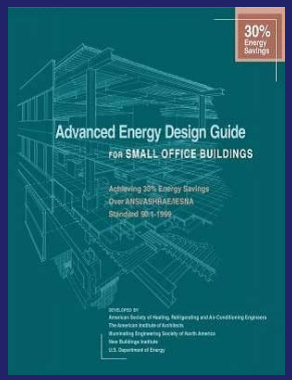
Agenda

Introduction

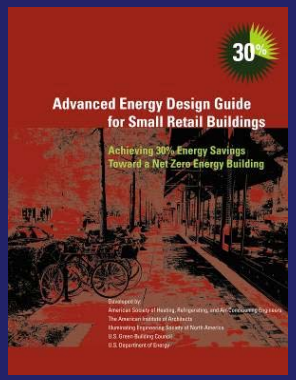
Background

AEDGs

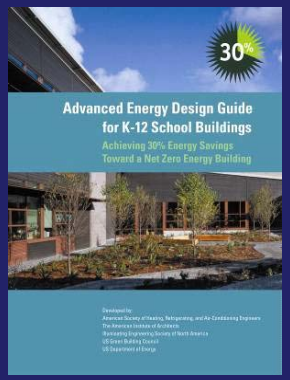
ASHRAE
Advanced Energy Design Guides



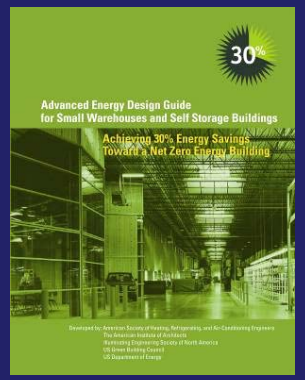
Office Bldgs.



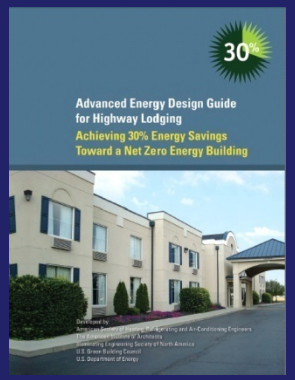
Retail Stores



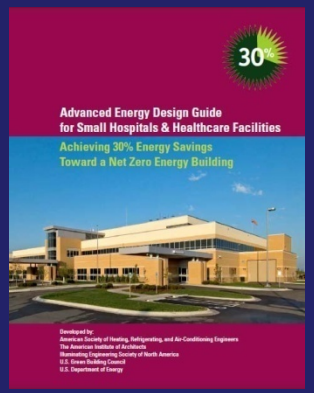
Schools K-12



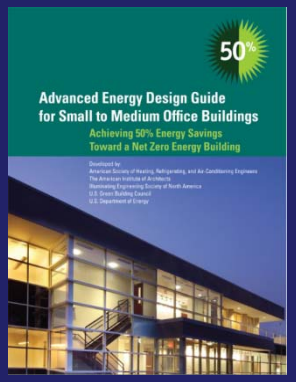
Ware houses

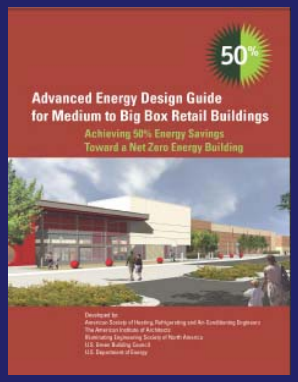


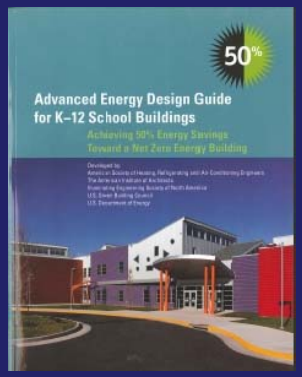
Highway Lodging

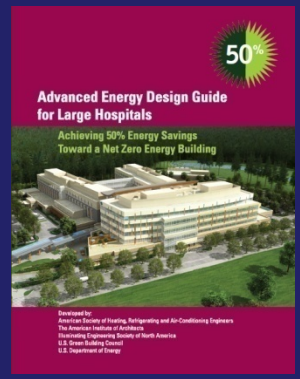


Health Care









Why develop AEDGs?

What are the Primary Driving Forces?

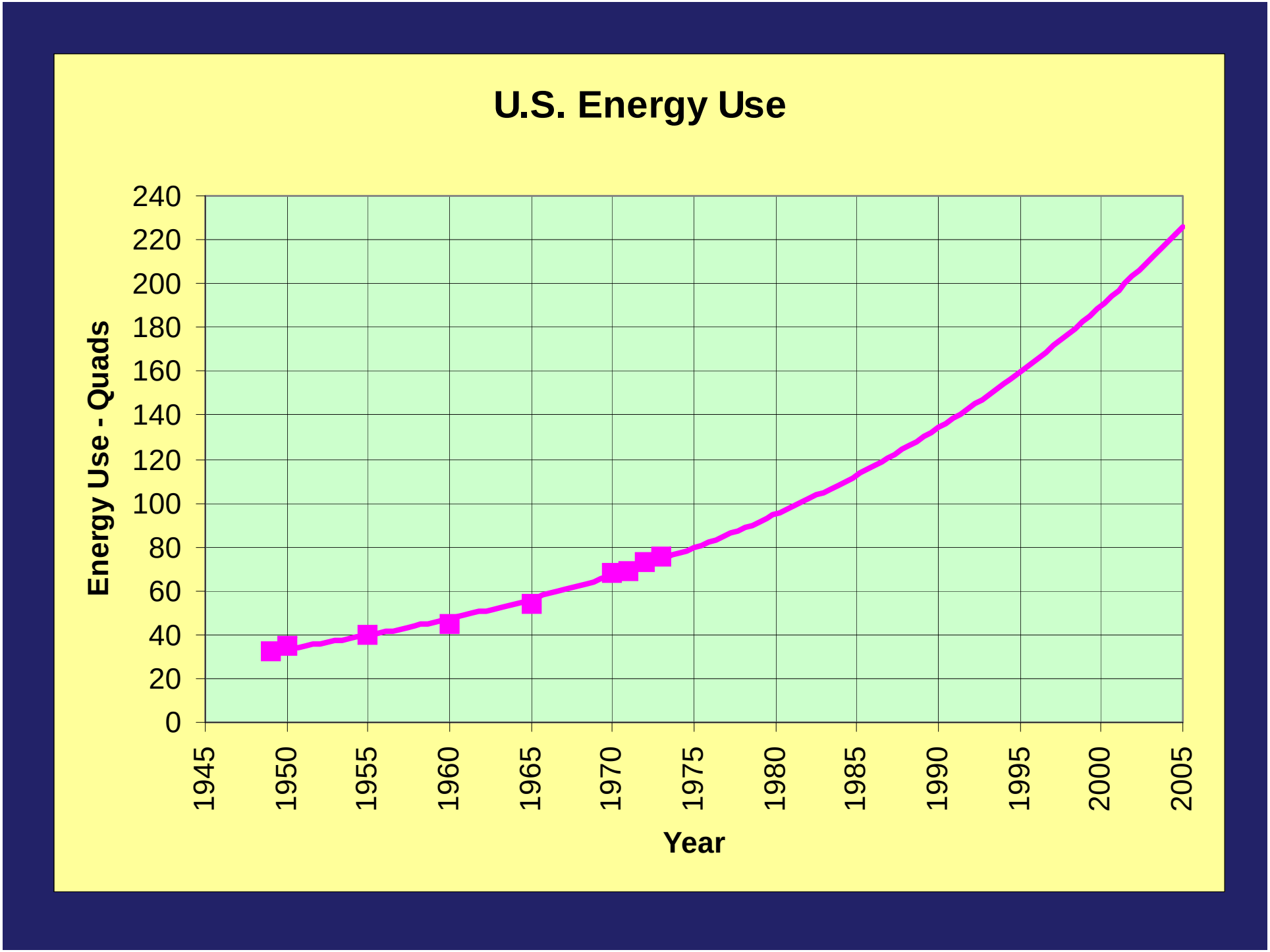
Primary Driving Forces

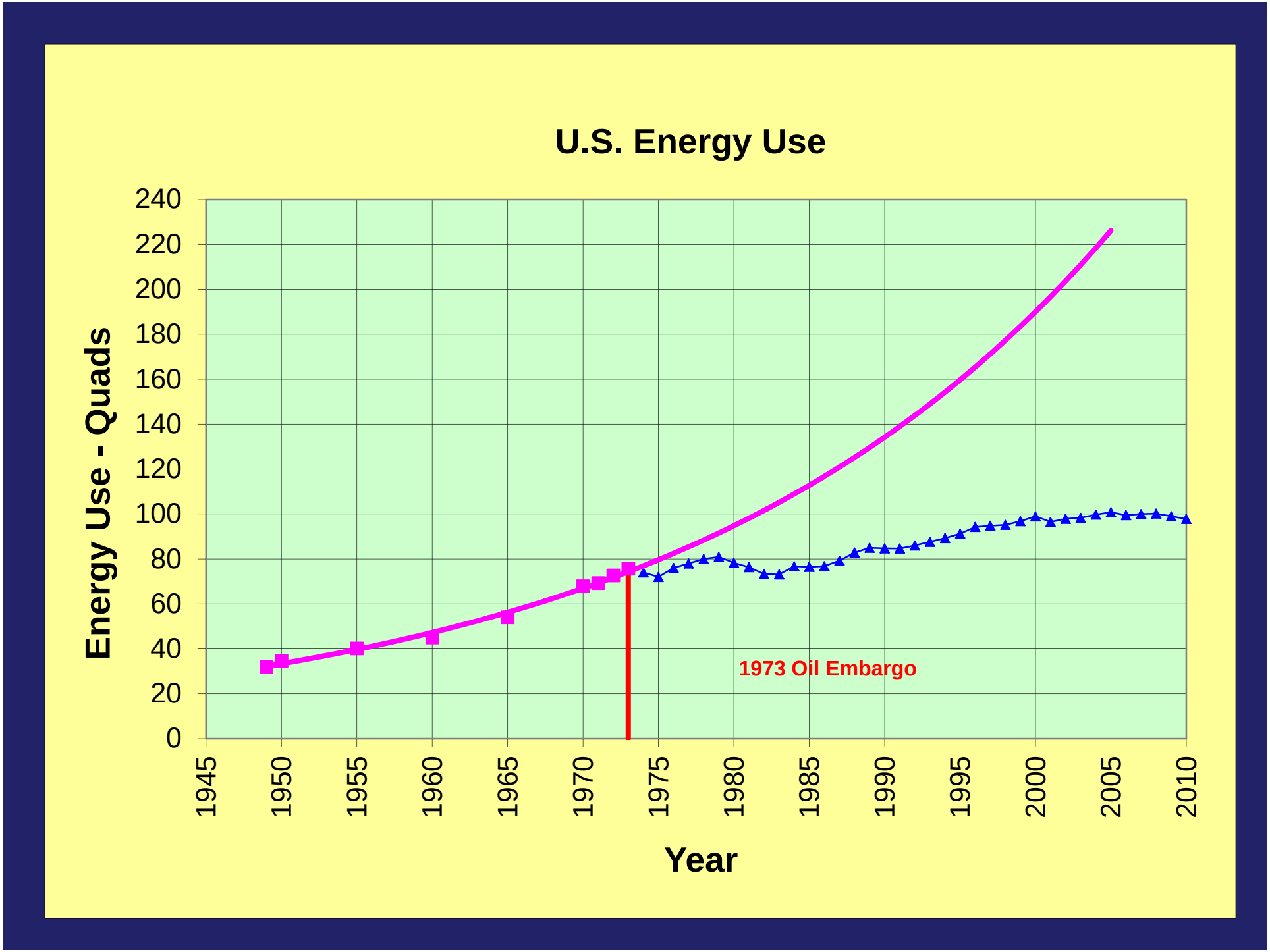
1 - Global Energy Use

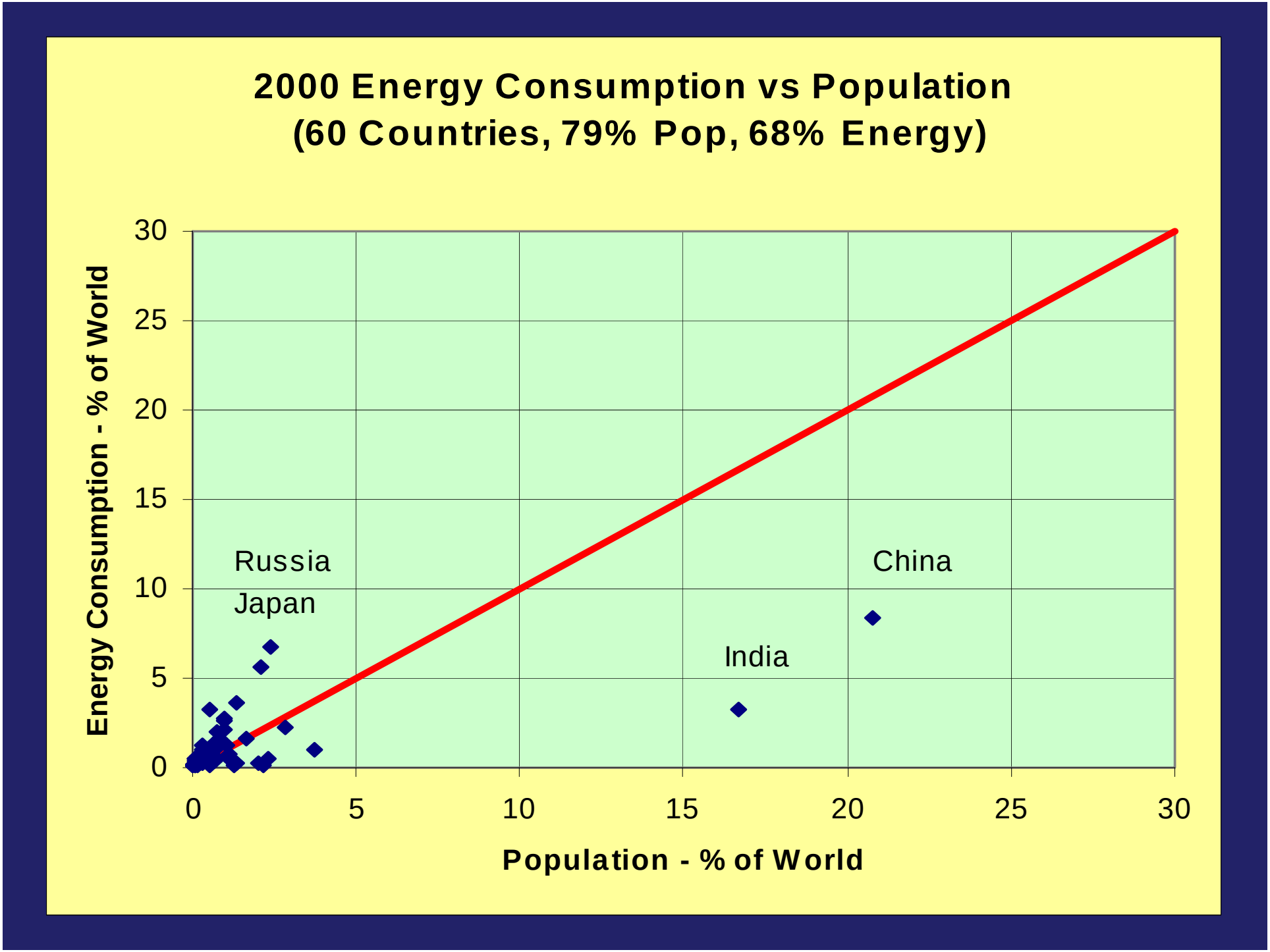
2 - Increasing Energy Prices

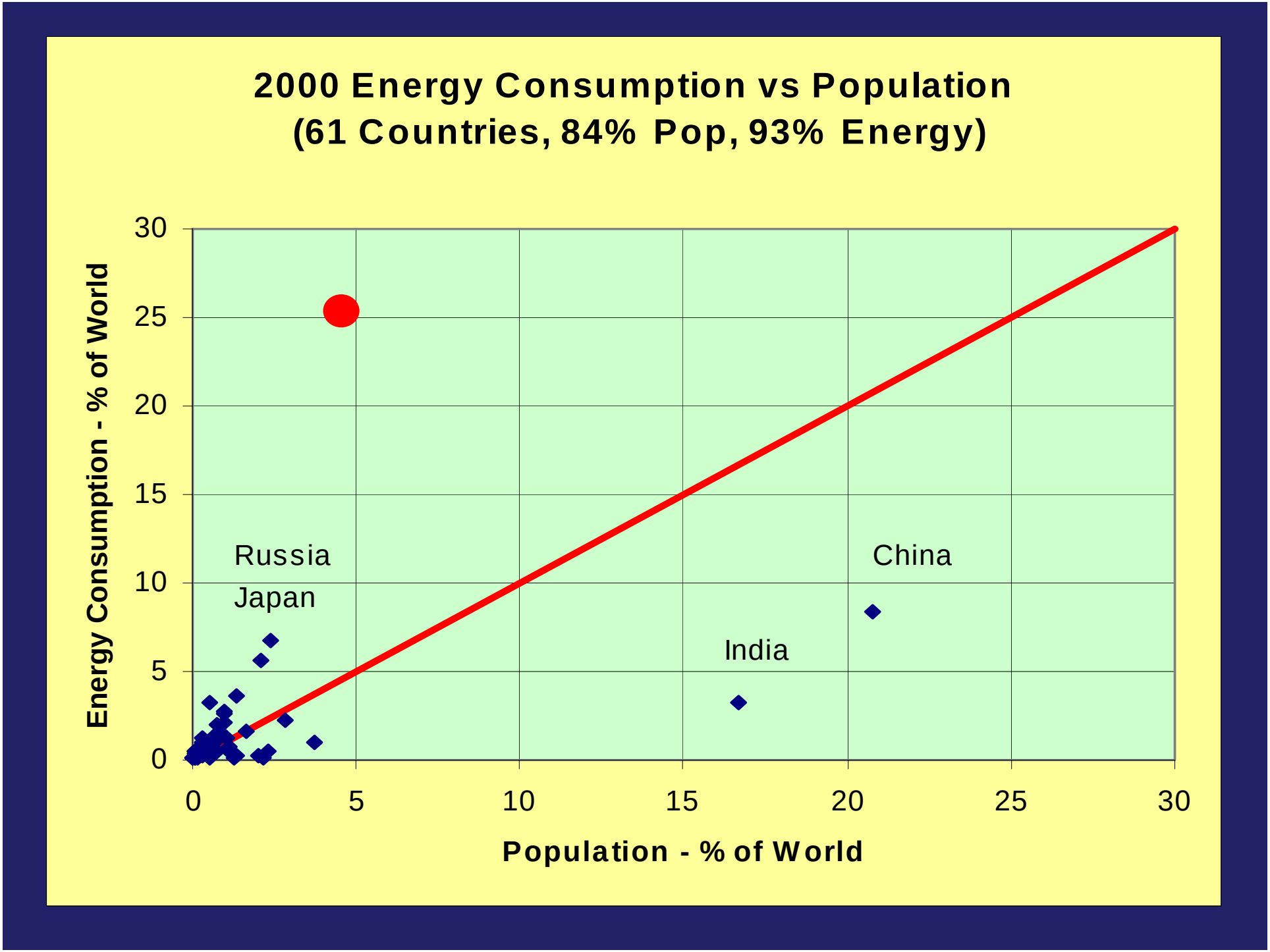
3 - Environmental Issues

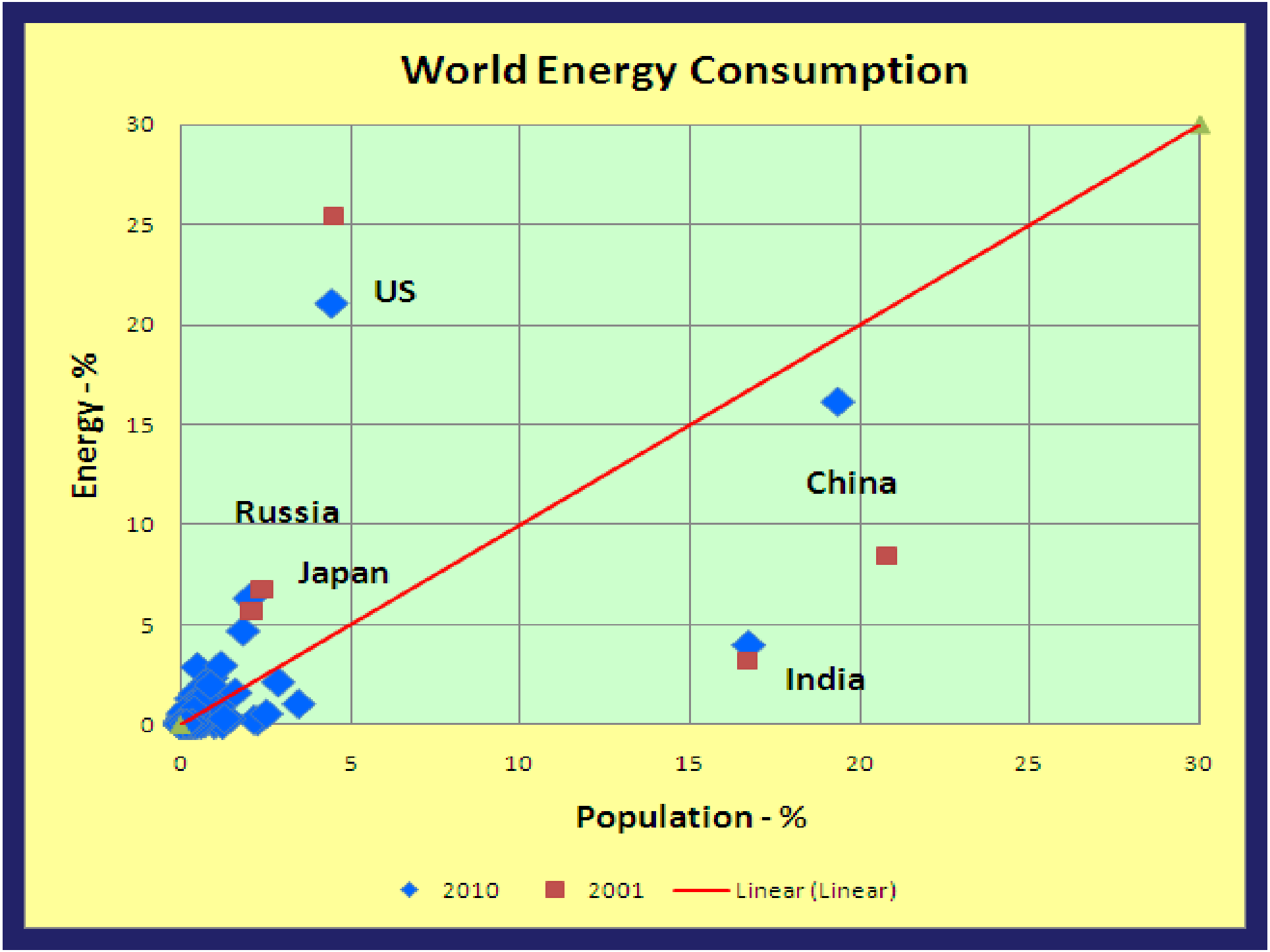
4 - AIA 2030 Challenge - NZE

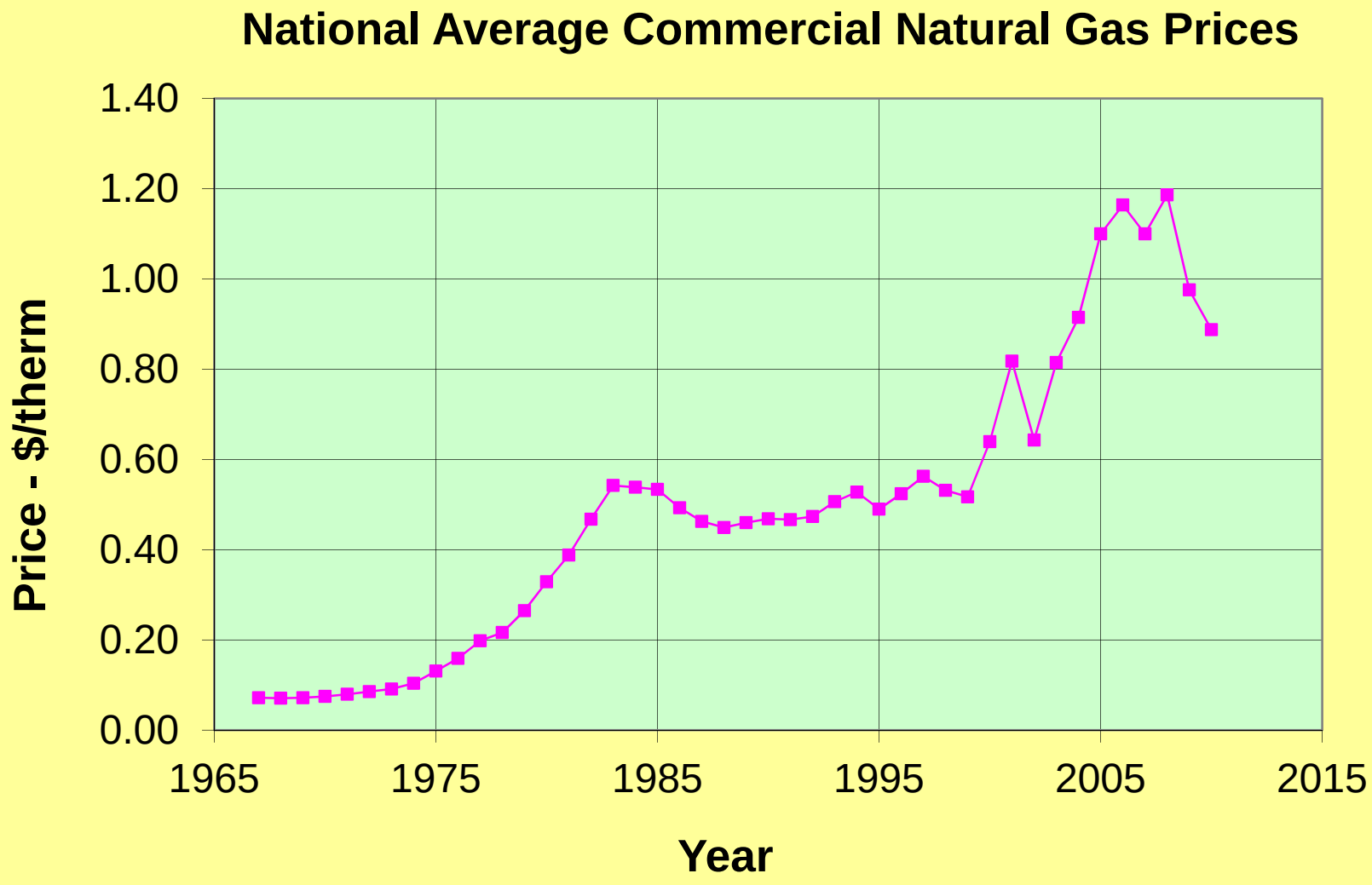

U.S. Energy Use
Energy Use - Quads
240
220
200
180
160
140
120
100
80
60
40
20
0
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Year


U.S. Energy Use
Energy Use - Quads
240
220
200
180
160
140
120
100
80
60
40
20
0
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year
1973 Oil Embargo

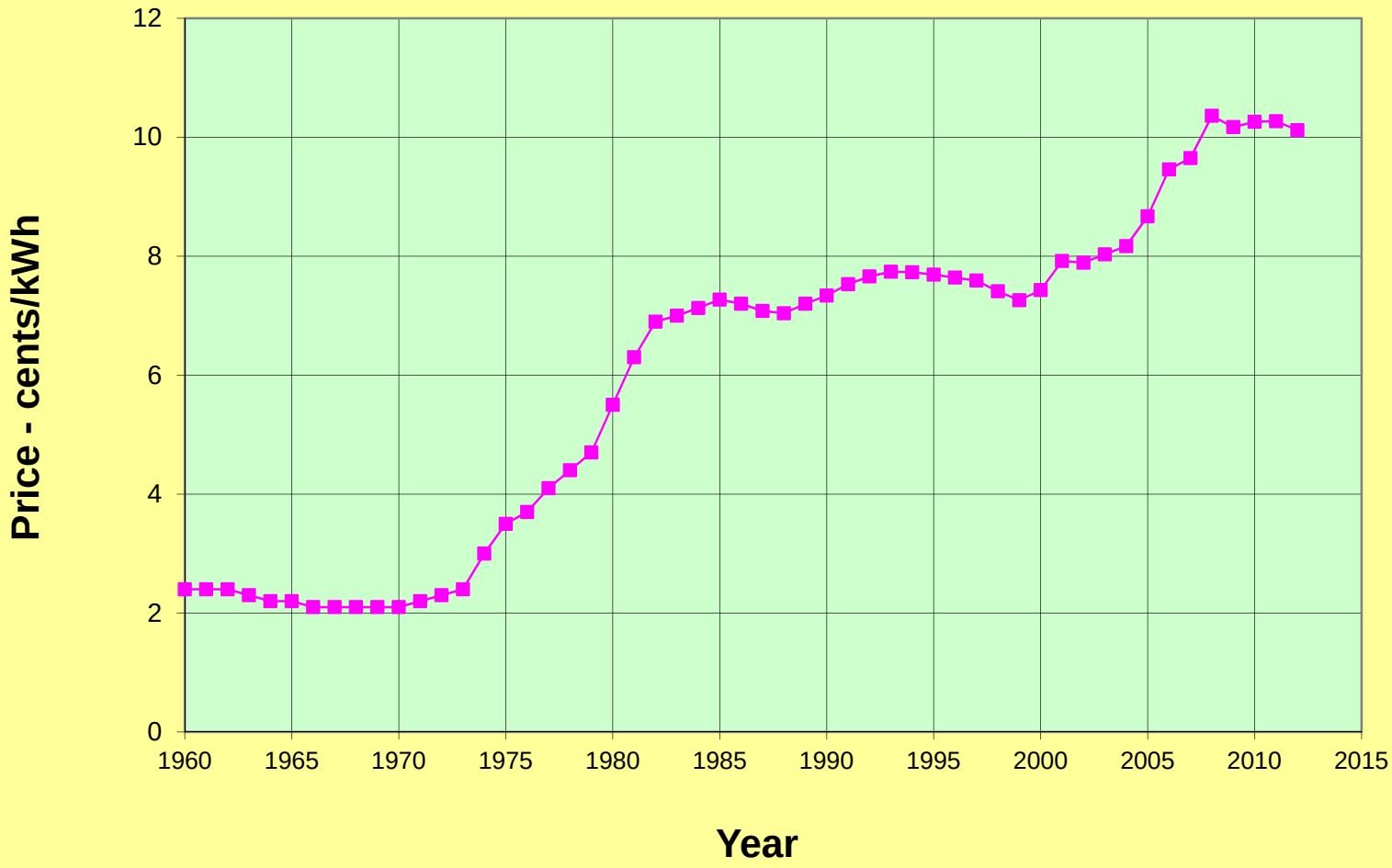

2000 Energy Consumption vs Population
(60 Countries, 79% Pop, 68% Energy)
Energy Consumption - % of World
Population - % of World
0
5
10
15
20
25
30
Russia
Japan
China
India


2000 Energy Consumption vs Population
(61 Countries, 84% Pop, 93% Energy)
Energy Consumption - % of World
Population - % of World
0
5
10
15
20
25
30
Russia
Japan
China
India

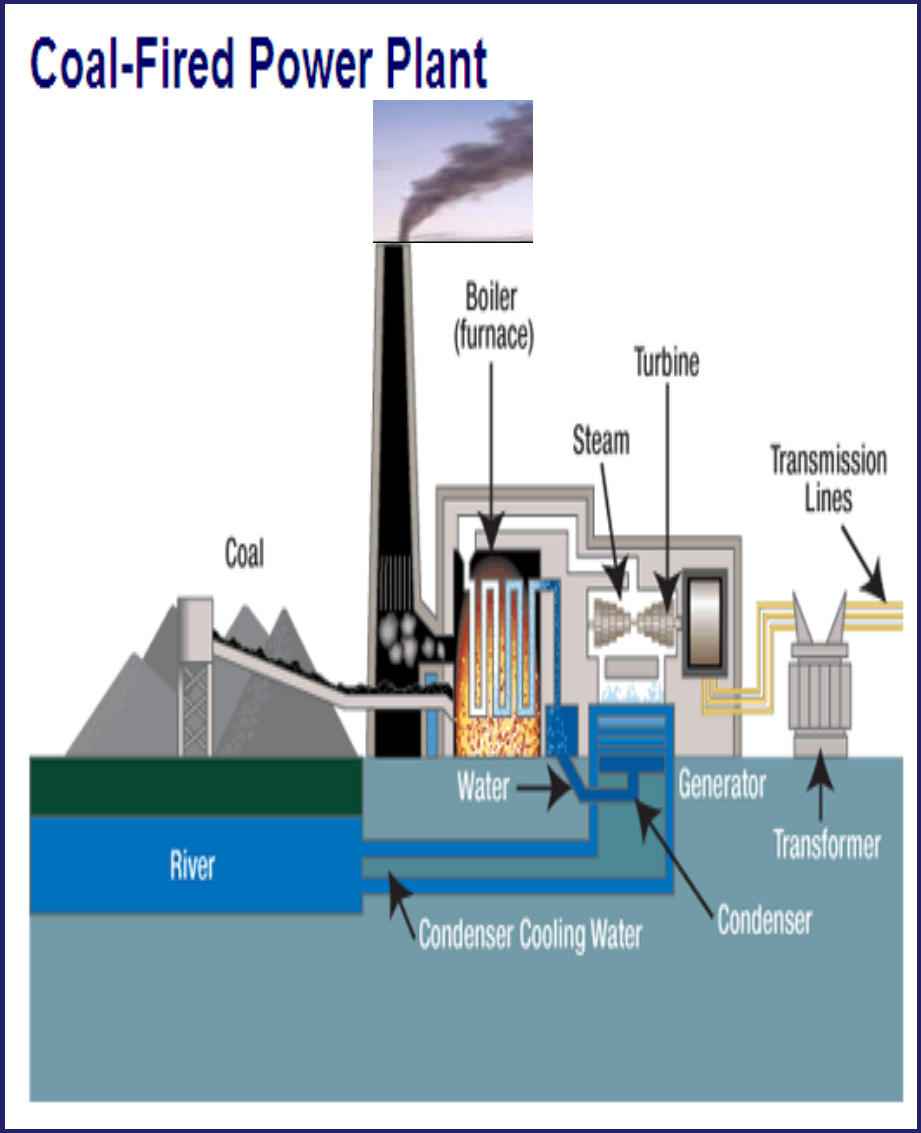

World Energy Consumption
Energy - %
Population - %
US
China
Russia
Japan
India
0
5
10
15
20
25
30
2010
2001
Linear (Linear)


National Average Commercial Natural Gas Prices
Price - $/therm
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
1965
1975
1985
1995
2005
2015
Year

National Average Commercial Electricity Prices



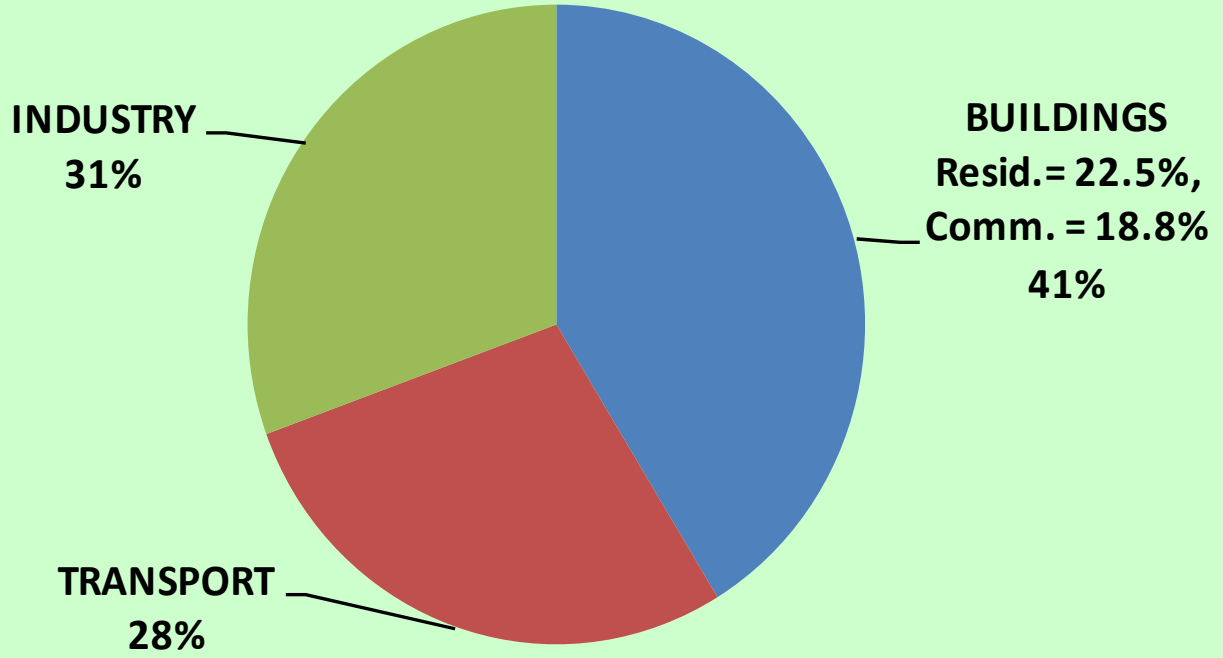
Environmental



500 megawatt:

- 1.4×10^6 tons coal
- 3.7×10^6 tons CO2
- 1.0×10^4 tons SO2
- 5.0×10^2 tons particulates
- 1.0×10^4 tons NOx
- 7.1×10^2 tons CO
- 2.2×10^2 tons VOC
- 170 lbs mercury
- 225 lbs arsenic
- 114 lbs lead
- 4 lbs cadmium

U.S. Energy Use



AIA 2030 Challenge

Edward Mazria, AIA

"Net Zero Energy Buildings by 2030"

Alignment on 2030 Challenge

AIA

ASHRAE

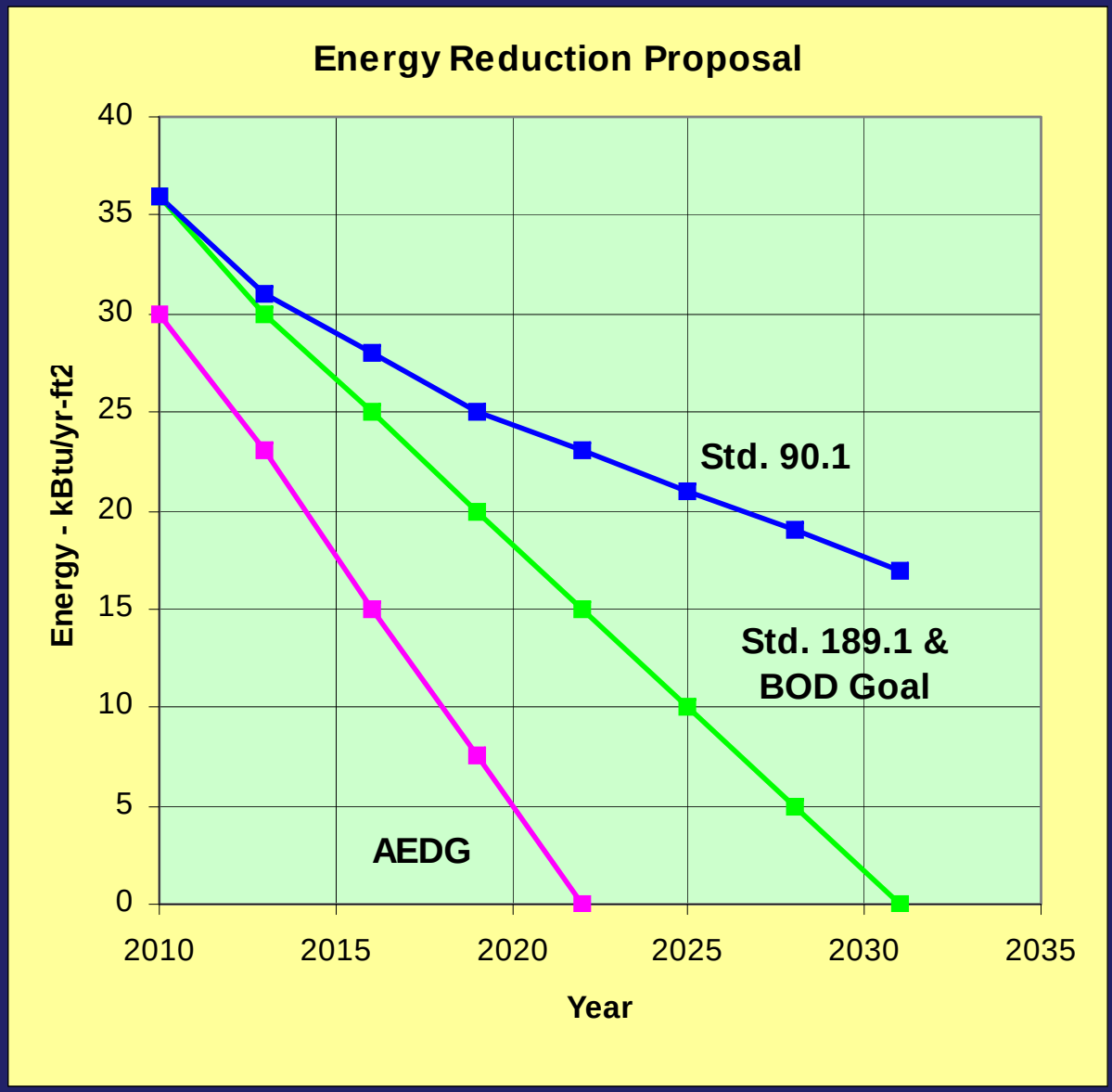
USGBC

U.S. Conference of Mayors

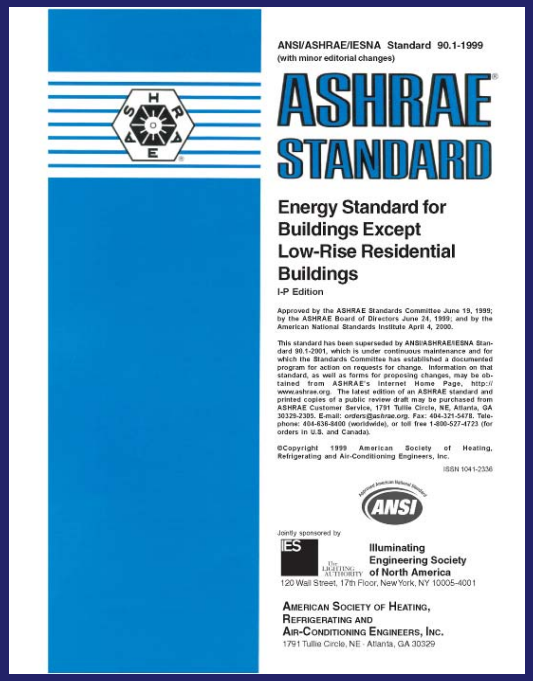
State of Florida

ASHRAE Board of Directors

(April 1, 2007)



Energy Code AEDGs



3 year development cycle
Consensus – Public Reviews
Technically Feasible
Economically Justified
Balanced
Code Language

1 year to complete
Peer Reviews
Two Manufacturers
30% to 50% Savings
Balanced
Recommendations

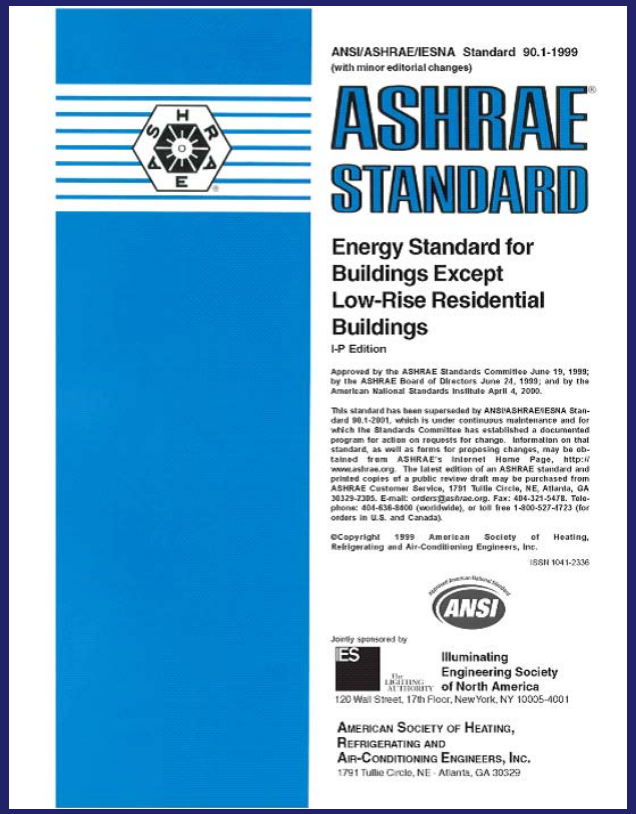
AEDG Background

USGBC - Leadership in Energy and Environmental Design (LEED)

- Certified, Silver, Gold, Platinum

ASHRAE Standard 90.1

- 30% Energy Savings - 1999
- 50% Energy Savings - 2004
- 75% Energy Savings



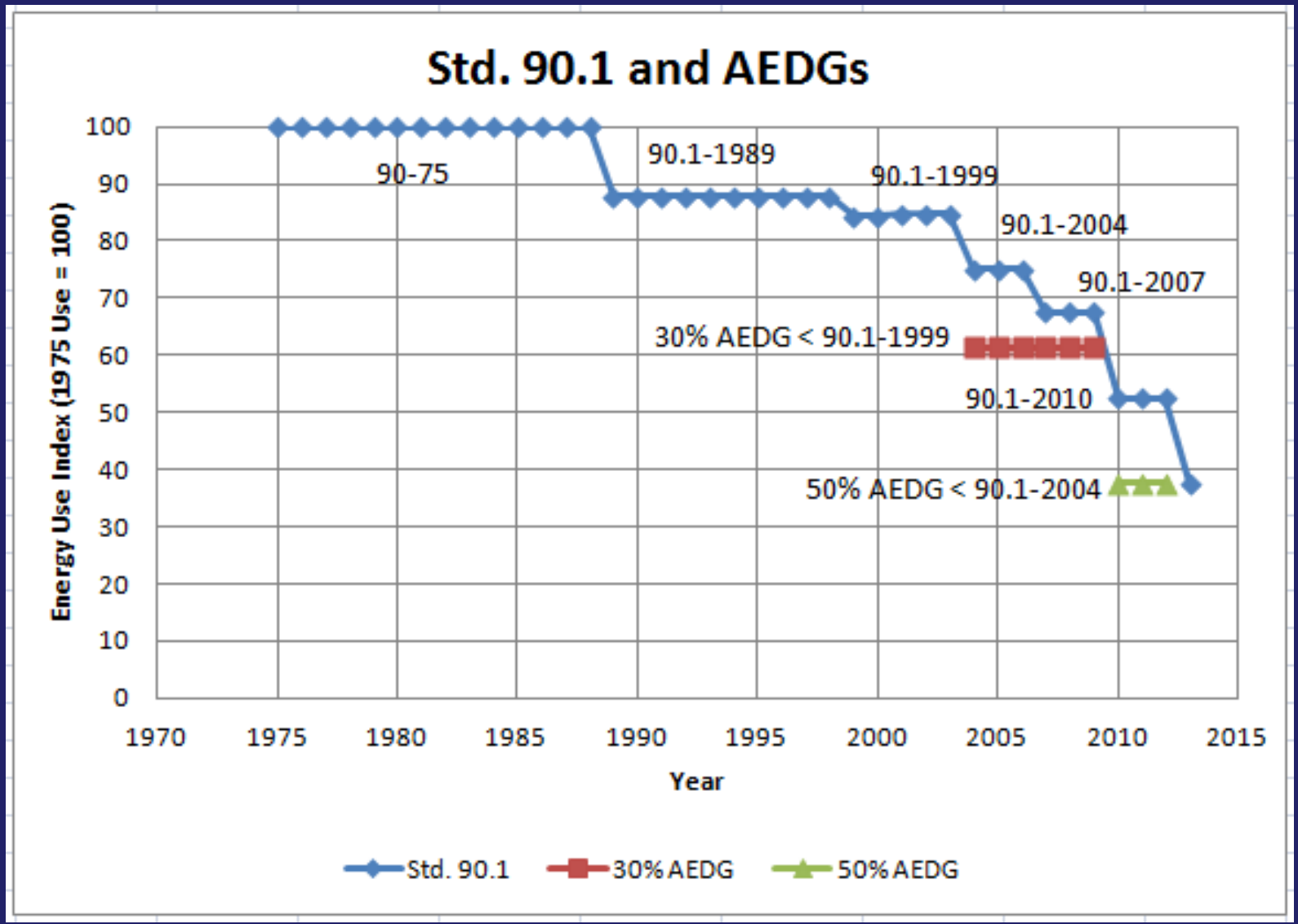
AEDG Background

Partner Organizations	Members
ASHRAE	55,000
AIA	83,000
IES	9,000
USGBC	25,000
U.S. Dept. of Energy (NREL, PNNL)	

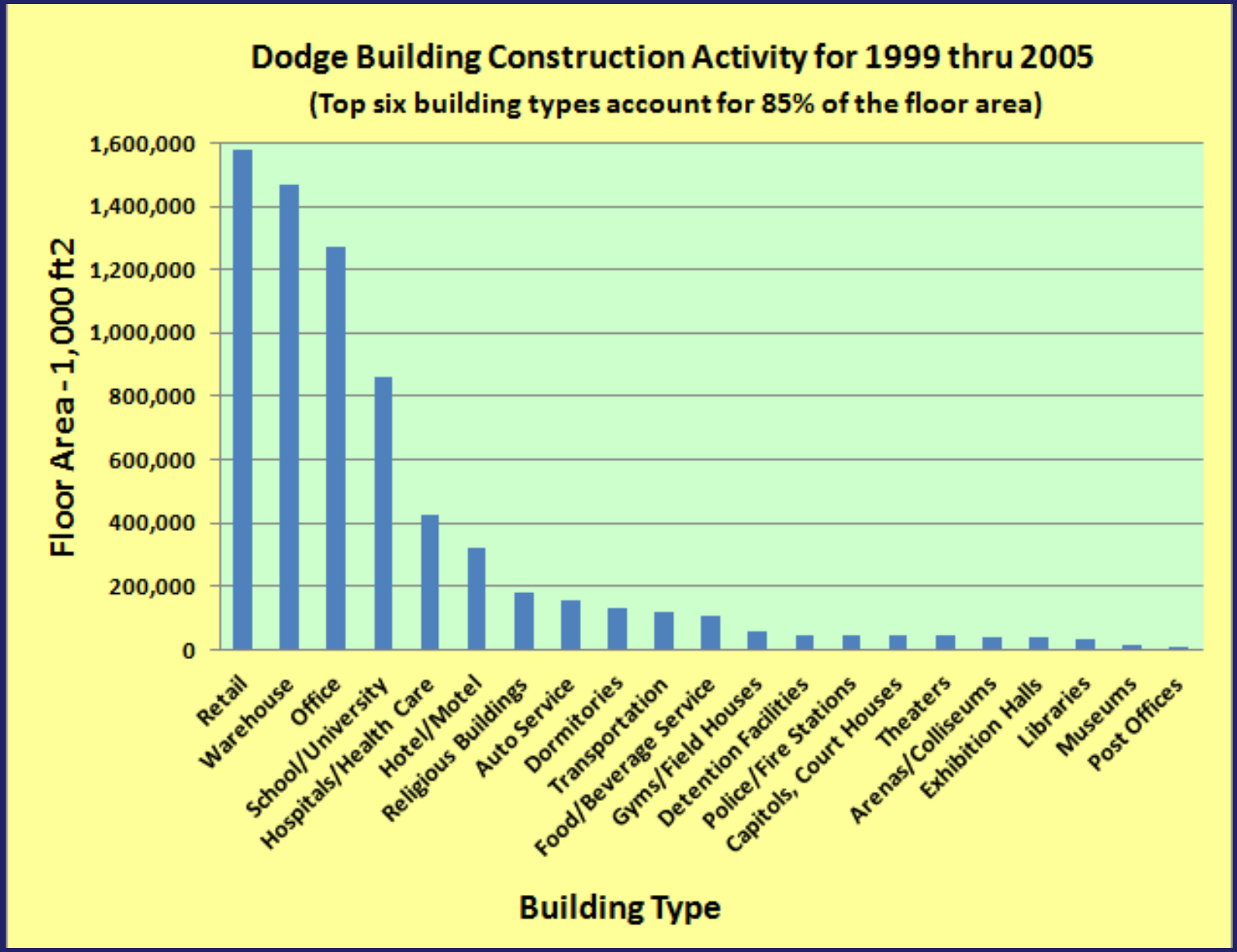
AEDG Goals

- Present *some ways, but not all or the only way* to build energy efficient buildings that use significantly less energy than those built to the minimum code requirements
- Progress toward a net zero energy building
- 30% energy savings when compared to ANSI/ASHRAE/IESNA Std. 90.1-1999
- 50% energy savings when compared to ANSI/ASHRAE/IESNA Std. 90.1-2004

Std. 90.1 & AEDG Energy Savings



SCOPE

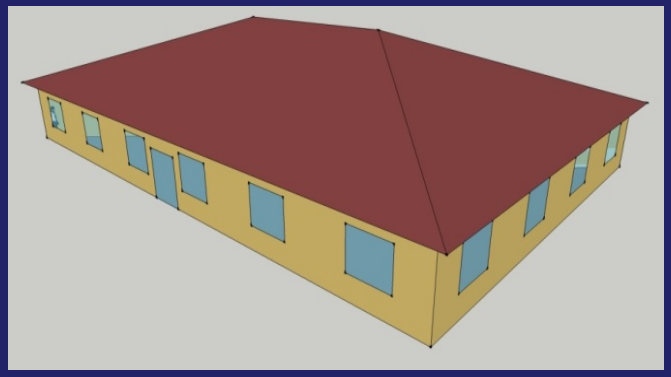

Dodge Building Construction Activity for 1999 thru 2005
(Top six building types account for 85% of the floor area)
Floor Area - 1,000 ft2
1,600,000
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
Retail
Warehouse
Office
School/University
Hospitals/Health Care
Hotel/Motel
Religious Buildings
Auto Service
Dormitories
Transportation
Food/Beverage Service
Gyms/Field Houses
Detention Facilities
Police/Fire Stations
Capitols, Court Houses
Theaters
Arenas/Colliseums
Exhibition Halls
Libraries
Museums
Post Offices
Building Type

Scope

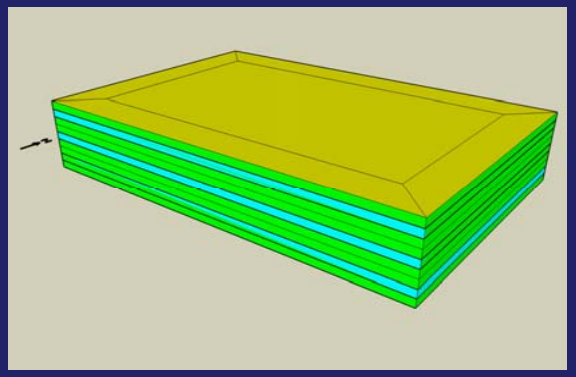
- Offices: 5,000 - 500,000 ft^2
- Retail: 7,500 - 100,000 ft^2
- Schools: 210,000 ft^2
  - Elementary, Middle, High Schools
- Warehouses: 50,000 ft^2
  - Bulk Storage with Office Space
  - Self Storage
- Highway Lodging: 45,000 ft^2
  - Exterior Entrances
  - Interior Corridor
- Health Care: 41,000 - 425,000 ft^2
  - Surgical Hospitals – 25 to 160 beds

Office Buildings

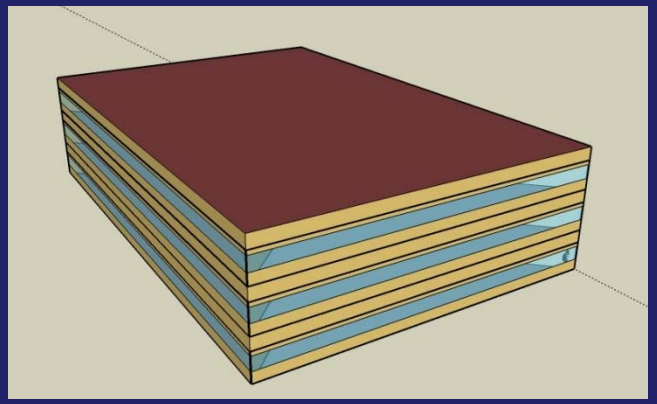
Small Office – 5,000 ft2



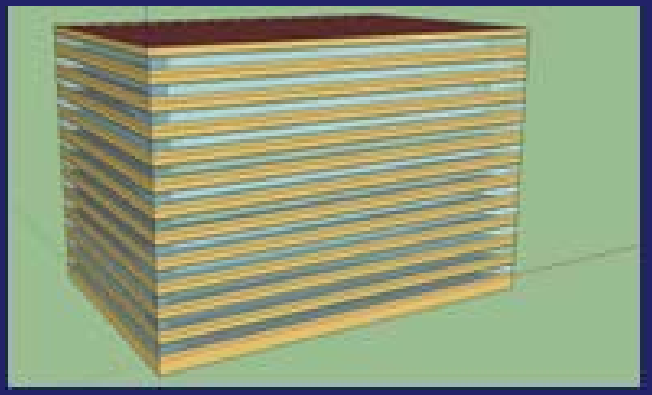
Small Office – 20,000 ft2



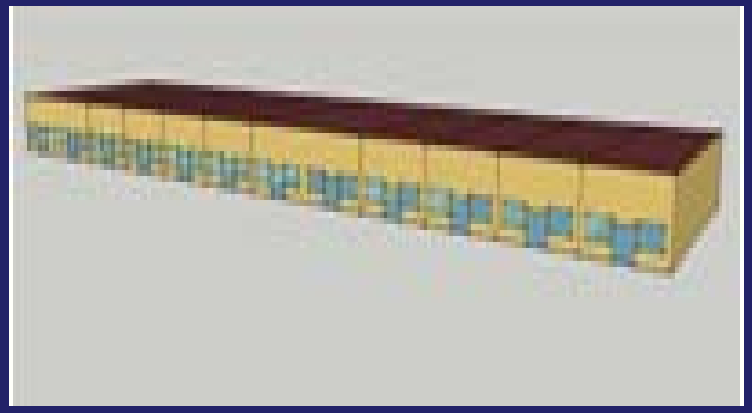
Medium – 53,600 ft2

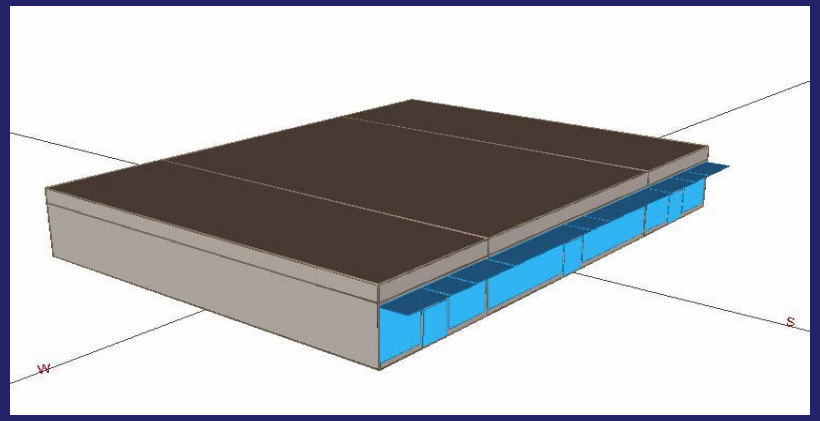


Large – 498,600 ft2



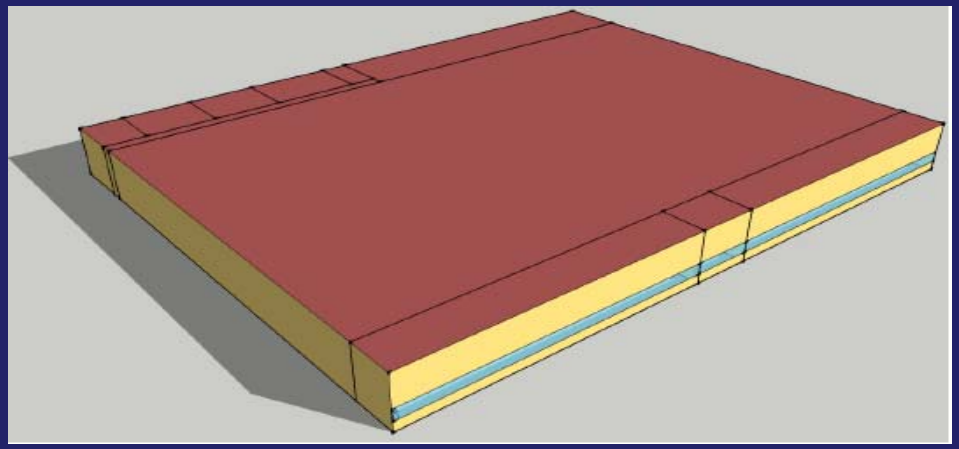
Retail Buildings





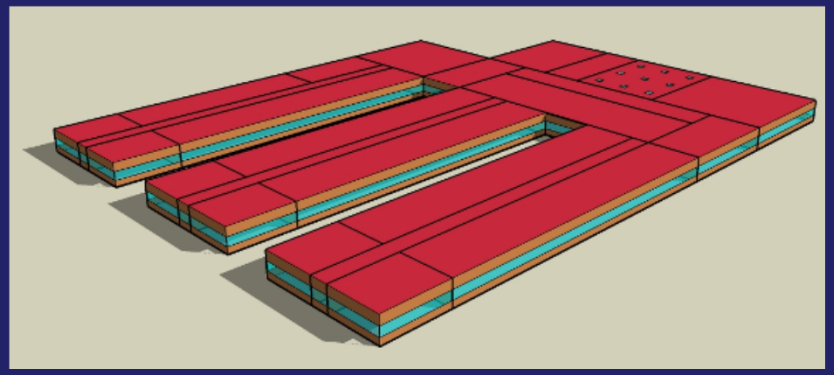
Strip Mall – 7,500 ft2 Stand-alone Retail – 15,000 ft2

Medium Box Retail – 40,500 ft2 and Big Box Retail – 99,225 ft2



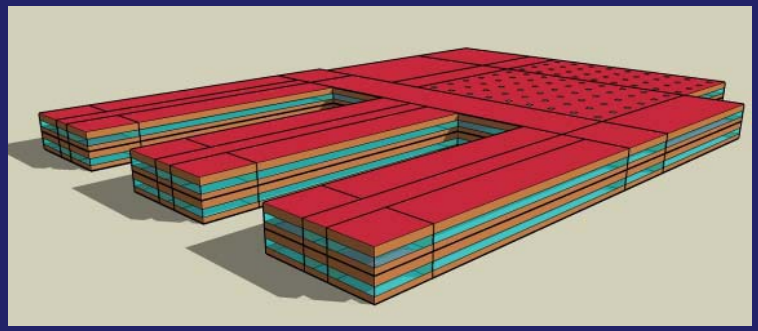
Schools K-12

Elementary



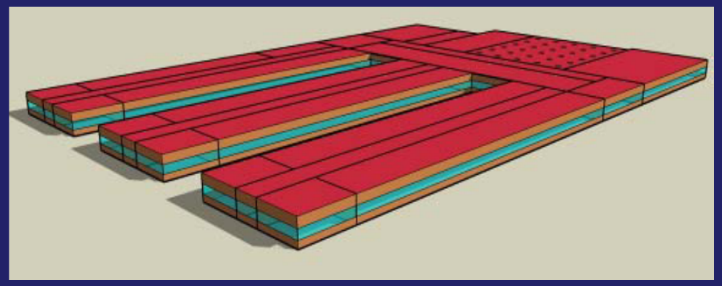
73,930 ft^2

High



210,810 ft^2

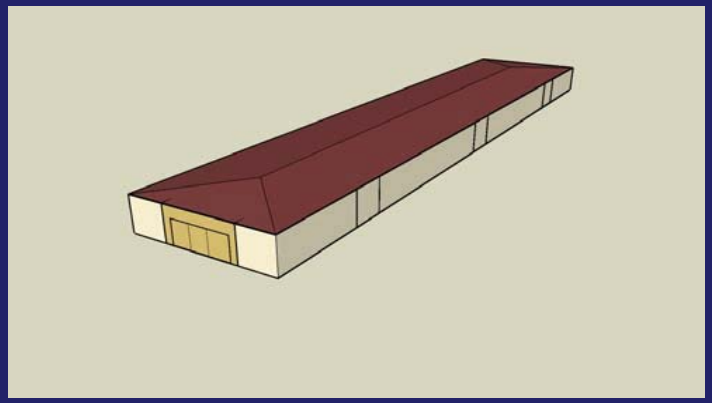
Middle



116,080 ft^2

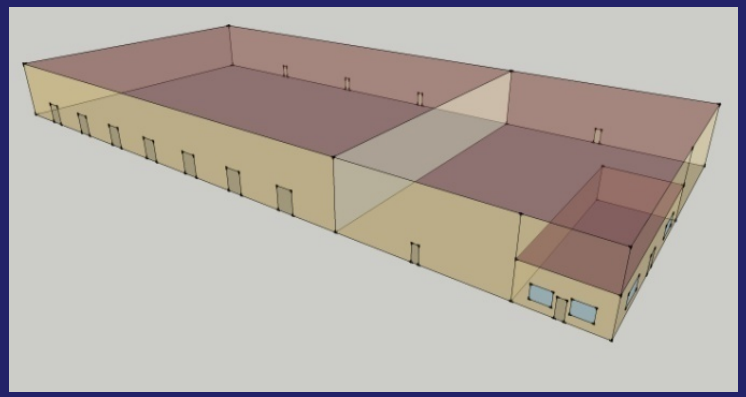
Warehouses and Self-Storage

Self Storage



8,000 ft^2

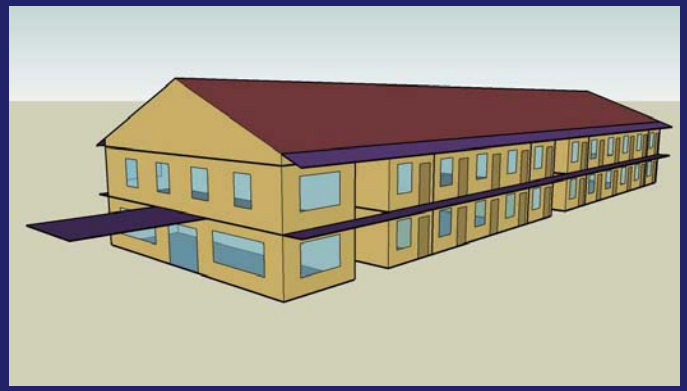
Non-refrigerated warehouse



50,000 ft^2

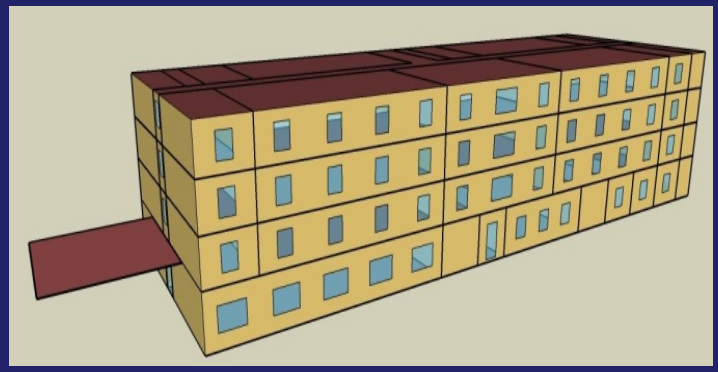
Highway Lodging

Exterior Walk Way



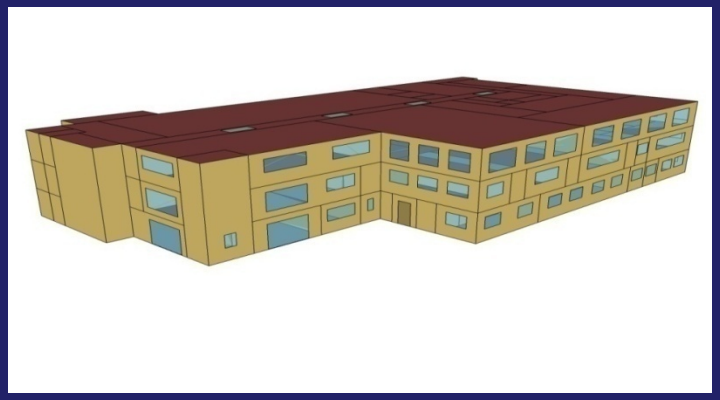
14,000 ft^2

Small Hotel

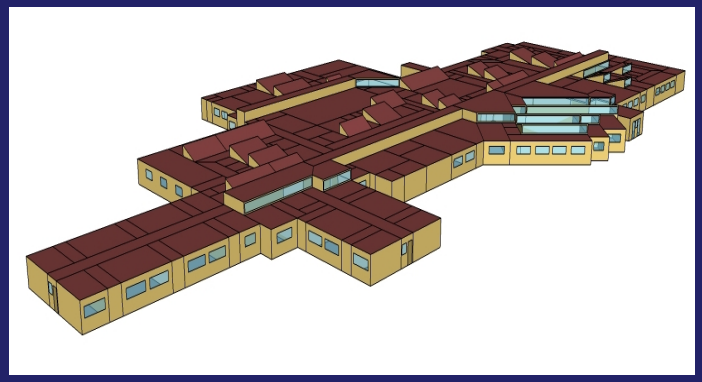


43,000 ft^2

Hospitals and Health Care

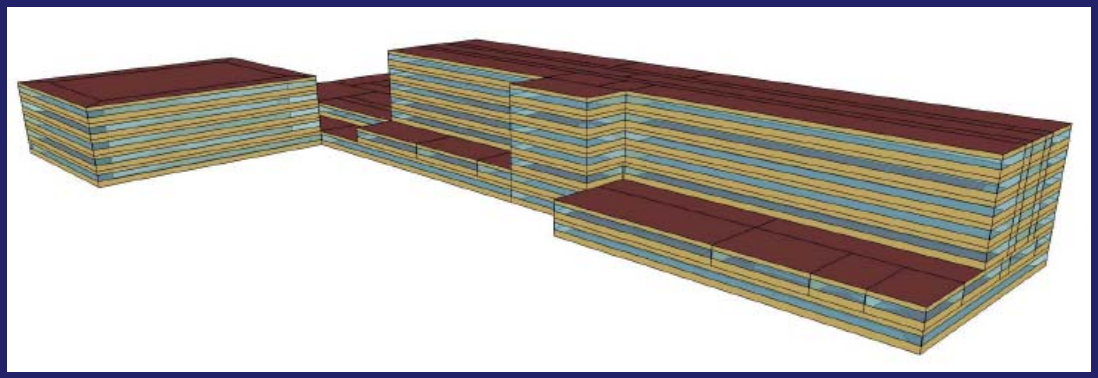


Surgery Center – 41,000 ft2



Medium Hospital –65,000 ft2

Large Hospital – 425,000 ft2 – 160 patient beds



Development Process

1 - Collaboration of Partner Organizations
2 - Steering Committee – Scoping Document
3 - Project Committee – 6 to 14 Members
4 - Focus Group – 6 to 8 Members
5 - Peer Reviews – 35%, 65%, 90% Drafts
6 - Respond to Peer Review Remarks
7 - Publication

Design Strategy

Improve Energy Efficiency

Better Envelope

Lower LPD

Higher HVAC Efficiencies

Design Strategy

Change Architectual Design

Building Features

1 - Building Shape

2 - Building Size

3 - Number of Stories

4 - Building Orientation

5 - Building Occupancy Type

Design Strategy

Energy Conservation Measures

Envelope

Lighting – Daylighting

Equipment – Energy Star

SWH

Design Strategy

HVAC

- Packaged Single - Zone Air Source HP
- WSHP with DOAS
- VAV DX w/Indirect Gas - Fired or Elec. Internal Heat and Elec. Perimeter Heat
- VAV CHW
- Fan Coils w/ DOAS
- Radiant Systems w/DOAS
- GSHP w/DOAS
- VAV Air – Handling System w/DOAS

Design Strategy

HVAC

- Packaged Variable Volume DX Air Conditioners
- Packaged Constant Volume DX Air Conditioners w/DOAS
- Packaged Single Zone Air Source HP w/DOAS
- Packaged Single Zone WSHP w/DOAS
- Central Air-Handling System
- Mixed Air VAV System w/Separate OA Treatment and Heat Recovery
- Radiant System w/DOAS and Displacement Ventilation and Exterior Automated Shades

What's in an AEDG?

Foreword – Schools, Health Care and all 50% AEDGs

1 - Introduction – Essentials of Achieving the Savings

2 - Integrated Design Process/Strategies

3 - Energy Modeling and Benchmarking Strategies

4 - Recommendations by Climate (the specifics)

5 - How to Implement Recommendations (hints, cautions)

Appendices

- A – Envelope Thermal Performance Factors
- B – International Climate Zones
- C – Commissioning

Using an Integrated Design Approach to Achieve Energy Savings

- A narrative discussion of the design and construction process that points out the opportunities for energy savings in each phase of design
- Includes reference tables that leads the user through the process of identifying, selecting energy savings measures, and defining the responsible party to meet major energy design goals

Development of Recommendations

- Recommendations for Envelope, Lighting, HVAC, and Service Hot Water that achieve at least 30% or 50% whole building energy savings
  - Additional Savings Strategies are included, but not needed to achieve target energy savings
  - Use practical off-the-shelf technologies and strategies available from multiple manufactures
- Energy is the independent variable & cost-effectiveness (e.g. payback) is the dependent variable
- Recommendations modeled to verify savings

Critical Issues

Offices – Night Ventilation, Plug Loads

Retail – Merchandise Display

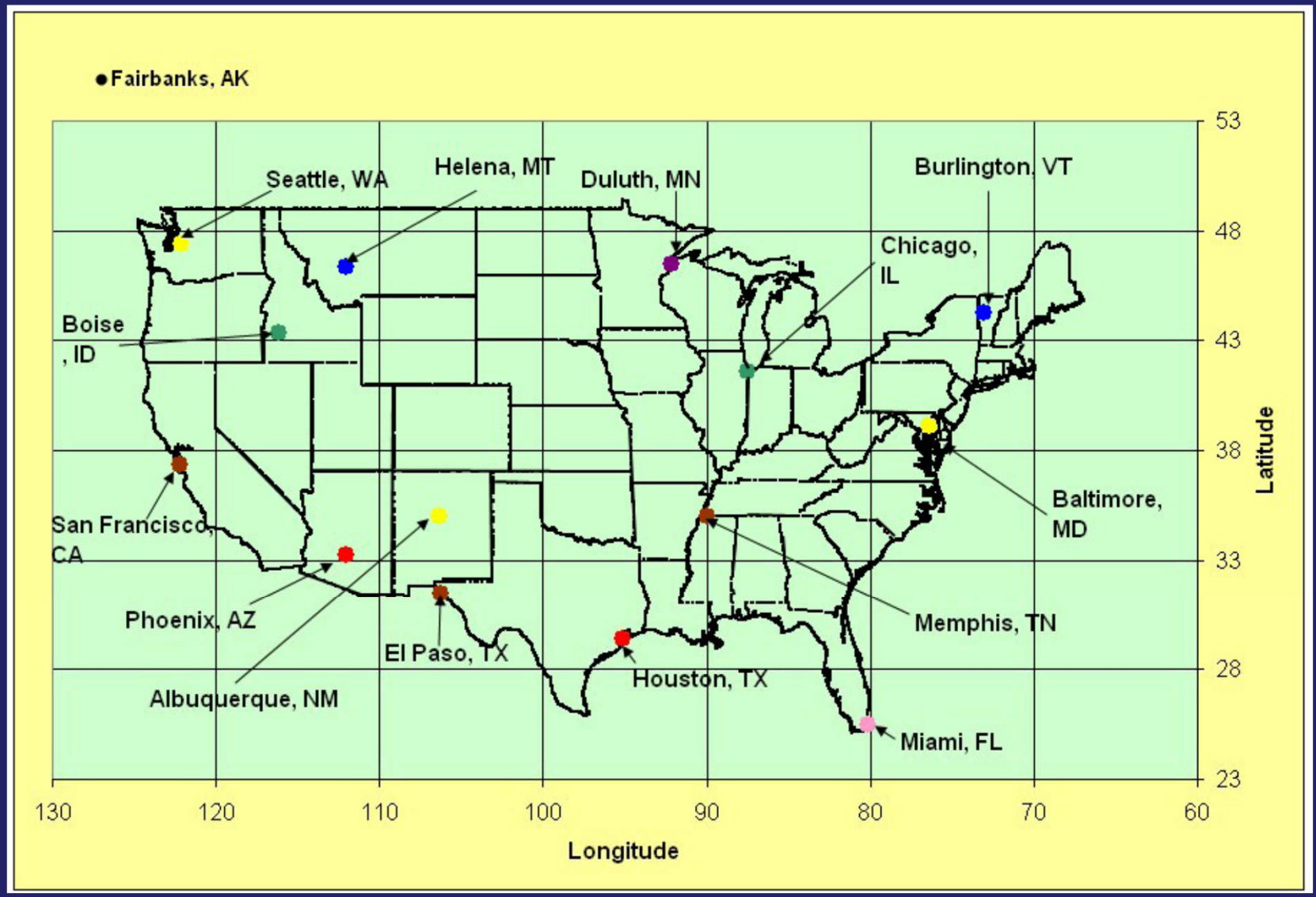
Schools – Daylighting, Ventilation, Kitchens

Warehouses – Loading Docks and Trucks

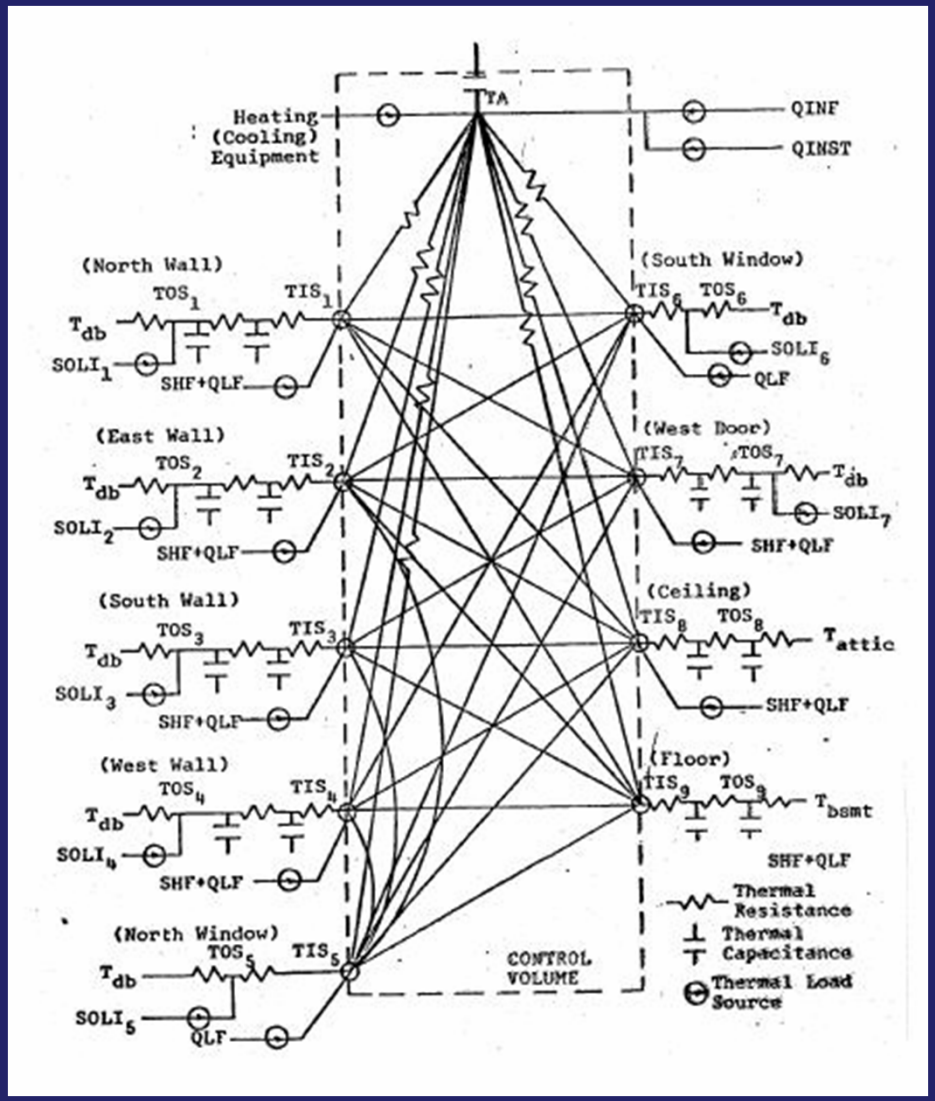
Highway Lodging – Laundry

Health Care – Ventilation

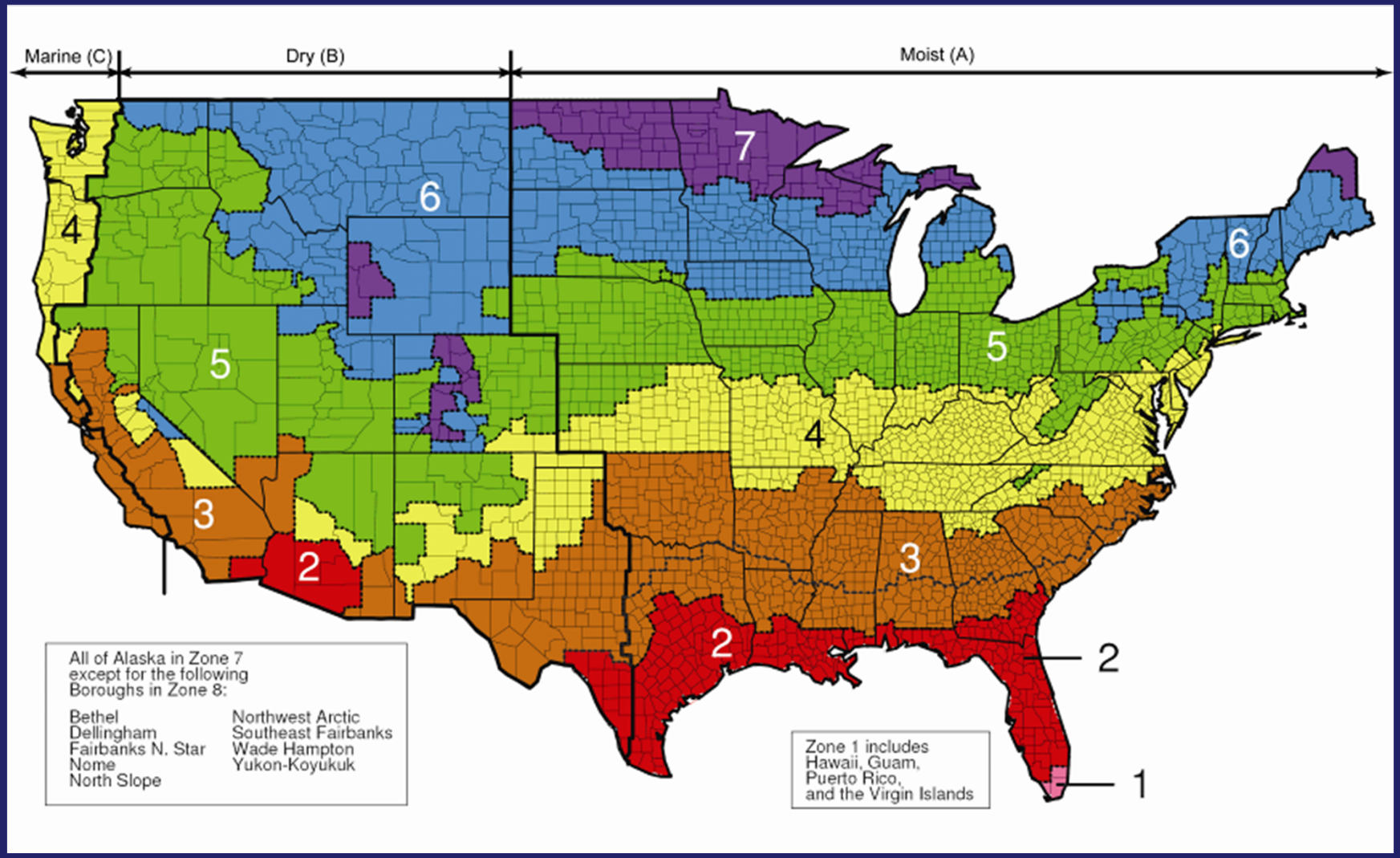
15 Representative Locations

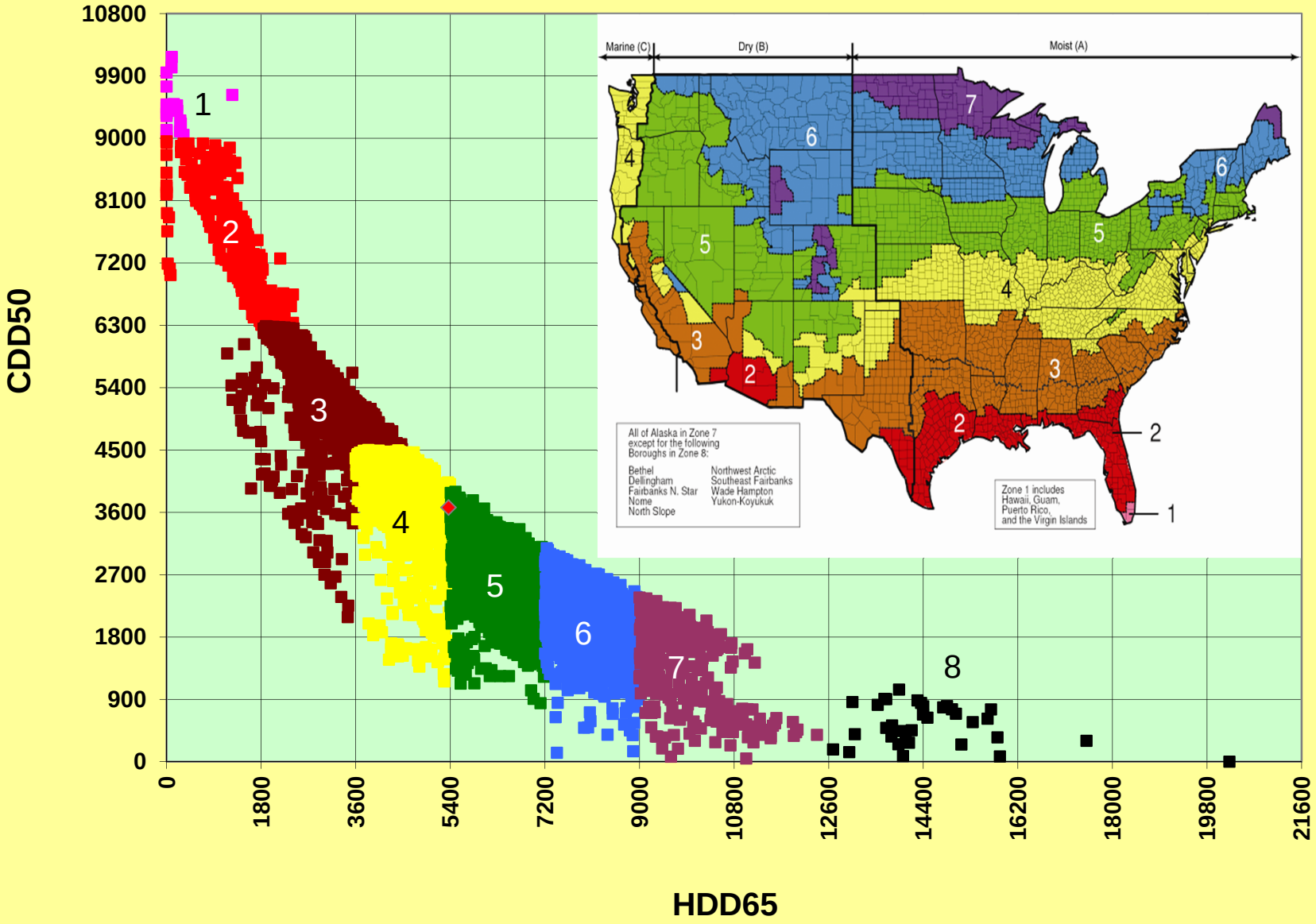


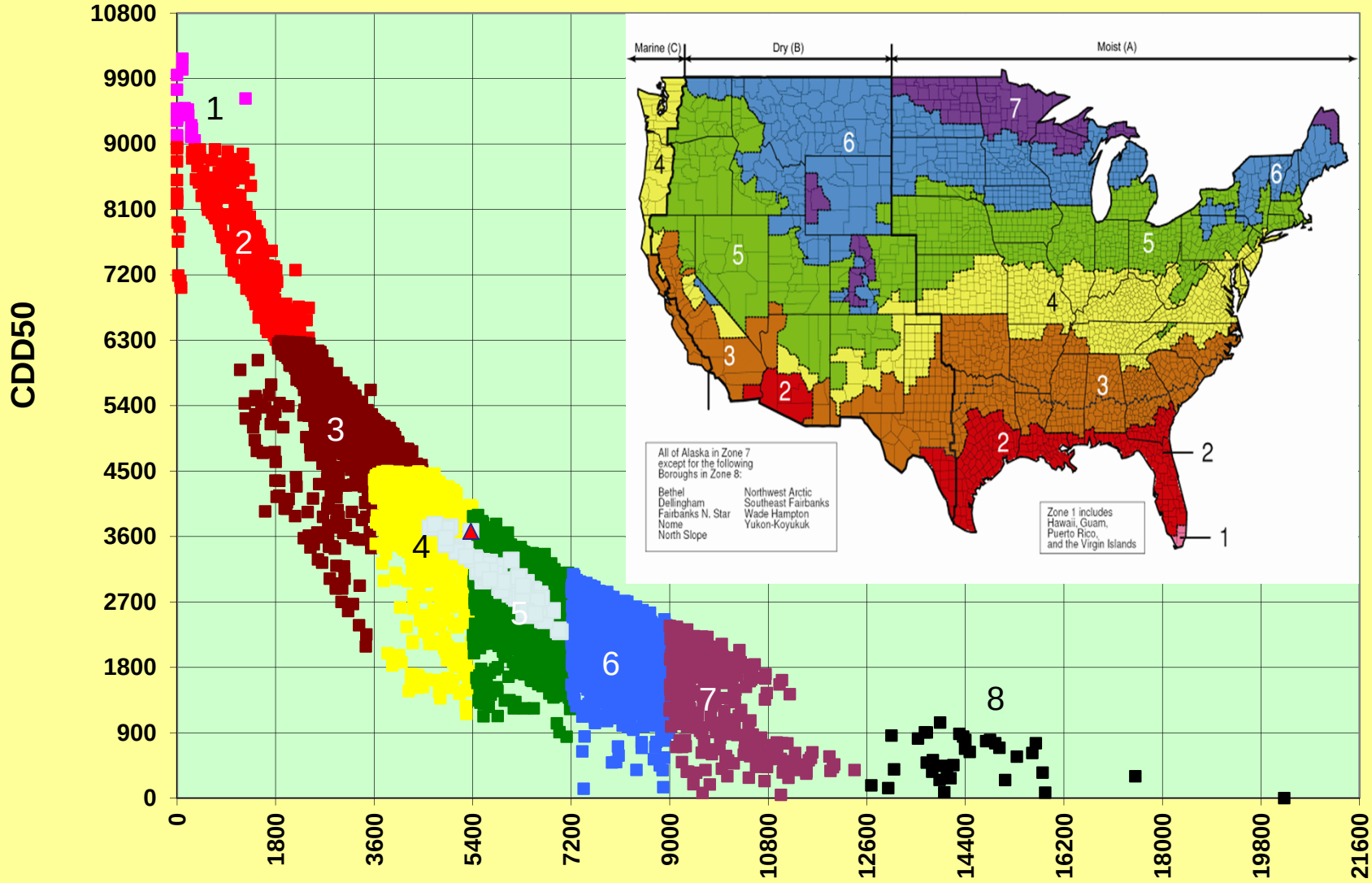
EnergyPlus Electrical Analog



Recommendation Tables by 8 Climate Zones




CDD50
10800
9900
9000
8100
7200
6300
5400
4500
3600
2700
1800
900
0
HDD65
0
1800
3600
5400
7200
9000
10800
12600
14400
16200
18000
19800
21600
1
2
3
4
5
6
7
8
Marine (C)
Dry (B)
Moist (A)
All of Alaska in Zone 7 except for the following Boroughs in Zone 8:
Bethel
Dellingham
Fairbanks N. Star
Nome
North Slope
Northwest Arctic
Southeast Fairbanks
Wade Hampton
Yukon-Koyukuk
Zone 1 includes Hawaii, Guam, Puerto Rico, and the Virgin Islands


CDD50
HDD65
10800
9900
9000
8100
7200
6300
5400
4500
3600
2700
1800
900
0
0
1800
3600
5400
7200
9000
10800
12600
14400
16200
18000
19800
21600
1
2
3
4
5
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Climate Zone Recommendations

- Envelope
- Lighting
- HVAC
- SWH

Envelope

Roofs

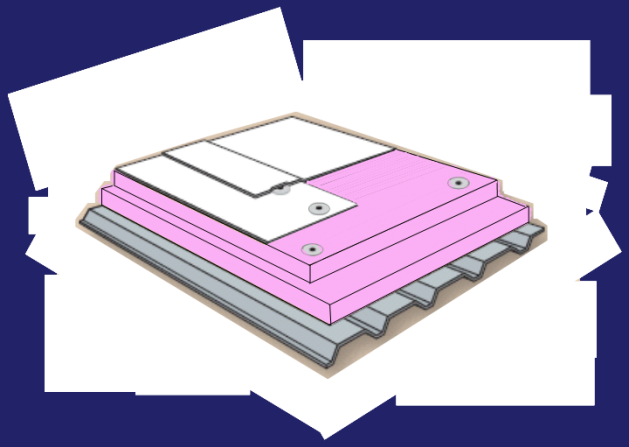
Walls

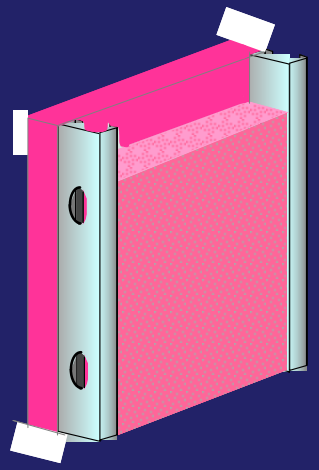
Floors

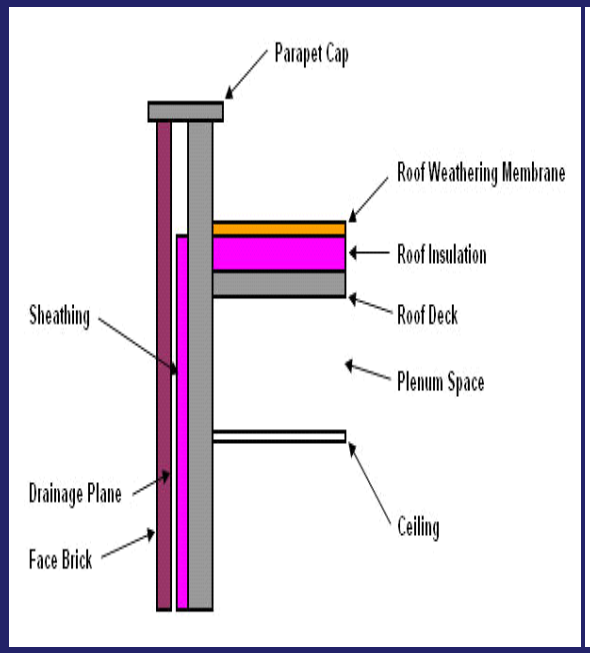
Slabs

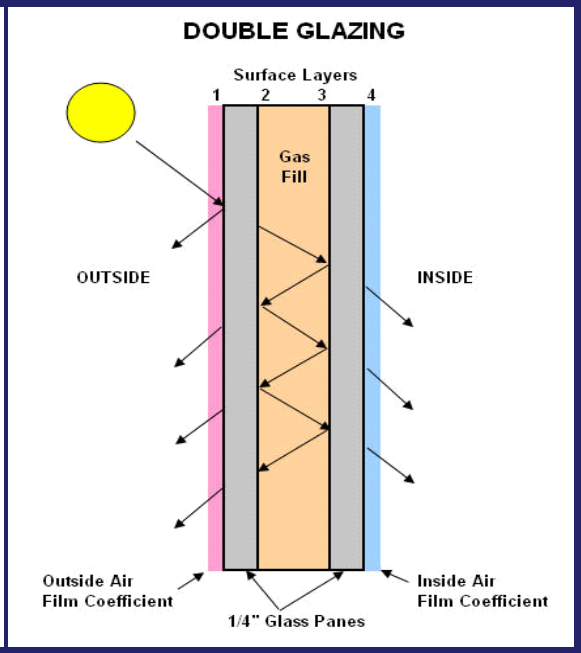
Doors

Fenestration





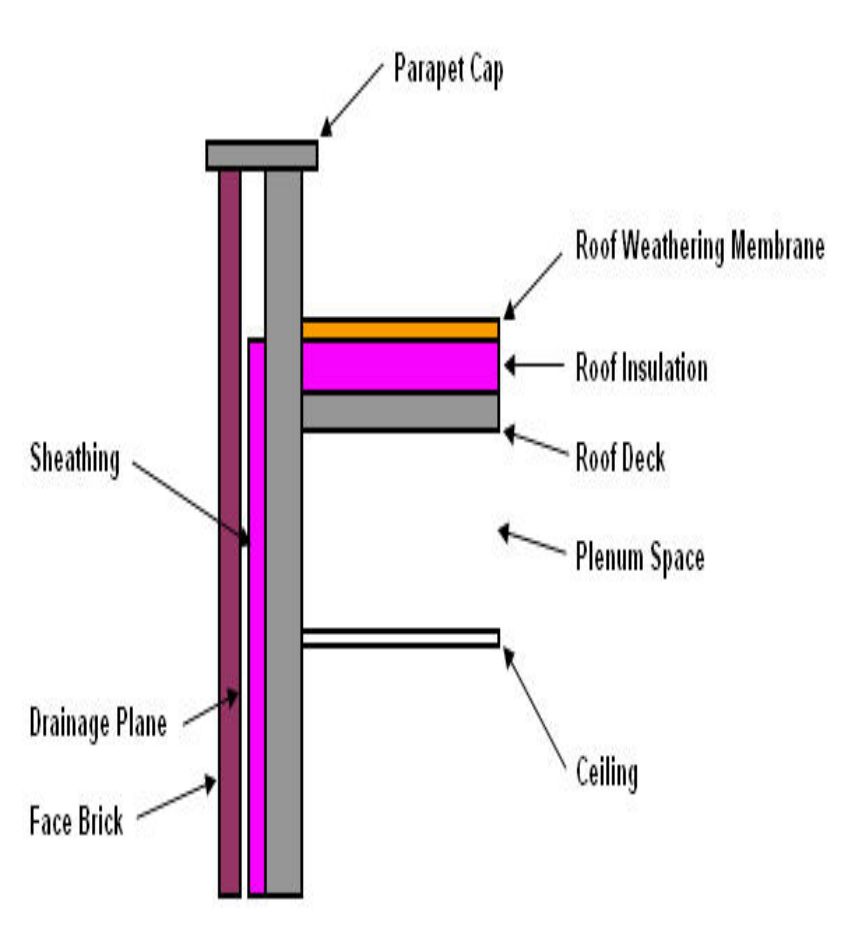




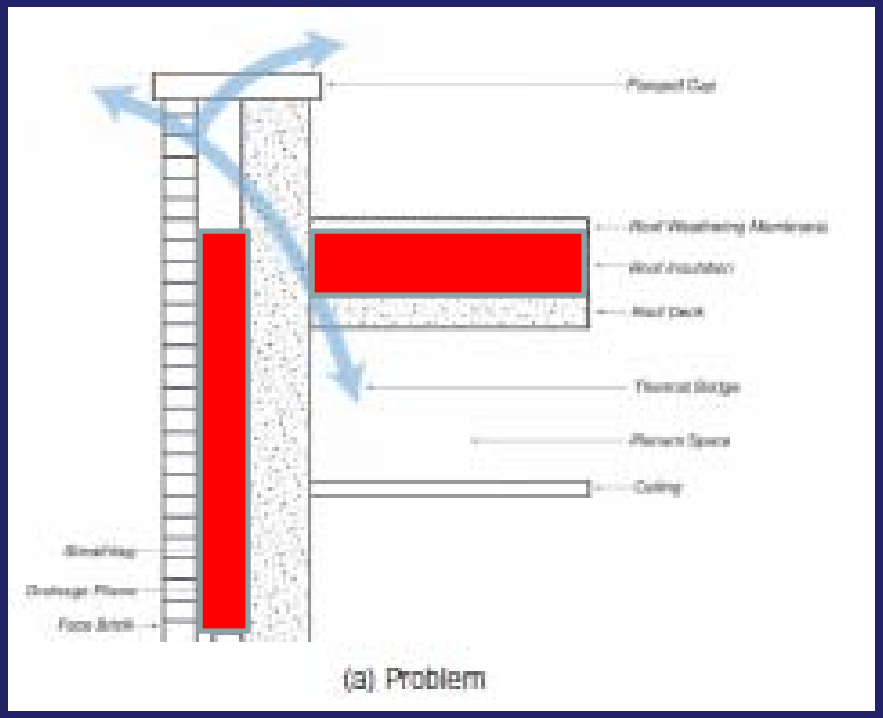
Envelope

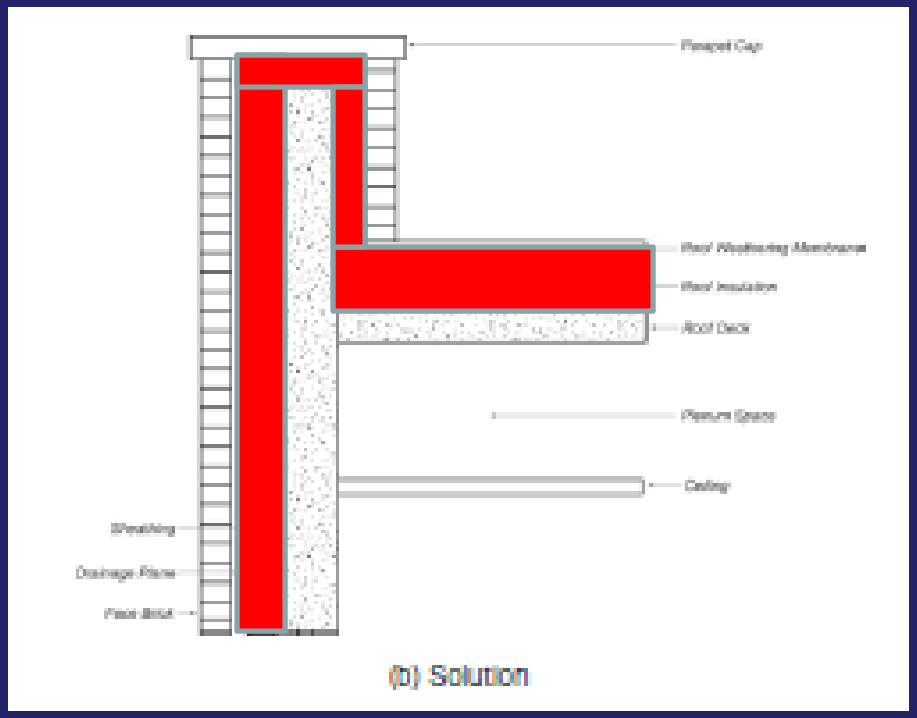
Climate Zone 5 Recommendations for K-12 Schools			
Item	**Component**	**Recommendation**	**How-To-Tip**
Roof	Insulation above deck	R-25 c.i.	EN1-2
	Attic and other	R-38	EN3, EN15-16, EN18
	Metal building	R-13 + R-19	EN3-4, EN15, EN18
	SRI	Comply with Std. 90.1	EN1
Walls	Mass (HC > 7 Btu/ft^2-°F)	R-11.4 c.i.	EN5, EN15, EN18
	Steel framed	R-13 + R-7.5 c.i.	EN6, EN15, EN18
	Wood framed and other	R-13 + R-3.8 c.i.	EN7, EN15, EN18
	Metal building	R-19 + R-5.6 c.i.	EN7, EN15, EN18
	Below-grade walls	R-7.5 c.i.	EN8, EN15, EN18
Floor	Mass	R-10.4	EN9, EN15, EN18
	Steel framed	R-30	EN10, EN15, EN18
	Wood framed and other	R-30	EN10, EN15, EN18
Slabs	Unheated	Comply with Std. 90.1	EN11, EN17-18
	Heated	R-15 for 24 in.	EN12, EN17-18
Doors	Swinging	U-0.70	EN13, EN18
	Nonswinging	U-0.50	EN14, EN18
Vertical Fenestration	Total fenestration to gross wall area ratio	35% Max	EN20
	Thermal transmittance	U-0.42	EN19, EN24, EN28
	SHGC - all types and orientations	SHGC-0.40	EN19, EN24, EN28
	Exterior sun control (S, E, W only)	Projection Factor > 0.50	EN21, EN23, EN26

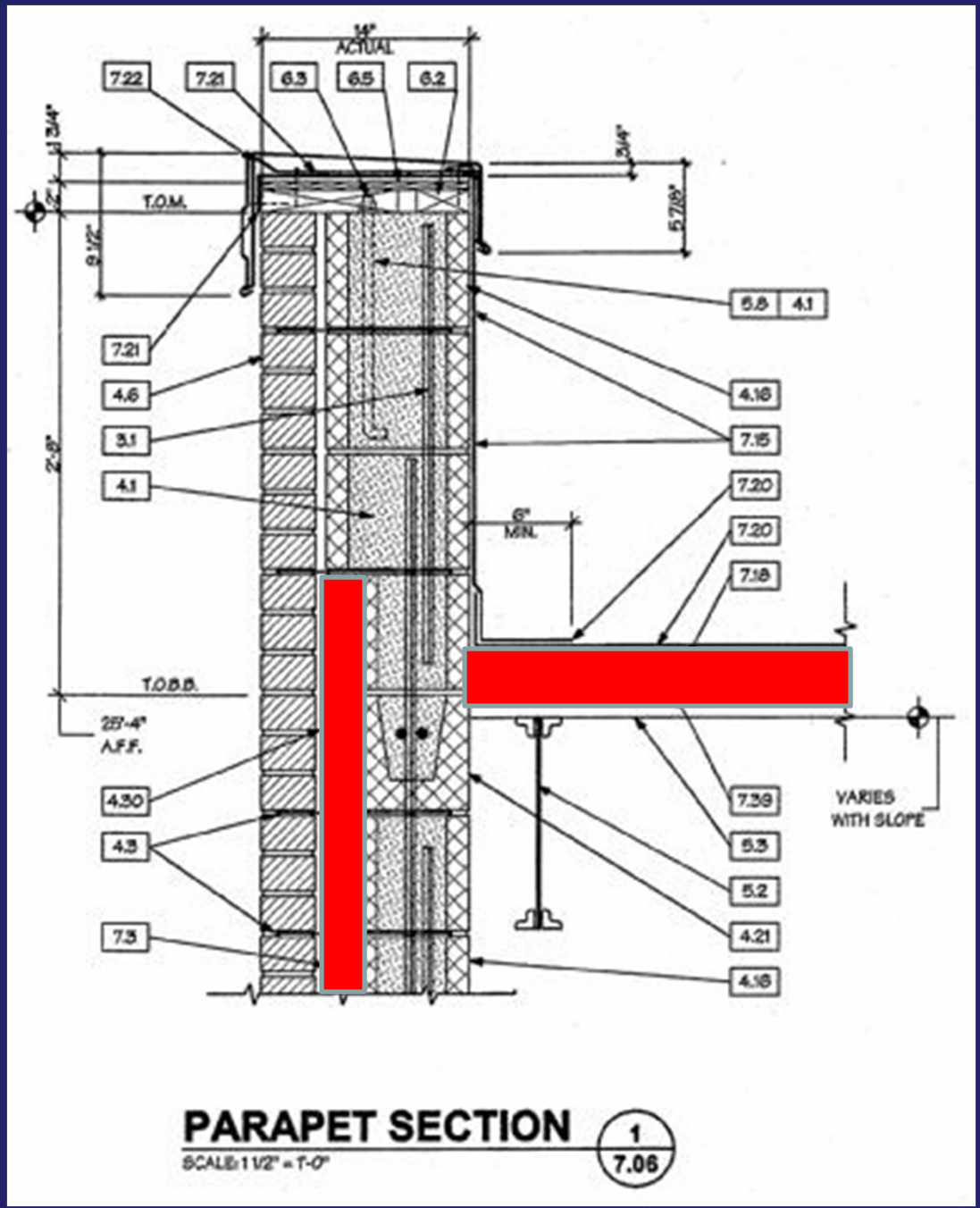
Parapet


Parapet Cap
Roof Weathering Membrane
Roof Insulation
Roof Deck
Sheathing
Plenum Space
Drainage Plane
Ceiling
Face Brick

Parapet



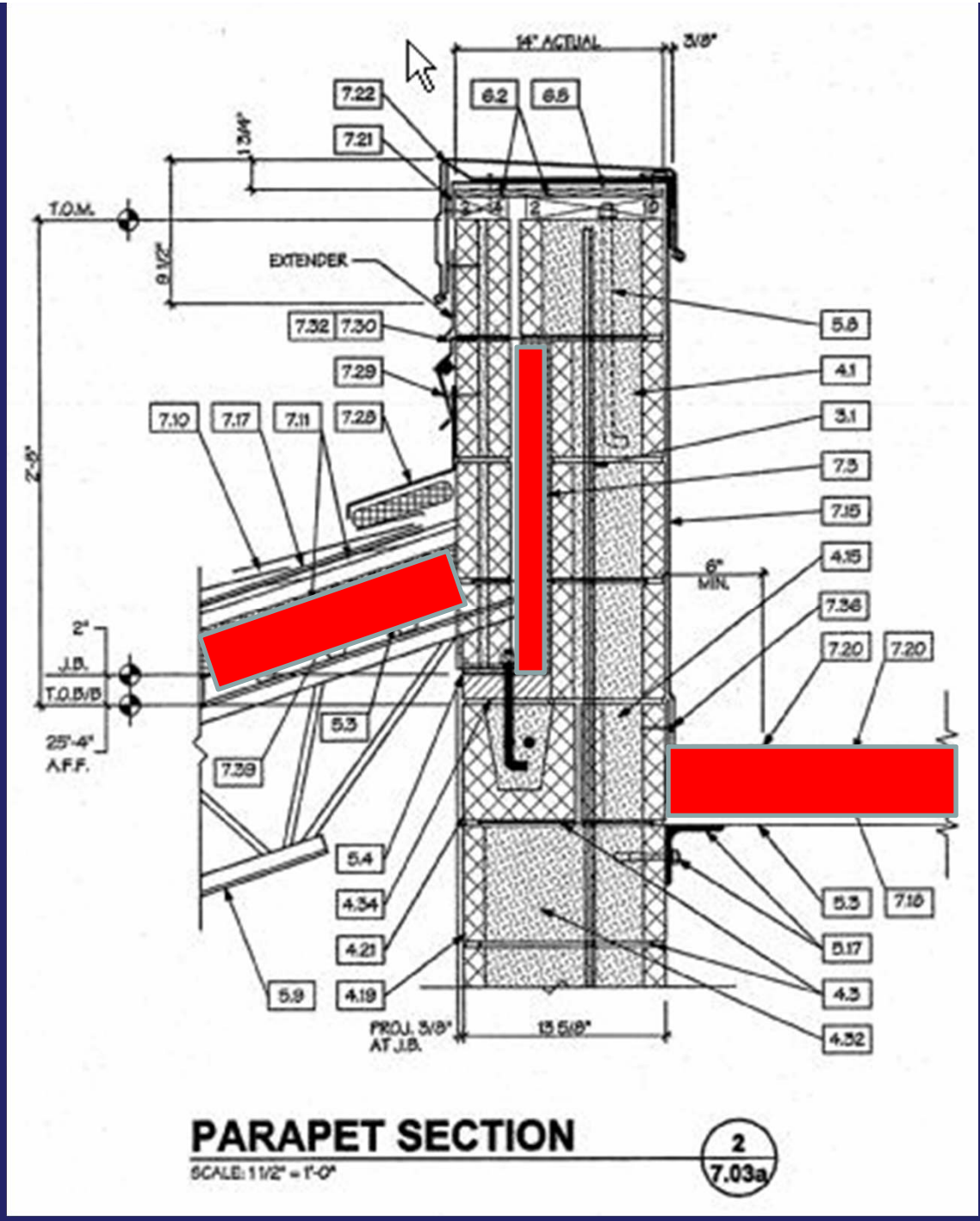




PARAPET SECTION

1
7.06

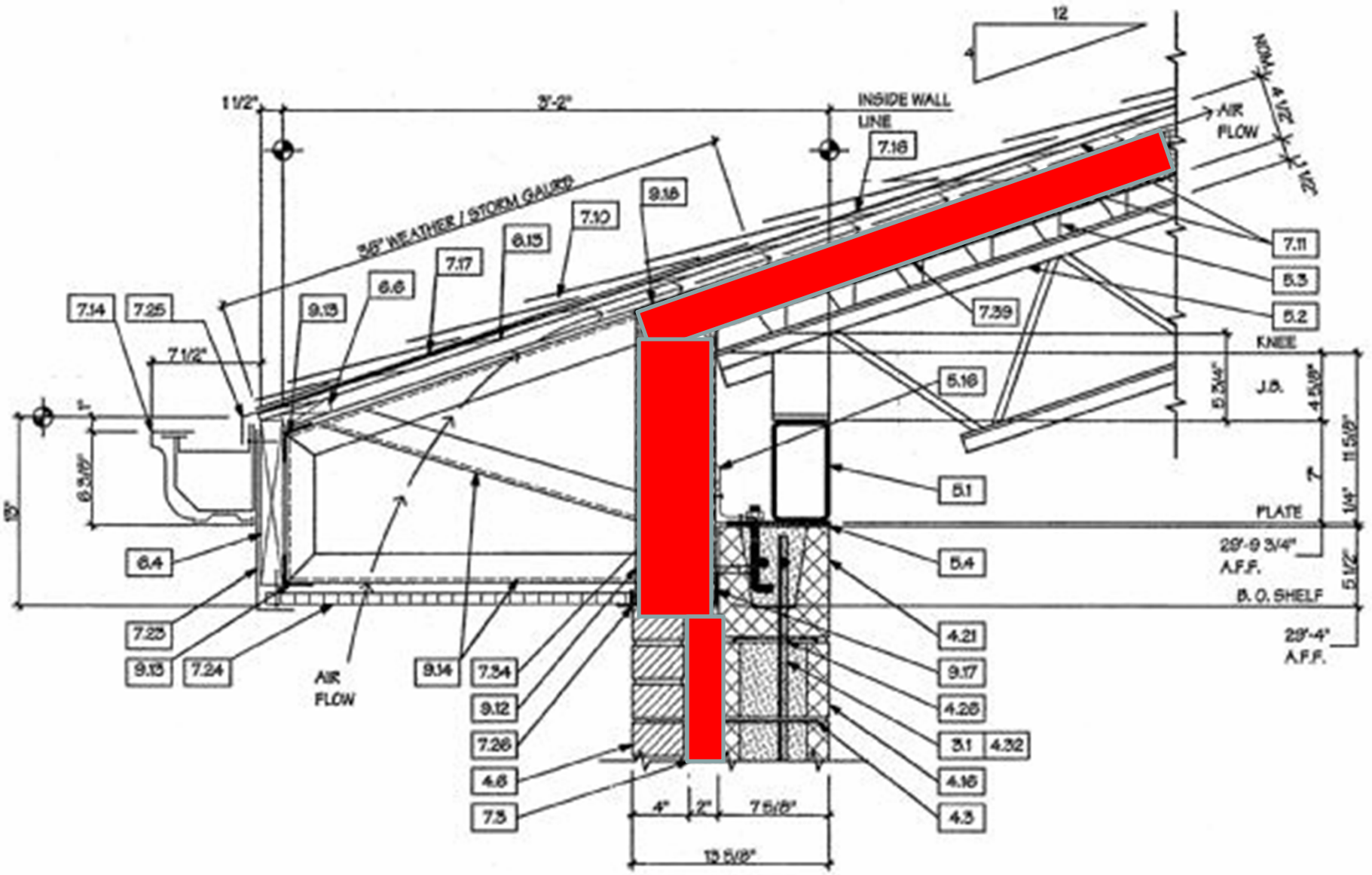
SCALE: 1 1/2" = 1'-0"



PARAPET SECTION

SCALE: 1 1/2" = 1'-0"

2
7.03a



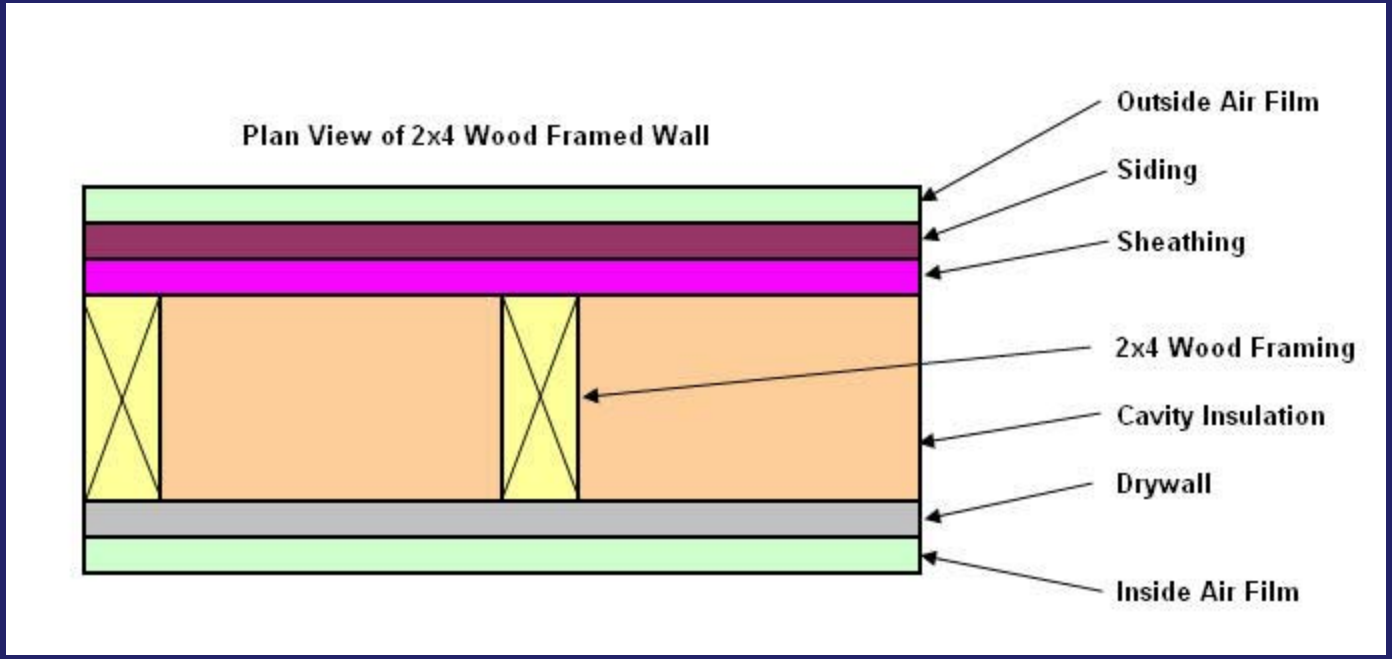
EAVE SECTION

SCALE: 1 1/2" = 1'-0"

6
7.03

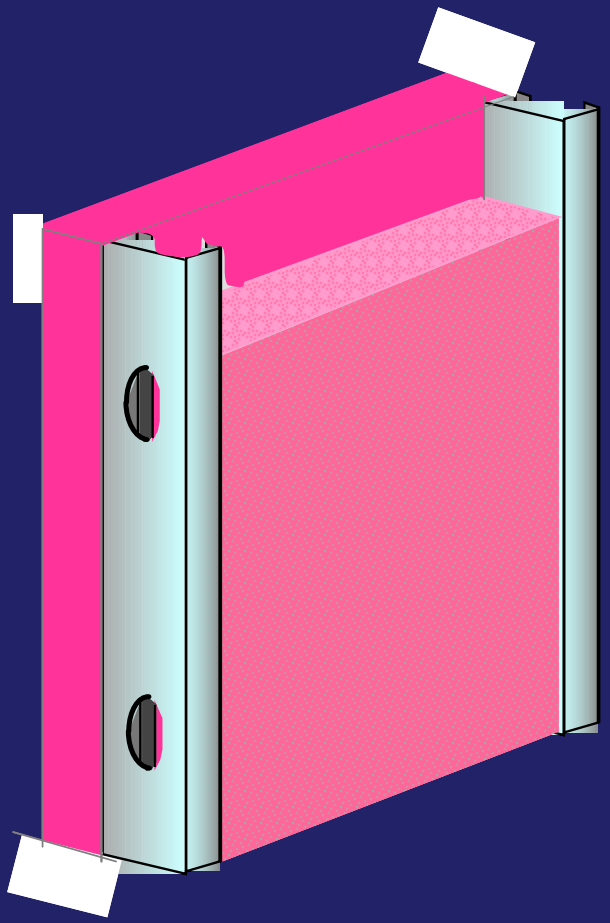
Walls
Wood Framing

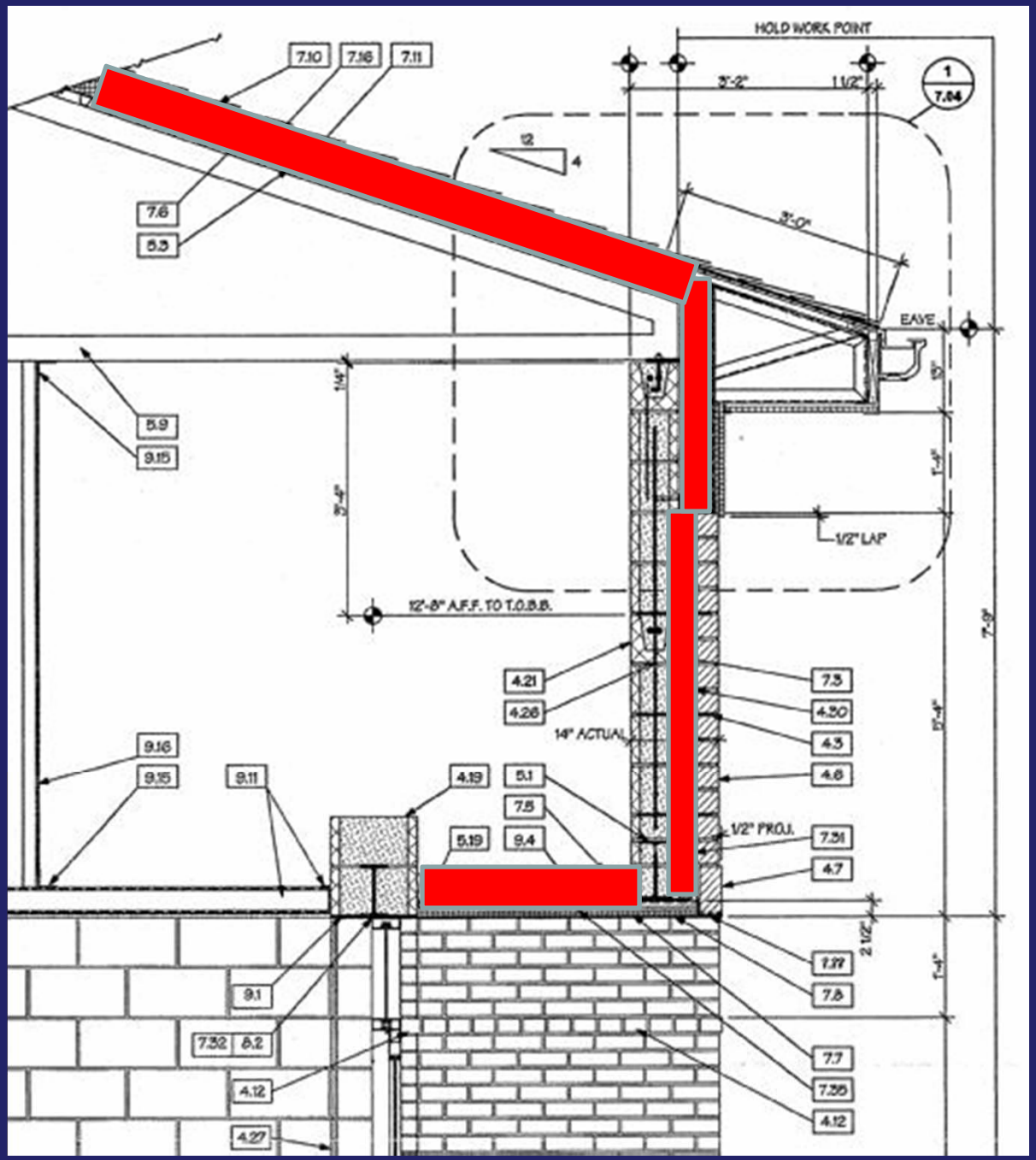
	90.1-1999		AEDG
Zone	13/14	17	4 & 5
R-value	13	13	13 + 3.8 c.i.



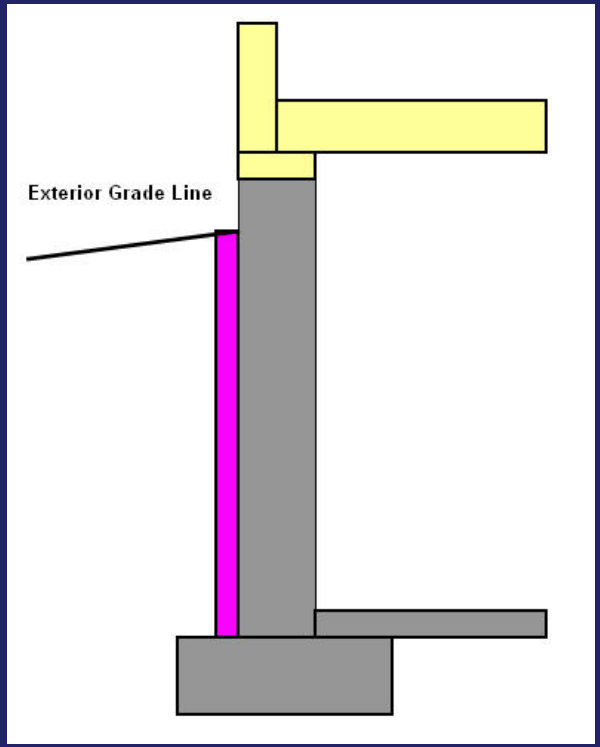
Walls
Steel Framing

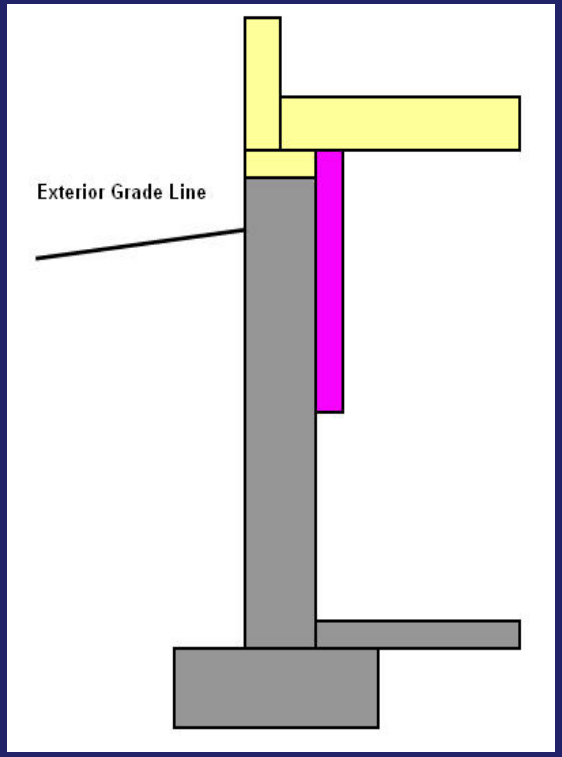
	90.1-1999		AEDG
Zone	13/14	17	4 & 5
R-value	13	13	13 + 7.5 c.i.



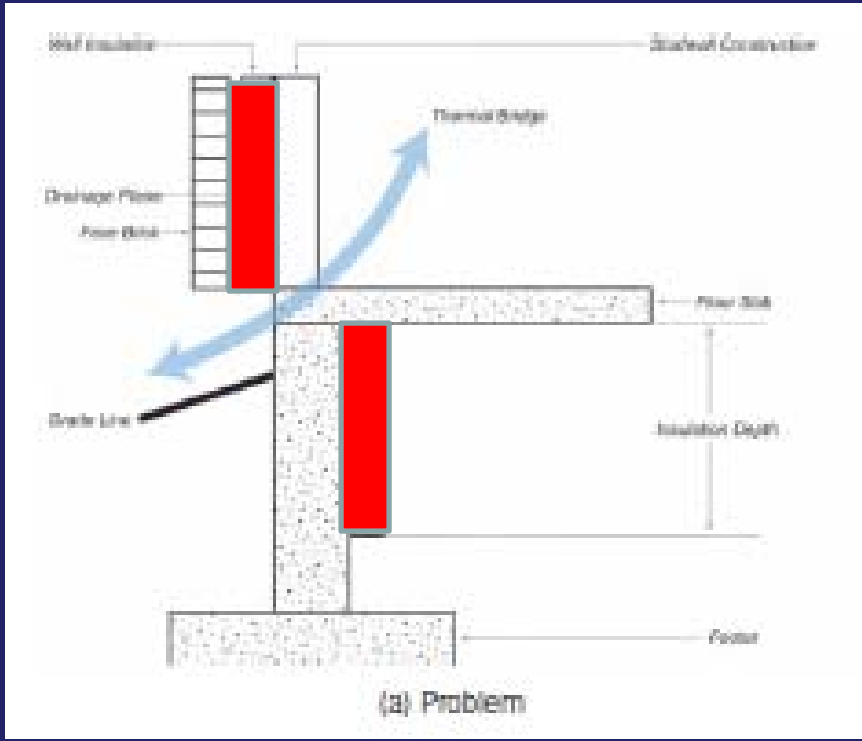

HOLD WORK POINT
7.10
7.16
7.11
3'-2"
1 1/2"
1
7.04
12
4
7.6
5.3
3'-0"
EAVE
5.9
9.15
1'-4"
3'-4"
1/2" LAP
12'-8" A.F.F. TO T.O.S.B.
7'-9"
4.21
4.26
7.3
4.20
4.3
14" ACTUAL
4.6
9.16
9.15
9.11
4.19
5.1
7.5
1/2" PROJ.
7.21
5.19
9.4
4.7
2 1/2"
7.17
7.8
9.1
7.7
7.32
5.2
7.25
4.12
4.12
4.27

Below Grade Walls

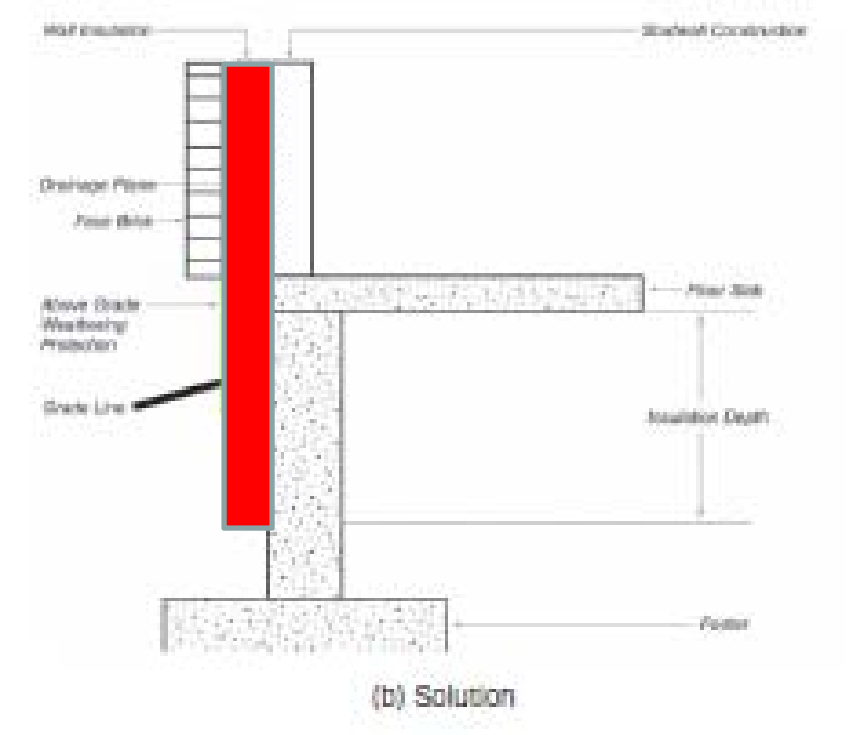




Below Grade Walls



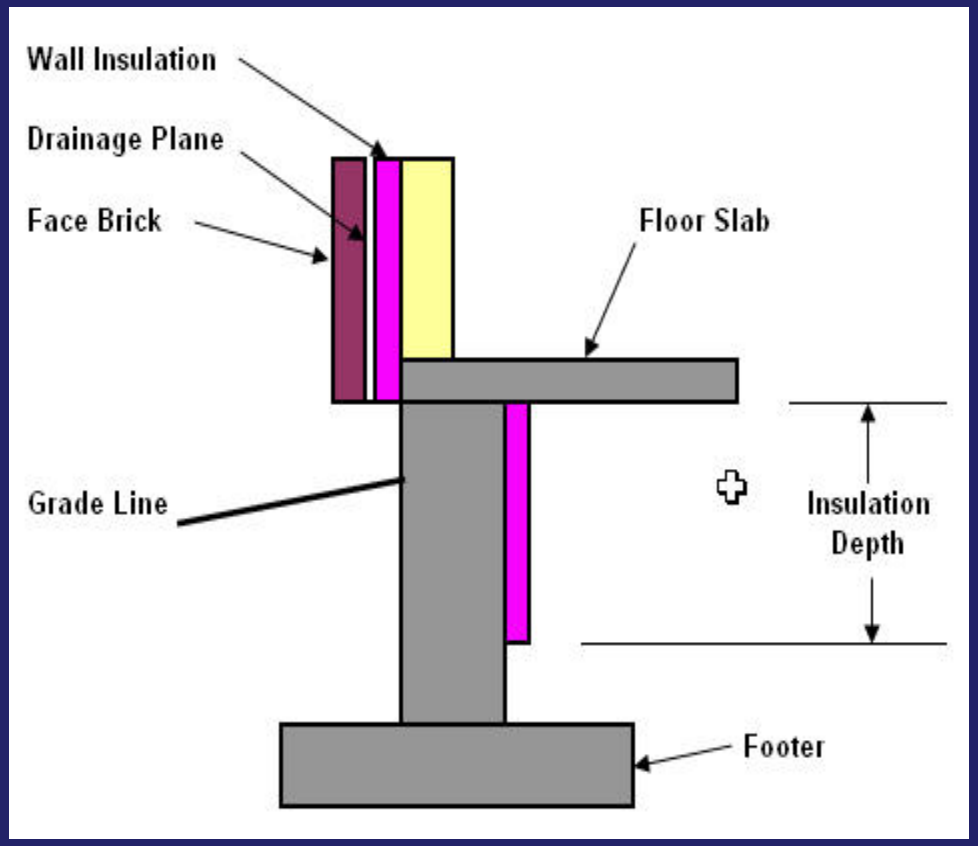
(a) Problem

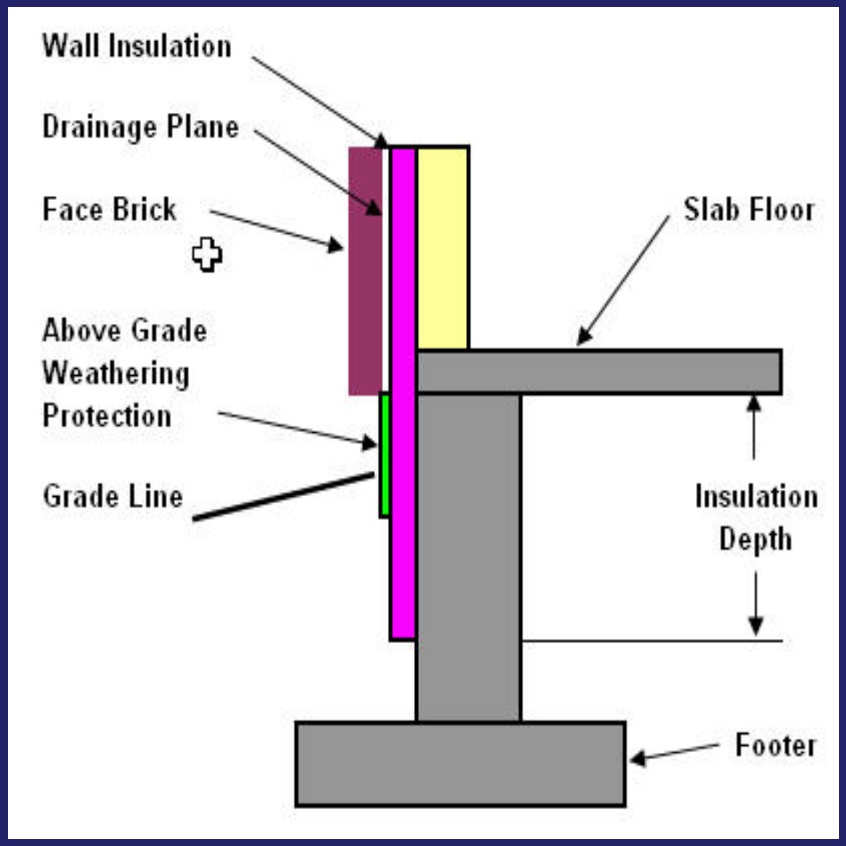


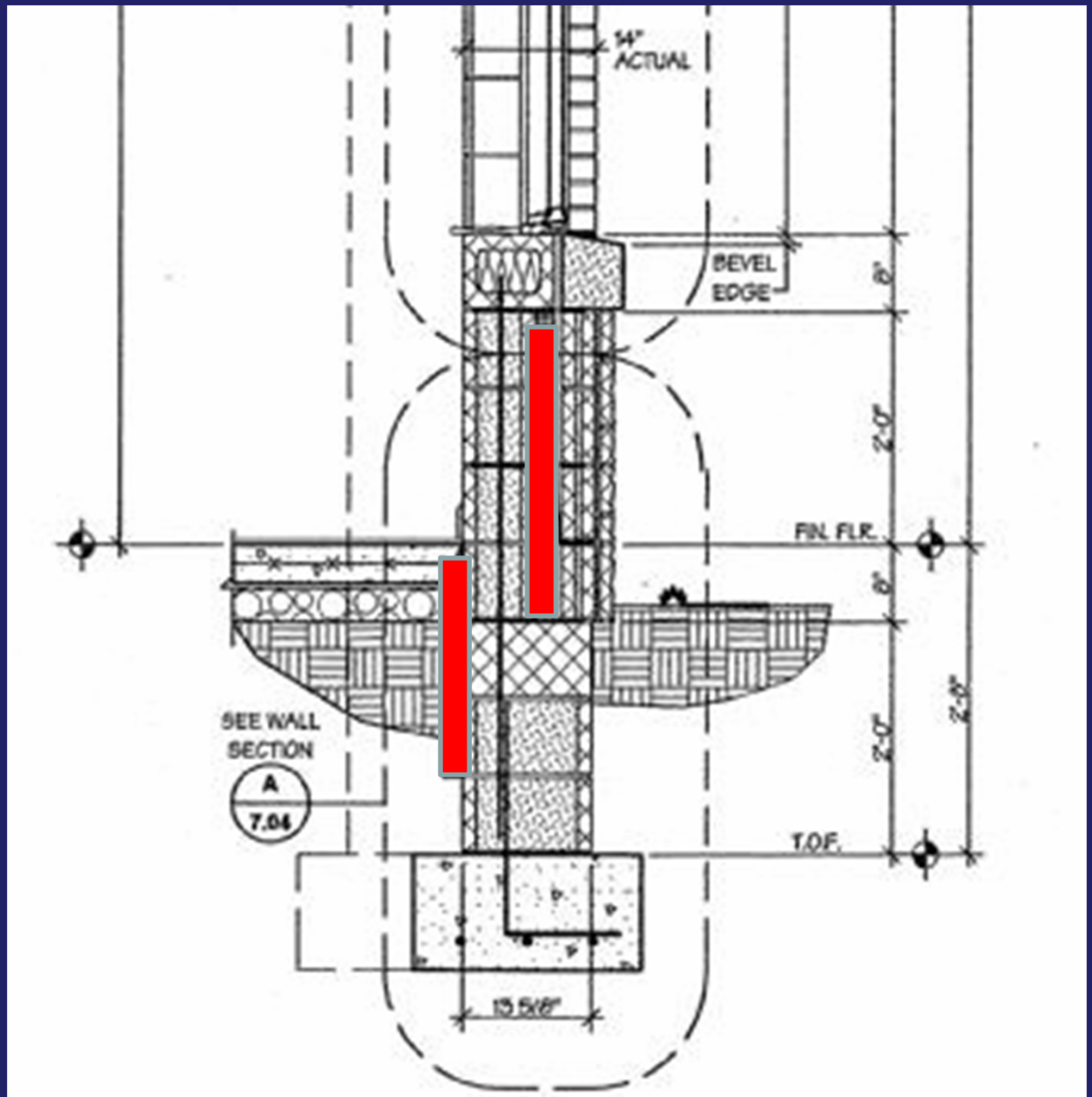
(b) Solution

Slab-on-Grade Heated

	90.1-1999		AEDG
Zone	13/14	17	4 & 5
R-value	7.5/24”	10/36”	15/24”





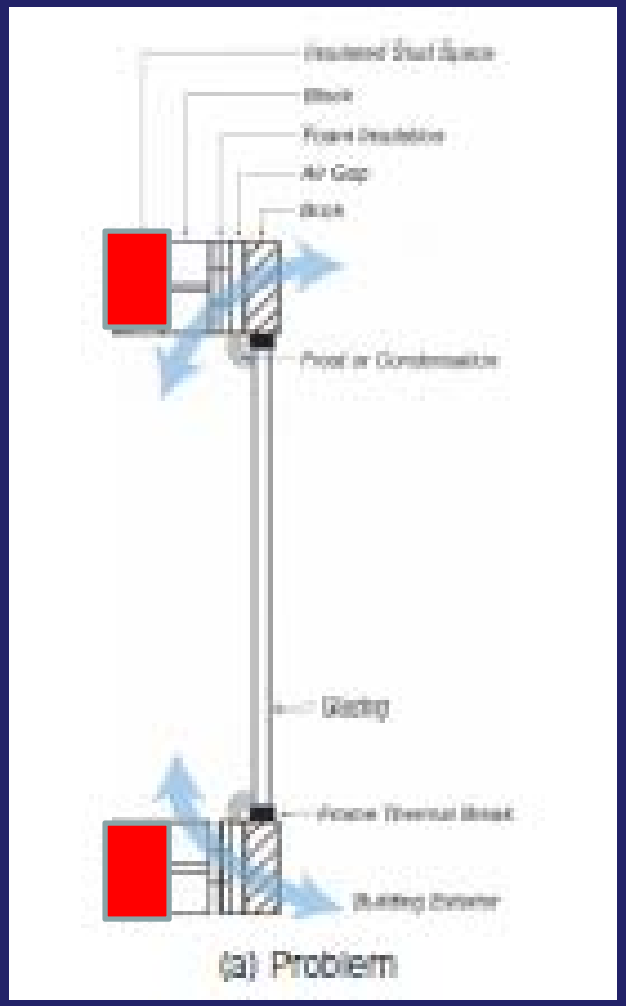


WALL SECTION

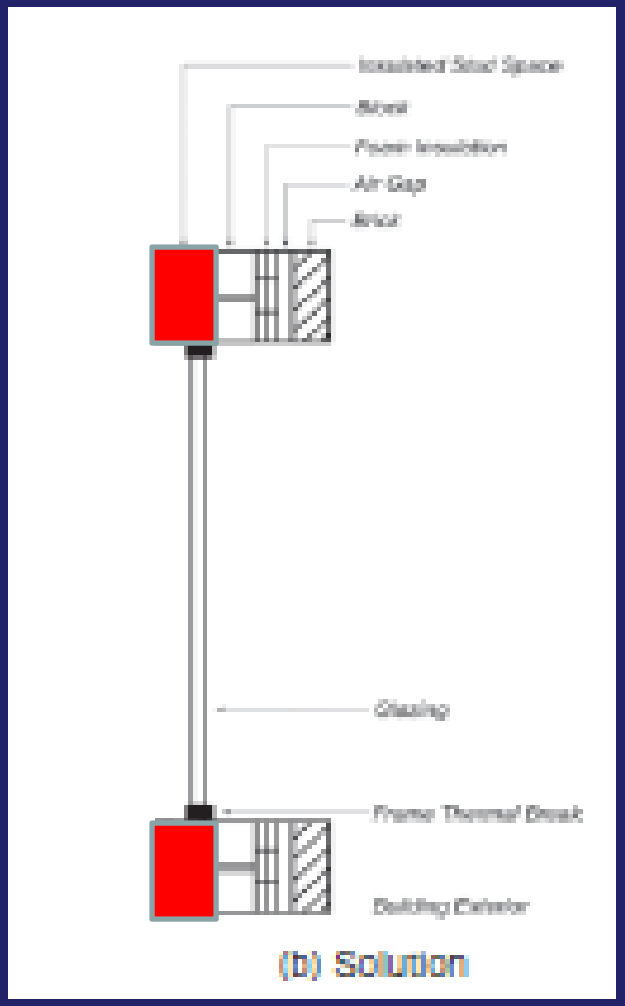
SCALE: 3/4" = 1'-0"

C
7.04

Windows



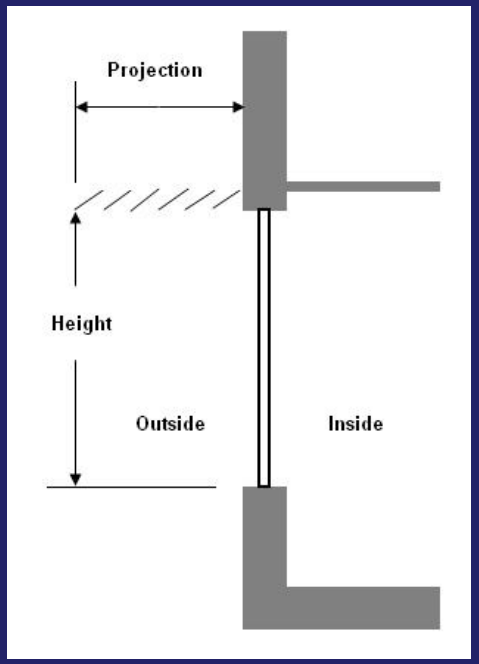
(a) Problem

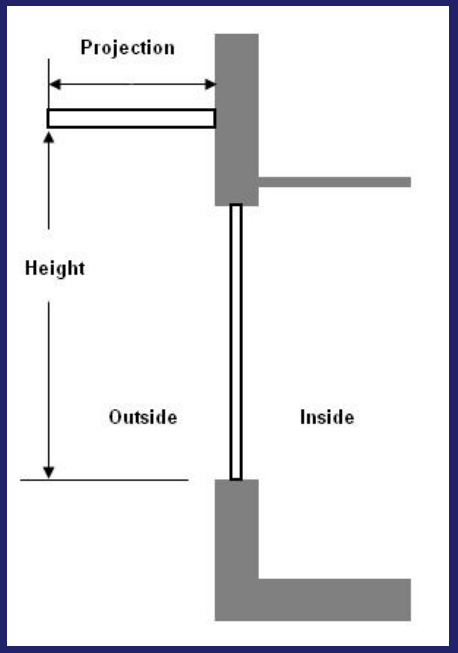


(b) Solution

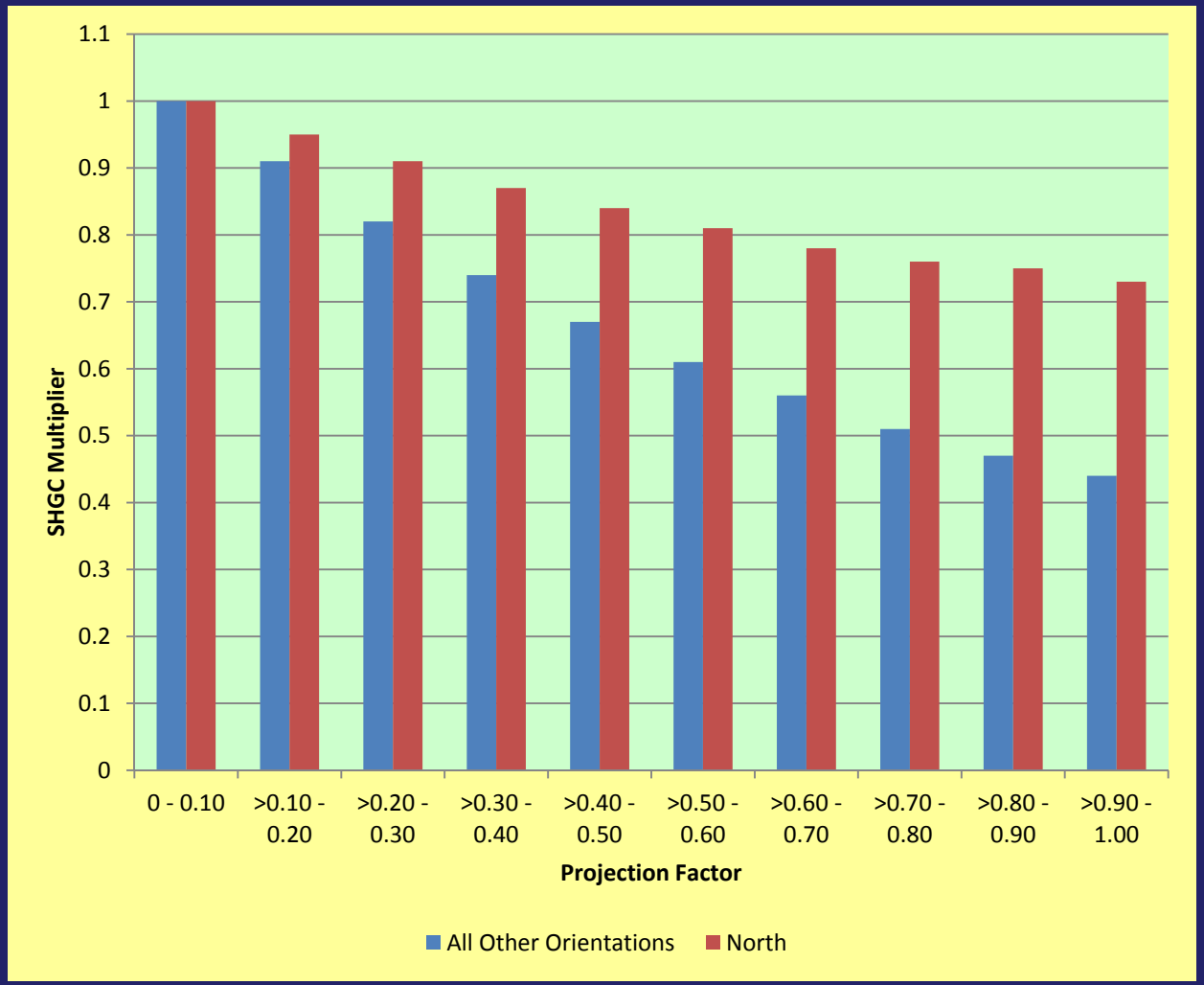
Projection Factor

$$\text{Minimum Projection Factor} = \frac{\text{Projection}}{\text{Height Above Sill}}$$





SHGC Multipliers for Projection Factors



Air Infiltration

Continuous Air Barrier System

1 - Exterior envelope

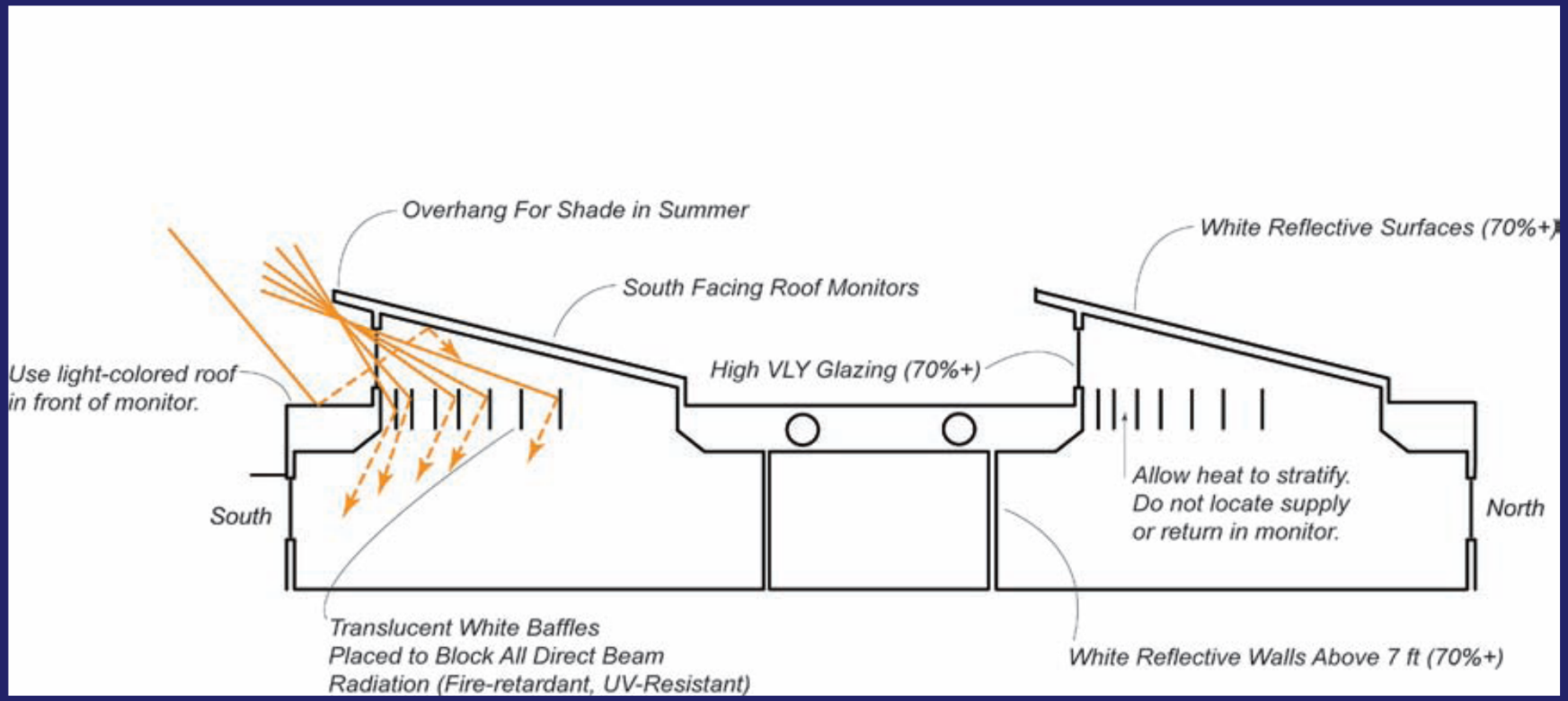
2 - Interior separations between conditioned and unconditioned spaces

Lighting

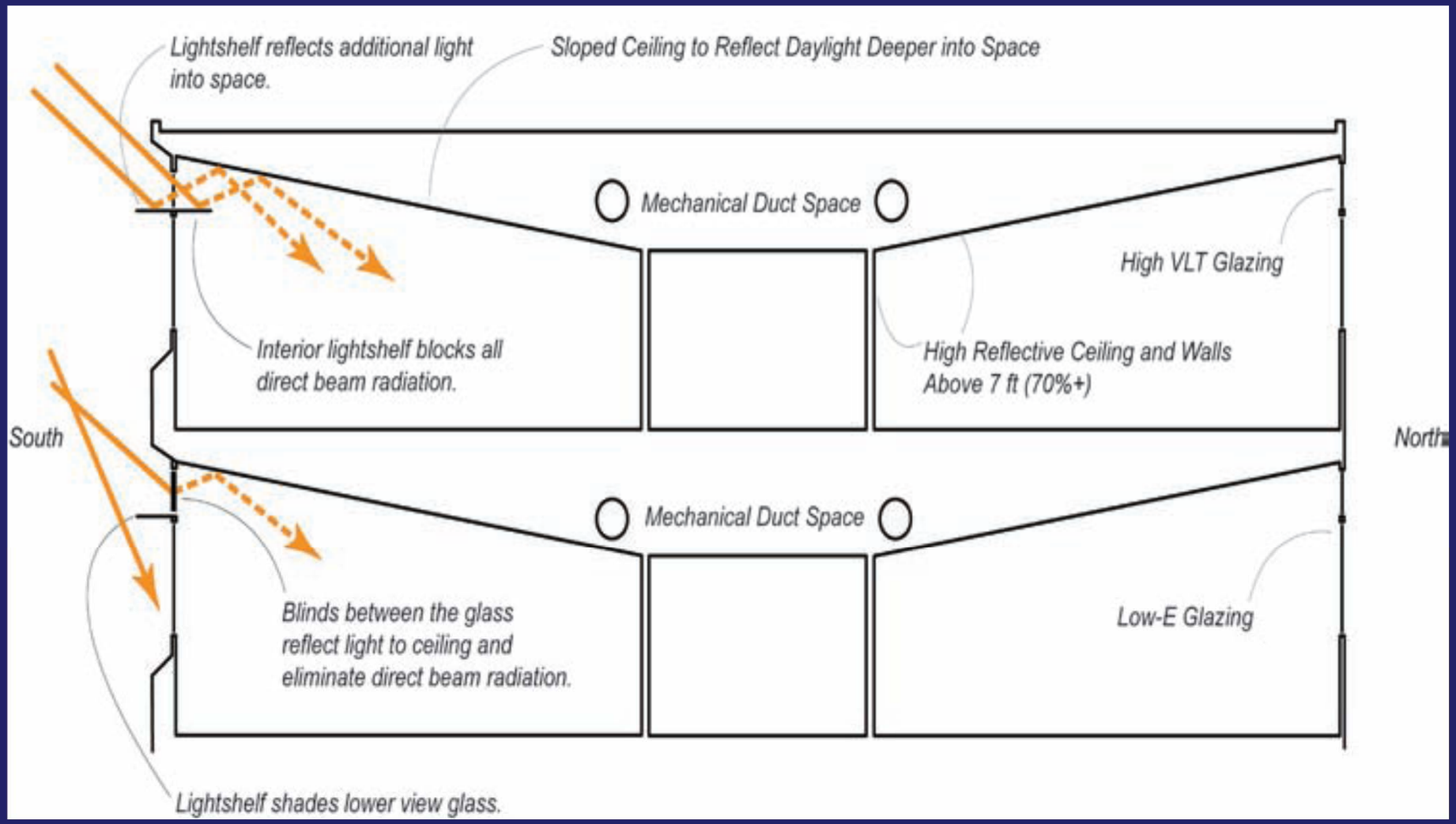
- Interior Finishes
- Interior Lighting
  - Daylighted Option
  - Nondaylighted Option

Toplighting

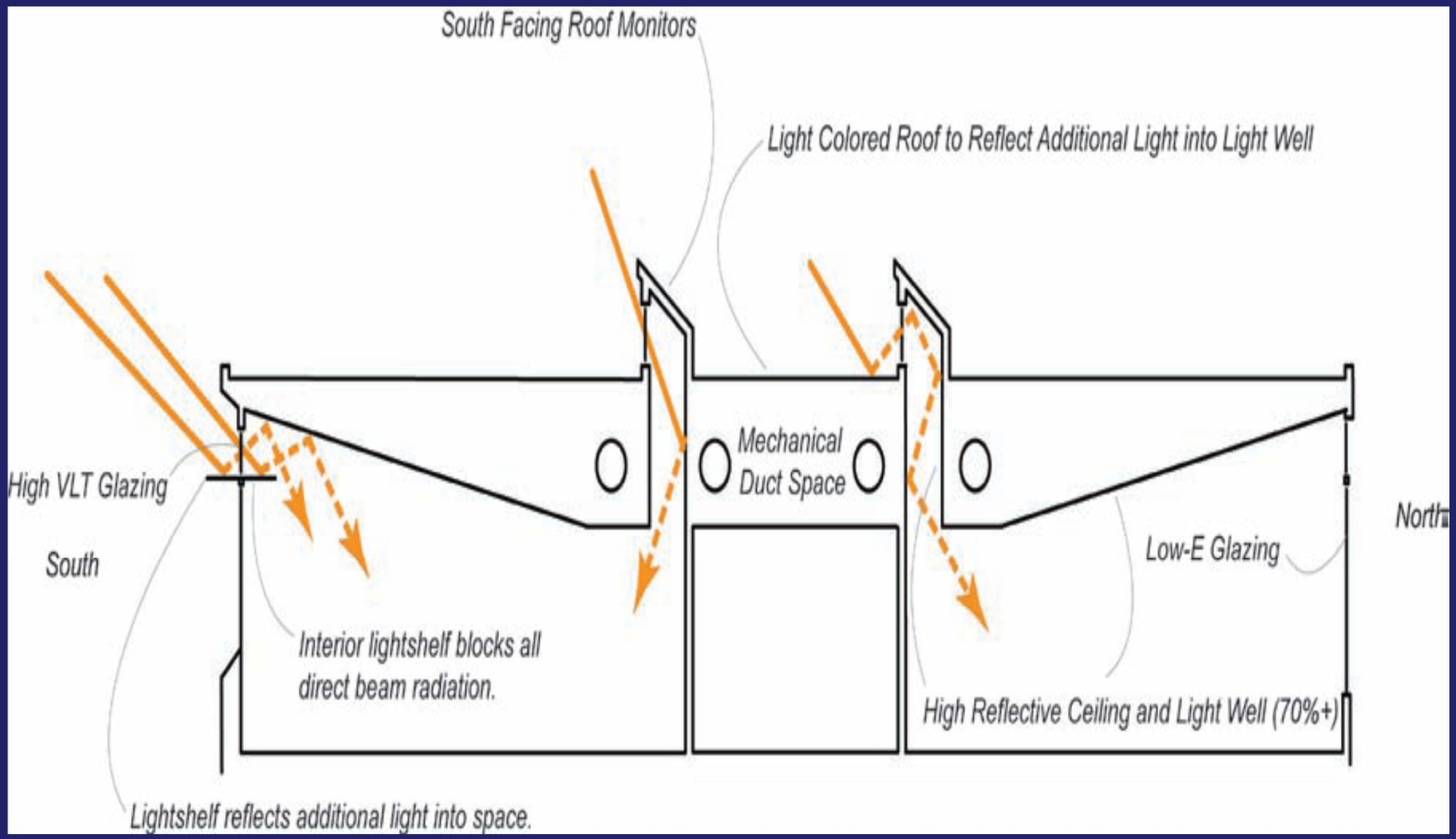
- Daylighting for top floor or single story
- North or South facing clerestories



Sidelighting



Sidelighting with Toplighting



Lighting

Climate Zone 5 Recommendations for K-12 Schools			
Item	**Component**	**Recommendation**	**How-To-Tip**
Interior Finishes	Interior room surface average reflectance	70%+ on ceilings and walls aboave 7 ft 50%+ on walls below 7 ft	DL14, EL1
Interior Lighting - Daylighted Option	Classroom daylighting (daylighting fenestration to floor area ratio)	Toplighted - South-facing roof monitors: 8%-11% North-facing roof monitors: 12%-15%	DL1-19, DL28-35
		Sidelighted - South-facing: 8%-11% North-facing: 15%-20%	DL1-19, DL20-27
		Combined toplighted and sidelighted - South-facing sidelighted: 6%-8% Toplighted: 2%-3% North-facing sidelighted: 9%-13% Toplighted: 3%-5%	DL1-19, DL20-35
	Gym toplighting (daylighting fenestration to floor area ratio)	South-facing roof monitors: 5%-8% North-facing roof monitors: 7%-10%	DL1-19, DL36-37
	LPD	1.2 W/ft^2 maximum	EL9-16
	Light source system efficacy (linear fluorescent)	75 mean lm/W minimum	EL2-3, EL5
	Light source system efficacy (all other sources)	50 mean lm/W minimum	EL4-5
	Occupancy controls	Manual on, auto off all zones	EL6, EL8, DL16
	Dimming controls daylight harvesting	Dim all fixtures in classrooms and gym and other fixtures within 15 ft of sidelighting edge and within 10 ft of toplighting edge	DL16
Interior Lighting - Nondaylighted Option	LPD	1.1 W/ft^2	EL9-16
	Light source system efficacy (linear fluorescent)	85 mean lm/W minimum	EL2-3, EL5
	Light source system efficacy (all other sources)	50 mean lm/W minimum	EL4-5
	Occupancy controls - general	Manual on, auto off all zones	EL6, EL8, DL16
	Dimming controls daylight harvesting	Dim fixtures within 15 ft of sidelighting edge and within 10 ft of toplighting edge	DL16

HVAC

Climate Zone 5 Recommendations for K-12 Schools

Item	Component	Recommendation	How-To Tip
Packaged DX Rooftops (or DX Split Systems)	Air conditioner (<65 kBtu/h)	13.0 SEER	HV1, HV7–8, HV10
	Air conditioner (≥65 and <135 kBtu/h)	11.0 EER	
	Air conditioner (≥135 and <240 kBtu/h)	10.8 EER	
	Air conditioner (≥240 kBtu/h)	10.0 EER and 10.4 IPLV	
	Heat pump (<65 kBtu/h)	13.0 SEER/7.7 HPSF	
Packaged DX Rooftops (or DX Split Systems)	Heat pump (≥65 and <135 kBtu/h)	10.6 EER/3.2 COP	HV1, HV7–8, HV10
	Heat pump (≥135 kBtu/h)	10.1 EER and 11.0 IPLV/3.1 COP	
	Gas furnace (<225 kBtu/h)	80% AFUE or E_t	
	Gas furnace (≥225 kBtu/h)	80% E_c	
	Economizer	>54 kBtu/h	HV13
	Ventilation	Energy recovery or demand control	HV9, HV11–12, HV14
	Fans	Constant volume: 1 hp/1000 cfm Variable volume: 1.3 hp/1000 cfm	HV19
WSHP System	Water-source heat pump (<65 kBtu/h)	Cooling: 12.0 EER at 86F Heating: 4.5 COP at 68F	HV2, HV7–8, HV10
	Water-source heat pump (≥65 kBtu/h)	Cooling: 12.0 EER at 86F Heating: 4.2 COP at 68F	
	GSHP (<65 kBtu/h)	Cooling: 14.1 EER at 77°F and 17.0 EER at 59°F Heating: 3.5 COP at 32°F and 4.0 COP at 50°F	HV2, HV7–8, HV10, AS4
	GSHP (≥65 kBtu/h)	Cooling: 13.0 EER at 77°F and 16.0 EER at 59°F Heating: 3.1 COP at 32°F and 3.5 COP at 50°F	
	Gas boiler	85% E_c	HV2, HV7, HV10
	Economizer	Comply with Standard 90.1*	HV13
	Ventilation	DOAS with either energy recovery or demand control	HV9, HV11–12, HV14
	WSHP duct pressure drop	Total ESP < 0.2 in. H_2O	HV19
Unit Ventilator and Chiller System	Air-cooled chiller efficiency	9.6 EER and 11.5 IPLV	HV3, HV7–8, HV10, HV25
	Water-cooled chiller efficiency	Comply with Standard 90.1*	HV3, HV7–8, HV10, HV25
	Gas boiler	85% E_c	HV3, HV7, HV10, HV26
	Economizer	>54 kBtu/h	HV13
	Ventilation	Energy recovery or demand control	HV9, HV11–12, HV14
	Pressure drop	Total ESP < 0.2 in. H_2O	HV19

HVAC

Climate Zone 5 Recommendations for K-12 Schools			
Item	**Component**	**Recommendation**	**How-To Tip**
Fan Coil and Chiller System	Air-cooled chiller efficiency	9.6 EER and 11.5 IPLV	HV4, HV7–8, HV10, HV25
	Water-cooled chiller efficiency	Comply with Standard 90.1*	HV4, HV7–8, HV10, HV25
	Gas boiler	85% E_c	HV4, HV7, HV10, HV26
	Economizer	Comply with Standard 90.1*	HV13
	Ventilation	DOAS with either energy recovery or demand control	HV9, HV11–12, HV14
	Pressure drop	Total ESP < 0.2 in. H_2O	HV19
Packaged Rooftop VAV System	Rooftop air conditioner (≥240 kBtu/h)	10.0 EER and 10.4 IPLV	HV5, HV7–8, HV10
	Gas furnace (≥225 kBtu/h)	80% E_c	
	Gas boiler	85% E_c	HV5, HV7, HV10, HV26
	Economizer	>54 kBtu/h	HV13
	Ventilation	Energy recovery or demand control	HV9, HV11–12, HV14
	Fans	1.3 hp/1000 cfm	HV19
VAV and Chiller System	Air-cooled chiller efficiency	9.6 EER and 11.5 IPLV	HV6–8, HV10, HV25
	Water-cooled chiller efficiency	Comply with Standard 90.1*	HV6–8, HV10, HV25
	Gas boiler	85% E_c	HV6–7, HV10, HV26
	Economizer	>54 kBtu/h	HV13
	Ventilation	Energy recovery or demand control	HV9, HV11–12, HV14
	Fans	1.3 hp/1000 cfm	HV19
Ducts and Dampers	Outdoor air damper	Motorized	HV11, HV13
	Friction rate	0.08 in. w.c./100 ft	HV16
	Sealing	Seal Class B	HV18
	Location	Interior only	HV16
	Insulation level	R-6	HV17

HVAC System Report Card

No.	System	Energy Efficiency	Sound	IAQ	First Cost	Maintenance	System Life	Overall
1	Packaged Rooftop (CV or VAV)	C	A	C	A	A	15 to 20	
2	WSHP - Boiler/Tower	A	B	A	B	B	5 to 10, (longer for boiler)	
3	Unit Ventilators and Chillers	B	C	A-	A	C	25	
4	Fancoils and Chillers	B	B	A	B	C	25	
5	GSHP	A+	B	A	C	B+	5 to 10, (50 yrs for loop)	
6	Packaged Rooftop VAV with Reheat	B	A	B	B+	A	15 to 20	

SWH

Climate Zone 5 Recommendations for K-12 Schools			
Item	**Component**	**Recommendation**	**How-To-Tip**
SWH	Gas storage (>75 kBtu/h)	90% E_t	WH1-5
	Gas instantaneous	0.81 EF or 81% E_t	WH1-5
	Electric (storage or instantaneous)	EF > 0.99 - 0.0012 x volume	WH1-5
	Pipe insulation (d<1.5 in/d≥1.5 in	1in./1.5 in.	WH6

Validation

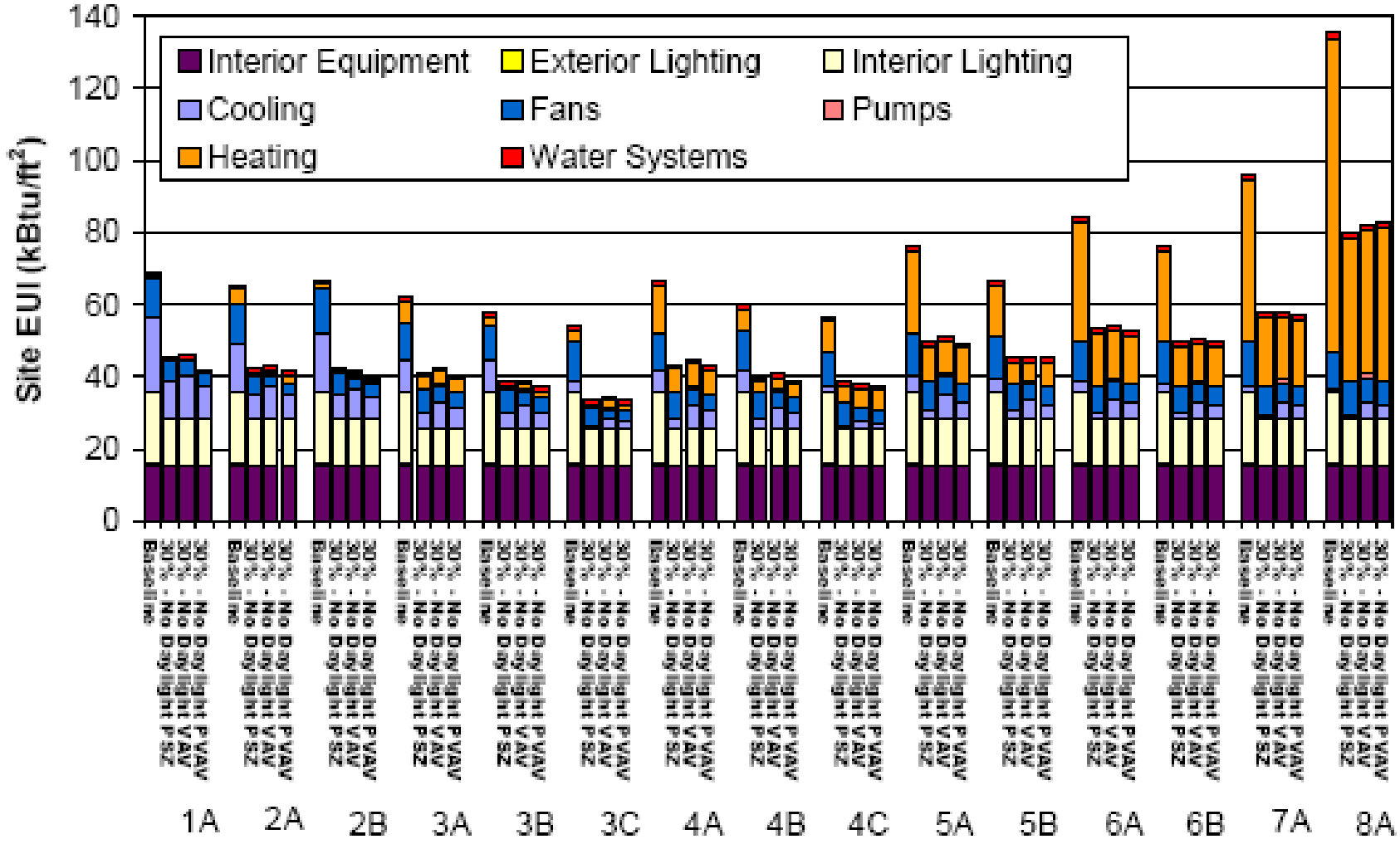


Figure 4-2 Elementary End Uses: No Daylighting

Technology Examples and Case Studies

Case Studies

Present techniques and methods that are discussed in the Guide.

How-To-Implement Recommendations

		30%						50%			
Topic		**Office**	**Retail**	**K-12**	**WH**	**HL**	**HC**	**SMO**	**K-12**	**Big Box**	**Hospitals**
Envelope	EN	42	32	28	27	25	31	40	33	27	29
Daylighting	DL	13	10	37	10	11	28	20	42	10	21
Electric Lighting	EL	17	28	16	21	21	32	25	25	33	24
Exterior Lighting	EX	8	4	4	4		3				
Plug Loads	PL	3	5		5	5	5	6	6	8	17
Kitchen Equipment	KE								7		
Service Water Heating	WH	6	6	6	6	8	6	6	7	6	7
HVAC	HV	23	23	32	24	26	27	36	28	31	41
Quality Assurance	QA	16	16	13	16	17	11	14	18	17	21
Additional Savings	AS			8				7	6	1	5
Renewable Energy	RE					4		3	4	4	4
Natural Ventilation	NV							10			
Electrical Distribution Systems	ED					3					3
Ventilation Control	VC				1	2					
Miscellaneous Appliances	MA					2					
Ground Coupled Heat Pumps	GCHP					1					
Water Conserving Equipment	WC					1					
Combined Heat and Power	CHP					1					
Other Hot Water Systems	HW					1					
Total		**128**	**124**	**144**	**114**	**128**	**143**	**167**	**176**	**137**	**172**

Additional Savings

- Energy Star Appliances
- Exterior Lighting
- Ventilation Control
- Electrical Distribution Systems
- Plug and Phantom Loads
- Ground Source & Ground Coupled Heat Pumps
- Peak Demand Reduction
- Photovoltaic Systems
- Solar Hot-Water Systems
- Daylighting
- Water Conservation

Table A1. Envelope Thermal Performance Factors

Opaque Construction Options

Roof Assemblies

Insulation Above Deck

R	U
25	0.039

Metal Building

R	U
19	0.065
13 + 13	0.055
13 + 19	0.049
19 + 19	0.046

Attic and Other

R	U
30	0.032
38	0.027
60	0.017

Walls, Above Grade

Mass Walls

R	U
5.7 c.i.	0.151
7.6 c.i.	0.123
9.5 c.i.	0.104
11.4 c.i.	0.090
13.3 c.i.	0.080
15.2 c.i.	0.071

Metal Building

R	U
16	0.093
19	0.084
19+5.6 c.i.	0.057
19+11.2 c.i.	0.043

Steel Framed

R	U
13	0.124
13+3.8 c.i.	0.084
13+7.5 c.i.	0.064
13+10 c.i.	0.034

Wood Framed and Other

R	U
13	0.089
13+3.8 c.i.	0.064
13+7.5 c.i.	0.051
13+10 c.i.	0.045

Walls, Below Grade

Below Grade Walls

R	C
7.5 c.i.	0.119
15 c.i.	0.063

Floors

Mass

R	U
4.2 c.i.	0.137
6.3 c.i.	0.107
8.3 c.i.	0.087
10.4 c.i.	0.074
12.5 c.i.	0.064
16.7 c.i.	0.051

Steel Framed

R	U
19	0.052
30	0.036
38	0.032

Wood Framed and Other

R	U
19	0.051
30	0.033

Slabs

Unheated	
R-in	**F**
7.5-12	0.54
15-24	0.52
20-24	0.51
Heated	
R-in	**F**
7.5-12	1.02
7.5-24	0.95
10-24	0.90
15-24	0.86
15-Full	0.44

Commissioning

Design

Construction

Operation

Conclusions

- 30% to 50% Site Energy Savings
- Dedicated Commitments
- Specific Building Types
- Prescriptive Recommendations
- Climate Sensitive
- One Way, Not the Only Way

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6 - Health Care	– 35,448
7 - Small – Medium Office	– 41,328
8 - K-12 Schools	– 15,638
9 - Large Box Retail	– 18,461
10 - Large Hospitals	- 7,338

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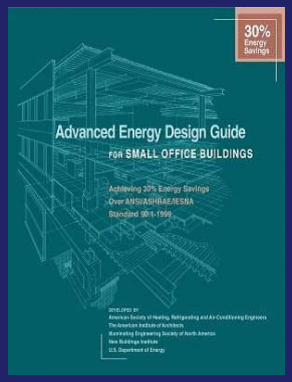
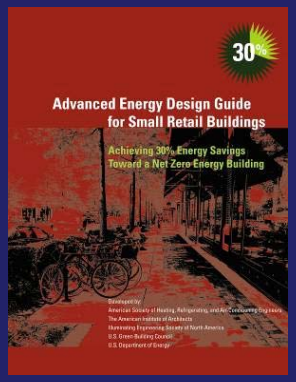
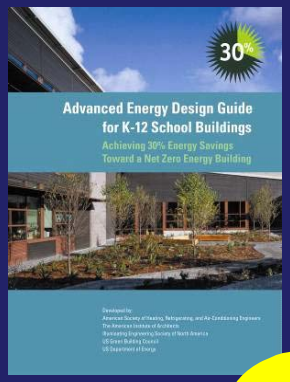
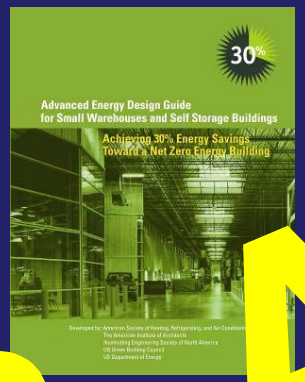
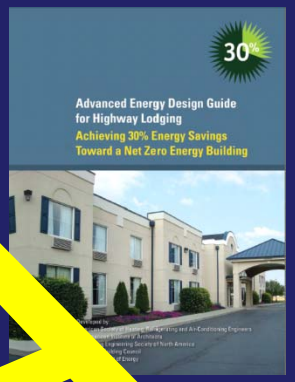
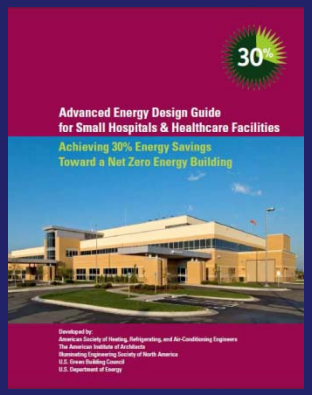












Office Bldgs.

Retail Stores

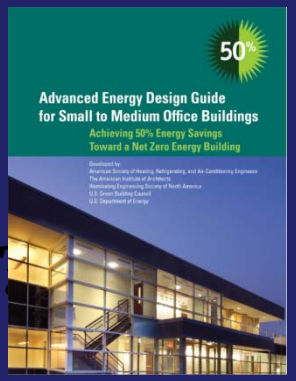
Schools K-12

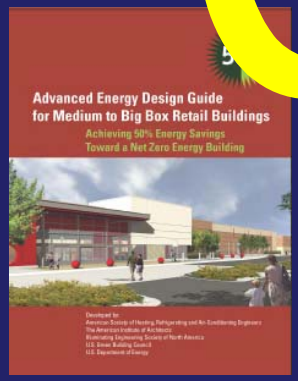
Ware Houses

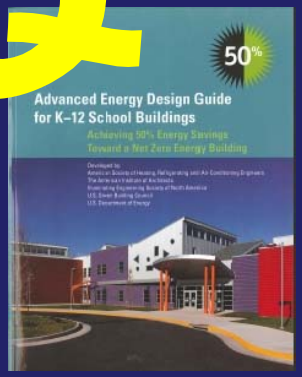
Highway Lodging

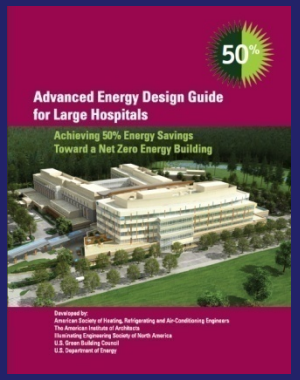
Health Care

Q & A









Merle McBride, Ph.D., P.E.