ENERGY-10

DESIGNING LOW ENERGY BUILDINGS USING ENERGY-10

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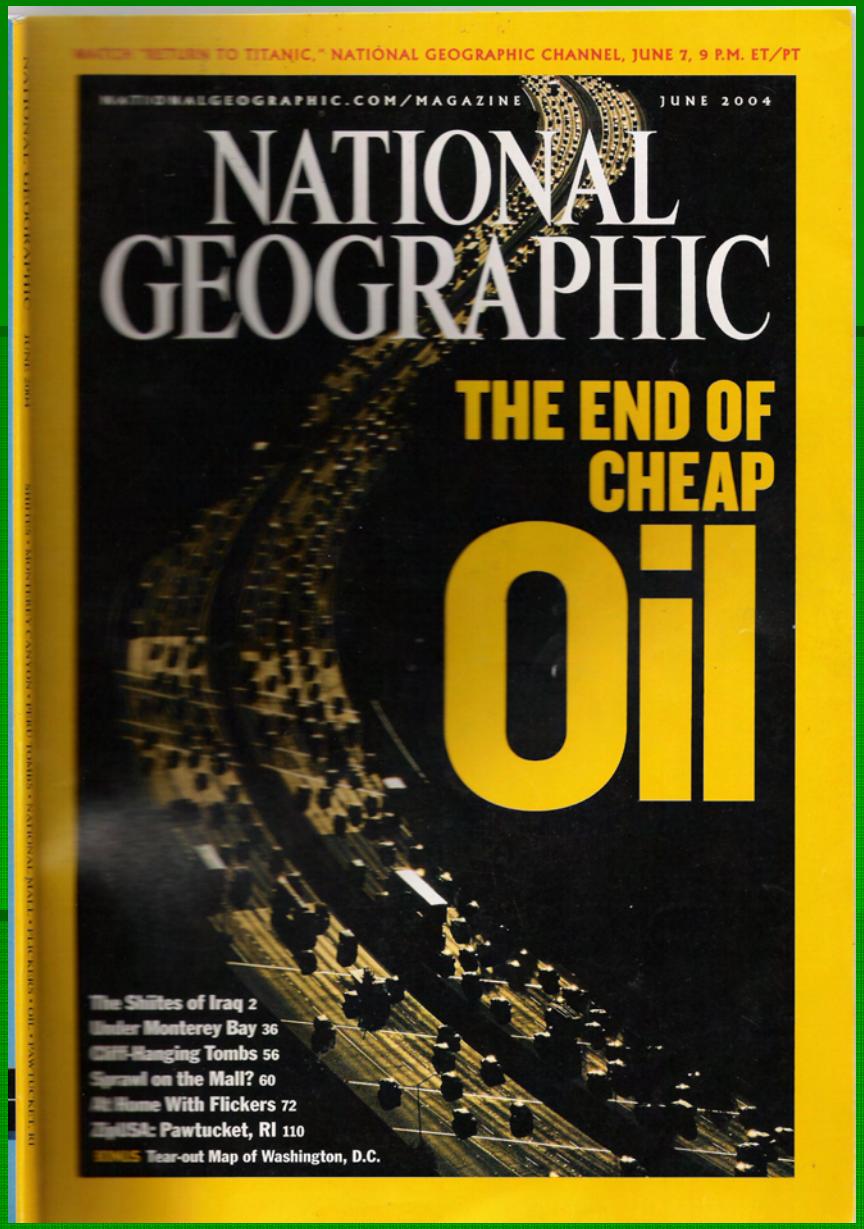
Tierra Concrete Homes, Inc.

July 20, 2006

National Renewable Energy Lab
Golden, CO

AGENDA

- 8:30 Introduction and overview of Energy-10
- 9:00 Building Form and Envelope
- 9:45 Passive Solar and Thermal Mass
- 10:15 Break
- 10:30 Daylighting, Shading
- 12:00 Lunch
- 1:00 EE Lighting, HVAC
- 1:45 Solar Strategies: PV and Solar Hot Water
- 2:15 Weathermaker
- 2:30 Break
- 2:45 Integrated Design and Cost Analysis
- 4:00 Adjourn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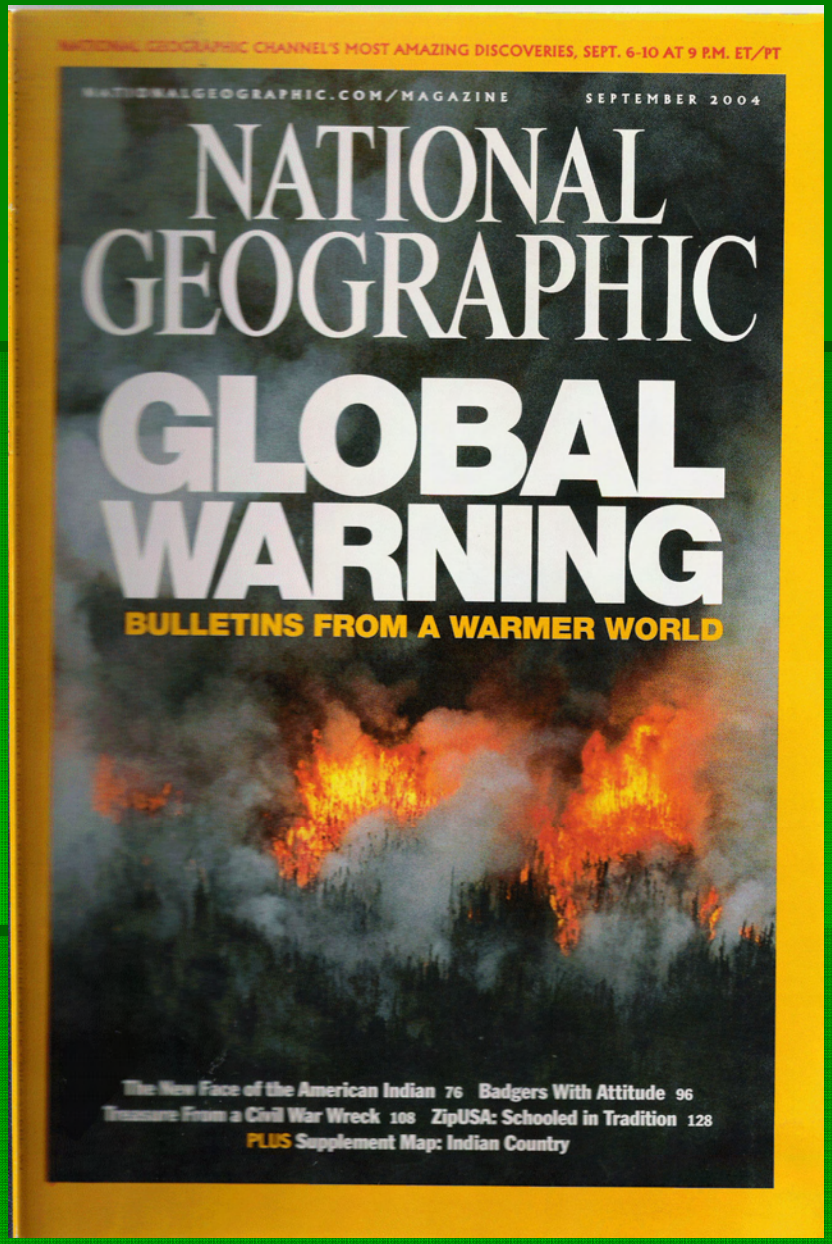
NATIONALGEOGRAPHIC.COM/MAGAZINE
JUNE 2004
NATIONAL GEOGRAPHIC
THE END OF CHEAP Oil
The Shiites of Iraq 2
Under Monterey Bay 36
Cliff-Hanging Tombs 56
Sprawl on the Mall? 60
At Home With Flickers 72
ZipUSA: Pawtucket, RI 110
BONUS Tear-out Map of Washington, D.C.


NATIONAL GEOGRAPHIC CHANNEL'S MOST AMAZING DISCOVERIES, SEPT. 6-10 AT 9 P.M. ET/PT
NATIONALGEOGRAPHIC.COM/MAGAZINE
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NATIONAL GEOGRAPHIC
GLOBAL WARNING
BULLETINS FROM A WARMER WORLD
The New Face of the American Indian 76
Badgers With Attitude 96
Treasure From a Civil War Wreck 108
ZipUSA: Schooled in Tradition 128
PLUS Supplement Map: Indian Country

More intense storms result from global warming

House for sale
Some assency required

Durability of Concrete

Energy Wasted in Leaky Houses

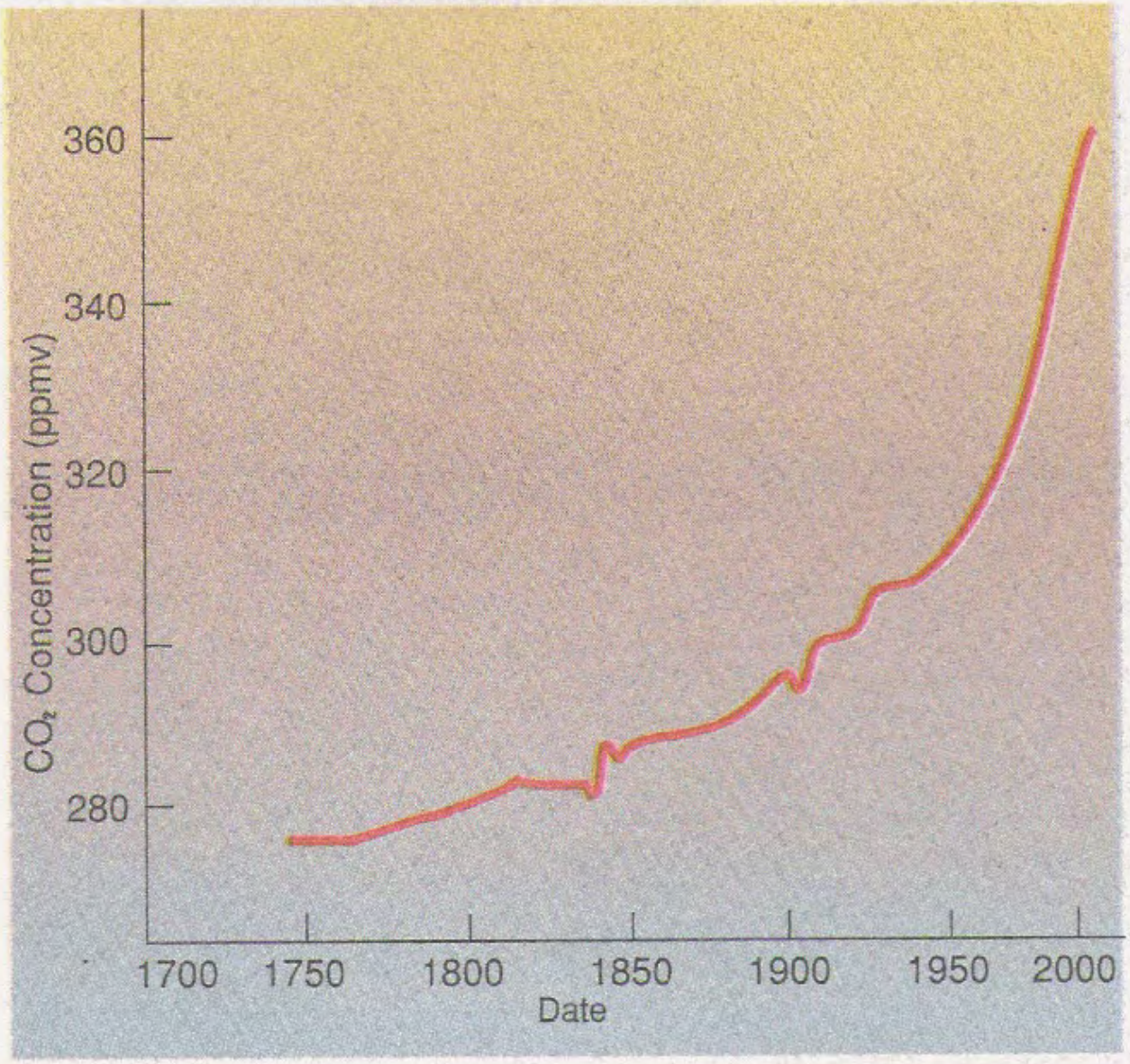
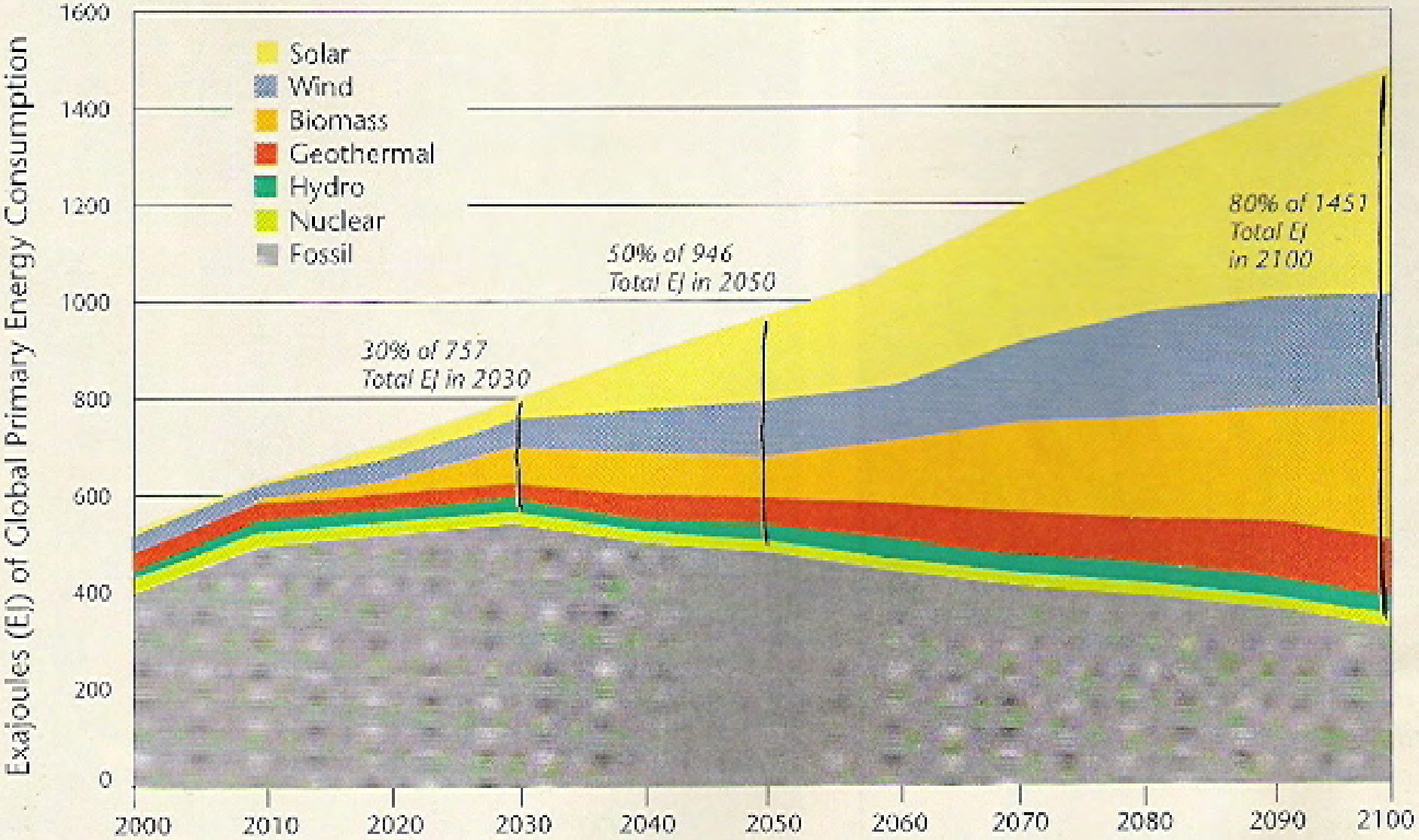
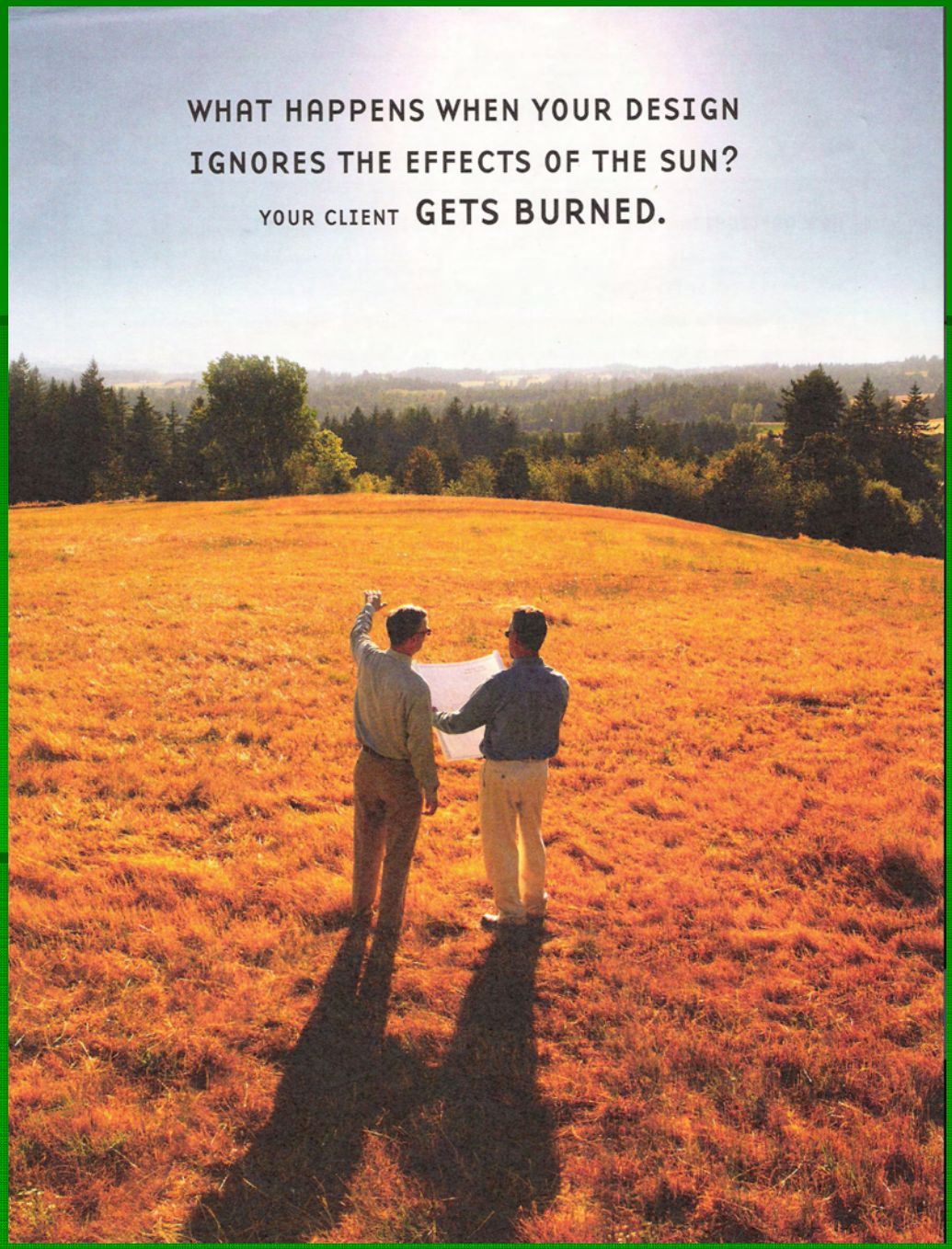

360
340
320
300
280
CO_2 Concentration (ppmv)
1700
1750
1800
1850
1900
1950
2000
Date

Figure 1

Filling the Carbon-Neutral Gap to Approach 550 ppm CO_2: The 10/20/50% Usage Pattern




WHAT HAPPENS WHEN YOUR DESIGN
IGNORES THE EFFECTS OF THE SUN?
YOUR CLIENT GETS BURNED.

Designing Low Energy Buildings

Process

*Site

*Form and Envelope

*Passive Solar

*Electrical Systems

*Mechanical Systems

*Design Integration

Building Form and Envelope

selective pathway

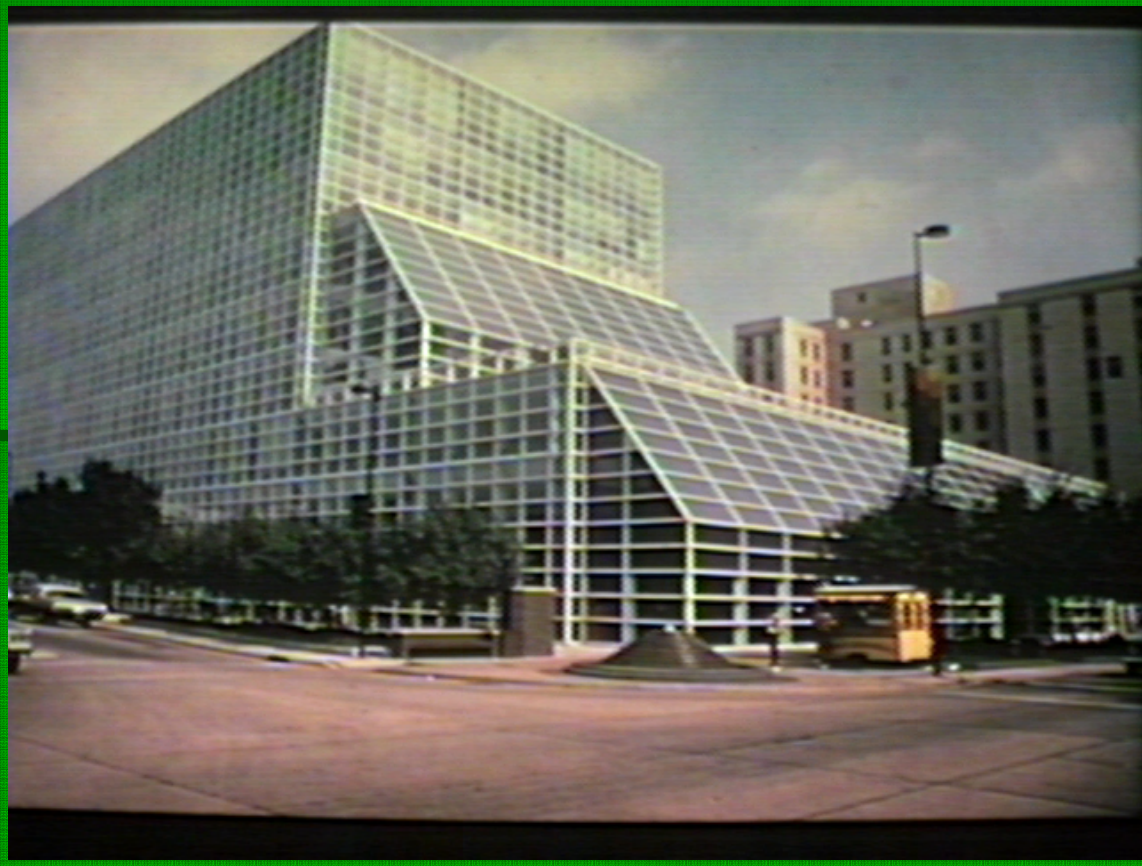
to take advantage of natural energy flows and minimize undesirable thermal transfer.

Climate vs. Internally Load Dominated Buildings

Stronger Connection to Nature

Building Form and Envelope

- This is NOT a climate responsive building!

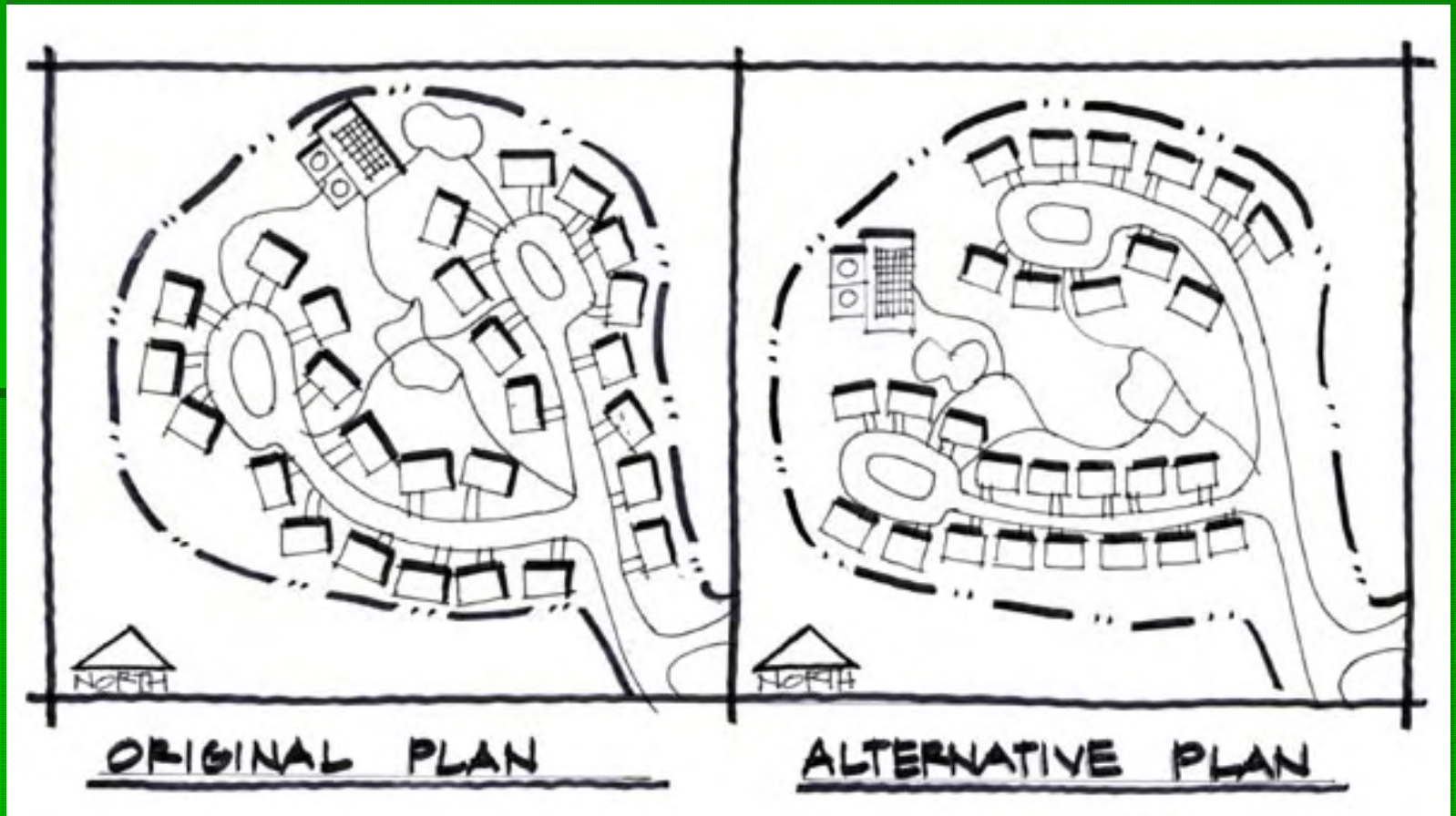


Strategies: Building Envelope

- Glazing and windows, placement and size
- Sun control and shading devices
- Insulation
- Roofing design
- Daylighting
- Passive Solar
- Heating

Building Siting and Orientation

- Integrate landscape architecture & planning
- Orient building to optimize solar and breezes



Glazing Considerations

ISSUES

- Climate
- Application
- Orientation Differences
- Cost Effective Technology

Specifications

- Heat Transfer
- Solar Heat Gains
- Daylight Transmittance
- Visual Reflectivity
- UV Transmittance

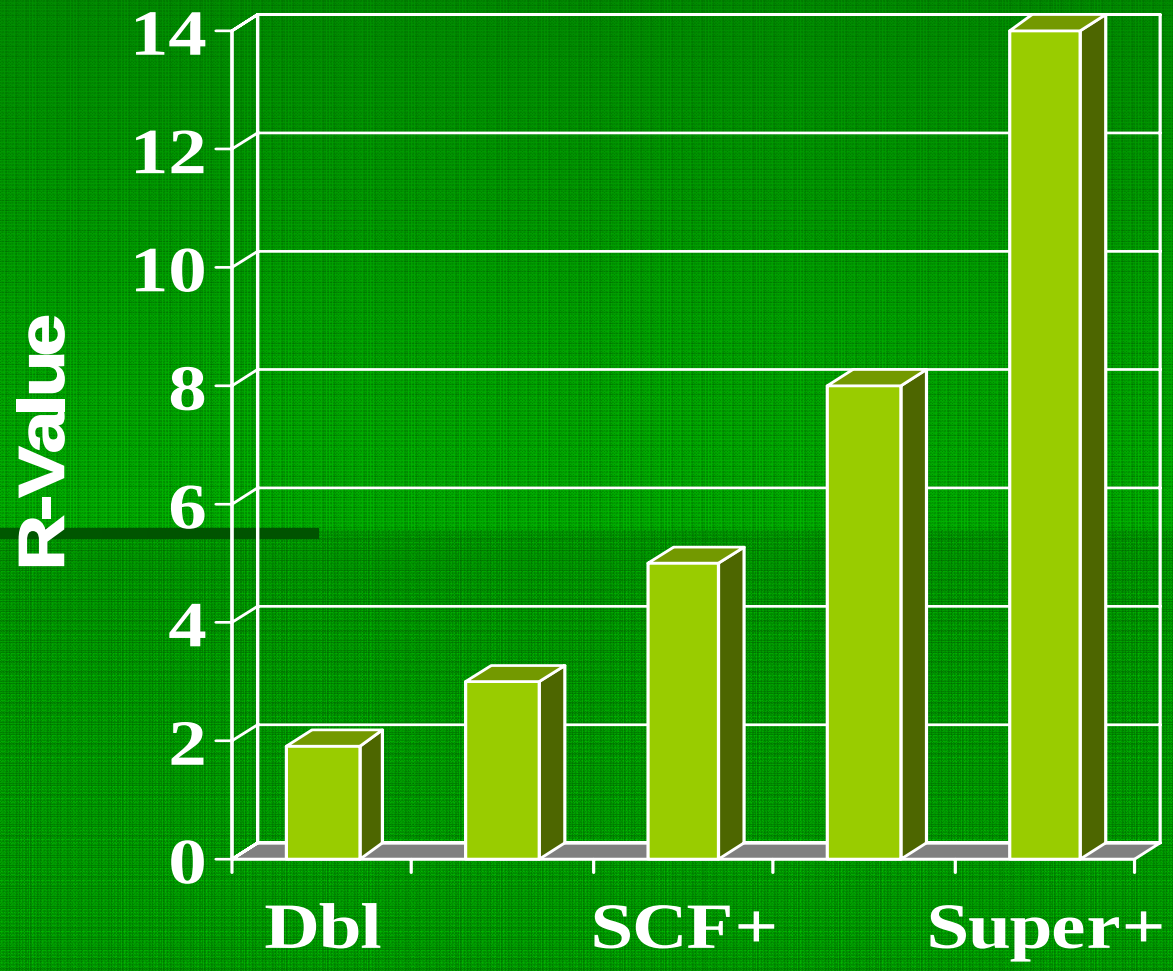
GLAZING SELECTION

Higher solar heat gain coefficient on the south facing wall for passive solar

DLEB, Section B,
Glazing, Page 72

Glazing

- **Resistance to thermal transfer**

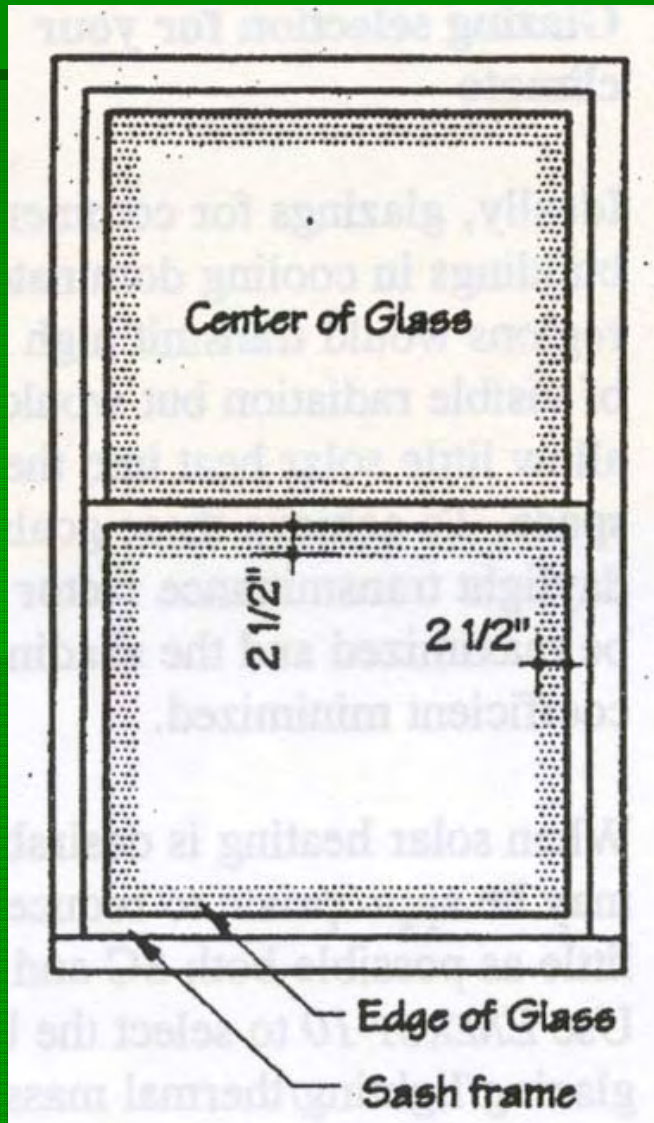


DLEB, Section B, Glazing, Page 71

Window Performance

RFA = Area (COG) + Area(PFD)

- Rough Frame Area
- Center of Glass
- Projected Frame Dimension

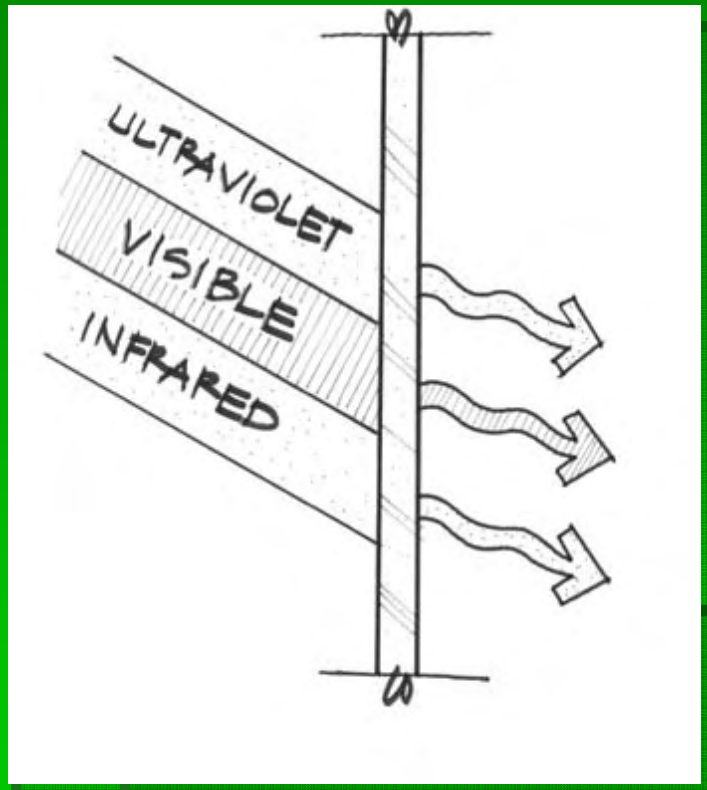


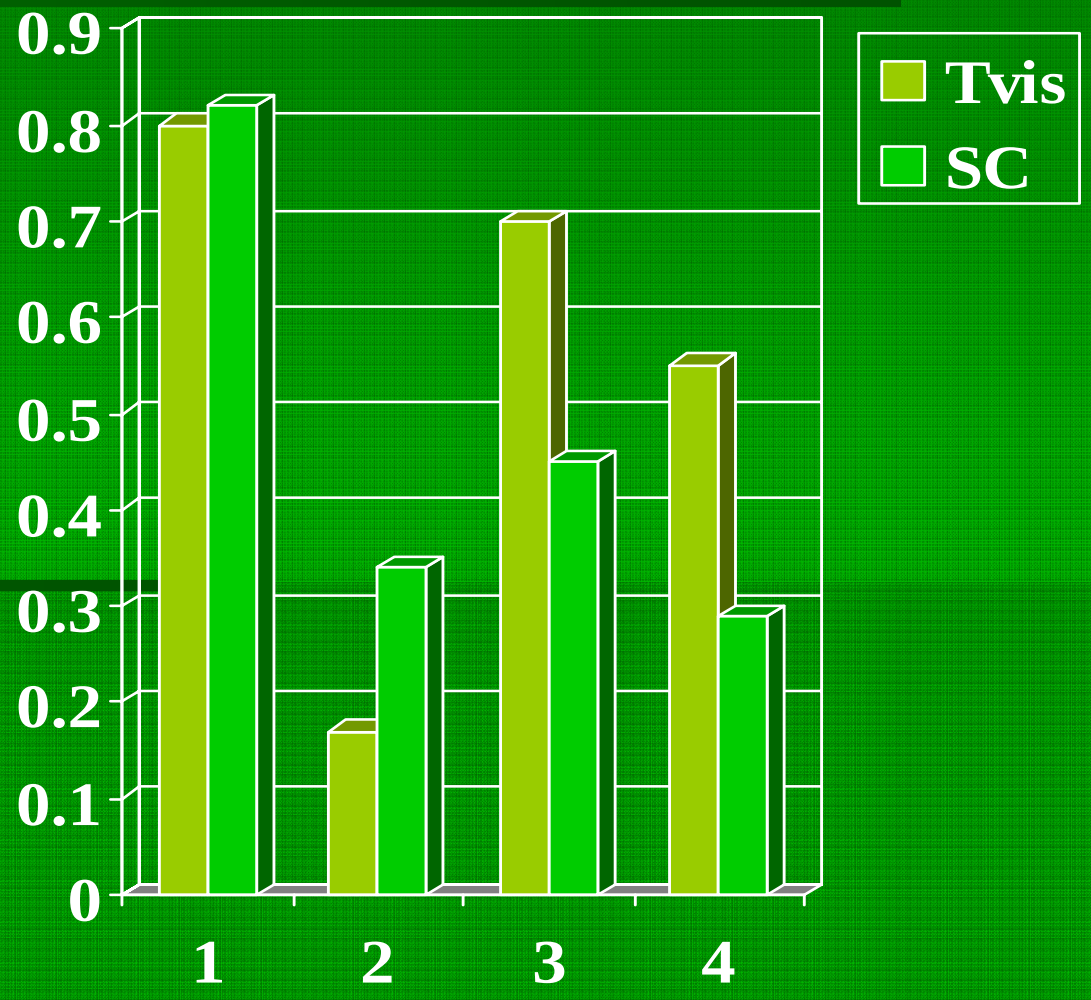
Sunshine

- Reflected
- Absorbed
- Transmitted

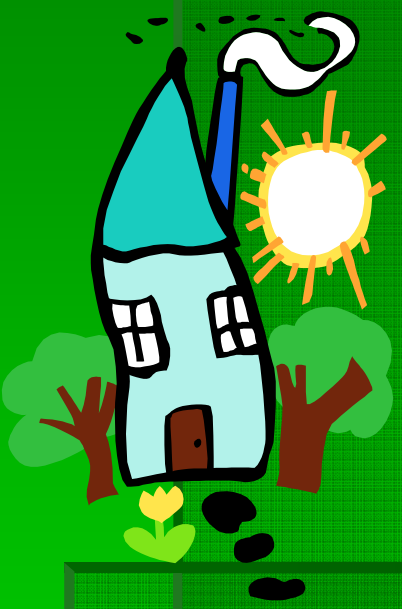
DLEB, Section B, Glazing, Page 70

Glazing Transmittance





Coolness Index



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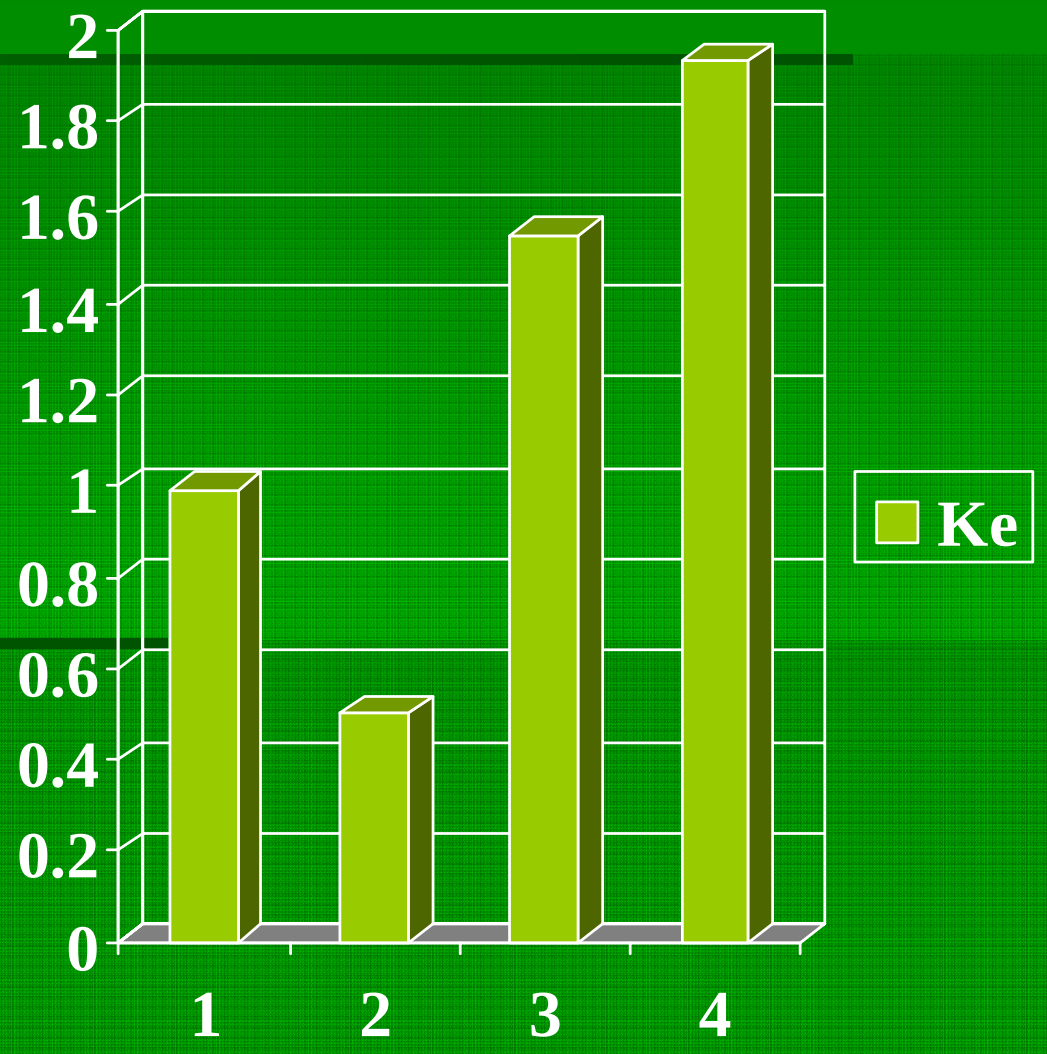
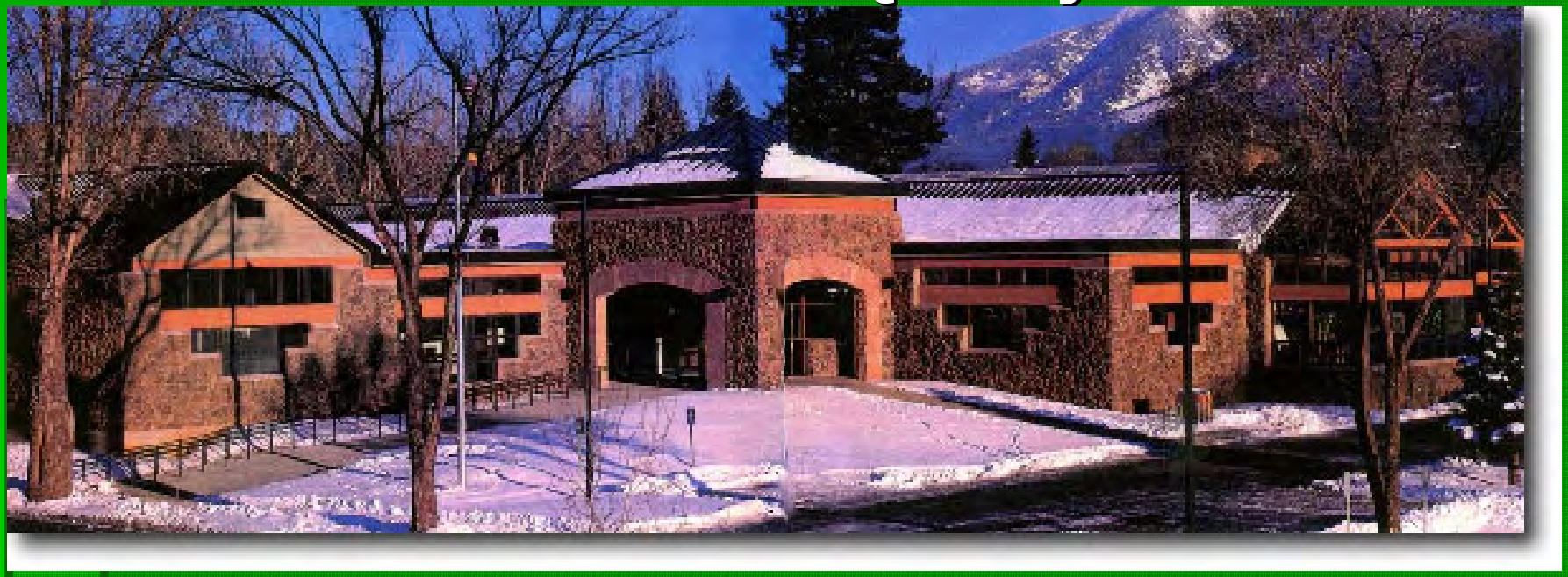


TUNED GLAZING

- Energy Efficiency
- Daylighting
- Environmental Quality

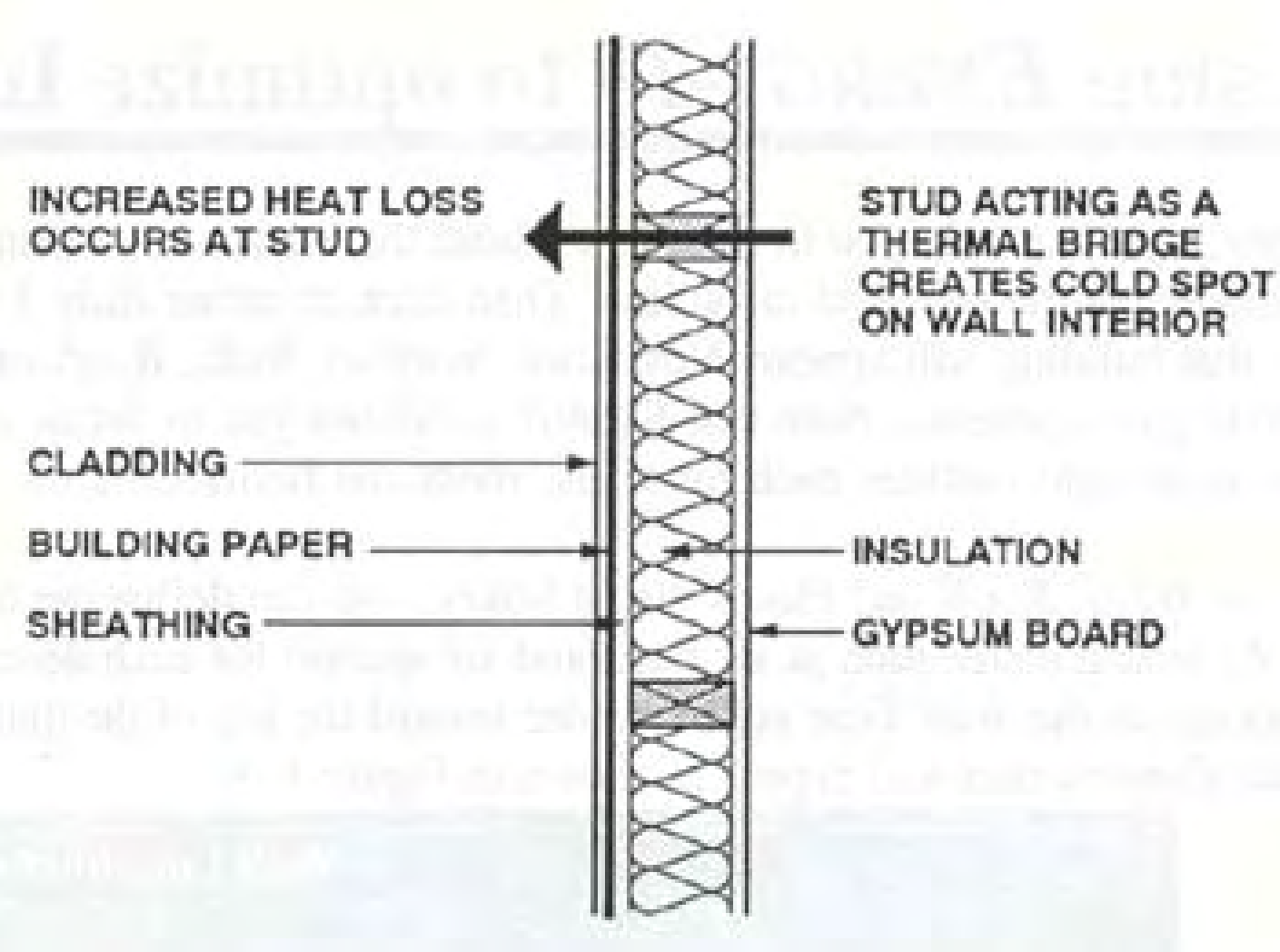


Insulation for Walls and Roof

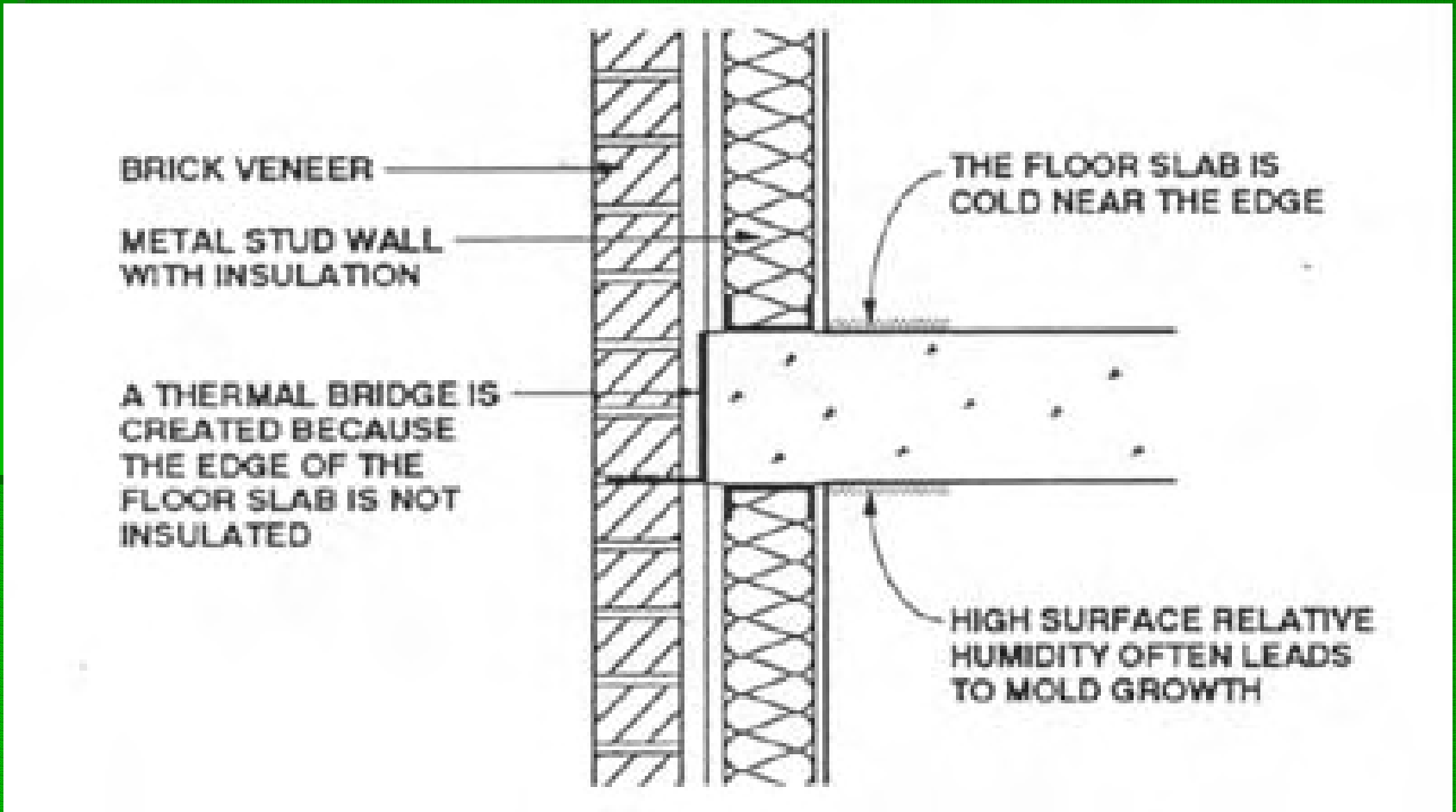
- Thermal Resistance
  - (R-value)
- Wall/Roof Components
  - Outside Air
  - Exterior Materials
  - Insulation/framing/mass
  - Interior Materials
  - Interior Air
- Heat Transfer Rate U=1/R

DLEB, Section F, Insulation, Page 97

Thermal Bridging



Thermal Bridging



Structural Insulated Panel

- Concrete walls insulated on the exterior.

Foundation/Basement Insulation

- Insulated forms

Roof Color-Low Solar Absorbance

- White Roof Alternative
- Thermoplastic Polyolefin (TPO)
- Carlisle “Sureweld”
- Hi Reflectivity
- No Plasticizers or Chlorines
- Recyclable

DLEB, Section G, Air Leakage Control, Page 101

Infiltration

- Often low in commercial buildings with lots of fixed windows
- Could be high in climate dominated building with lots of operable windows and poor construction quality
- Effective Leakage Area or Air Changes per Hour

Energy-10 Help Menu

Air Leakage Control

Analysis Methodologies

- Air Changes per Hour (ACH) Static
- Effective Leakage Area (ELA) Dynamic

•Sherman-Grimsrud Model

–ELA

–Delta T

–Wind Velocity

–Building Height

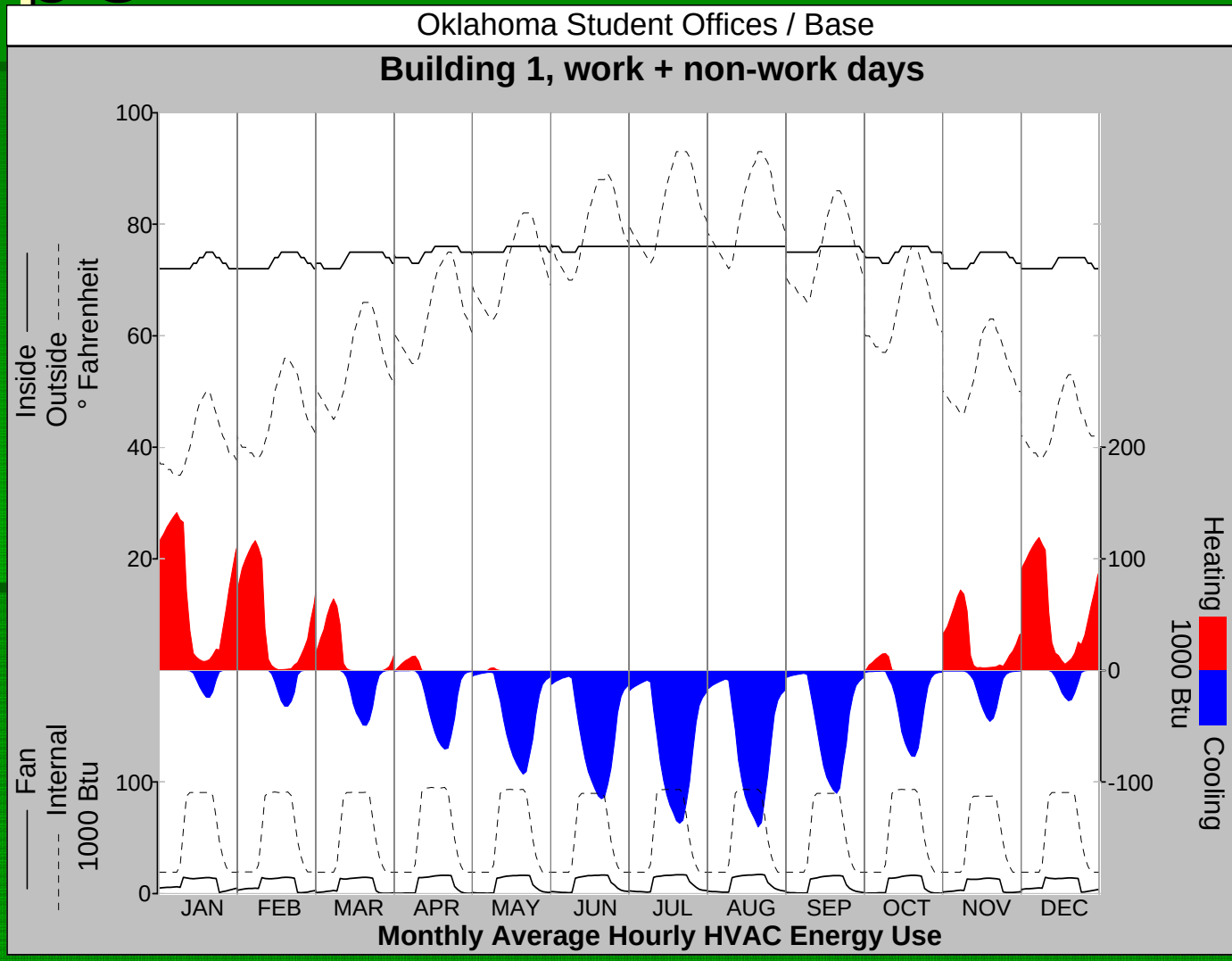
–Shielding Class

DLEB Design Recommendations within each section

Building Form and Envelope

Energy 10

- Insulation
- Air Leakage
- Glazing



Form and Envelope

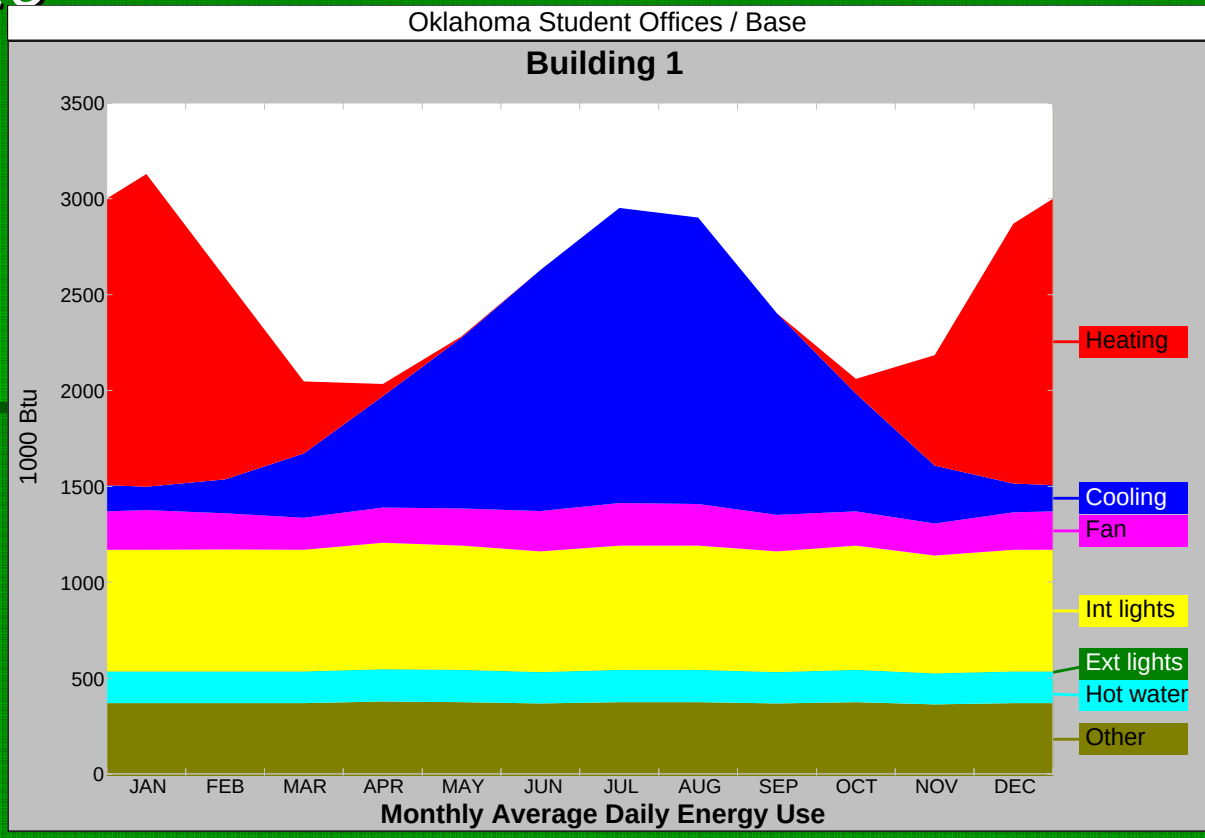
Design Process

- Define Problem
- Identify Range of Solutions
- Study Individual Effects
- Develop Design Strategies
- Study Combined Impacts
- Reiterate

Creating Green Architecture through Form and Envelope

ENERGY-10

- How do we evaluate form and envelope strategies using *ENERGY-10*



PASSIVE SOLAR DESIGN

Orientation

Solar Declination

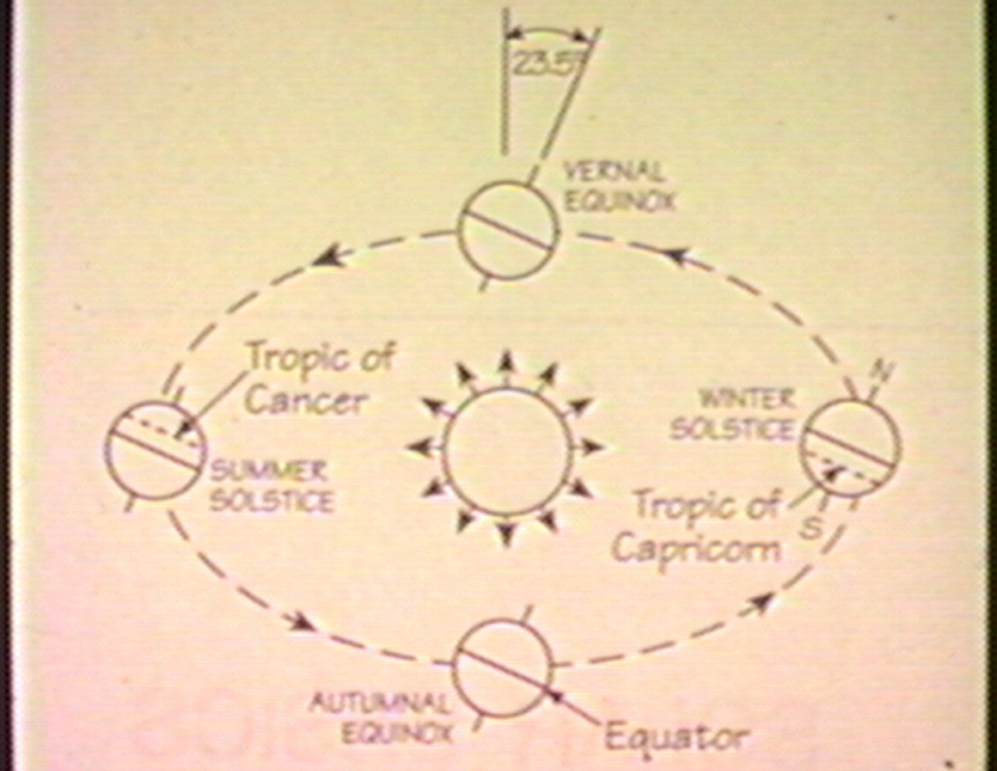


FIGURE 3.1 Earth's orbit around the sun.

Passive Solar Heating and Cooling

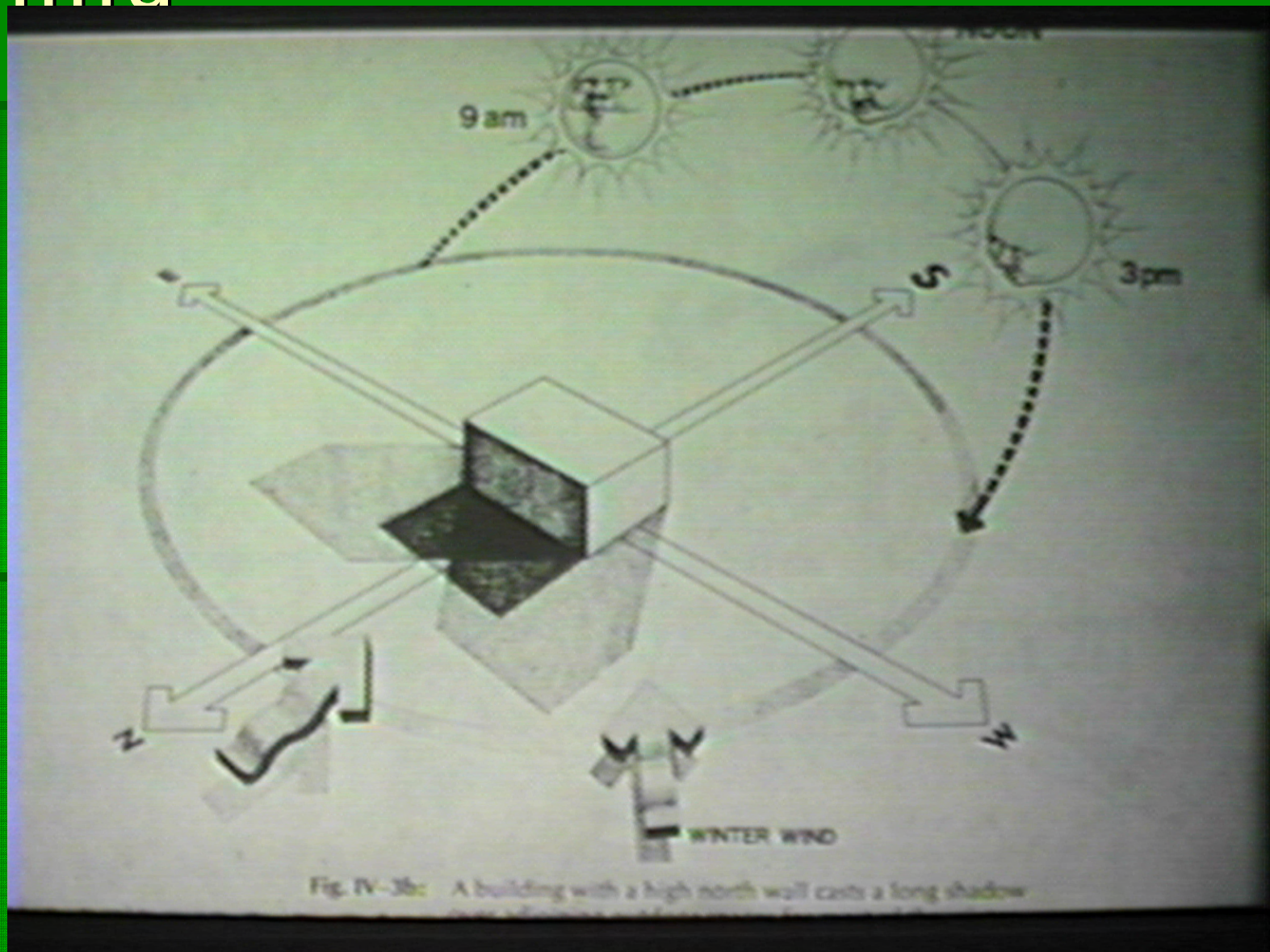


Fig. IV-3b: A building with a high north wall casts a long shadow

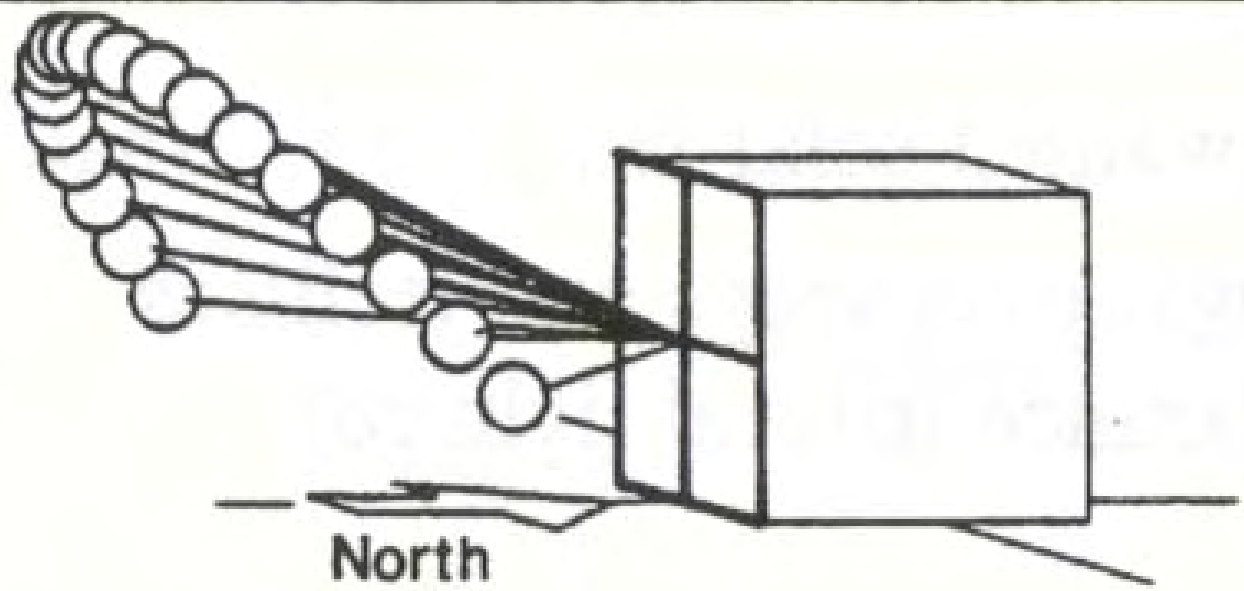
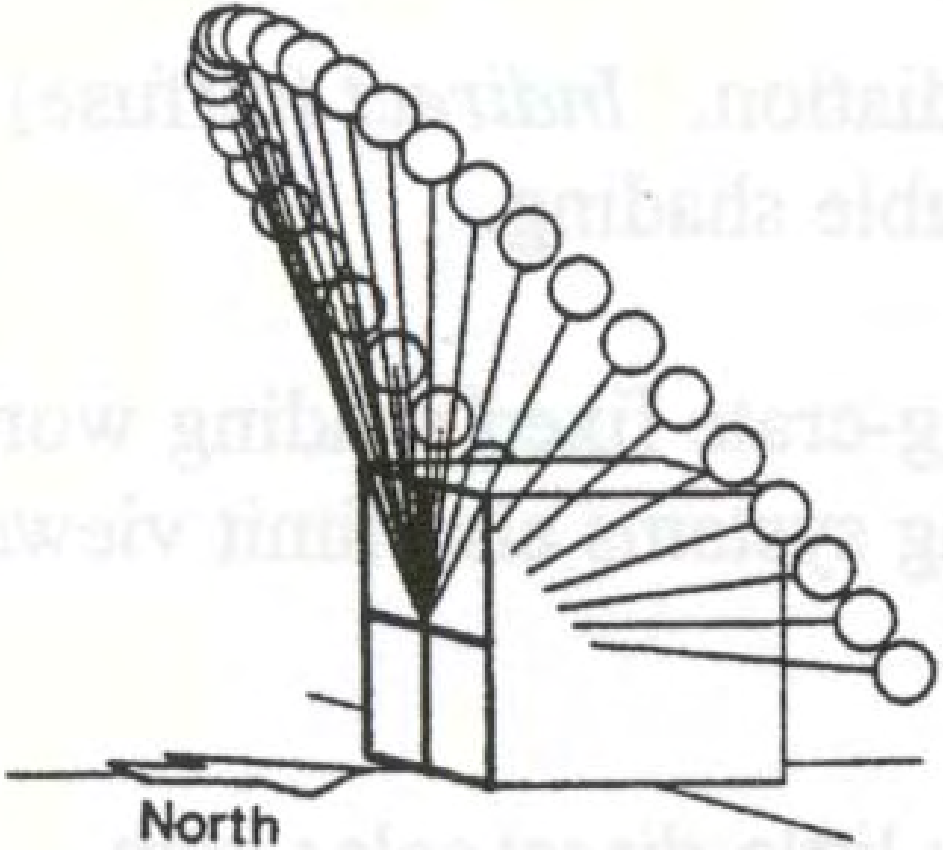
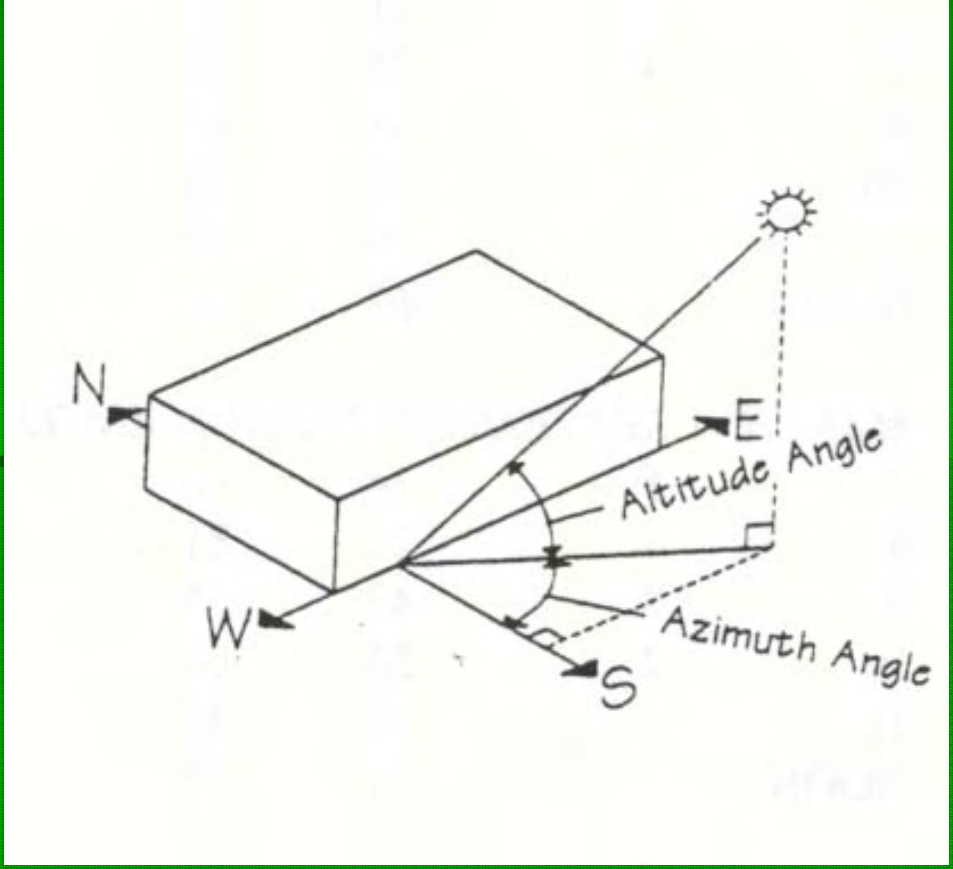


Fig. 4-3. Winter sun angles on a south-facing vertical surface

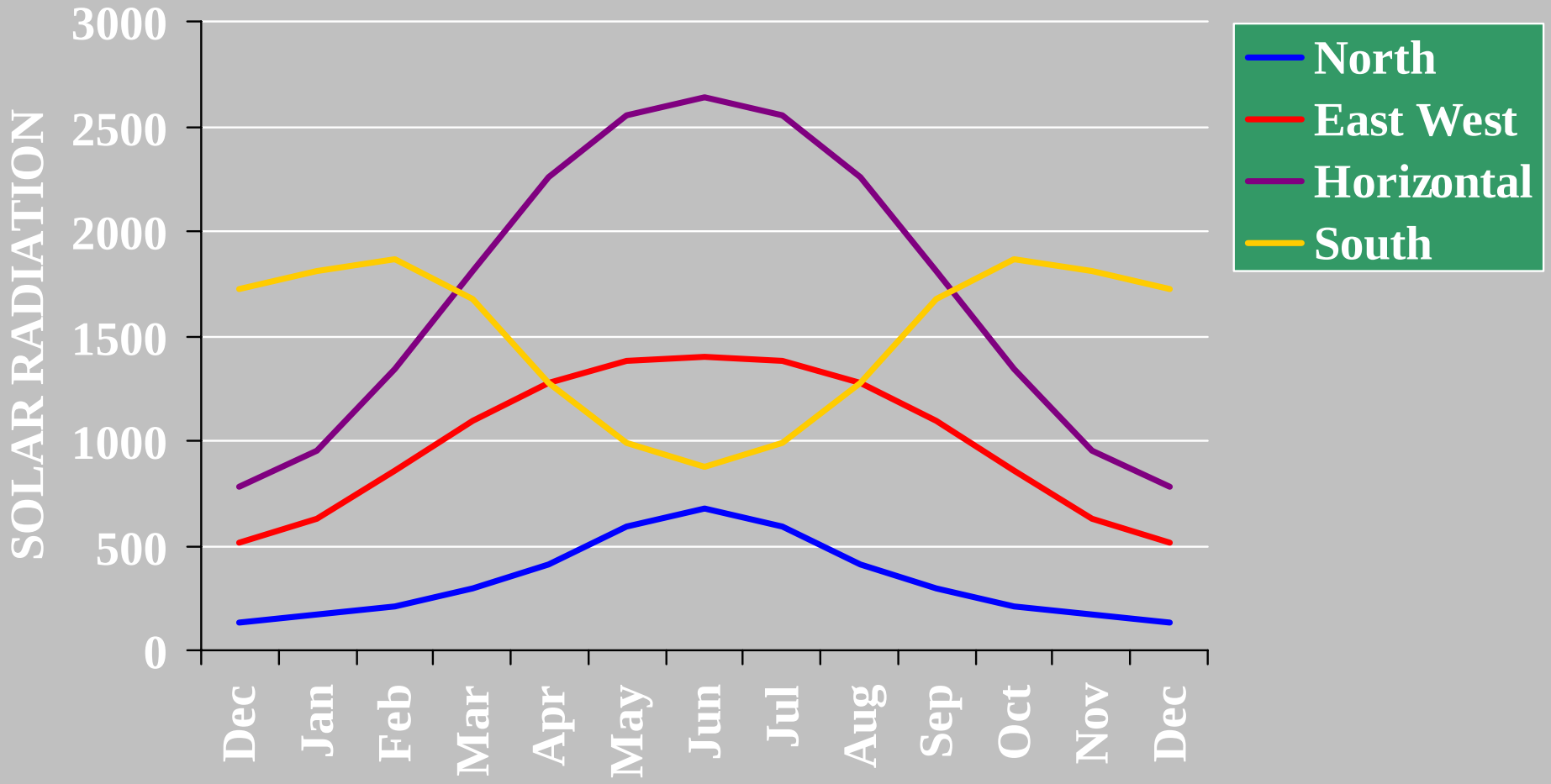


Summer sun angles on a south-facing vertical surface

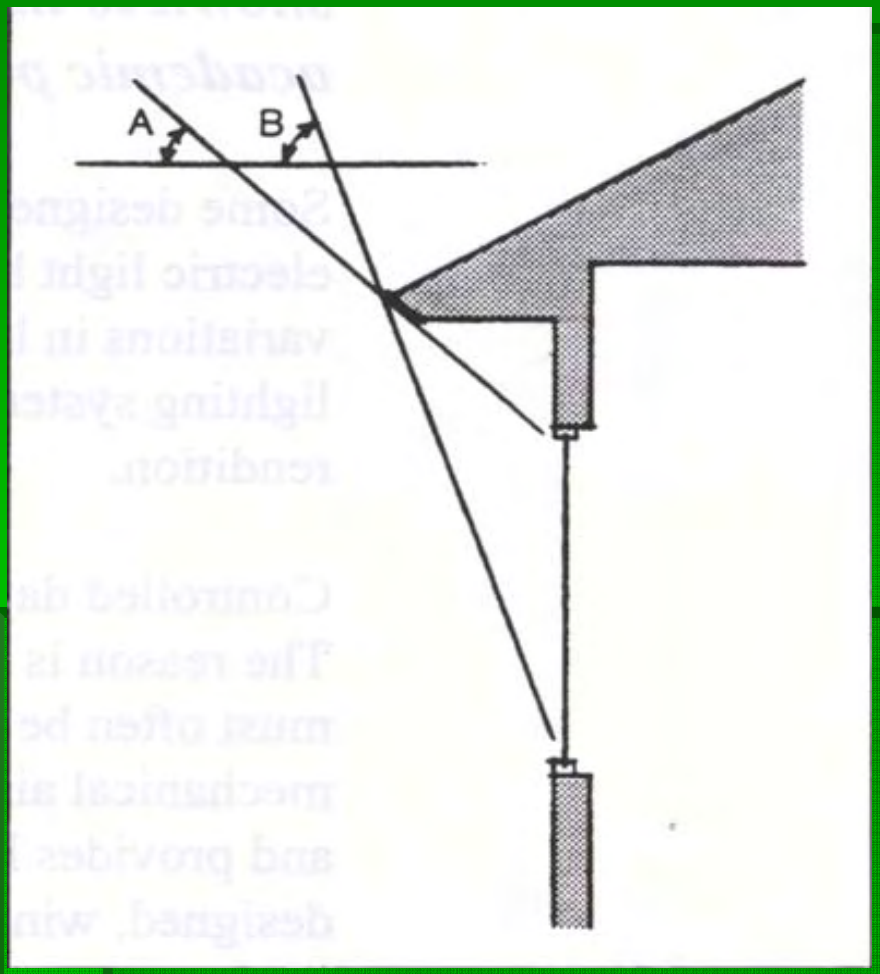
Recommended orientation is 15 degrees



Window Characteristics



Optimum projection factor



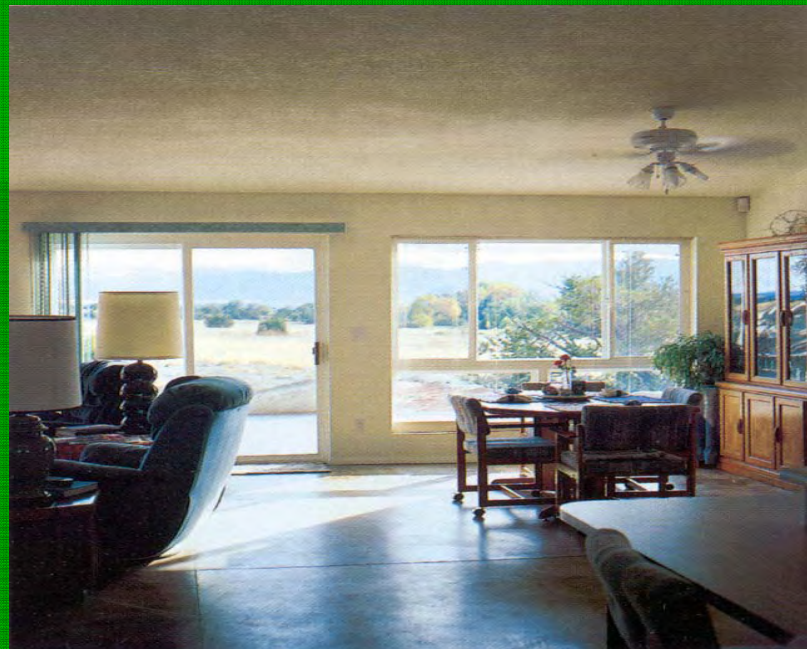
RECOMMENDED WINDOW AREA

- Guideline for percent of floor area:
- North 4%
- East 4%
- South 12%
- West 2%

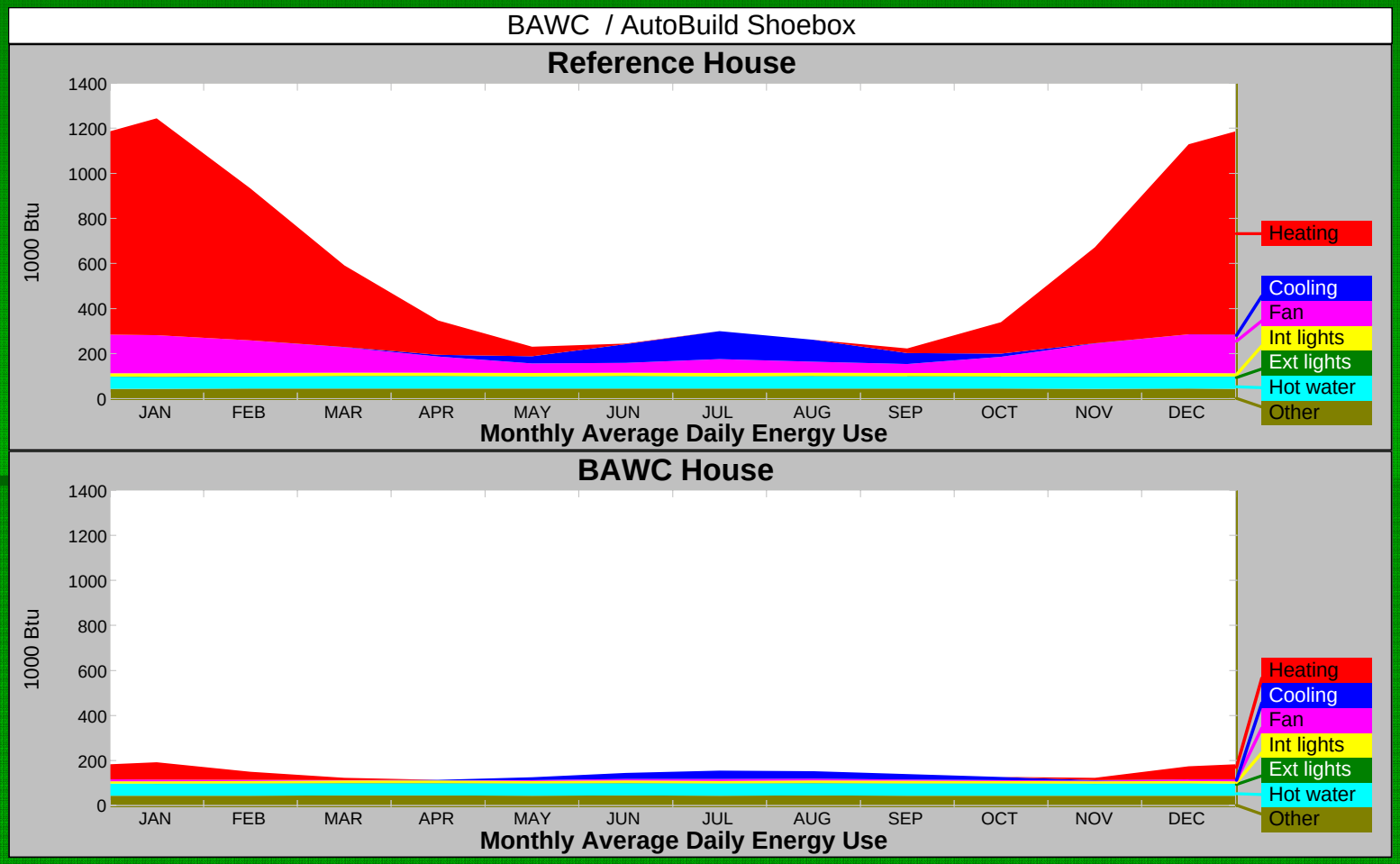
SOUTH FACING GLASS

10 – 12 % OF FLOOR AREA

WITH THERMAL MASS



Energy-10
Monthly Energy Use



Space layout

- Active spaces on south
  - Living, bedrooms
  - Entrance, dining
- Buffer spaces on north
  - Closets
  - Restrooms
  - Storage
  - Garage

Protect the north from cold winter winds

Clerestory for heat and light

Passive Solar Heating & Cooling

1. Elongate east-west
2. Organize plan
3. Use high performance glazing
4. Locate solar glazing for winter sun angles
5. Incorporate sun control
6. Open floor plan

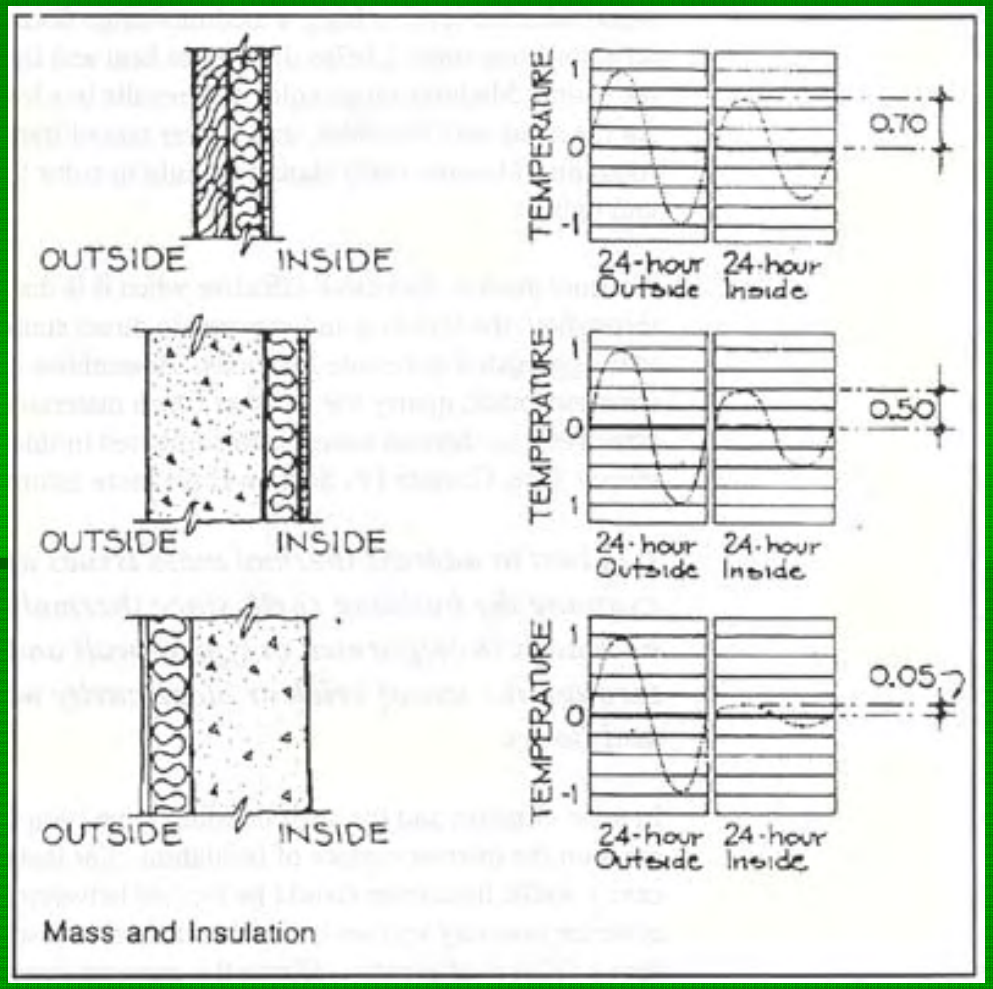
USE OF THERMAL MASS

Heat storage properties of materials

Figure H-1 DLEB

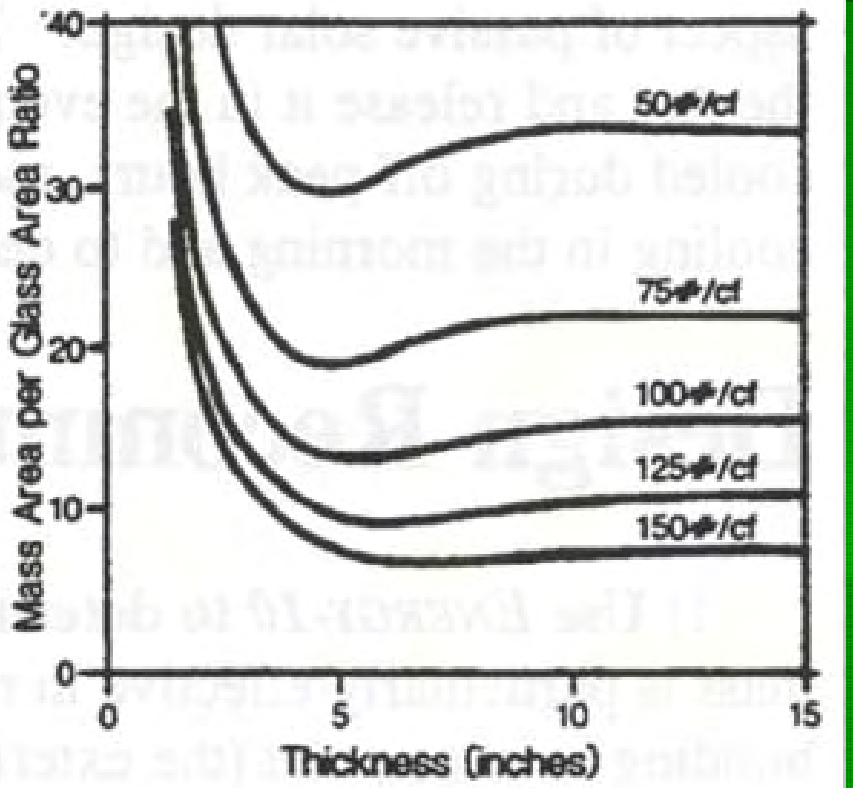
Material	Thickness (in.)	U-value	Time-lag
Brick	4	0.61	2 1/2 hr
	12	0.31	8 1/2 hr
Concrete	4	0.85	2 1/2 hr
	12	0.55	8 hr
Insul. Fibrbd.	2	0.16	40 min
Wood	2	0.30	1 hr

Mass effectiveness



Mass and Insulation

Mass to glass ratio



Mass Thickness
The effectiveness of thermal mass depends on the density of the material and thickness. This graph is for wall or ceiling mass in the direct gain space.

Examples of passive solar concrete homes

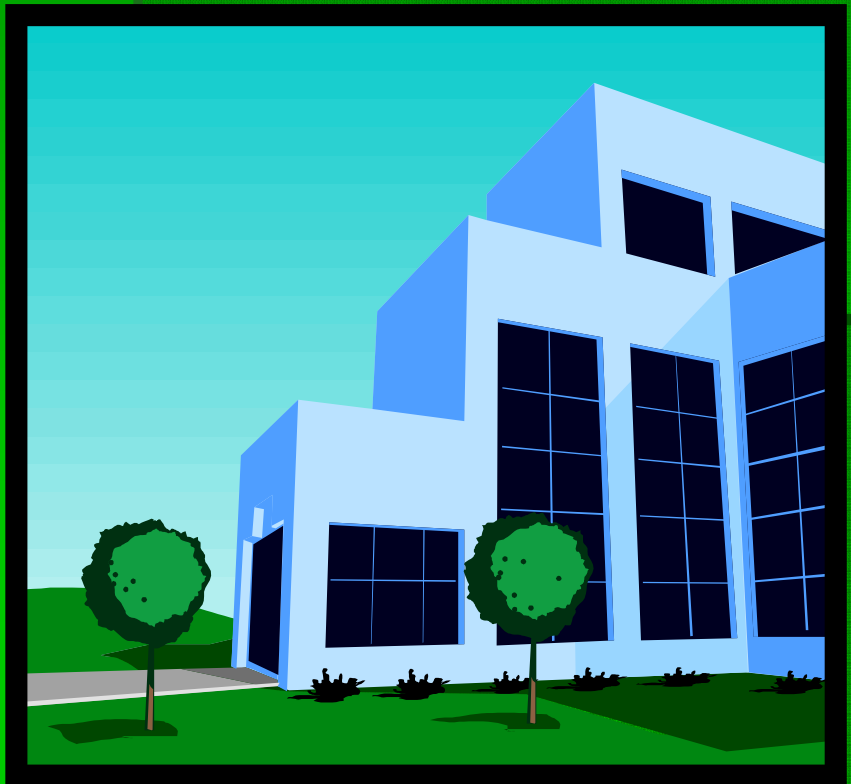
Office DEPOT

North and West

South and East

Spring & Fall
“Shoulder Seasons”

Deciduous trees can block 30% of solar gain in winter



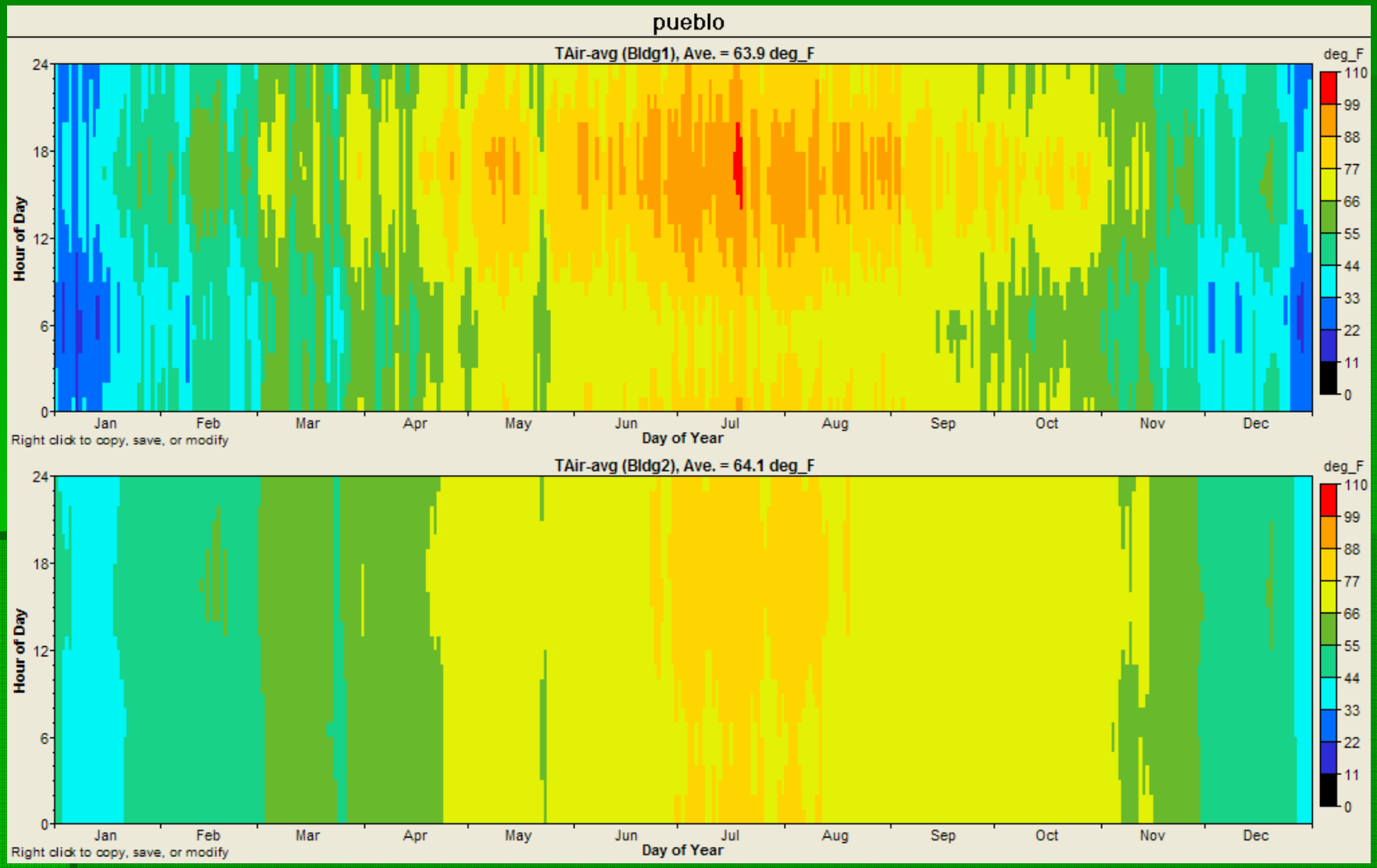
Passive solar homes come in many shapes and sizes.

Thermal Mass
Design Recommendations

1. Place most of mass within conditioned space
2. Allow temperature swings
3. Consider exterior thermal mass (walls, floor)
4. Plan for mass early in design process

YOUR GOAL:
Happy Building Owners

Energy-10 Analysis of Passive Solar &Thermal Mass



Daylighting…

The intentional, <u>controlled</u> use of natural light to displace artificial lighting.

Daylighting involves the integrated whole building design with the proper balance of heating, cooling and lighting energy.

Lighting in architecture is both a quantitative and qualitative issue

Daylighting

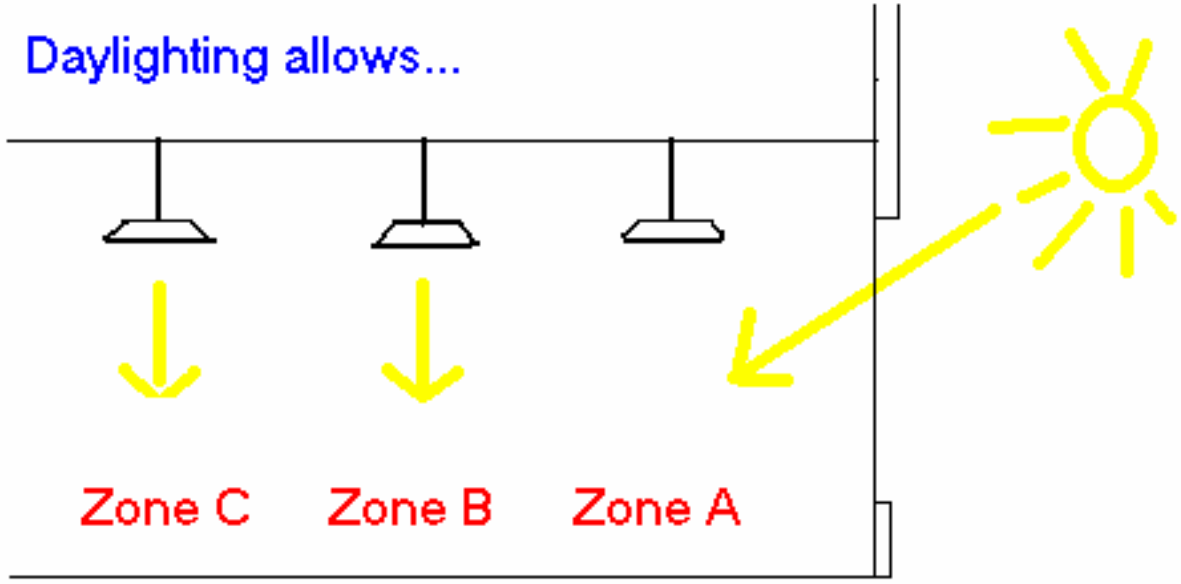
Need to control glare with baffles to diffuse natural light in buildings

Daylighting controls should reduce electric lights in response to natural light available.

Daylighting can significantly reduce the need for artificial lighting.

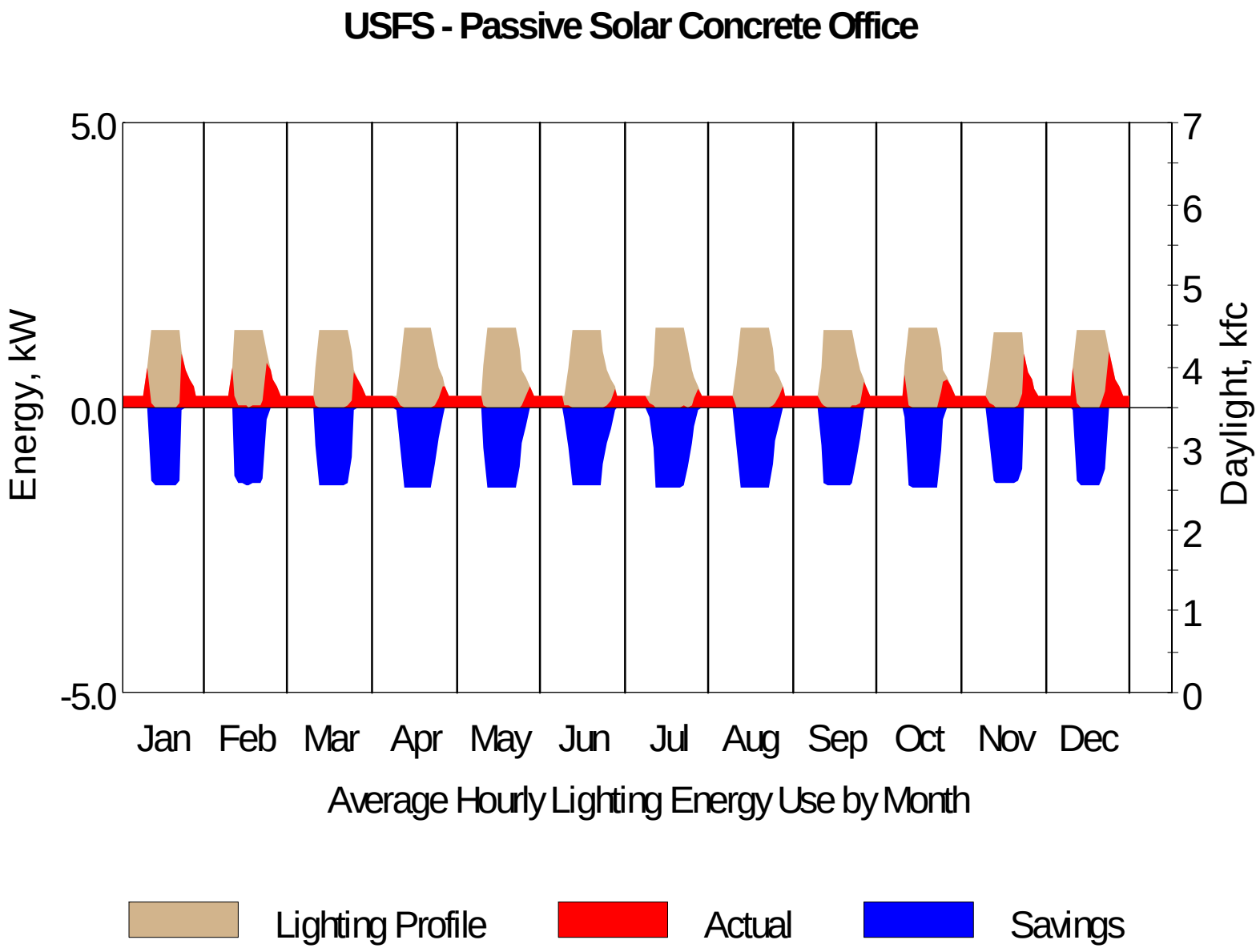
- The higher the daylight source, the deeper into the building the light will go.

Daylighting



DIMMING OR SWITCHING of electric light by zone to conserve energy

Residential daylighting is often overlooked.

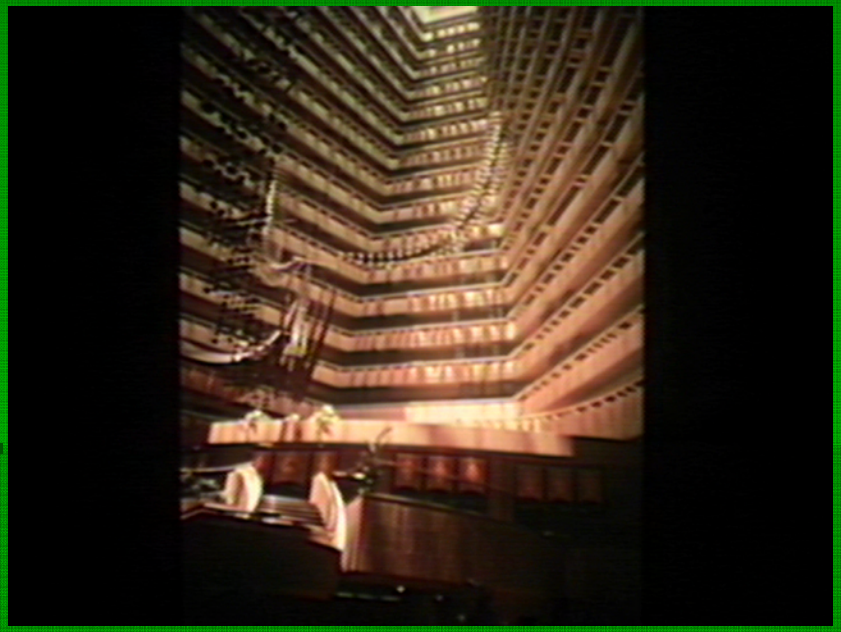

USFS - Passive Solar Concrete Office
5.0
0.0
-5.0
Energy, kW
7
6
5
4
3
2
1
0
Daylight, kfc
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Average Hourly Lighting Energy Use by Month
Lighting Profile
Actual
Savings

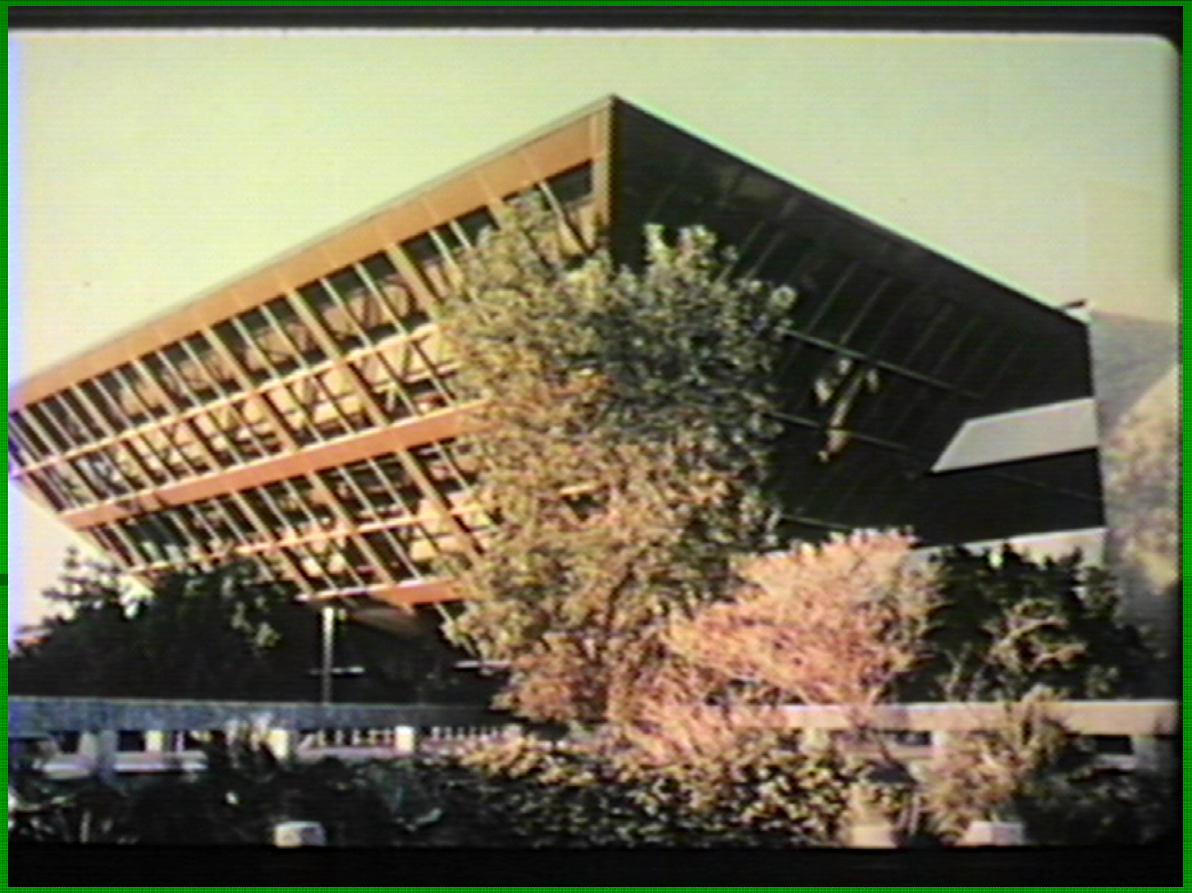
SHADING

Direct sun is not always desirable.

Shading on east and west facades will differ from south.

Balancing heating, cooling and lighting strategies can be creative.





Simple overhangs work well on south.

Design shading devices to specific locations

How ENERGY-10 analyses daylighting and shading

Lighting

- Energy Efficient Lighting
- Daylighting
- Integration of daylighting and electric lighting

Brighten Surfaces
Reduce brightness differences

Lighting

- Output~Quantity~Productivity
  - Quality
  - Comfort
  - Aesthetics
- Input~power~expense
  - Energy
  - Initial cost
  - Maintenance

LPW (Lumens per Watt)

- A measurement of efficiency
- Amount of light energy produced for each watt of power consumed

GSA recommended levels

- Halls, Corridors 10 fc
- Work stations 30 fc
- Display area 50 fc
- Difficult work areas 100fc

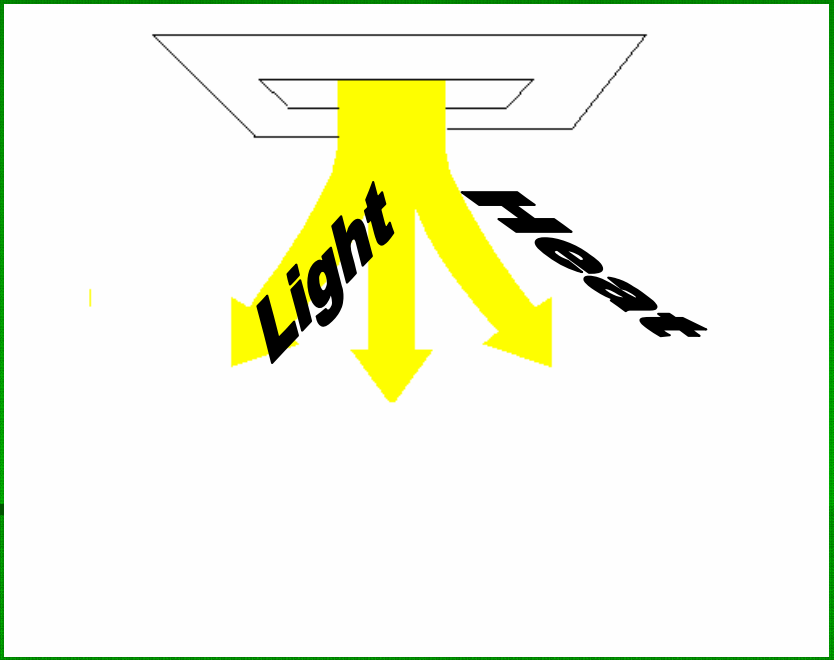
The required illumination required depends upon:

- Age
- Importance of the task
- Difficulty of the task

Task and ambient lighting approaches address specific lighting needs.

Electric lights produces light and heat

- Incandescent lights are 90% efficient heaters that happen to put out 10% of energy in light.



Washington metro station indirect lighting

Task lighting with glare

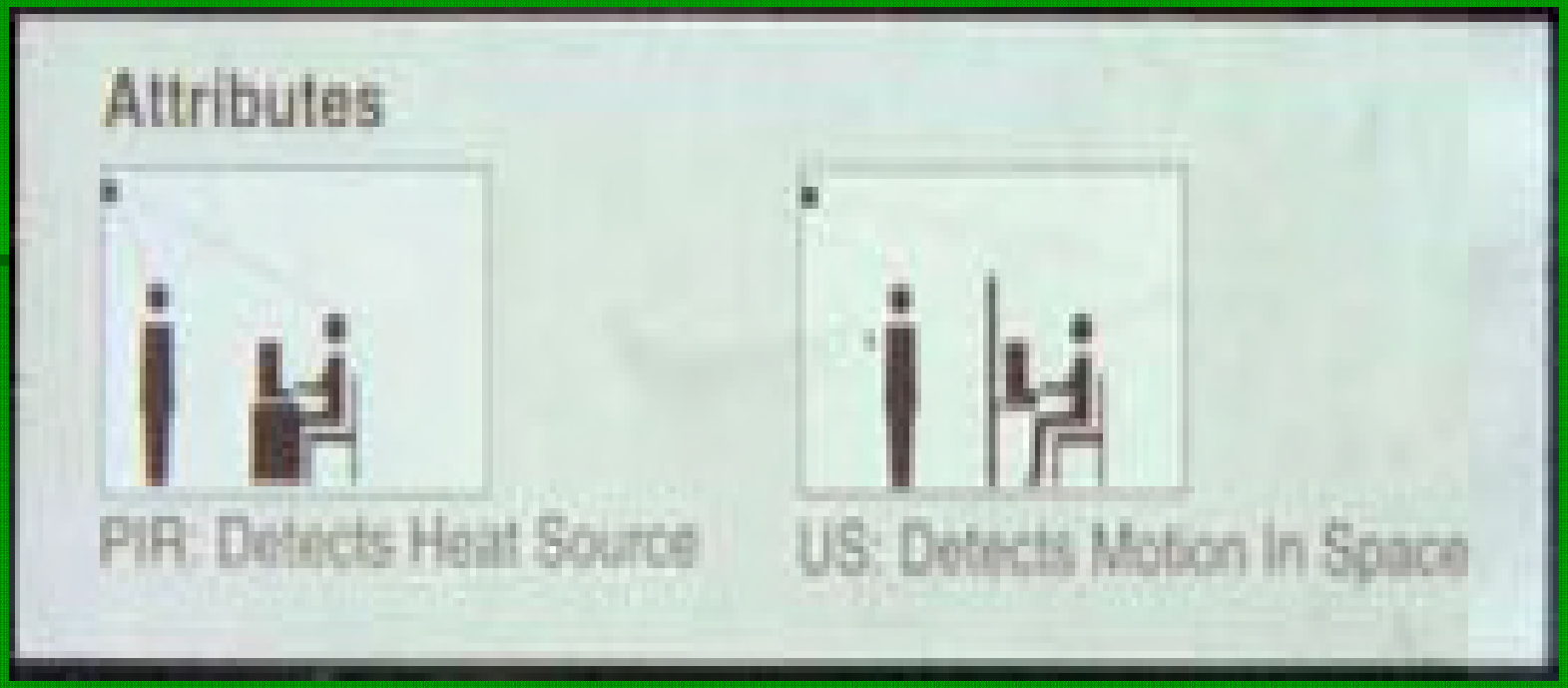
Computer screen with reflection

Fluorescent lamps T12, T8, T5

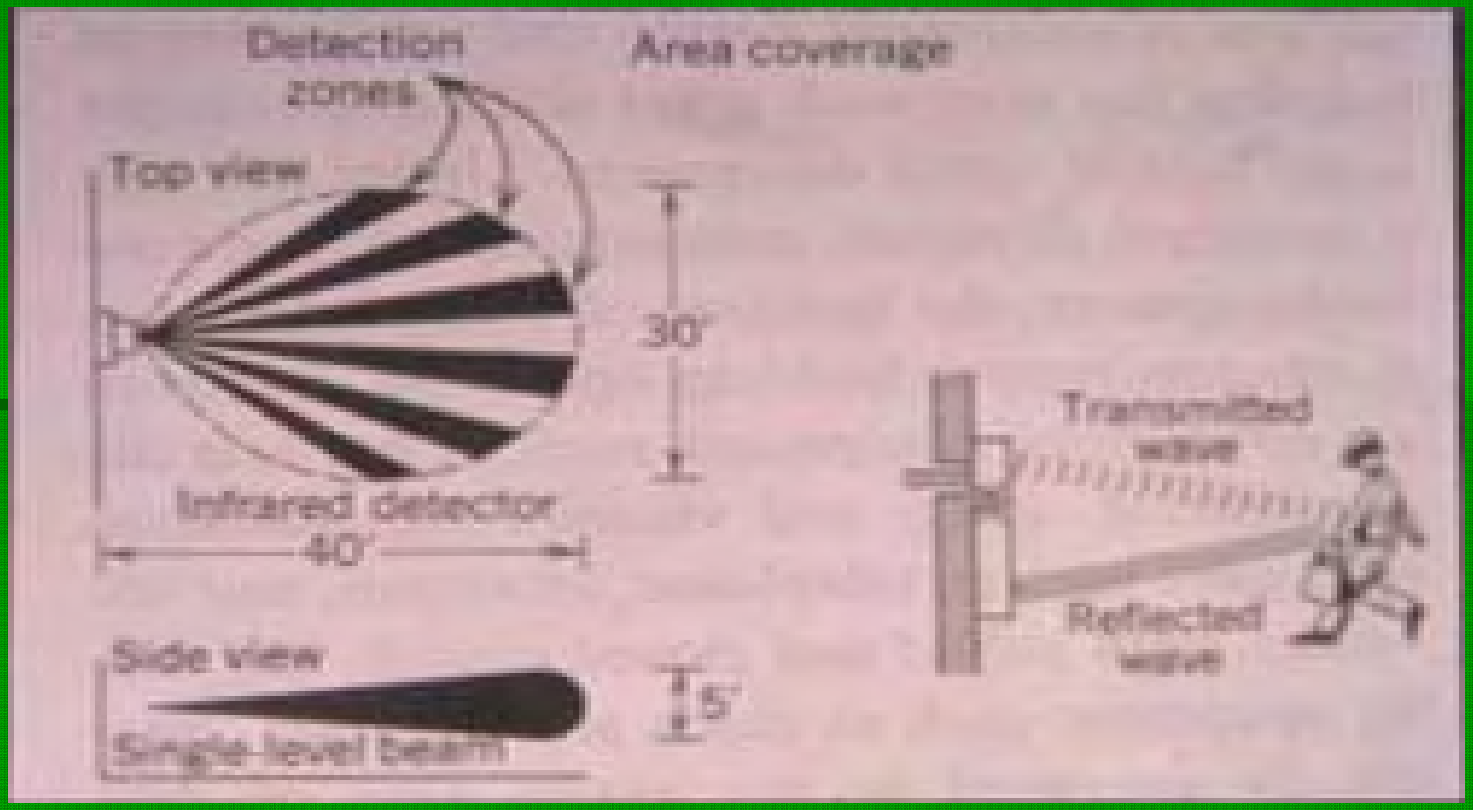
Control strategies

- Scheduling
- Tuning
- Lumen maintenance
- Daylighting

Attributes of detectors



Infrared detector



Coverage patterns

Percentage energy saved with different controls

- Daylight 57%
- Occupant 47%
- Time switch only 30%
- Full system 75%

Energy Efficient Lighting Design Recommendations (page 85)

1. Minimize installed lighting power density
2. Electric light is supplement to daylight
3. Coordinate lamp and ballast selection with lighting controls and windows
4. Use electronic ballasts
5. Evaluate the economics of ballast selection

Lighting controls Design Recommendations (page 91)

1. Consider compact fluorescent bulbs for accent lights
2. Locate occupancy controls in all spaces with intermittent occupancy
3. Focus controllers on high-payoff locations
4. Check whether a lighting control strategy also applies to the HVAC system
5. Reserve a portion of your budget for extra expenditure on lighting circuits

High Efficiency HVAC

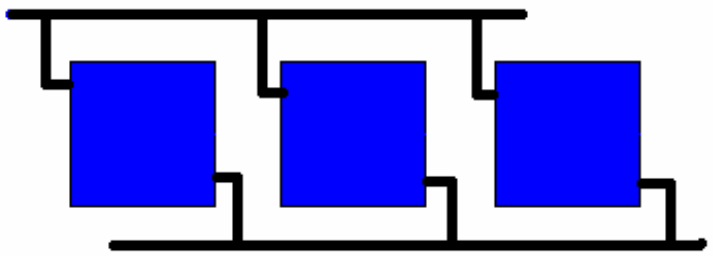
- There is a tendency within the industry to oversize equipment.
- Oversized equipment wastes energy because it is generally less efficient when it runs below full capacity.

HVAC Efficiency Ratings

- Boilers 90%
- Air-to-air heat pumps COP 3.0
- DX Air Conditioners SEER 13

Part-Load Efficiency

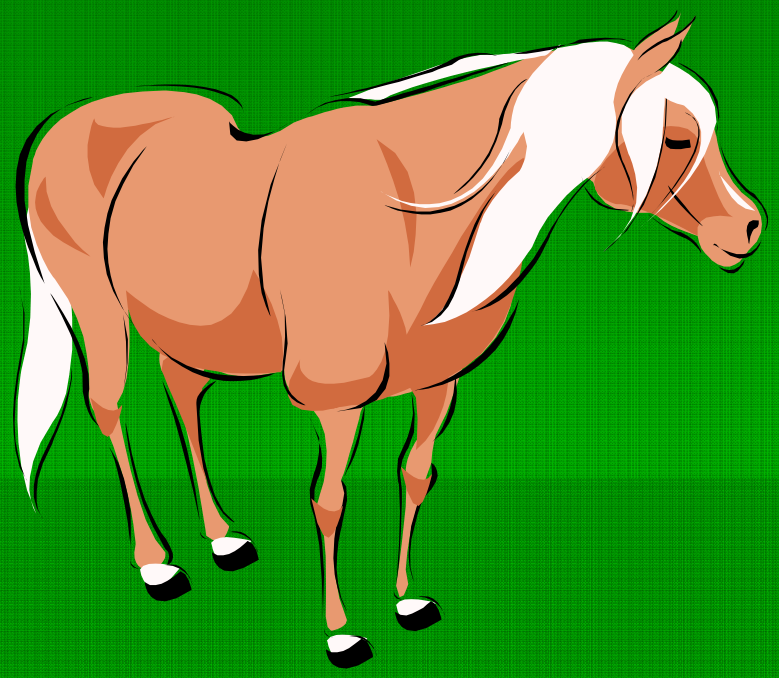
- Oversized equipment wastes energy
- A series of smaller boilers or chillers saves energy



Modular Boiler System
DLEB pages 130-131

Pumps, Fans and Motors

- Anything over one horsepower choose variable speed.



Factors Affecting Motor Efficiency

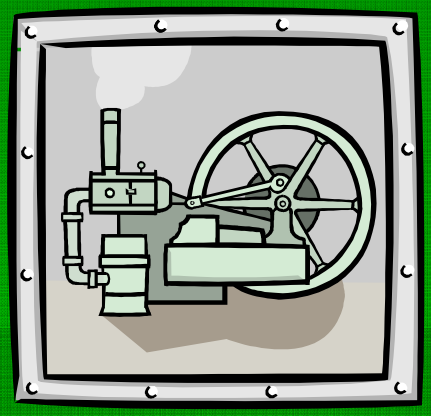
- Size of motor to the load
- Type of motor
- Motor design speed
- Type of bearings.

High Efficiency HVAC

- Design Recommendation:
  - Size the HVAC Equipment
  - Consider using modular equipment
  - Provide good controls
  - Specify efficient motors
  - Consider variable speed drives

HVAC Controls

- Variable Speed Drives
- Variable Air Volume (VAV)



- DLEB pages
- 135-142

HVAC Controls Design Recommendation

- Use set back thermostats for all building types
- Keep control systems as simple as possible
- Fully evaluate control strategies which reduce ventilation
- Integrate control systems with other computerized systems
- Match control systems with skill levels
- Avoid controls requiring regular maintenance
- Include directions in O&M manuals

Evaporative Cooling

- Site planning affects the habitability of spaces
- Evaporative cooling of courtyards is especially effective
- Design small and deep courtyards in hot, dry climates for shading
- Take advantage of the transpiration of plants
- Utilize evaporative coolers in hot, dry climates

Solar Hot Water Heating

- Solar hot water is most advantageous when DHW is required year-round.
- Select the DHW heater according to climate, cost and operational requirements.
- DLEB pg 147-150

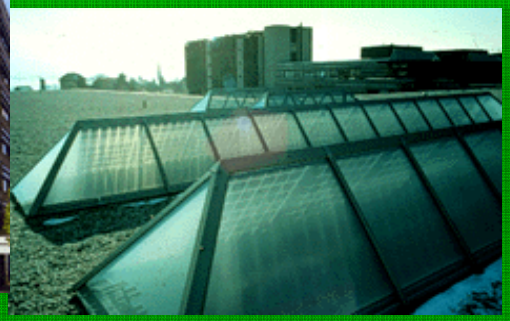
PV and Wind

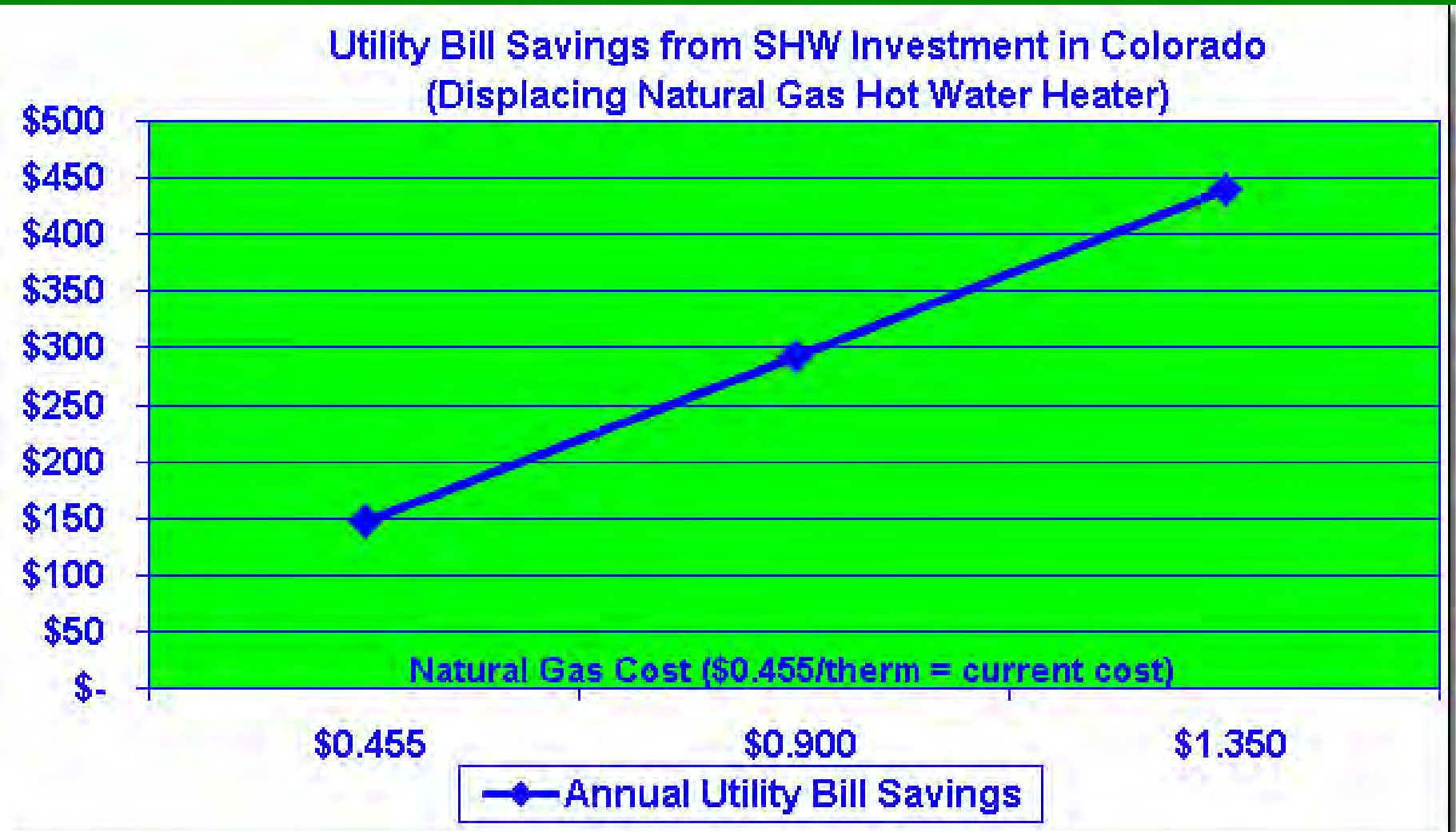
Next version of Energy-10 will have photovoltaics.

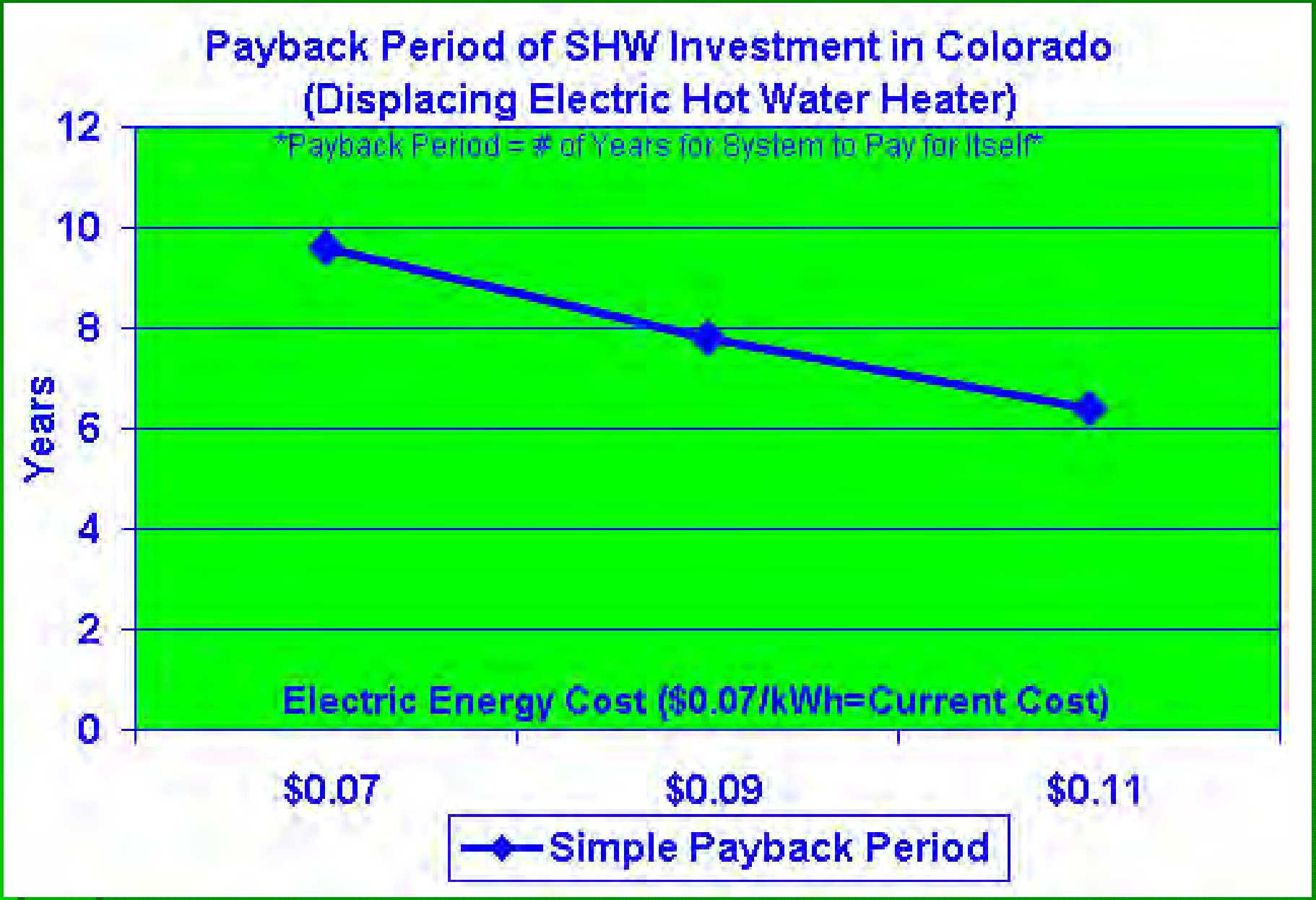
Photovoltaics (PV)

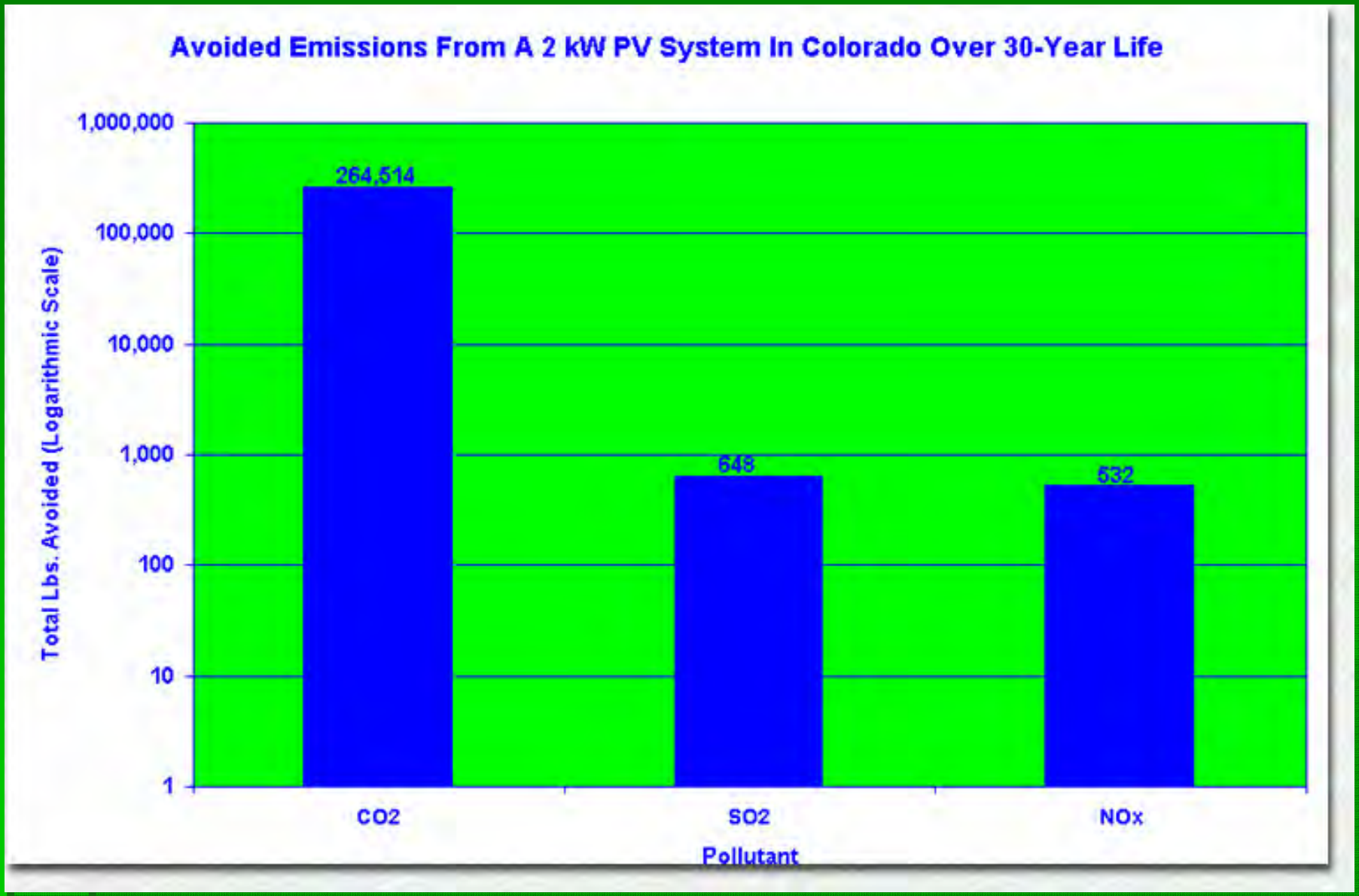
Mounting Options for PV

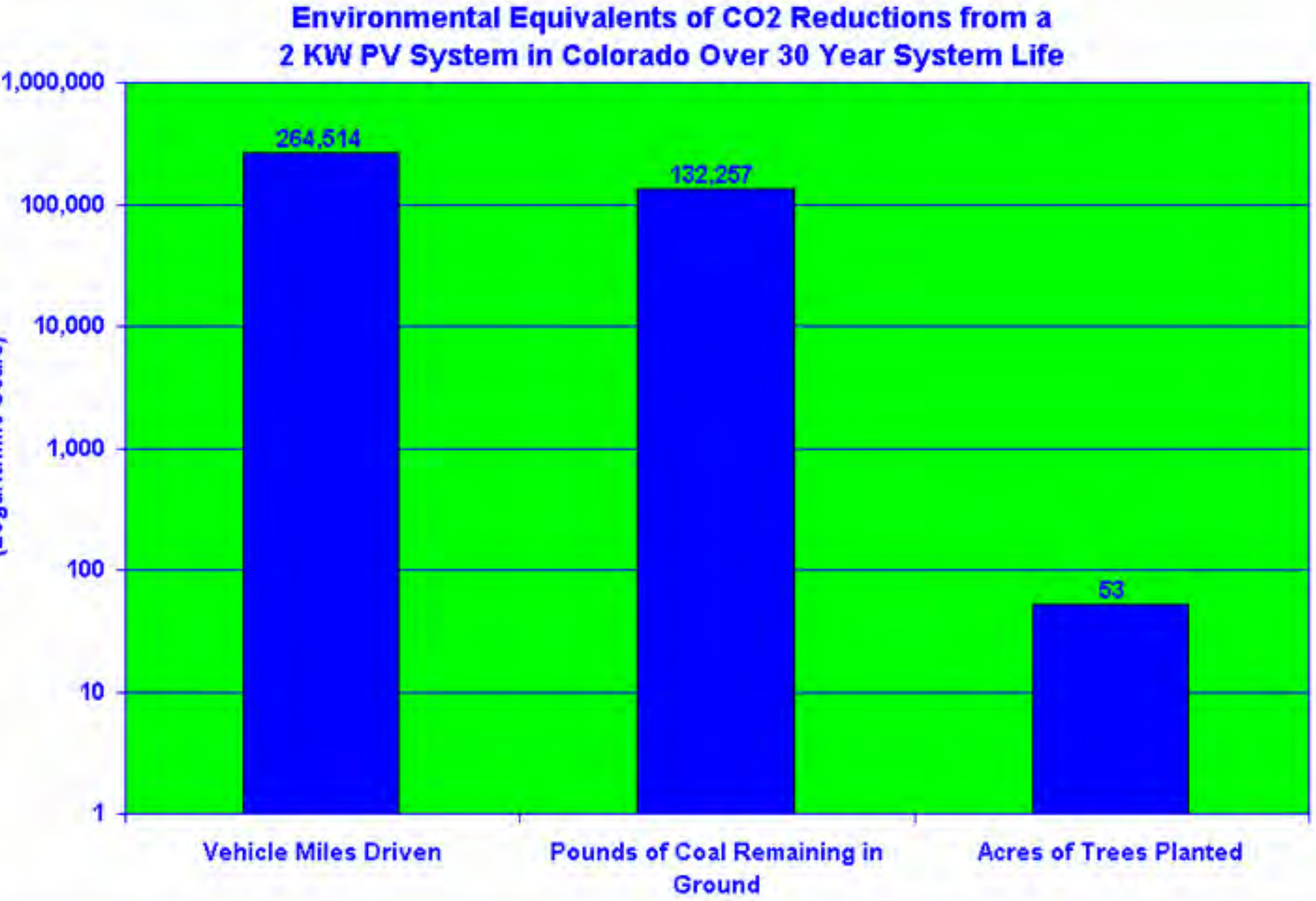
BIPV and AIPV: EU & Asia

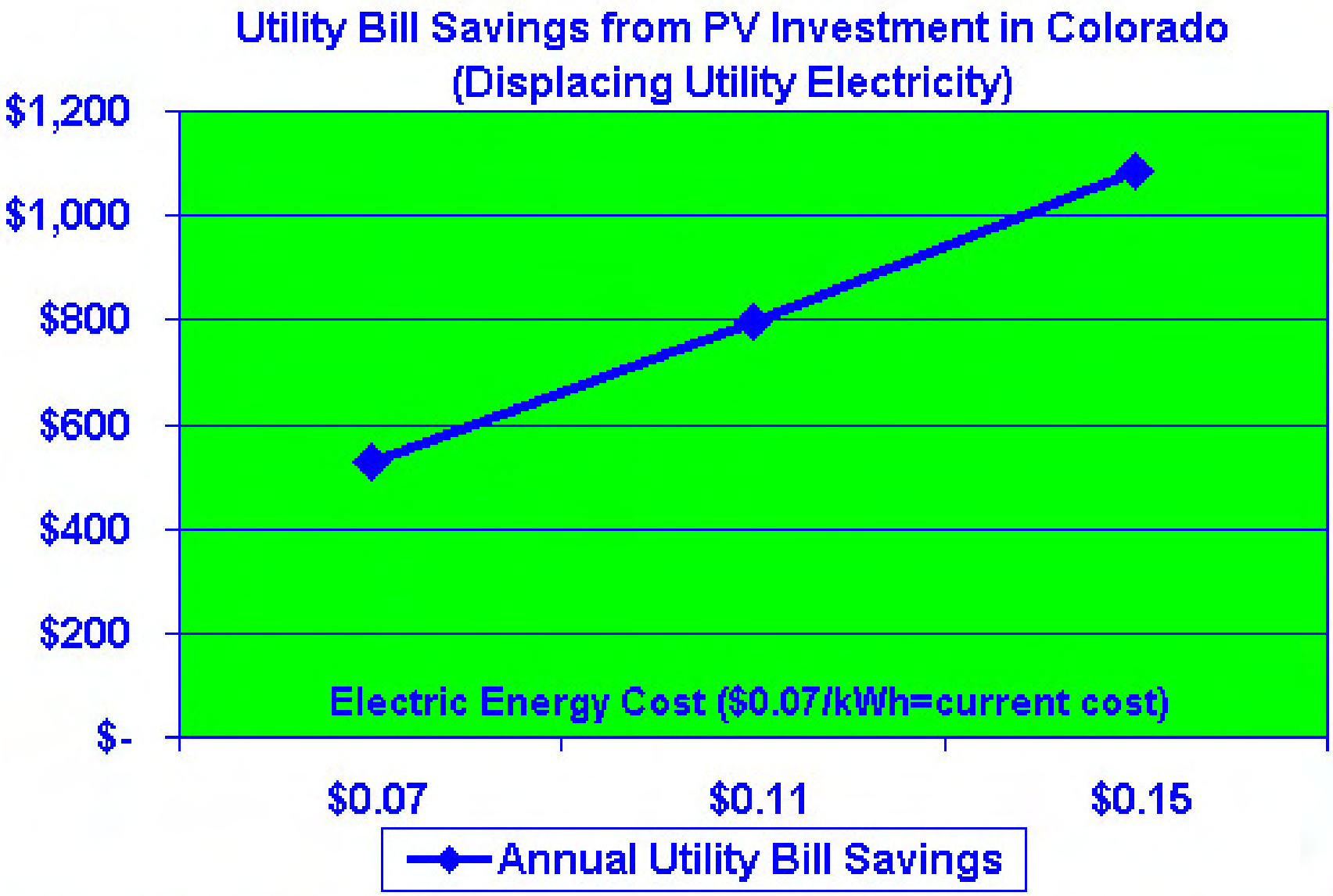


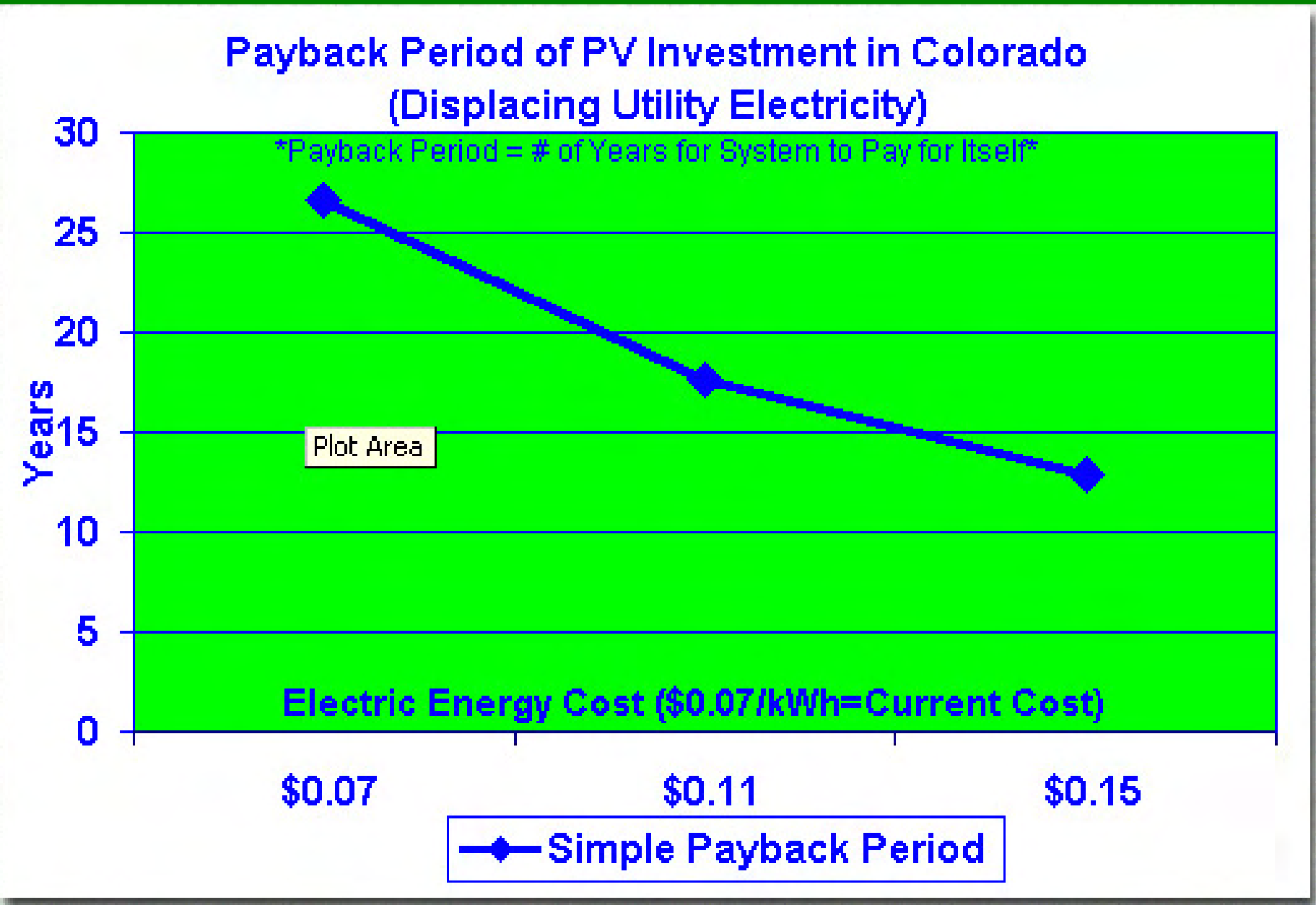

Utility Bill Savings from SHW Investment in Colorado
(Displacing Natural Gas Hot Water Heater)
$500
$450
$400
$350
$300
$250
$200
$150
$100
$50
$-
Natural Gas Cost ($0.455/therm = current cost)
$0.455
$0.900
$1.350
Annual Utility Bill Savings


Payback Period of SHW Investment in Colorado
(Displacing Electric Hot Water Heater)
Payback Period = # of Years for System to Pay for Itself
Years
12
10
8
6
4
2
0
Electric Energy Cost ($0.07/kWh=Current Cost)
$0.07
$0.09
$0.11
Simple Payback Period


Avoided Emissions From A 2 kW PV System In Colorado Over 30-Year Life
Total Lbs. Avoided (Logarithmic Scale)
1,000,000
100,000
10,000
1,000
100
10
1
264,514
648
532
CO2
SO2
NOx
Pollutant


Environmental Equivalents of CO2 Reductions from a
2 KW PV System in Colorado Over 30 Year System Life
1,000,000
100,000
10,000
1,000
100
10
1
264,514
132,257
53
Vehicle Miles Driven
Pounds of Coal Remaining in Ground
Acres of Trees Planted


Utility Bill Savings from PV Investment in Colorado
(Displacing Utility Electricity)
$1,200
$1,000
$800
$600
$400
$200
$-
Electric Energy Cost ($0.07/kWh=current cost)
$0.07
$0.11
$0.15
Annual Utility Bill Savings


Payback Period of PV Investment in Colorado
(Displacing Utility Electricity)
Payback Period = # of Years for System to Pay for Itself
Plot Area
Years
30
25
20
15
10
5
0
Electric Energy Cost ($0.07/kWh=Current Cost)
$0.07
$0.11
$0.15
Simple Payback Period