Good Building Design

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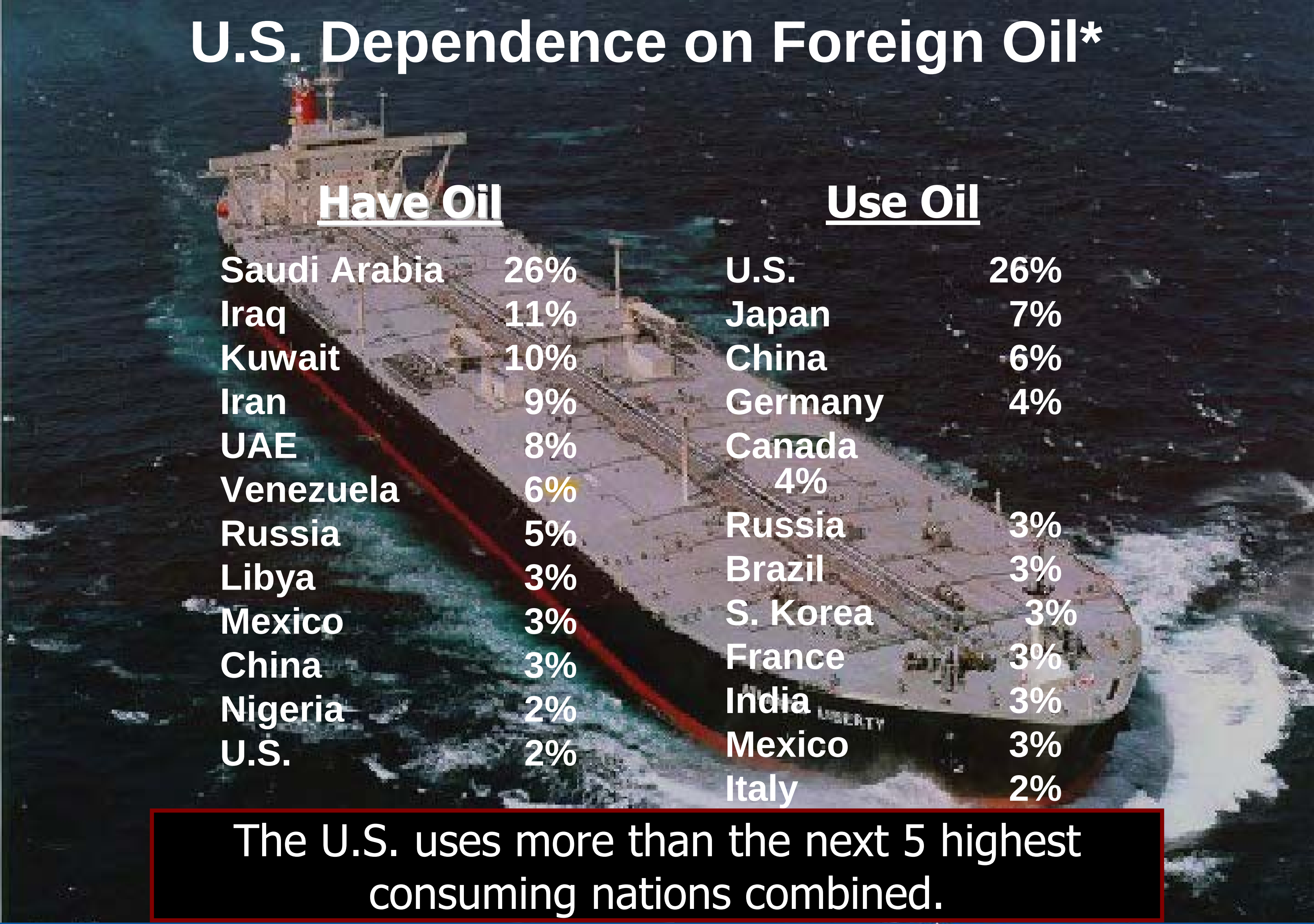


U.S. Dependence on Foreign Oil*

Have Oil		Use Oil	
Saudi Arabia	26%	U.S.	26%
Iraq	11%	Japan	7%
Kuwait	10%	China	6%
Iran	9%	Germany	4%
UAE	8%	Canada	4%
Venezuela	6%	Russia	3%
Russia	5%	Brazil	3%
Libya	3%	S. Korea	3%
Mexico	3%	France	3%
China	3%	India	3%
Nigeria	2%	Mexico	3%
U.S.	2%	Italy	2%

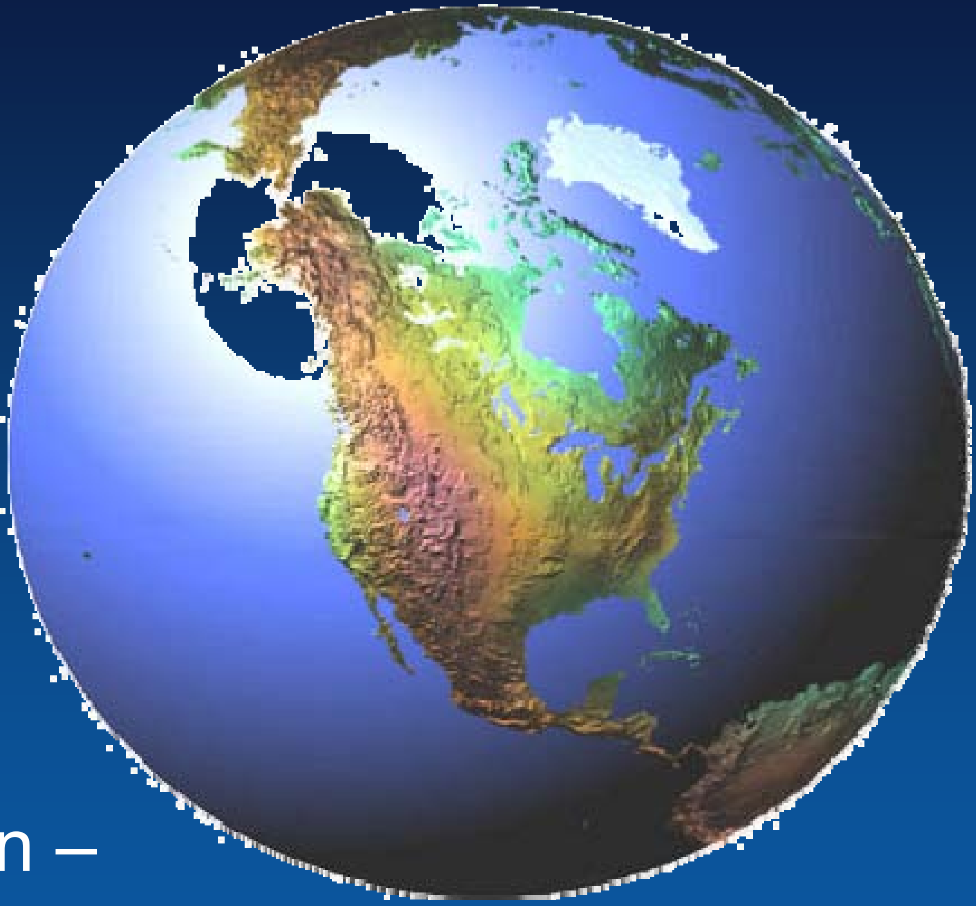
The U.S. uses more than the next 5 highest consuming nations combined.

* Updated March 2003. Source: International Energy Annual 2001 (EIA), Tables 11.4 and 11.10.

Humanity's Top Ten Problems

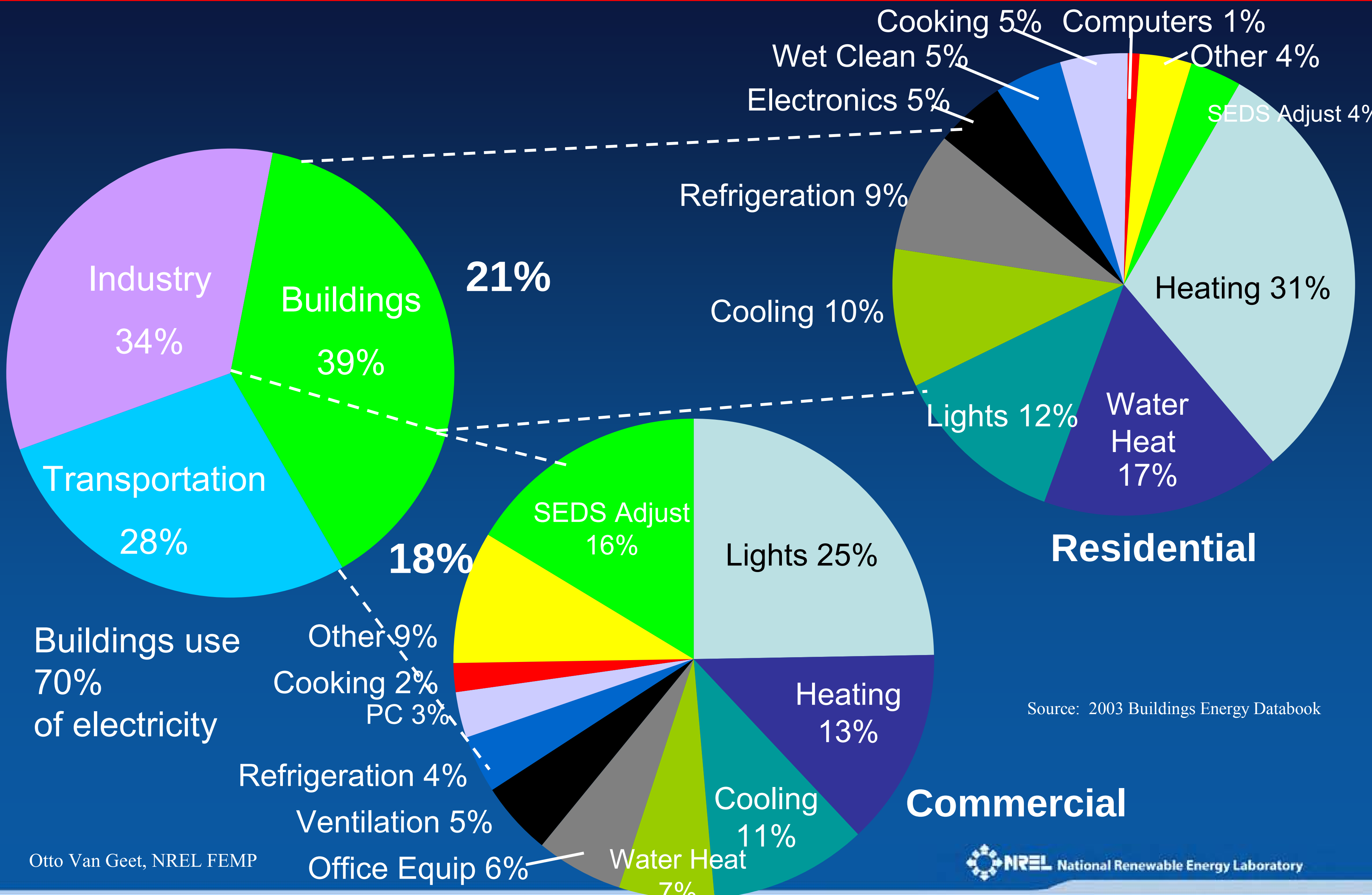
Robert Smally, Nobel Laureate

- Energy
- Water
- Food
- Environment
- Poverty
- Terrorism/War
- Disease
- Education
- Democracy
- Population (6.3 billion – 2003; 9-10 billion – 2050)



Don’t ever forget the bottom line – what we do matters!

Building Energy Use



Buildings use
70%
of electricity

Source: 2003 Buildings Energy Databook

Otto Van Geet, NREL FEMP

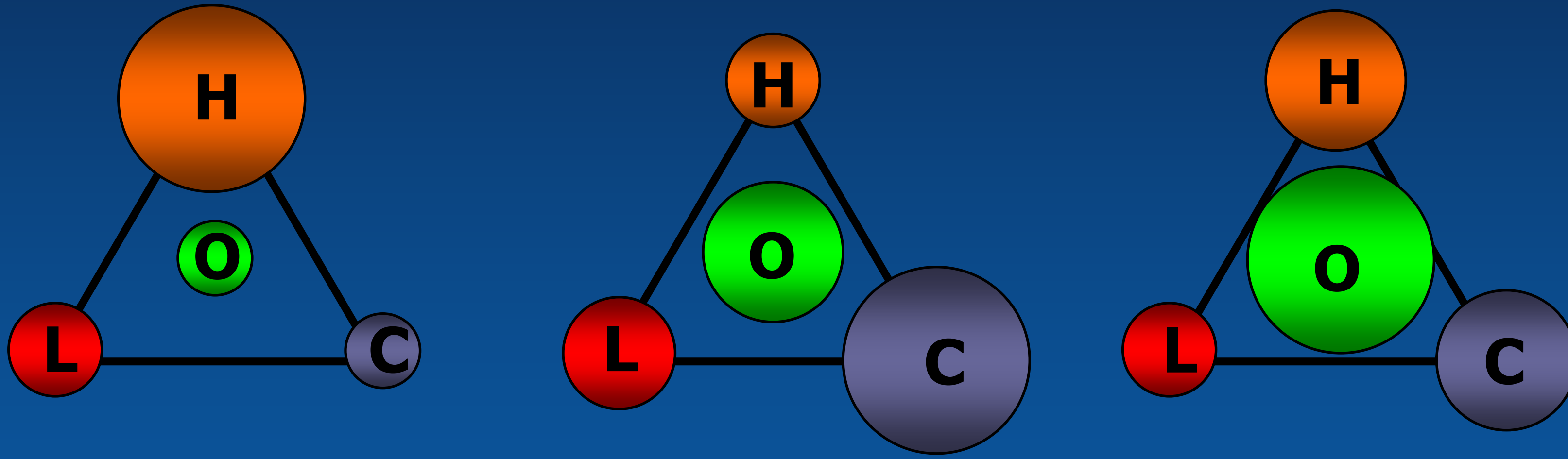
NREL National Renewable Energy Laboratory

Integrated Design Problem

Skin-Load Dominated (small building in a cold climate)

Internal-Load Dominated (large building in any climate)

Ventilation & Process-Load Dominated (any climate)



H = Heating load L = Lighting load C = Cooling load

O = Other, including ventilation & plug loads

Energy Efficiency then Renewables

- Every $ spent on efficiency saves at least as much as $2 spent on renewables
- Climate sensitive design (passive solar)
- Long axis of building faces south, south glass with overhangs, 7 – 12% glass area of building floor area
- Limit east, west and north glass

Vision

- Engineer ***whole-building systems*** that effectively integrate passive solar and efficiency strategies to optimize energy consumption such that minimal renewable energy sources can meet remaining needs.

A thought…

- Buildings mortgage the energy and environmental future of this country

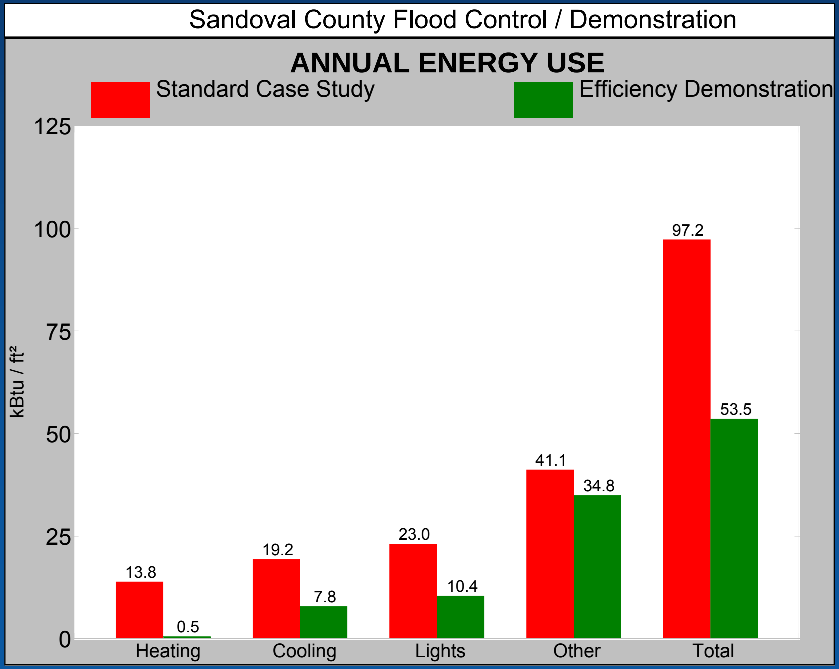
Design Considerations

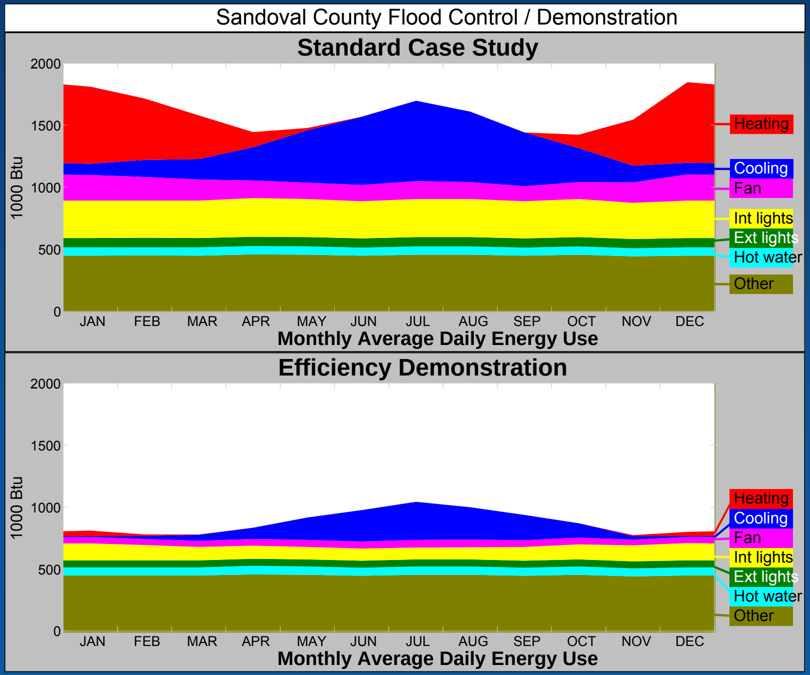
- Integrate energy efficiency and renewable energy early
- Use hourly energy simulations
- Architecture should work with the building’s energy needs
- Don’t sacrifice program
- Nine-step process created that integrates with the traditional design process

Gather data for Intelligent Decision Making…

Energy Modeling

- Considers building energy consumption during design phase to optimize energy use
- Several programs: eQuest, DOE2, Energy 10, etc.
- http://www.eere.energy.gov/buildings/highperformance/toolbox.html





LEED

LEADERSHIP IN ENERGY & ENVIRONMENTAL DESIGN

Leadership in Energy & Environmental Design

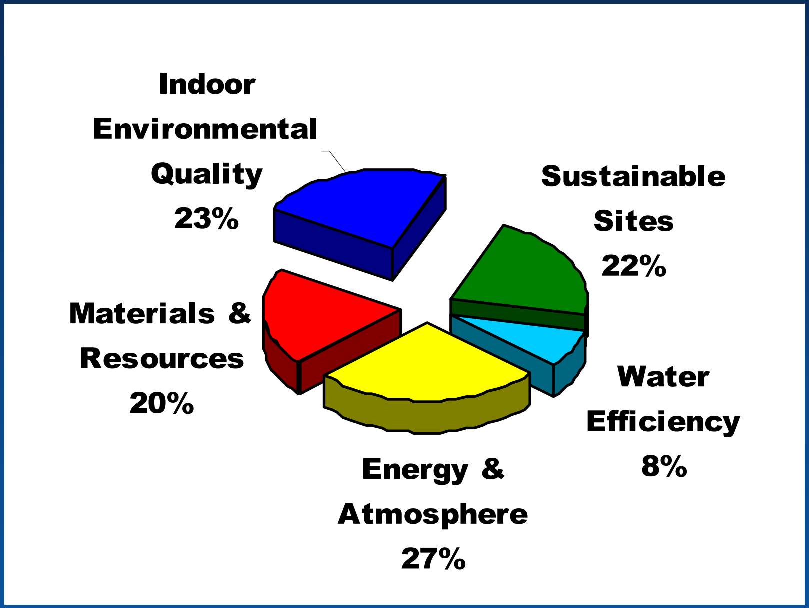
A leading-edge system for designing, constructing, and certifying the world's greenest buildings.

Provides a measure of success related to a national standard.

Similar to DOE program, Sustainable Building Council Guidelines and others

Be aware of LeED

- Energy performance

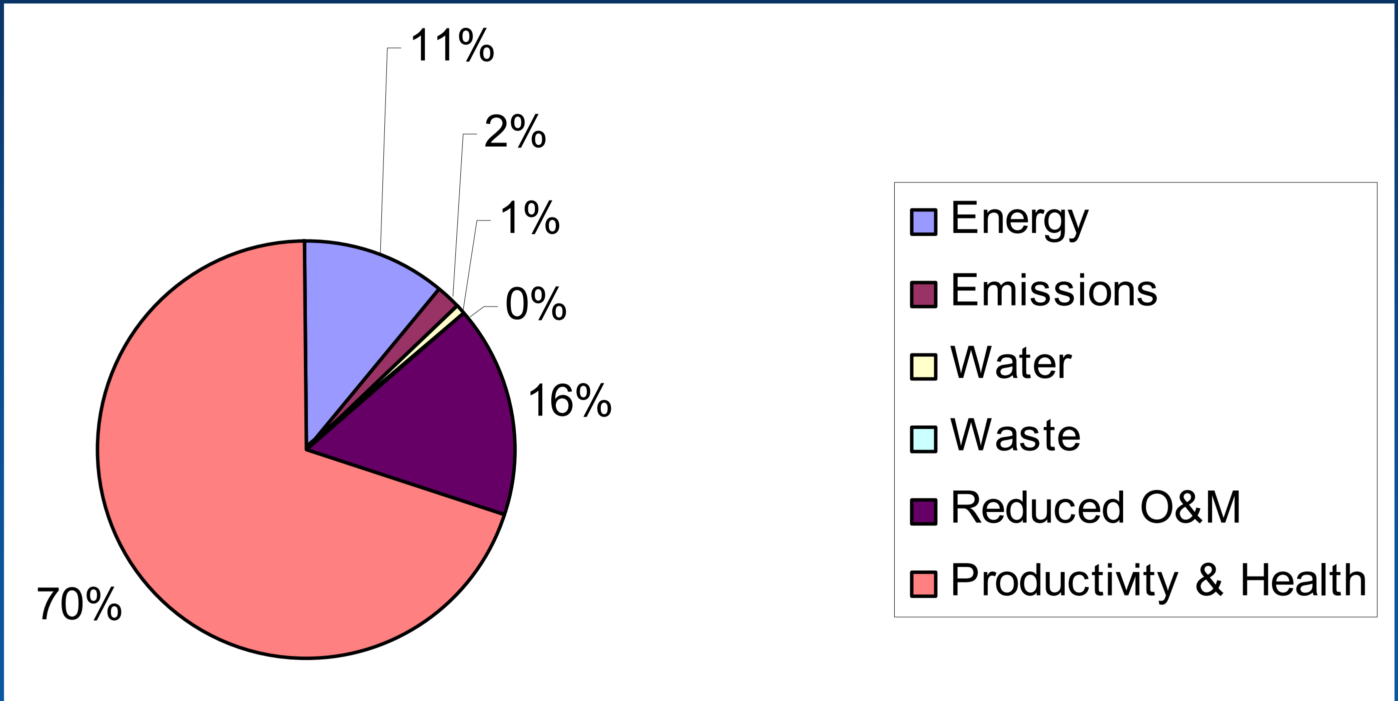


Values and "Cost-Effective"

- What is cost-effective?

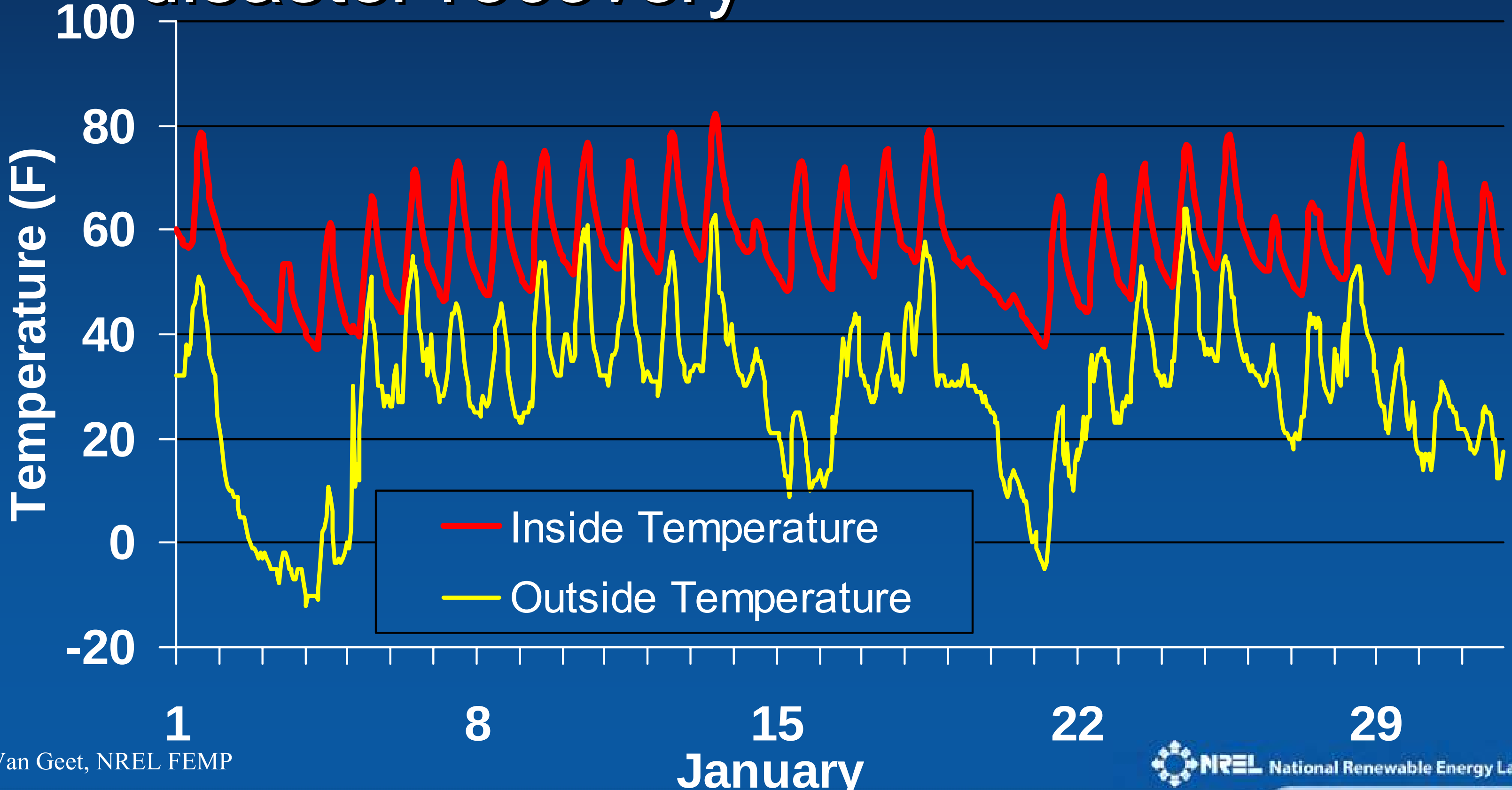
- Economic
- Operational reliability and power stability
- Higher user satisfaction and lower HR costs
- Environmental Impact
- Integrated the energy efficiency and architecture

On average, over a 30-year lifespan of a building, only 2% overall investment goes towards construction.



Values and "Cost-Effective"

- Risk management and disaster recovery



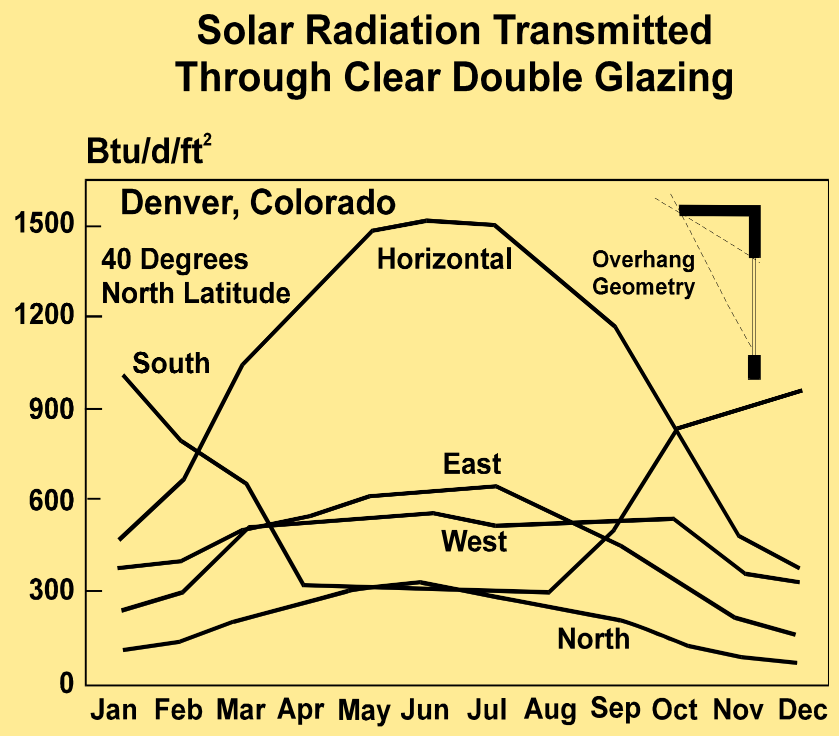
Nine-Step Design Process

ASHRAE Journal, December 1999

Pre-Design	Design	Construction & Commissioning
1. Simulate a base-case building model and establish goals	5. Architectural team prepares preliminary drawings	8. Rerun simulations before construction design changes
2. Complete parametric analysis	6. Design the HVAC system	9. Commission all equipment and controls. Educate building operator
3. Design team brainstorms solutions	7. Finalize plans and specifications	
4. Perform simulations based on base-case variants		

Glazing Orientation is Important

South glazing is uniquely capable of providing heat in winter and blocking heat gain in summer

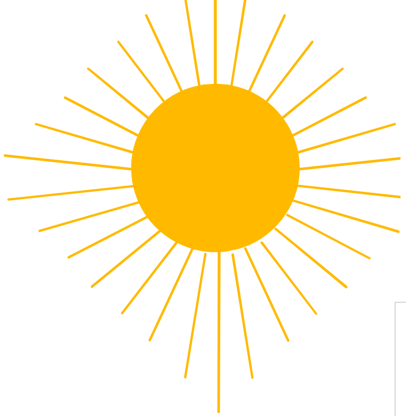


Source: Balcomb, J. D. (1994). *Integrated Design.*

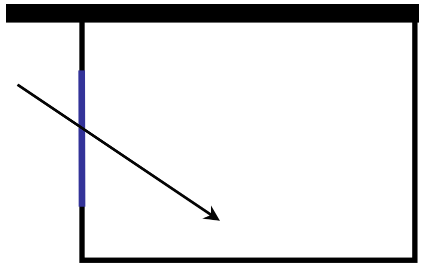
Glazing Considerations

- Climate
- Application
- Orientation
- Technology

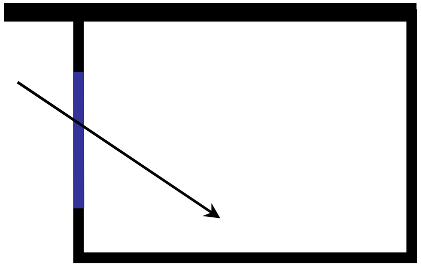
- Insulative Properties
  - Heat flow due to temperature difference (U-value)
- Solar Heat Gain Coeff.
  - Fraction of solar radiation that enters a building thru the window as heat gain
- Visible Transmittance
  - Fraction of total light transmitted in the visible portion of solar spectrum
- Visual Reflectivity
- National Fenestration Rating Council (NFRC)
- http://www.nfrc.org/



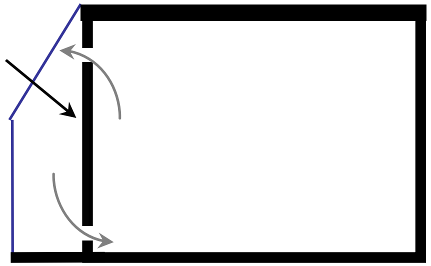
Passive Solar Strategies



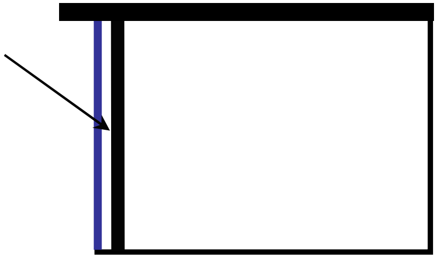
Sun tempered



Direct Gain

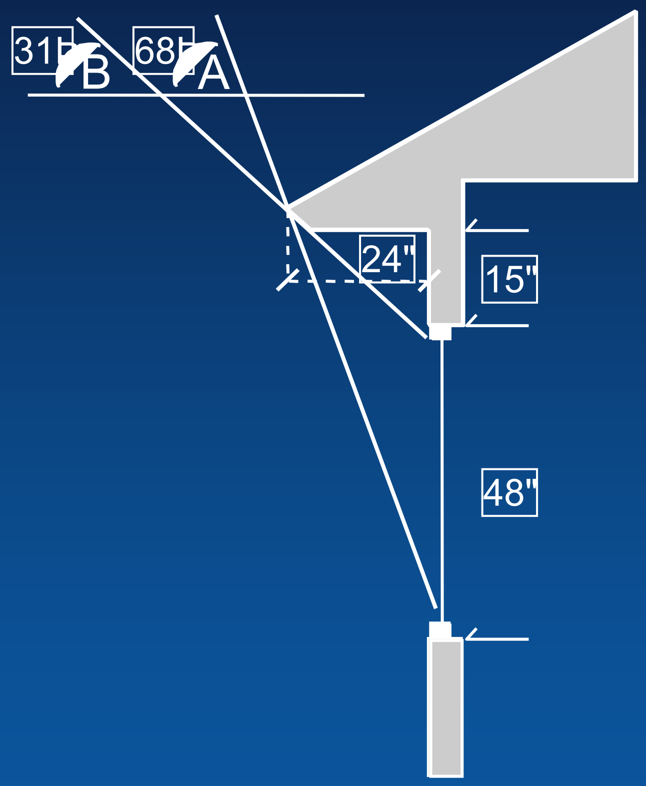


Sunspace



Thermal Storage Wall

Shading Geometry

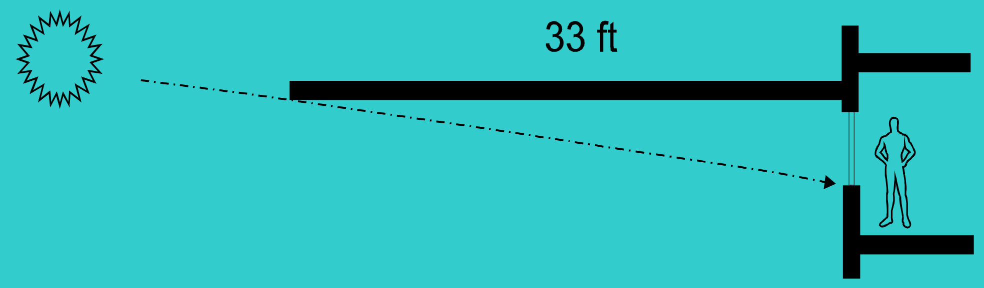


A. 68º angle with horizon fully shades the window in the summer (76.6º = sun's altitude @ 40º N latitude on June 21)

B. 31º angle with horizon allows full exposure of the window in winter (26.6º = sun's altitude @ 40º N latitude on Dec. 21)

Shading Orientation

- South facades
  - Simple overhangs
- North facades
  - No shading
- East & west facades
  - Minimize windows
  - Vertical fins
  - Awnings



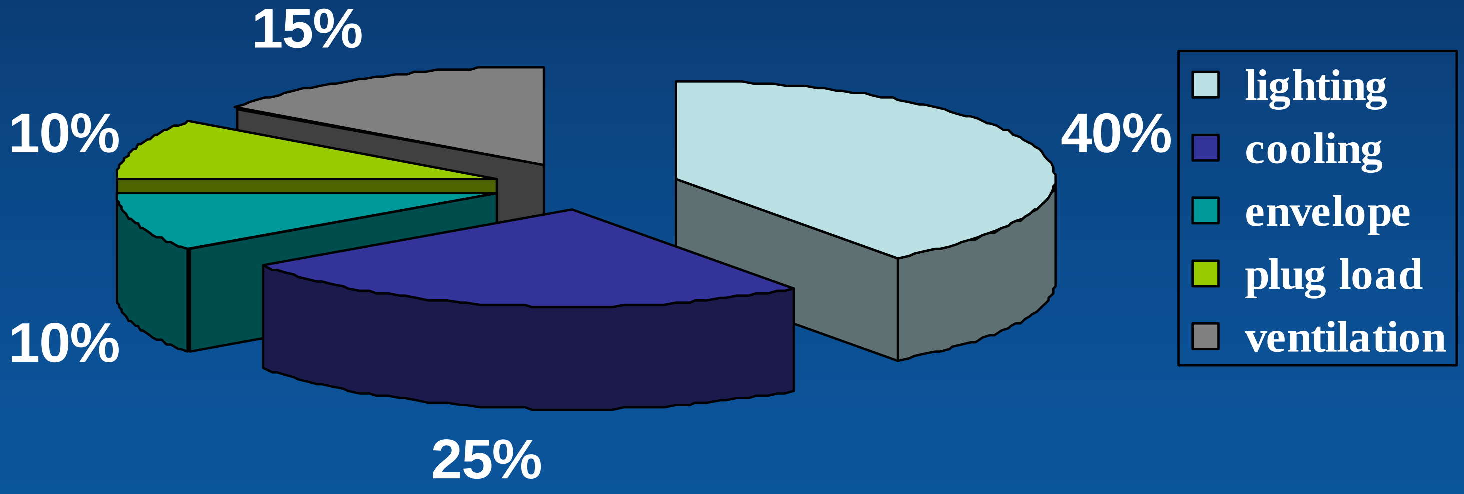
The 33-ft overhang needed to shade a 4-ft window on August 21 at 6 p.m. at 36° north latitude illustrates the futility of trying to fully shade east and west windows with horizontal overhangs.

Daylighting & Efficient Lighting

Otto Van Geet, NREL FEMP

Lighting Energy Consumption

In a typical commercial office building, lighting can be the largest energy load.

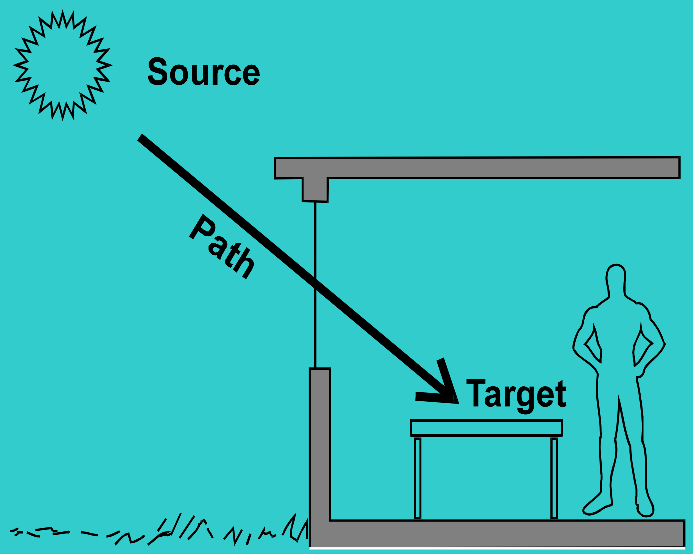


What is daylighting?

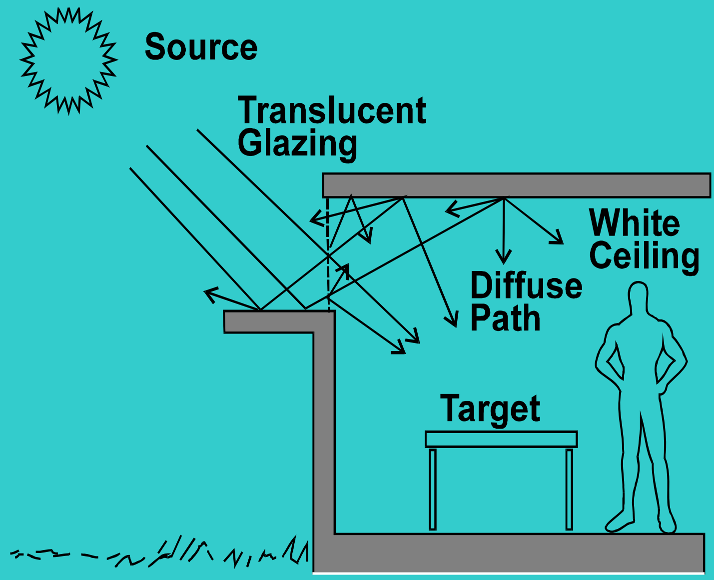
- Daylighting is the <u>controlled</u> admission of natural light into a building with artificial light fixtures dimmed or turned-off to save energy
- A well daylit space has relatively even brightness and reduced contrast ratios
- More windows do not make better daylighting

Otto Van Geet, NREL FEMP

Principles of Daylighting

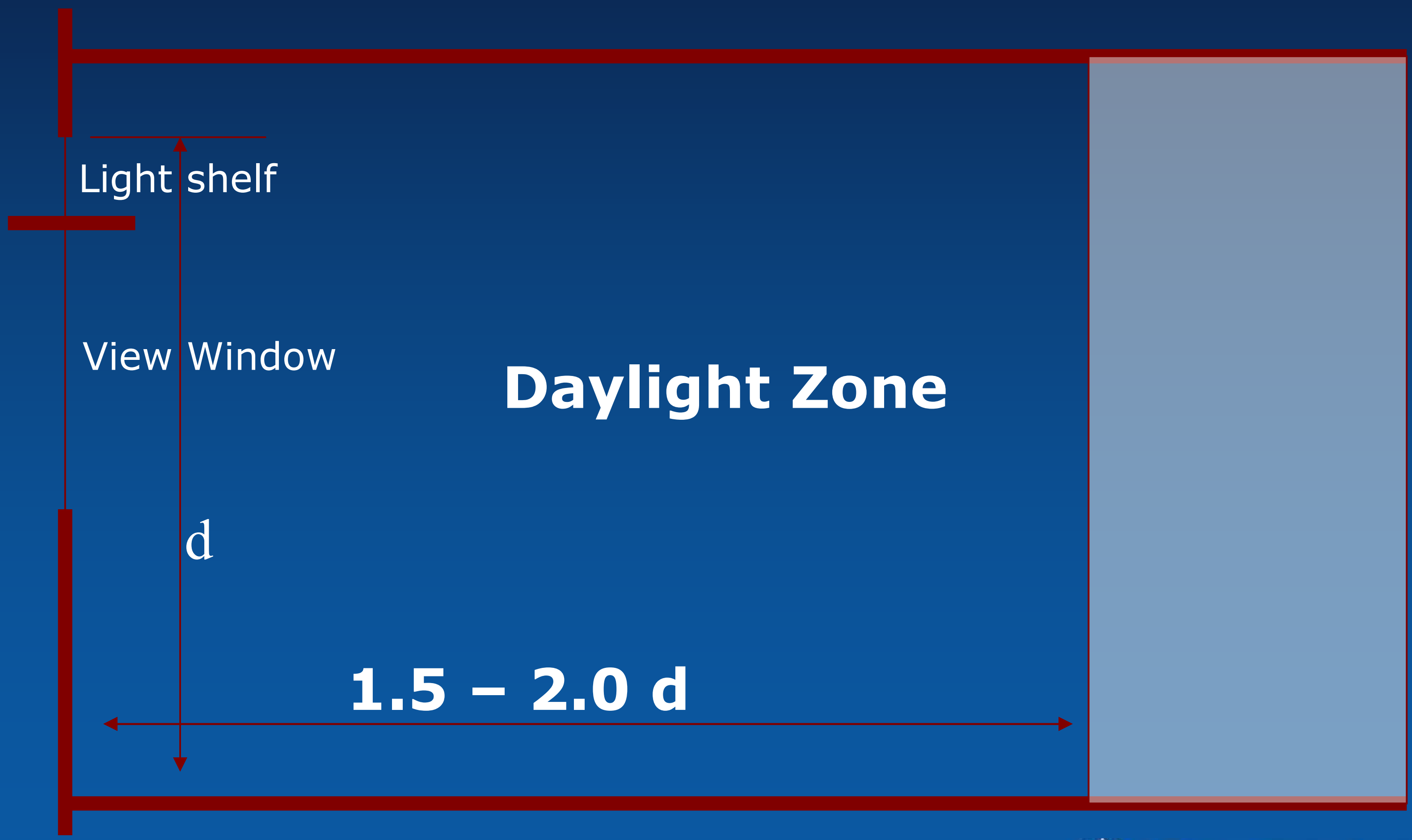


Direct sunlight is a potential source of glare and excess contrast.



Light shelves and other diffusing surfaces create more even illumination.

How far can you throw daylight?



Lighting Integration

Integration is the key to success!

- Natural & artificial light sources
- General ambient lighting & dedicated task illumination
- Lighting equipment & controls
- Schedules & energy management control system
- Commissioning for installation & operation
- Training for occupants & maintenance personnel

Daylighting Design

- Good access to south and north light; minimal east and west light
- Minimize direct beam sunlight on the task
- Reduce window glare and excess contrast ratios in the field of view
- Integrate with electric lighting through luminous controls to achieve energy savings
- Assure excess solar heat gain through windows is controlled

Otto Van Geet, NREL FEMP

Good daylighting …

Case Studies

Passive Solar Design

West side

East side

South side

Inside

Carlisle\Prythero residence, Lakewood,CO

Tierra Concrete Homes

Van Geet Residence

90% savings (modeled)

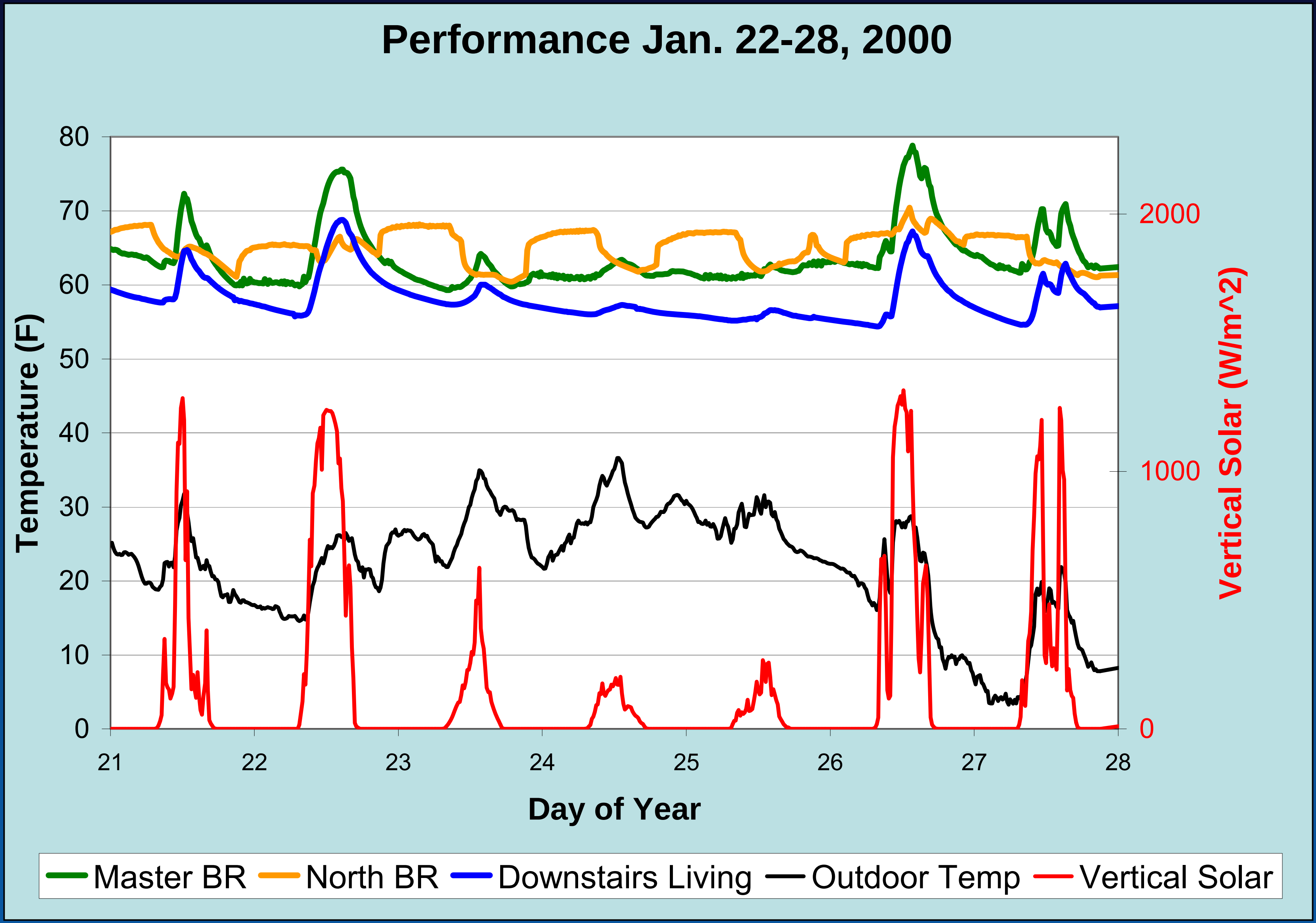
- 9300 ft
- 9600 HDD
- 0 CDD
- 3000 sqft.
- 4 bedroom; 3 bath
- 1.0 mile to power grid
- ASHRAE 2001 1st Place Technology Award winner
- Winner of CRES Housing Award

- Determined by simulation
- South and East: U=0.31; SC=0.75; SHGC=0.64
- All others: U=0.30; SC=0.47;SHGC=0.41
- 151 sq. ft. south glass, 12% glass to floor area
- Trombe wall integrated with view glass

Trombe Walls

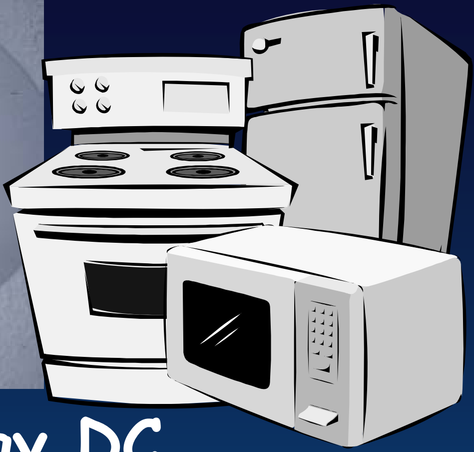
- Reach temperatures of 100°F inside house
- Cavity temperatures reach 160°F
- Provide delayed heating (6-8 hour delay)
- Double clear for Trombe walls, 144 sq. ft.
- Selective surface
- 16.5% glass and Trombe to house, 14% if garage included

Otto Van Geet, NREL FEMP



Performance Jan. 22-28, 2000
80
70
60
50
40
30
20
10
0
Temperature (F)
2000
1000
0
Vertical Solar (W/m^2)
21
22
23
24
25
26
27
28
Day of Year
Master BR
North BR
Downstairs Living
Outdoor Temp
Vertical Solar

Energy Efficient Appliances



- Low energy DC refrigerator (500 Wh/day-80% savings)
- Compact fluorescent fixtures or better (T-8)
- Switches to manage parasitic or phantom loads
- Energy Star appliances
- Horizontal Axis cloth Washers (1/2 energy, water, and soap)

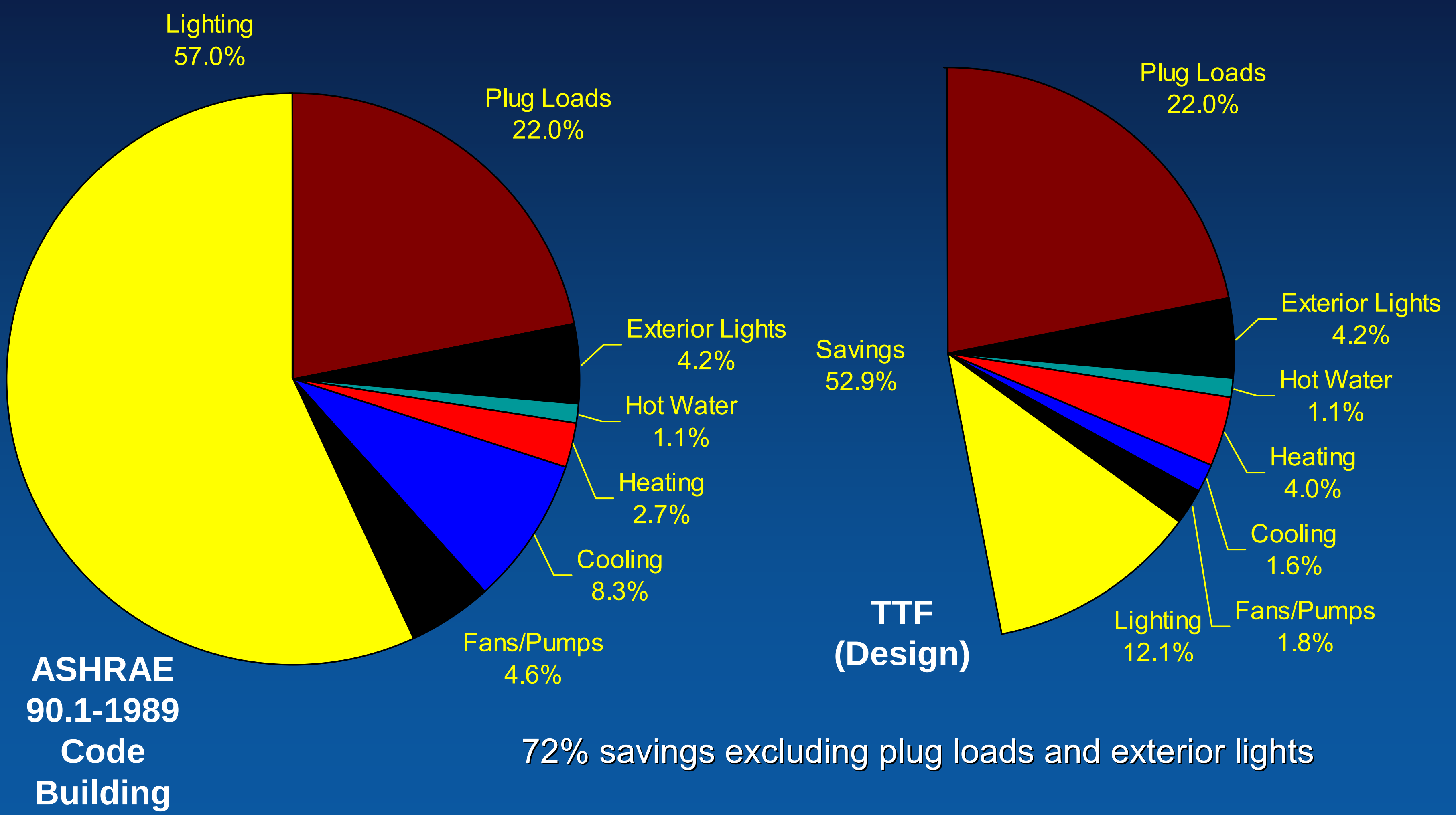
Van Geet Summary

- Less cost to build (wrt running utility line)
- 77% reduction from MEC1995 house as designed, 89% reduction as operated
- 87% of electricity from PV
- $200 average fuel (256 gallons propane average)

TTF (Thermal Test Facility)

- Completed in 1996 at a cost of $1 million dollars
- 10,000 sqft of laboratory and office space
- Building research laboratory
- Serves as a technological development and optimization testbed

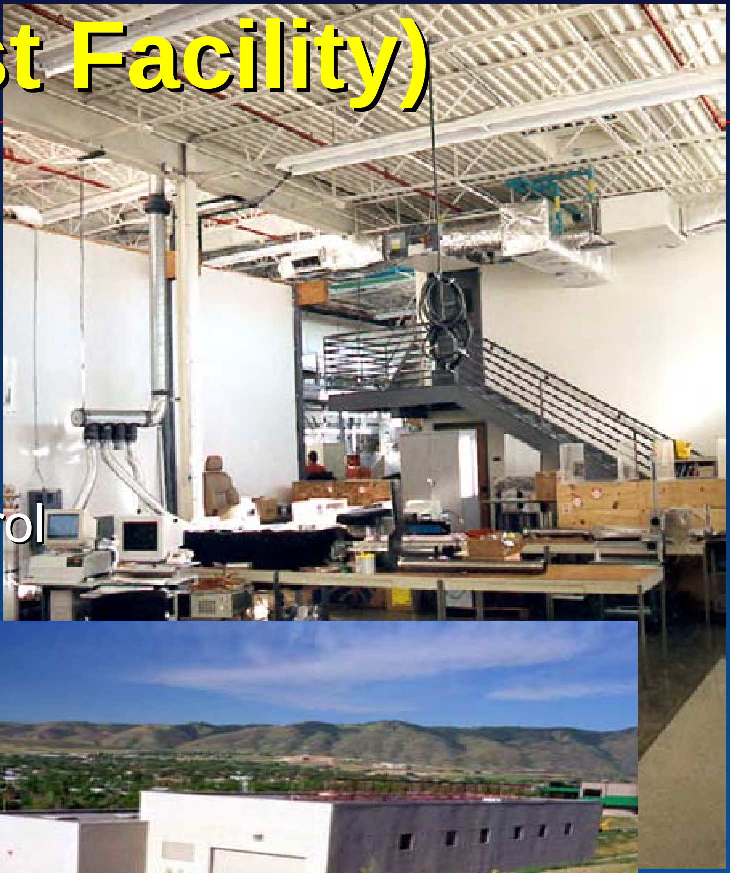
TTF Energy Costs and Savings



72% savings excluding plug loads and exterior lights

TTF (Thermal Test Facility)

- Energy Features
  - Daylighting (75%)
  - Direct/indirect evaporative cooling
  - Possibility of active solar hot water
  - Managed solar gains (overhangs)
  - High efficacy lighting with lighting control
  - Energy management system
  - Ceiling fans
  - Separate ventilation system
  - Passive solar gain with good thermal envelope
- 63% energy cost savings



Philip Merrill Environmental Center

- 4 kW PV
- LEED Platinum (V.1)
- 19% Energy Savings below ASHRAE 90.1-1999
- 27% Energy Cost Savings

Use of native landscaping further reduces water consumption.

Philip Merrill Environmental Center

- 31,200 ft^2 Office Building
- Owner – Chesapeake Bay Foundation
- Architect – SmithGroup
- Energy Consultant – SmithGroup
- LEED 1.0 Platinum Certified
- Annapolis, MD
- HDD [65^oF] – 4911
- CDD [65^oF] – 1134

Philip Merrill Environmental Center (Chesapeake Bay Foundation)

The center's toilets are non-flushing units that recycle waste and reduce the amount of water needed.

CBF Energy Efficient Features

- Well insulated envelope
- Ground-source heat pumps with desiccant wheel
- Natural ventilation
- Daylighting / Lighting system
- PV system
- Solar thermal water system
- Building energy management system

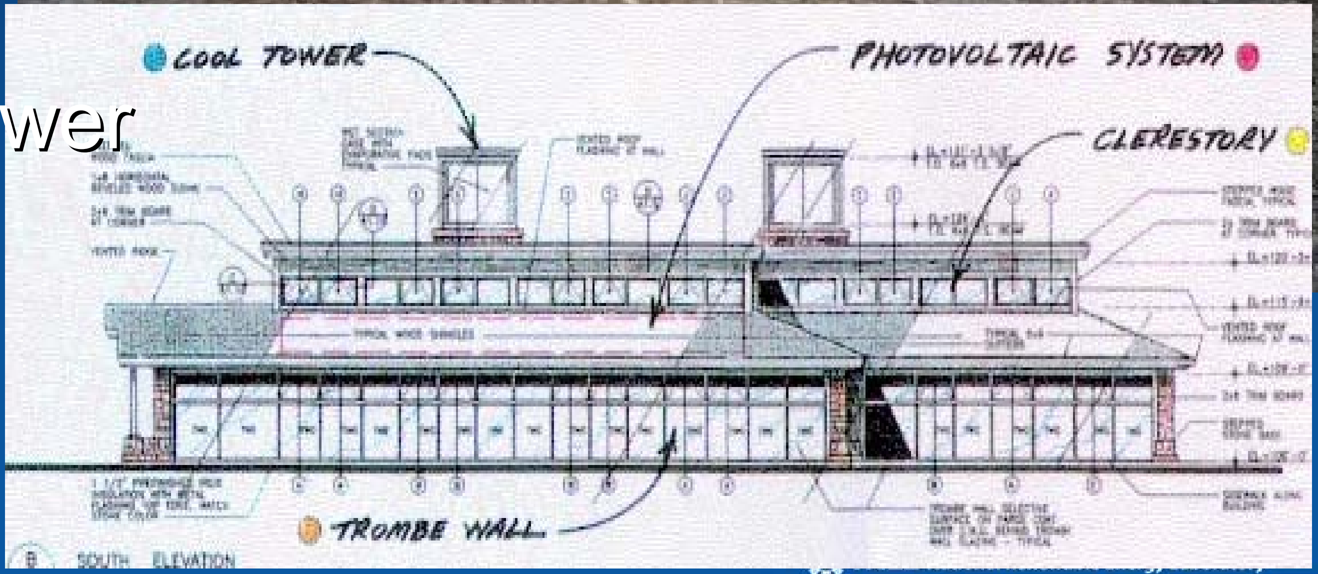
- 0.8 gal/day/person well water use

Zion National Park Visitor Center

Otto Van Geet, NREL FEMP

Zion National Park Visitor Center

- 70% energy cost savings *and* 30% capital cost reduction
- 10% PV power



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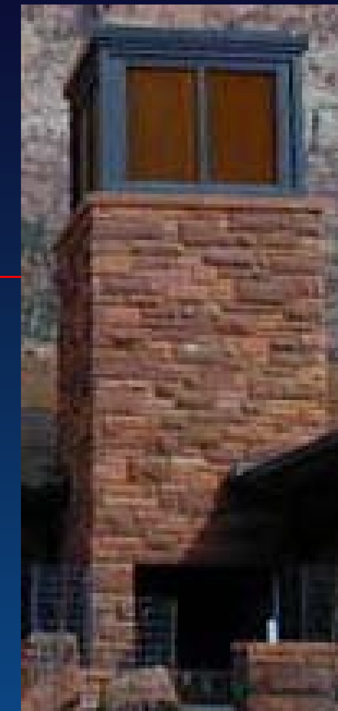
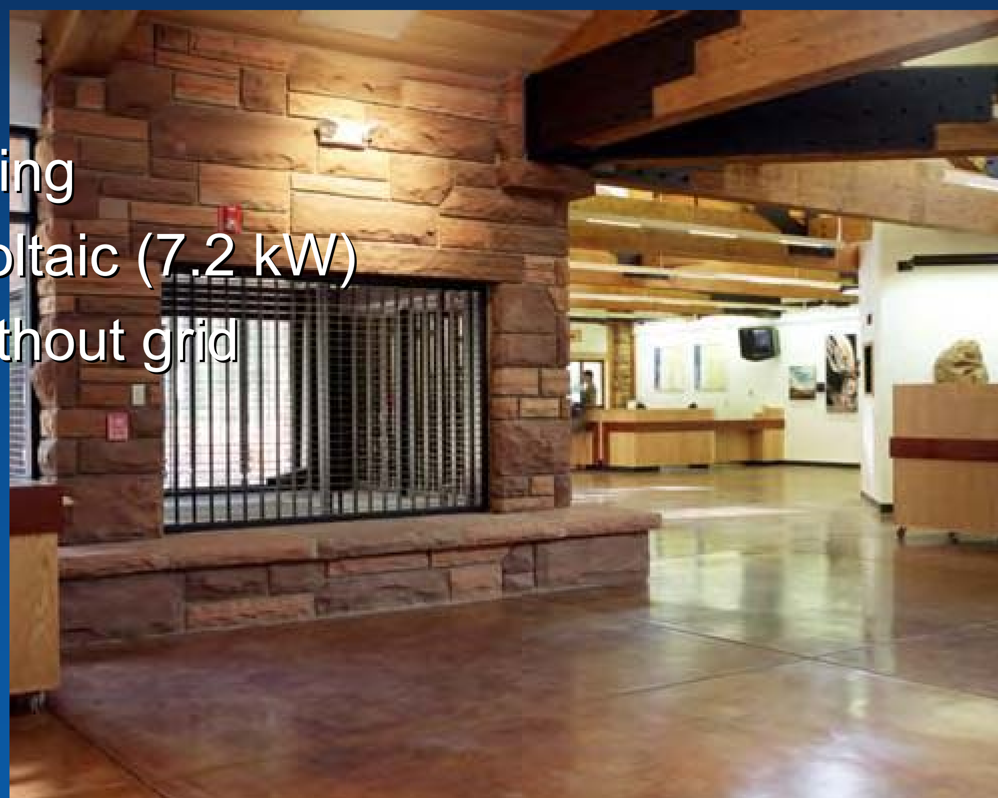
Zion Energy Features



- – Daylighting
- – Downdraft evaporative cooling
- – Trombe wall
- – Radiant heating
- – Roof photovoltaic (7.2 kW)
- – Operation without grid power



Solar Energy Technologies Program & FEMP Technical Assistance

Pinnacles National Monument (California)

- Remote PV-hybrid system
  - 9.6 kW PV with 20 kW propane backup generator provided an elegant solution for electricity in sensitive area (installed 1996)
  - LCC analysis: system costs $83k less than 2 replacement propane generators over 20-years
- **New GMP Project:** move facilities above flood plain
  - Sizing off-grid hybrid system
  - New efficient building design

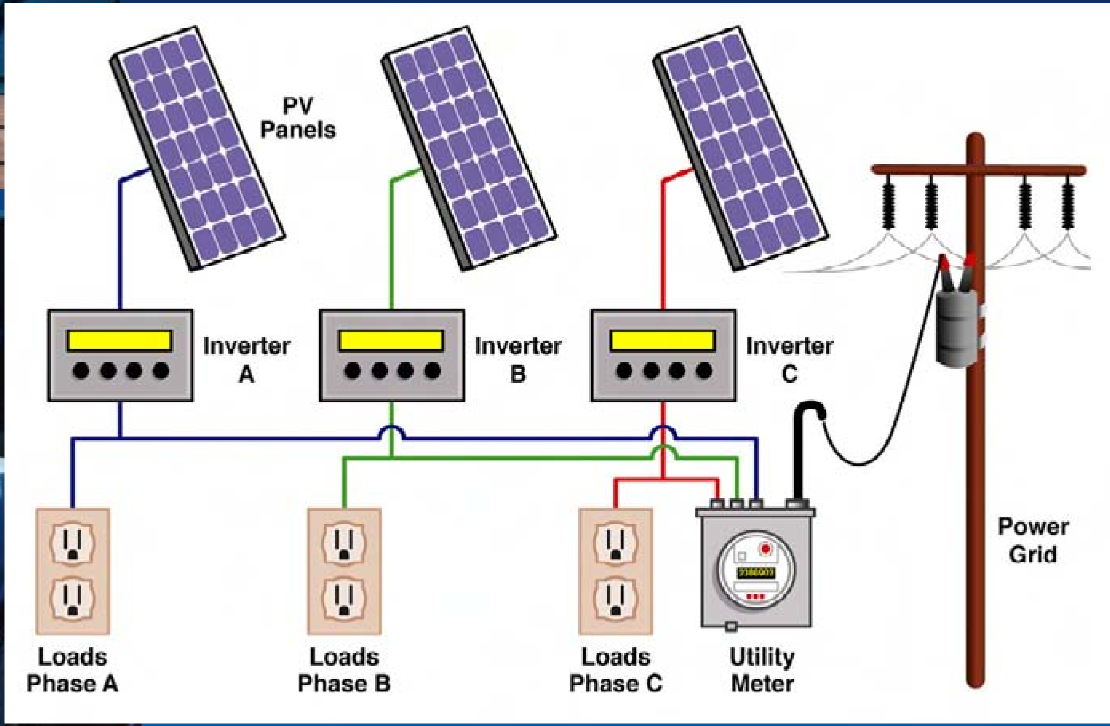
"The PV system … costs a fraction of what we used to pay each month to operate and maintain the diesel generators it replaces." —Gary Candelaria, former Pinnacles Superintendent

Renewable Energy at Pinnacles National Monument

BigHorn Center

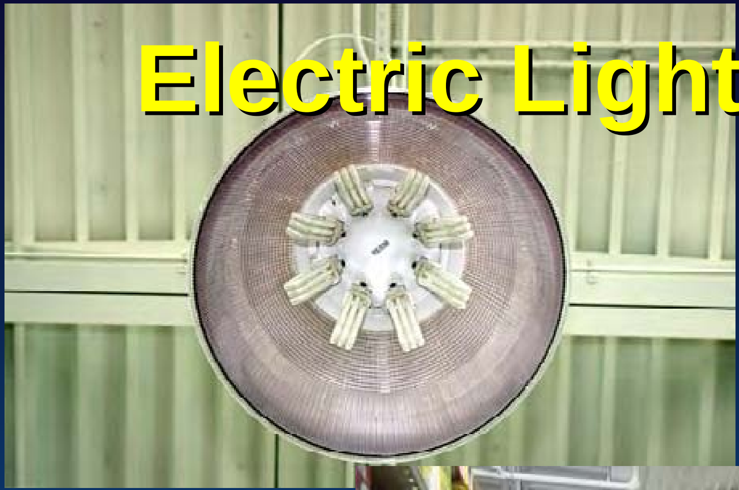
62% savings projected

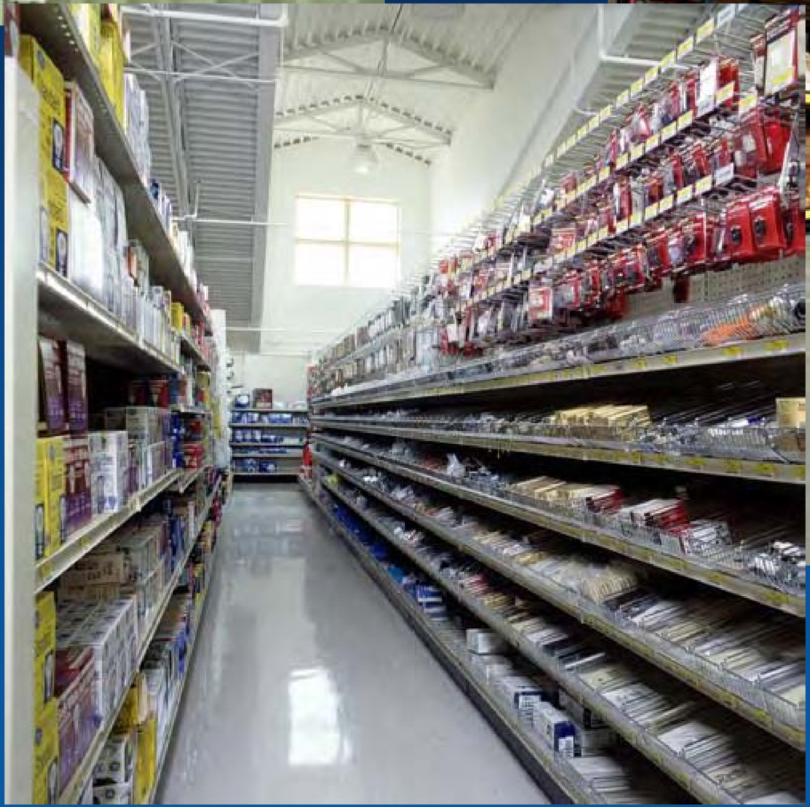
BigHorn Center (BIPV)



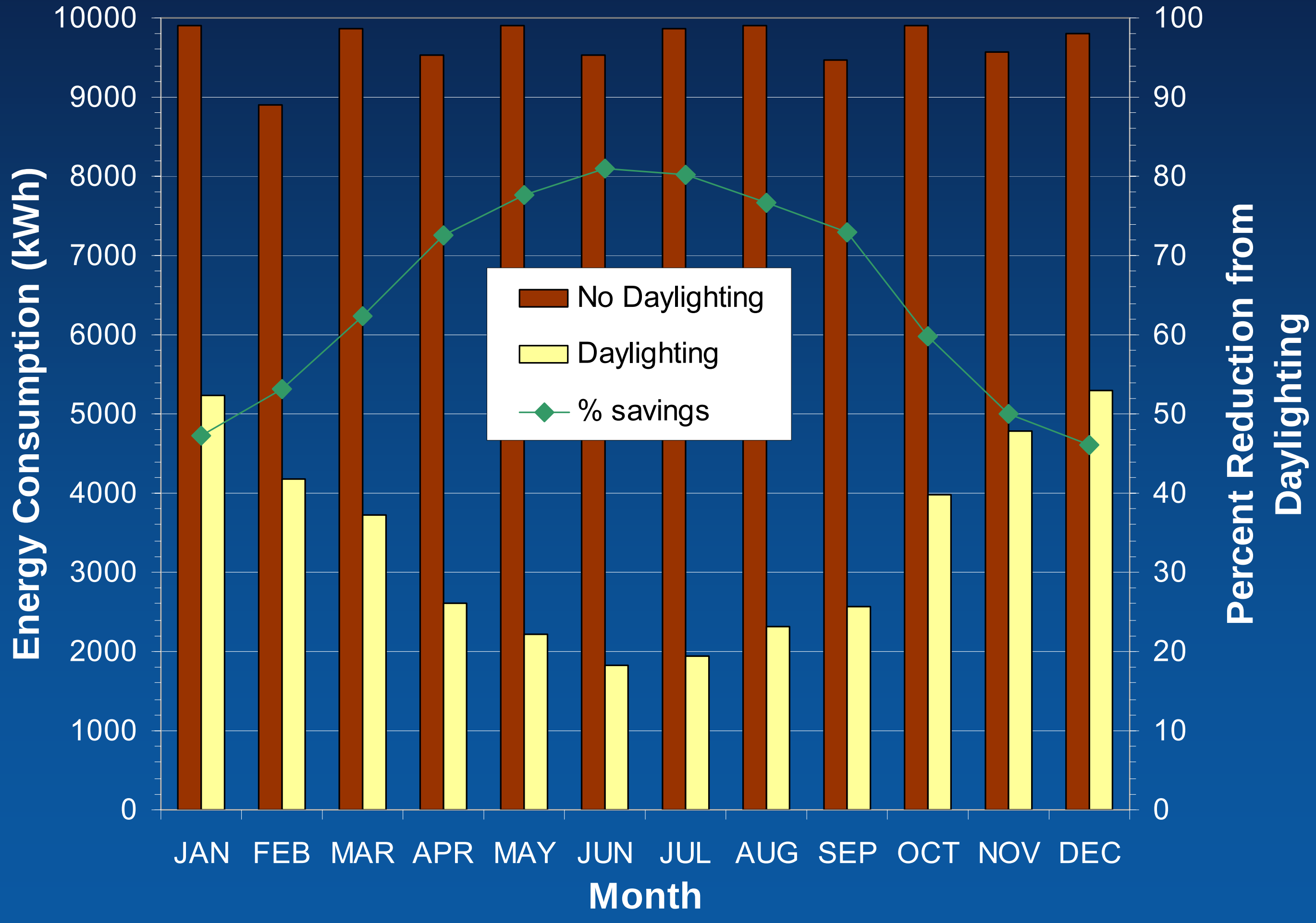
Daylighting

Electric Lighting and Daylighting

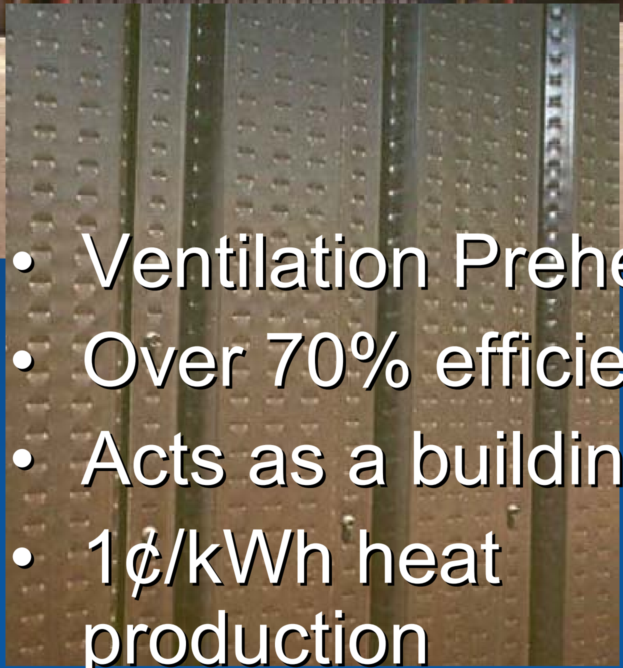




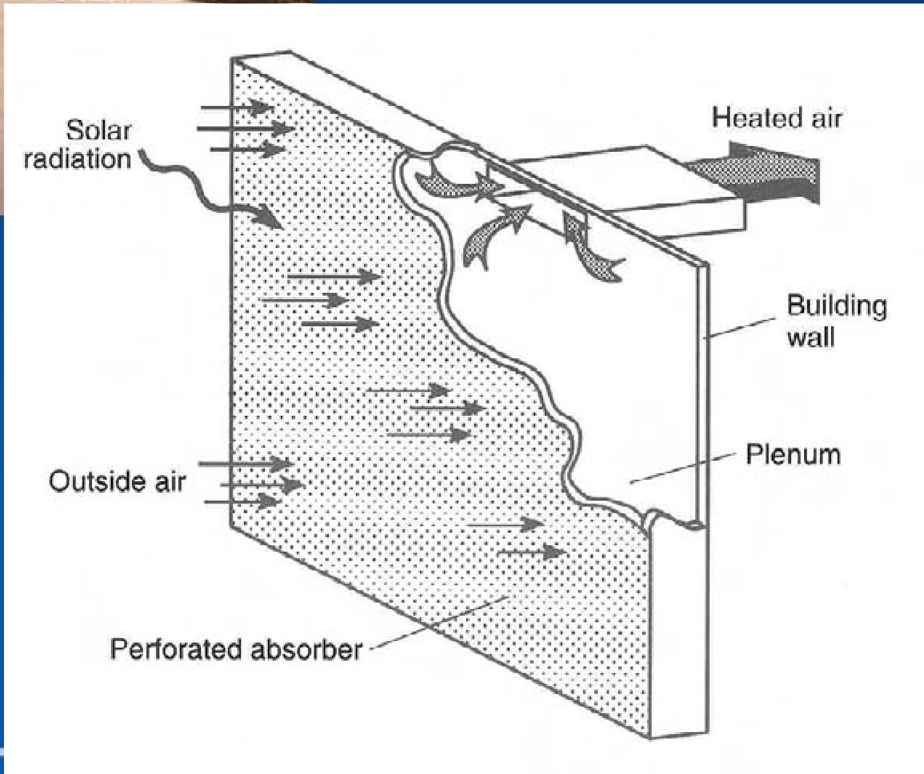
Daylighting System Expected Performance



Transpired Solar Collector



- Ventilation Preheat
- Over 70% efficient
- Acts as a building skin
- 1¢/kWh heat production



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Some Resources

- www.buildinggreen.com
- www.usgbc.org (LEED ratings)
- www.highperformancebuildings.gov
- www.aceee.org
- www.nrel.gov/data/pix
- http://www.eere.energy.gov/femp/

What to look for...

- General Rules for Buildings
- Long axis of building faces south
- Minimal **East and West** Windows
  - Should have low SHGC (<0.40)
- Maximize **South** Glazing with high glass for daylighting
  - Design overhangs to shade surfaces in summer
  - Use high SHGC (>0.60)
- Use **North** glass for daylighting and view glass
  - SHGC does not have big energy impact
- Motion and Daylight Sensors to harvest daylighting

What to look for… part II

- Good Insulation Packages
- Energy Star Appliances
- No incandescent lights
- Effective Energy Design
- HVAC sized for the building, type appropriate for climate (Evap cooling in SW, etc)
- Low-Energy is in the Building, not the HVAC system.
- Pay for added building costs with reduced HVAC.
- Use simulations to design building.

What to look for… and how to accomplish

- Low Maintenance design (Stucco, Masonry, clad windows, metal roof, etc.)
- Low water use design
- WHO ELSE IN YOUR TRIBE OR COMMUNITY CAN HELP?
- Who can provide required goods and services?
- How will project be funded?
- Sketch a project time line.

Discussion & Questions

Which of these strategies would you consider for your next building?