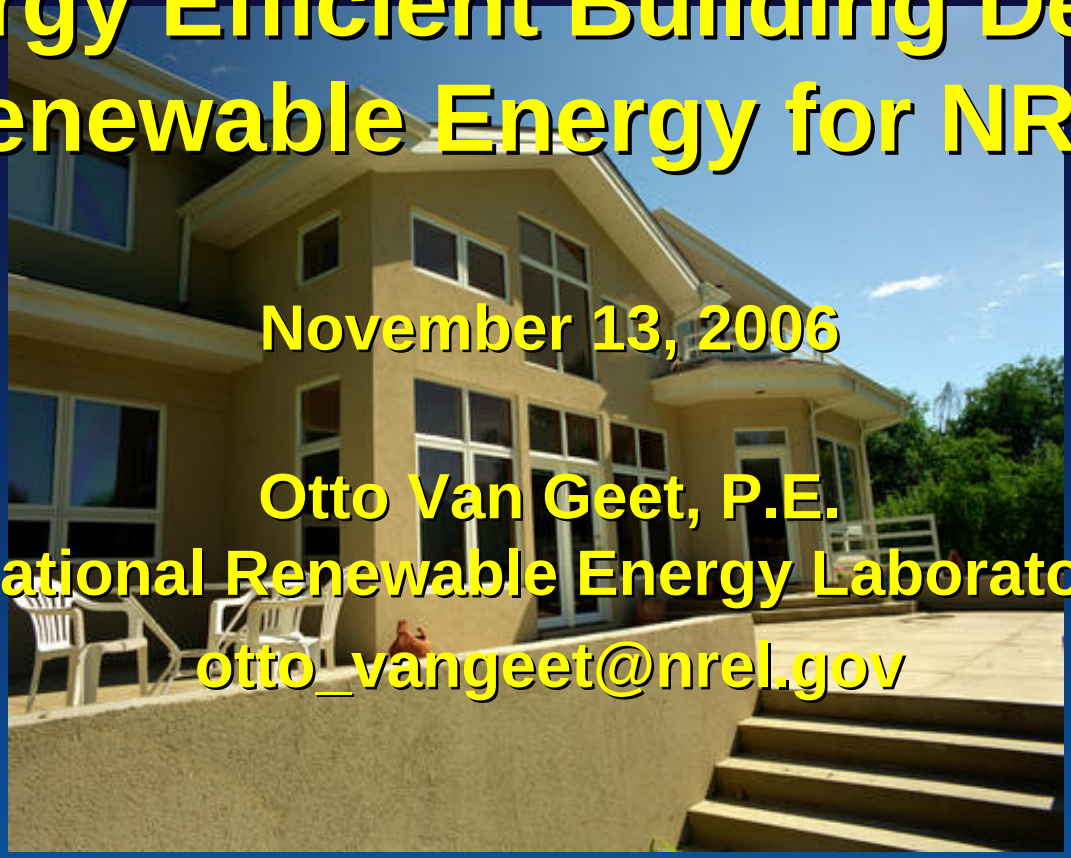
Energy Efficient Building Design Renewable Energy for NREL



November 13, 2006

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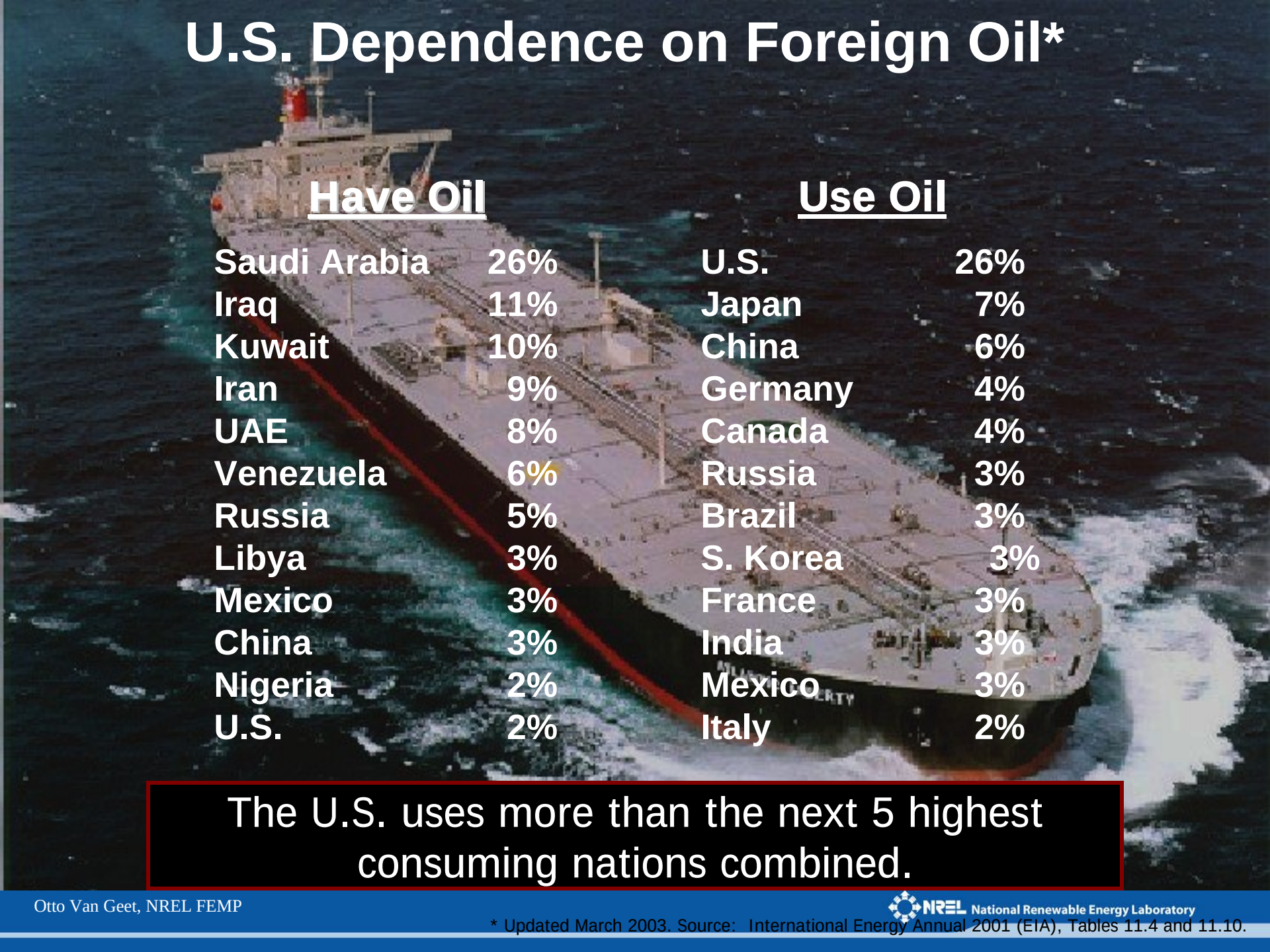
U.S. Dependence on Foreign Oil*



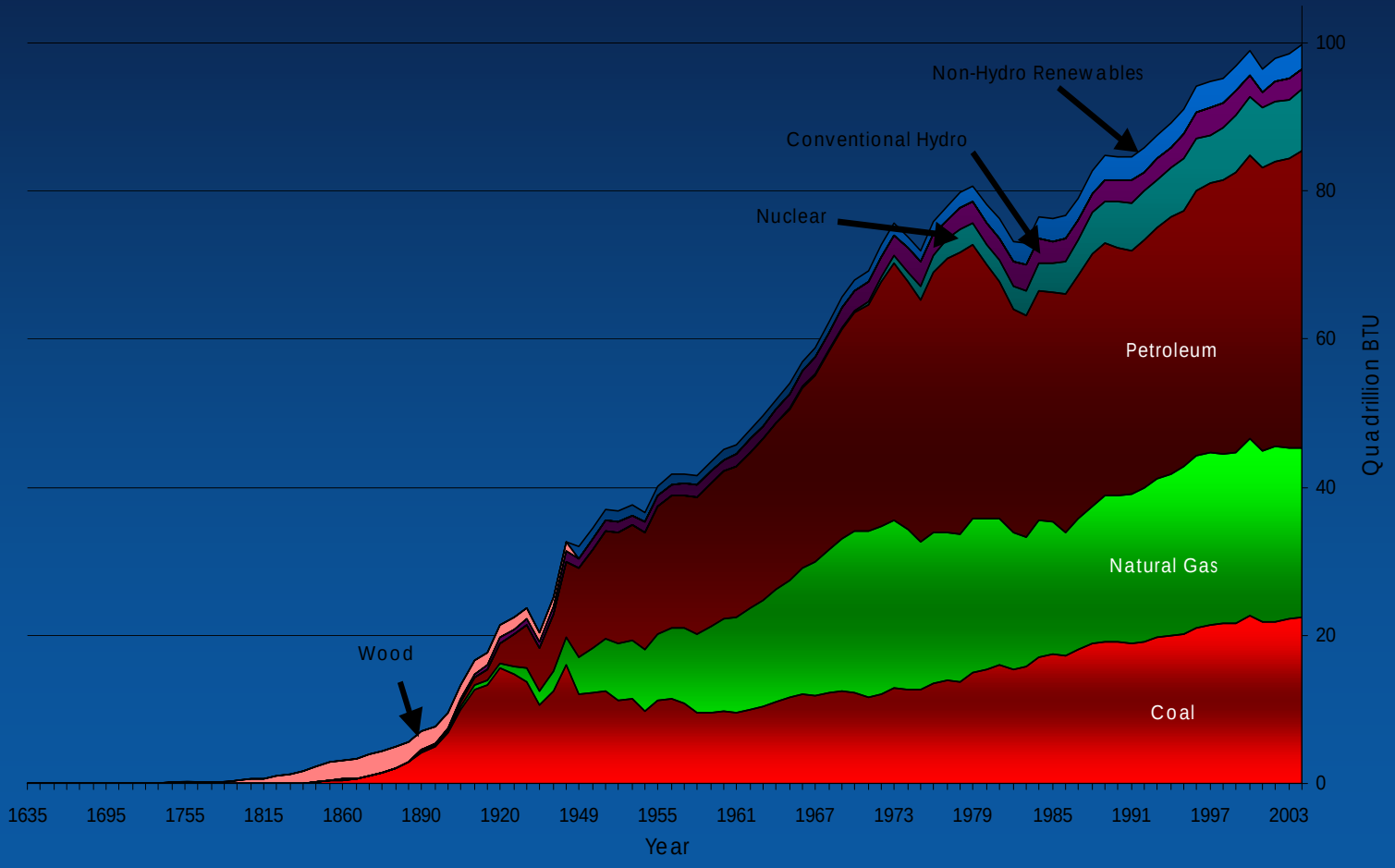
Have Oil		Use Oil	
Saudi Arabia	26%	U.S.	26%
Iraq	11%	Japan	7%
Kuwait	10%	China	6%
Iran	9%	Germany	4%
UAE	8%	Canada	4%
Venezuela	6%	Russia	3%
Russia	5%	Brazil	3%
Libya	3%	S. Korea	3%
Mexico	3%	France	3%
China	3%	India	3%
Nigeria	2%	Mexico	3%
U.S.	2%	Italy	2%

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.

Trends in U.S. Energy Use

U.S. Energy Consumption by Source:
1635-2004

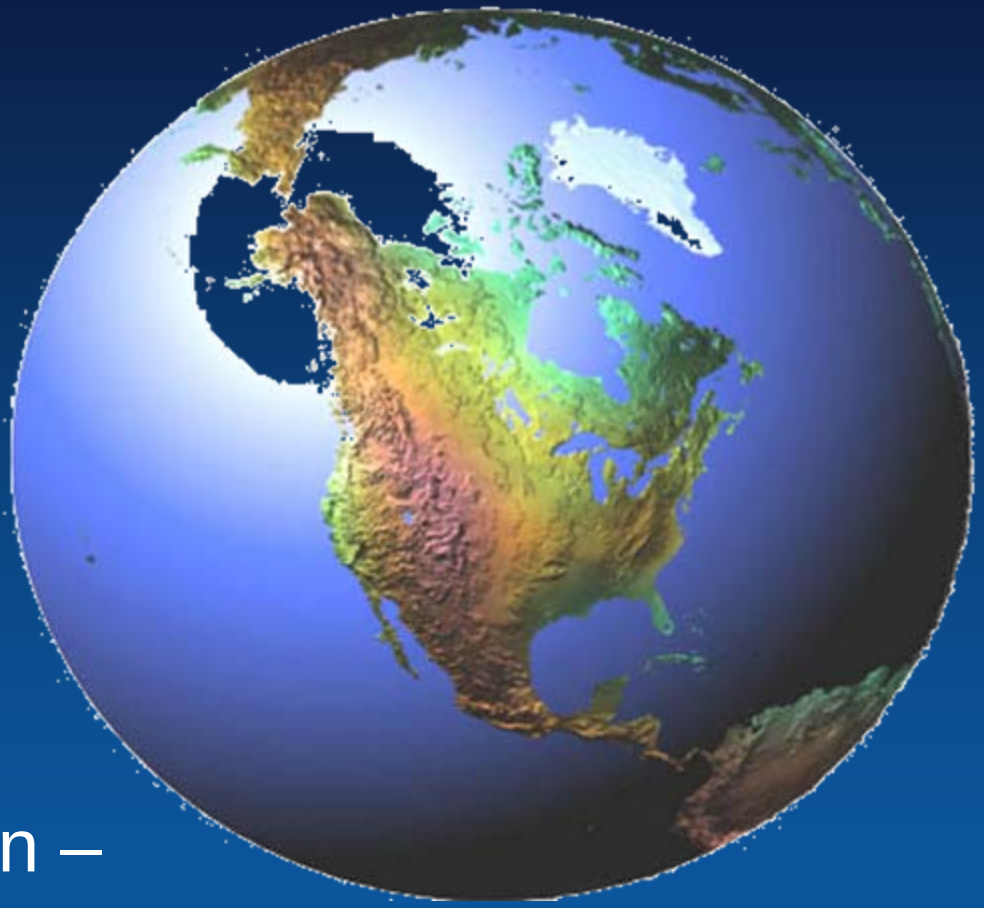


Source: Annual energy review and long term historical data. Energy Information Administration. 2005.

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)



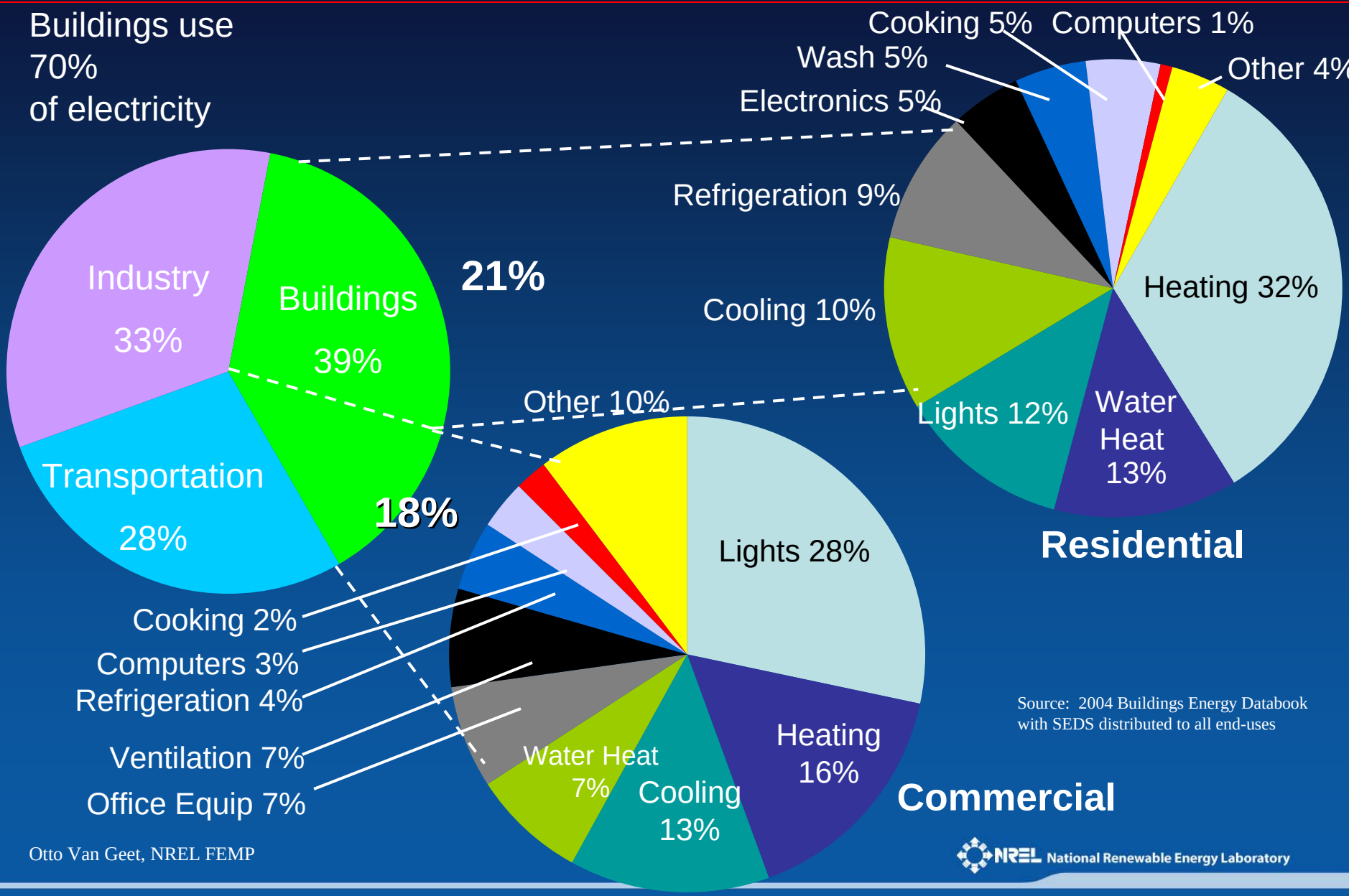
Don't ever forget the bottom line – what we do matters!

The Vision

Vehicles and Fuels + Energy Smart Buildings + Renewables =

A renewable energy community

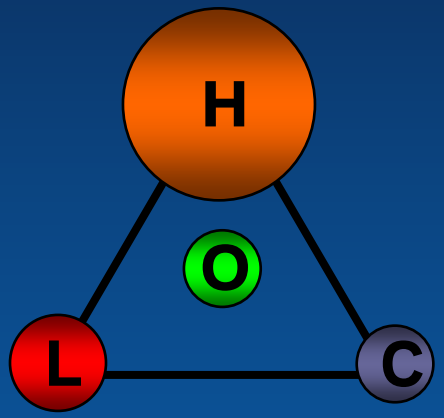
Building Energy Use



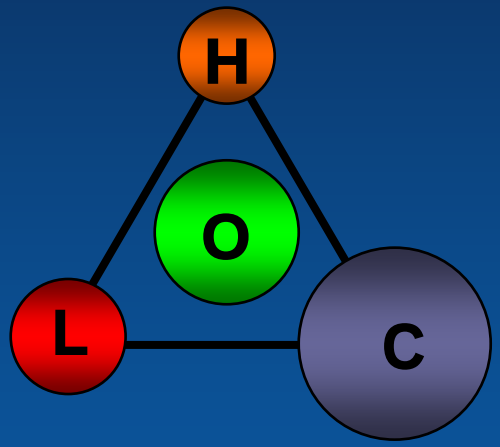
Source: 2004 Buildings Energy Databook with SEDS distributed to all end-uses

Integrated Design Problem

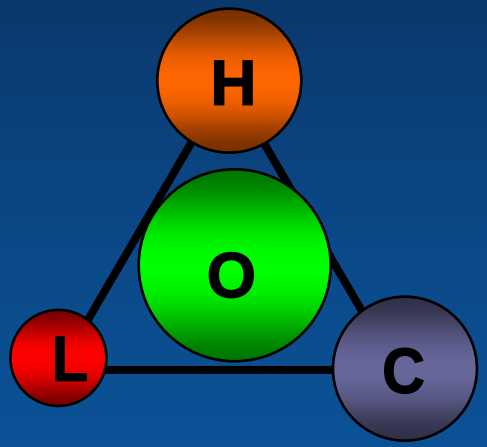
Skin-Load Dominated (small building in a cold climate)



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
- Do simple thing first, lighting, HVAC
- 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

Lighting Tips

- Turn off lights when not needed
- Install motion sensors on exterior lighting
- Install motion sensors or timers on interior lighting
- Do not turn on lights when daylight is sufficient
- Install task lighting in kitchens and offices
- Use 4-ft fluorescent fixtures with electronic ballasts in work areas (garages, laundry rooms)
- Replace incandescent, halogen, and spotlight bulbs/fixtures with CF bulbs/fixtures

Compact Fluorescents

- Use 1/4 to 1/3 the energy of incandescent
- Last 10 to 15 times longer than incandescents
- Come in a variety of sizes, wattages, and shapes
- Can buy them anywhere

Compact Fluorescent Lamps Replacement Example

- Replace four 100-W incandescent bulbs burning four or more hours per day with four 23-W fluorescent bulbs
- Save about 452 kWh and $82 over 3 years
- If all U.S. houses did the same, the amount of energy saved in 1 year would equal to the amount of energy consumed by 7 million cars

source: "Power$marts." Alliance to Save Energy, 1998.

Furnace Tips

- Look for heat inefficiencies
- Clean units/registers/filters
- Install ducts in conditioned space
- Seal ducts if ducts are accessible
- Insulate ducts in unconditioned spaces
- Install setback thermostats
- Purchase new furnace or boiler with high annual fuel utilization efficiency AFUE (>90%)

Thermostat Tips

- Set thermostat as low (for heating)/high (for cooling) as possible
  - Save 3% of total heating energy for each degree decrease in thermostat setpoint
- Cranking the temperature past the desired level will not heat/cool the house faster

Parasitic Losses

- Idle appliances waiting to receive signal from remote control (idle TVs and VCRs cost $30/yr/household in the U.S.)
- Any appliance with a digital clock
- Cordless telephones
- Computer and home office equipment that is left on all the time
- Purchase Energy-Star appliances with “sleep” features or turn off/unplug appliances when not in use

A thought…

- Buildings mortgage the energy and environmental future of this country

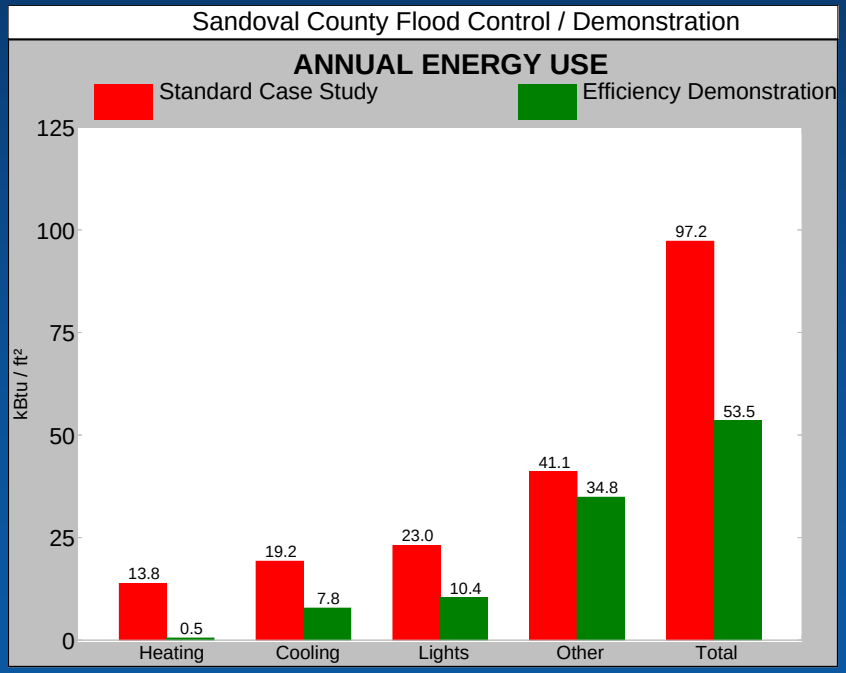
Design Considerations

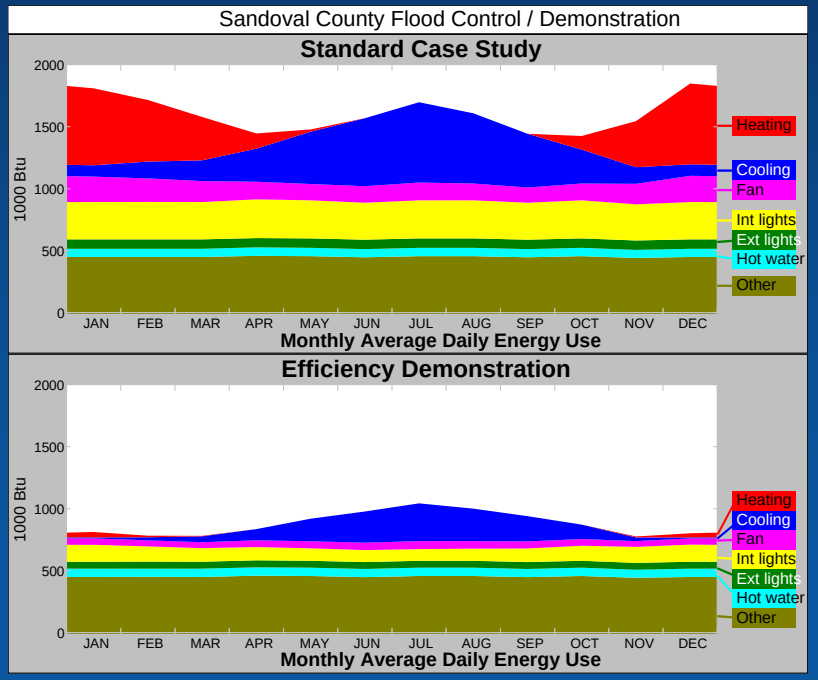
- Integrate energy efficiency and renewable energy early
- Use hourly energy simulations
- Architecture should work with the building's energy needs

Gather data for Intelligent Decision Making…

Energy Modeling

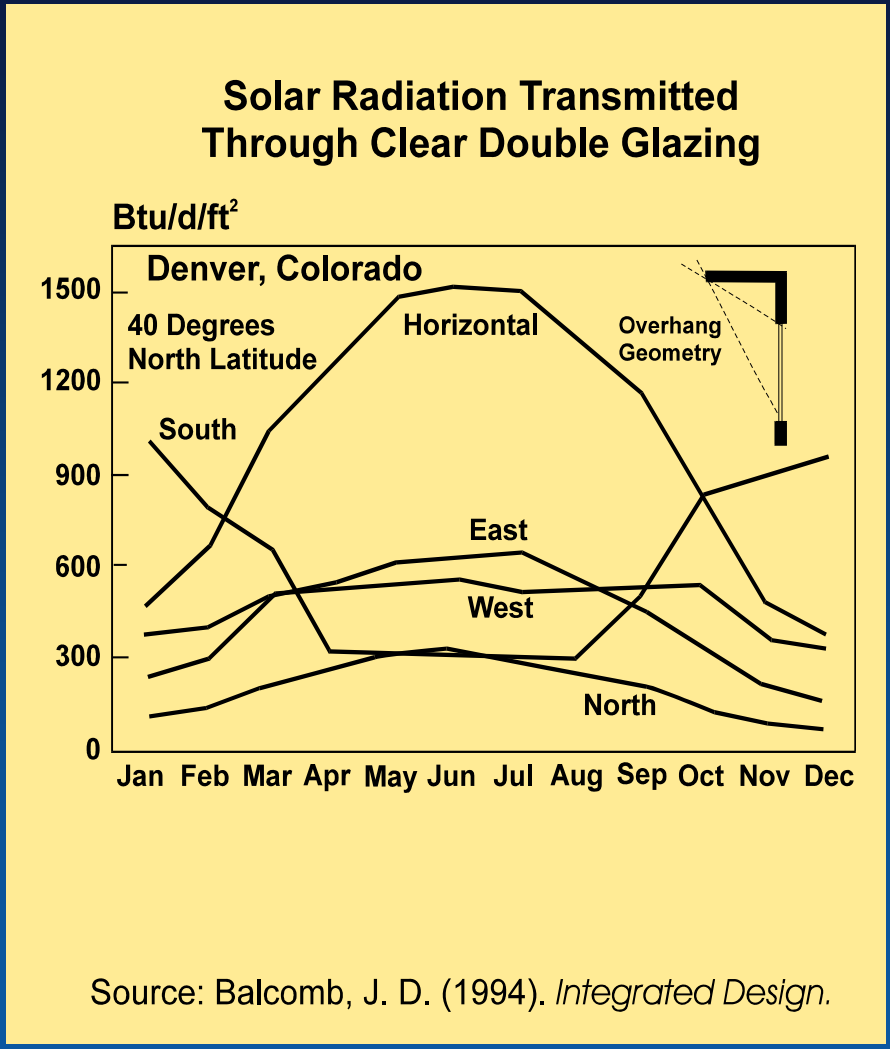
- Considers building energy consumption during design phase to optimize energy use
- Several programs: eQuest, DOE2, Energy 10, etc.
- http://www.eere.energy.gov/buildings/highperformance/toolbox.html





Glazing Orientation is Important

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



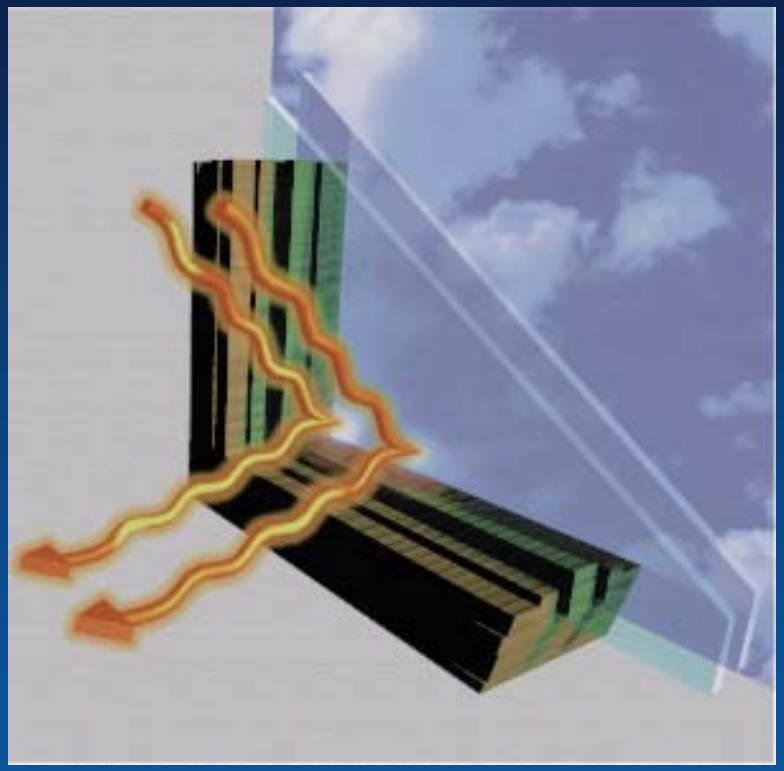
Source: Balcomb, J. D. (1994). *Integrated Design.*

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/

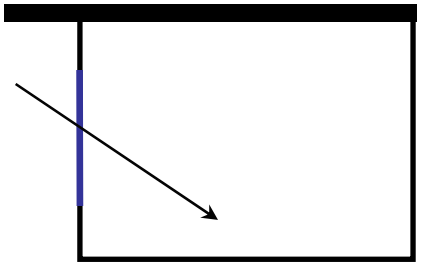
Low-E Windows



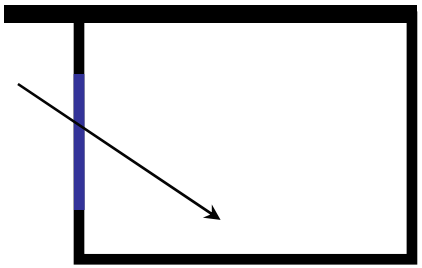
Cold-Climate Window

Warm-Climate Window
East and West facing

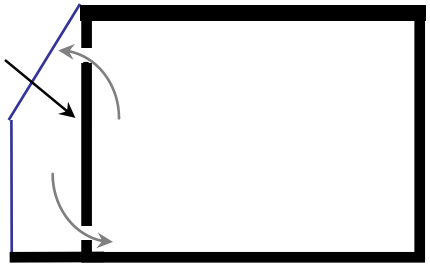
Passive Solar Strategies



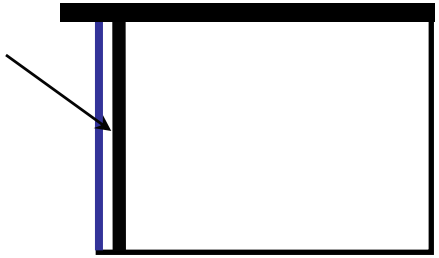
Sun tempered



Direct Gain

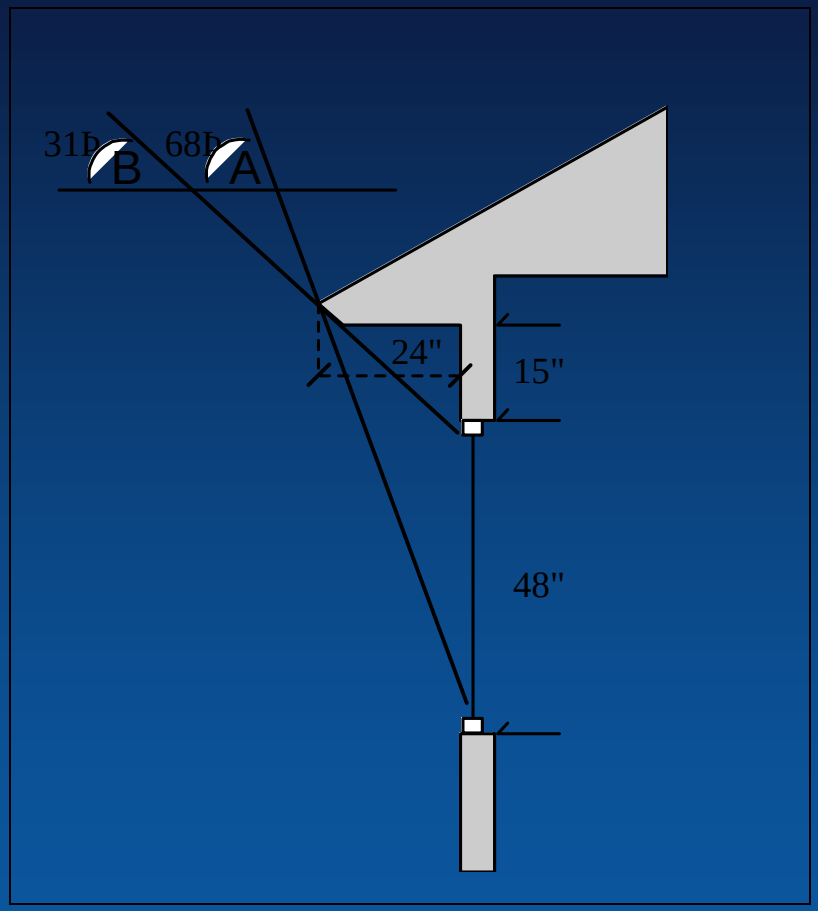


Sunspace



Thermal Storage Wall

Shading Geometry

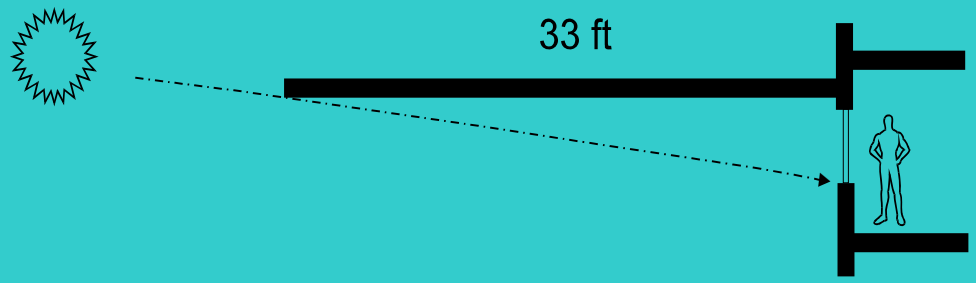


A. 68º angle with horizon fully shades the window in the summer (76.6º = sun's altitude @ 40º N latitude on June 21)

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



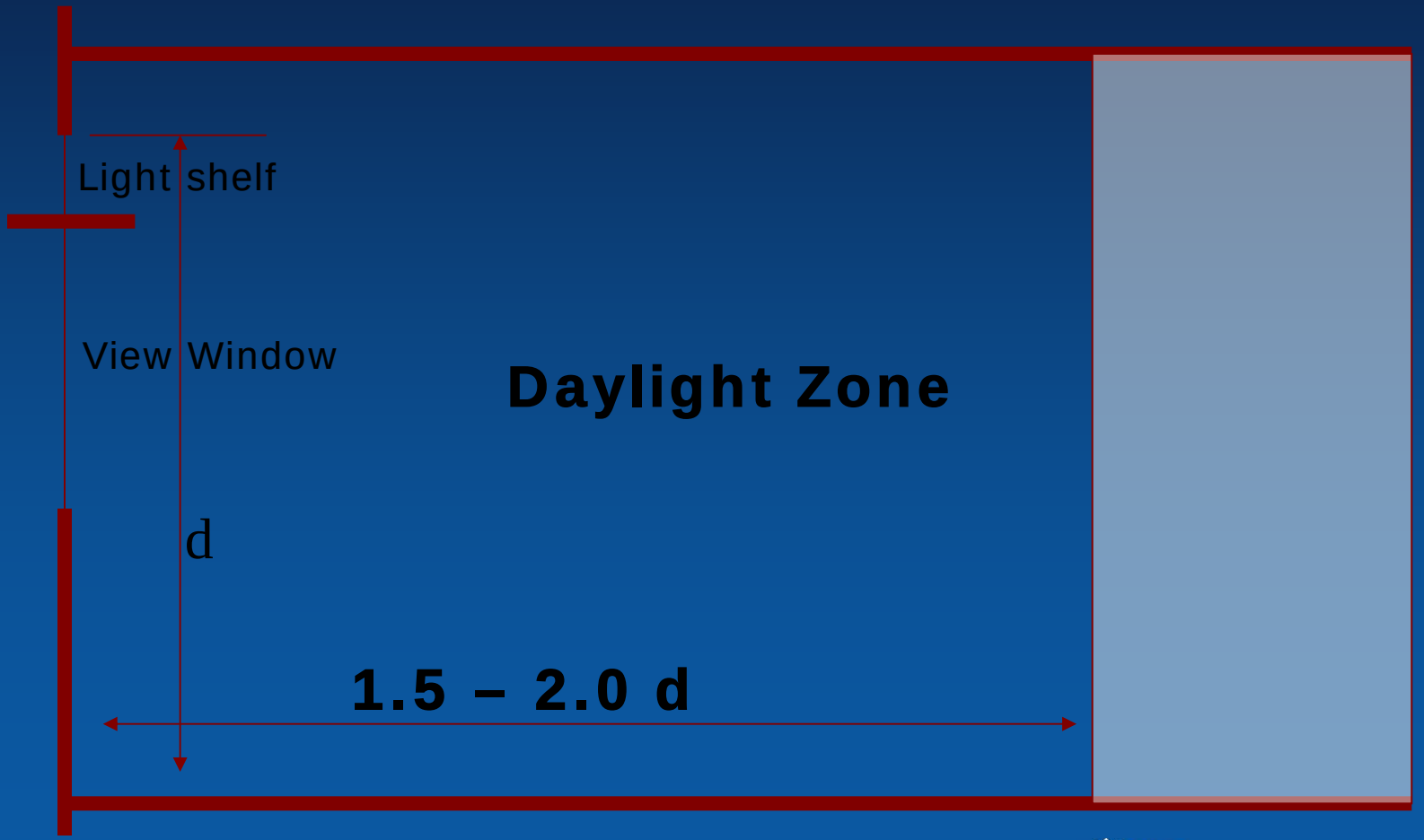
The 33-ft overhang needed to shade a 4-ft window on August 21 at 6 p.m. at 36° north latitude illustrates the futility of trying to fully shade east and west windows with horizontal overhangs.

General Rules for Buildings

Long axis of building faces south

- All windows have U<0.35
- 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
  - 7 – 12% glass area of building floor area
  - 7% for low mass to 12% for high mass construction
  - Use high SHGC (>0.50)
- Use **North** glass for daylighting and view glass
  - SHGC does not have big energy impact

How far can you throw daylight?



Passive Solar Design

West side

East side

Inside

South side

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

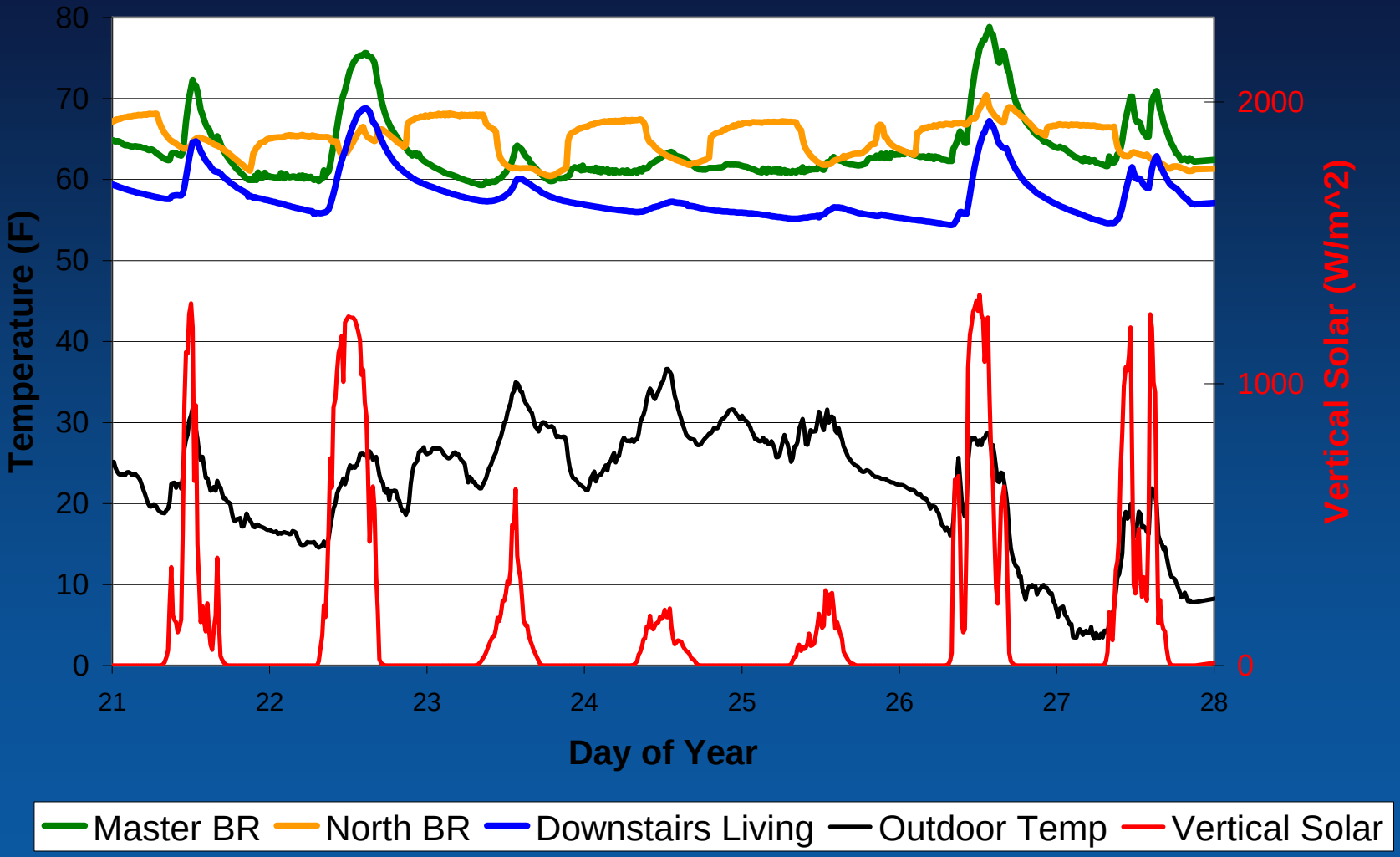
Glazing Selection

- 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

Performance Jan. 22-28, 2000



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)

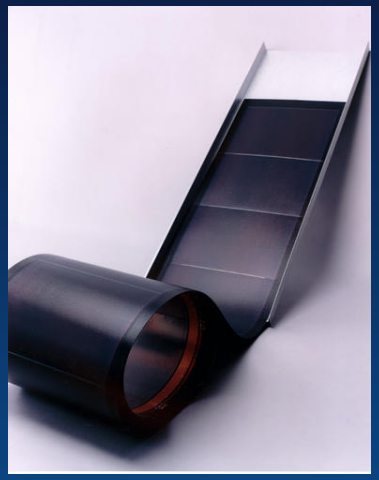
Van Geet Summary

- 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 (100 gallons propane average)

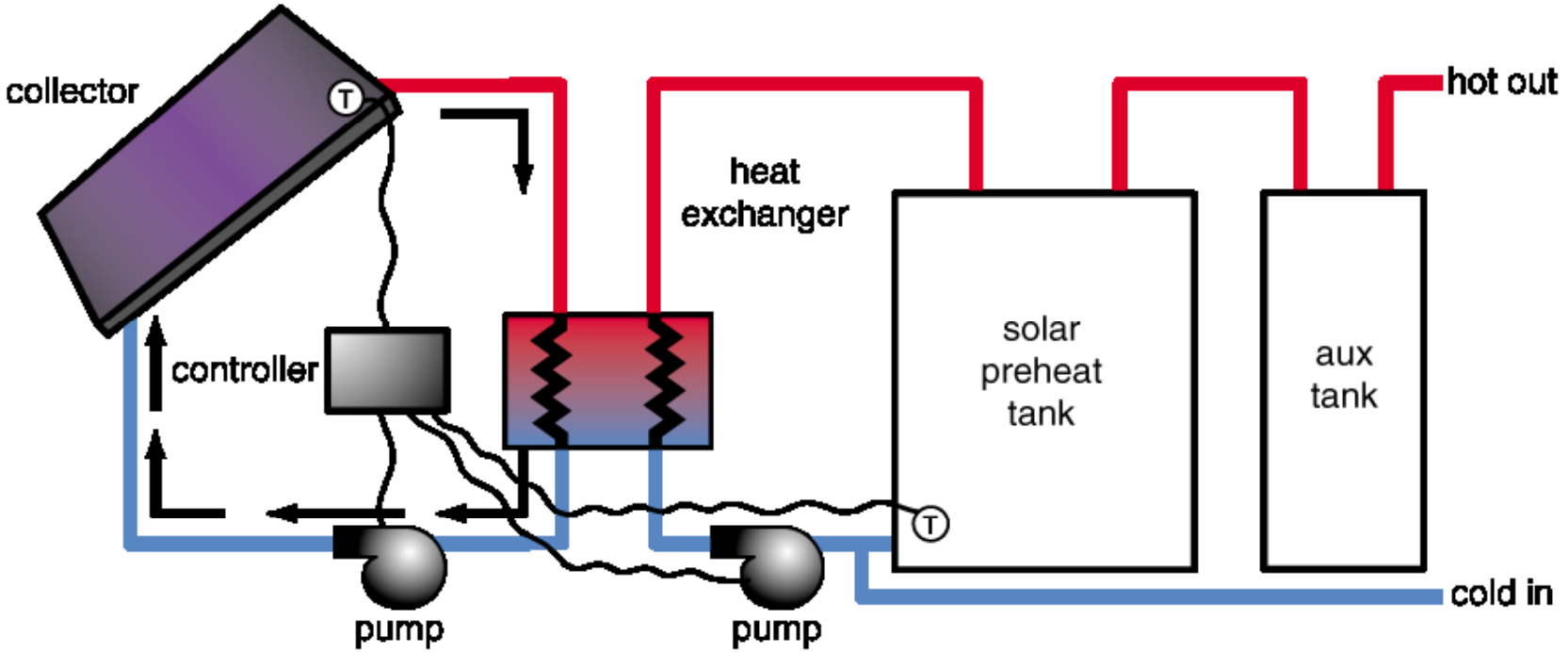
Solar can be attractively integrated into homes

Solar can be attractively integrated into homes

Examples of integrated solar roofing products

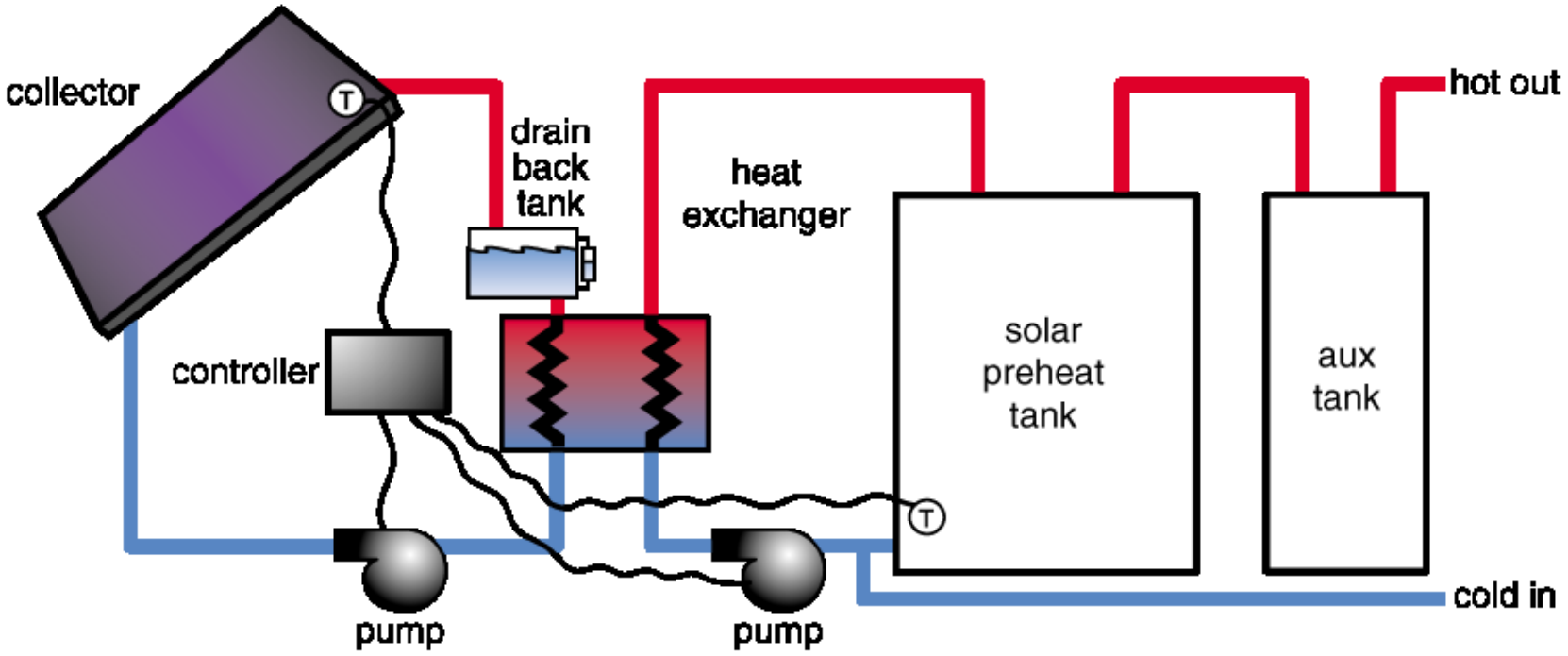


Active, Closed-loop (antifreeze), Indirect System



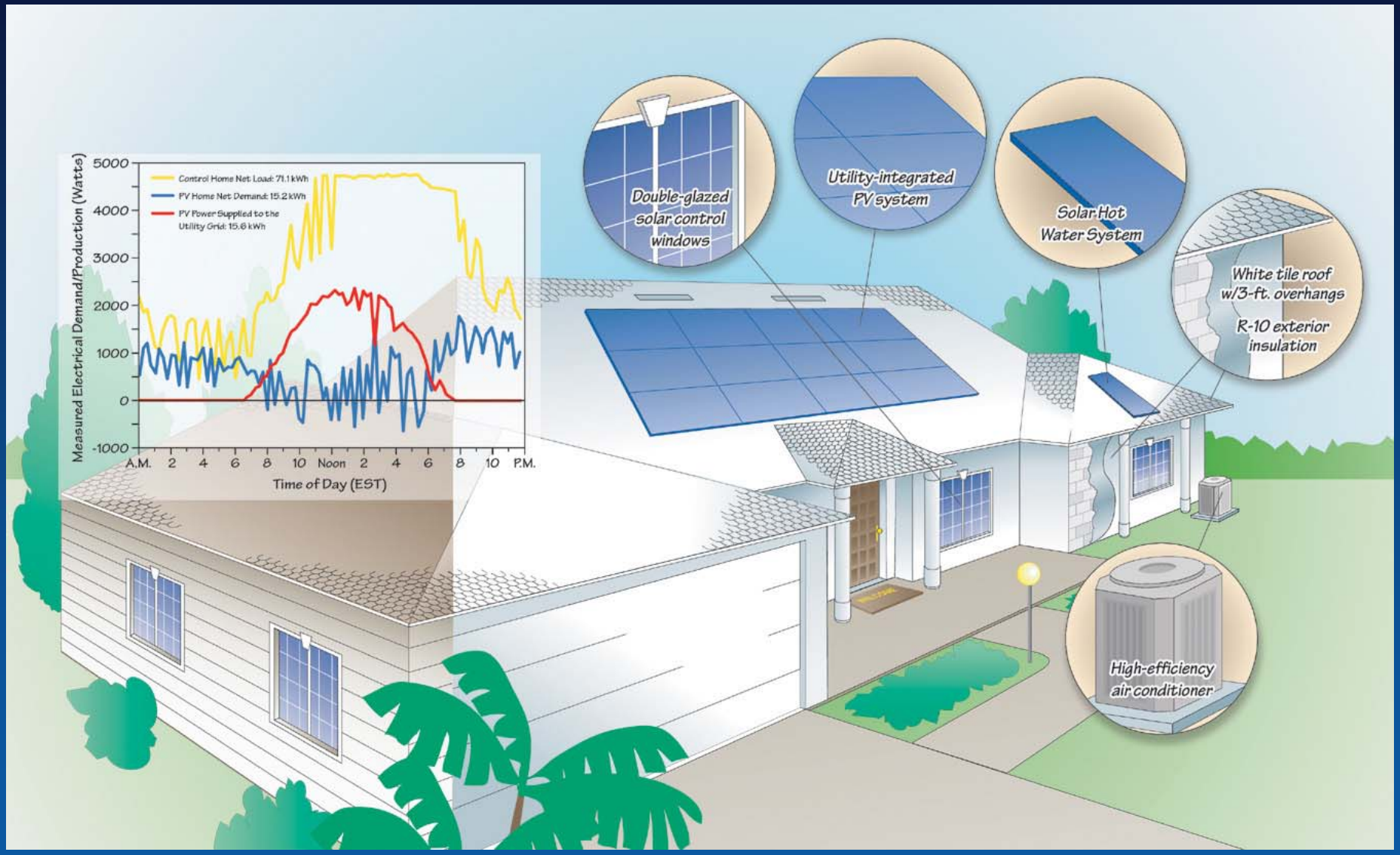
- Excellent freeze protection
- Good hard water tolerance
- High maintenance requirements

Active, Closed-loop, Drain-back, Indirect System



- Good freeze protection
- Overheat protection
- Good hard water tolerance
- High maintenance requirements

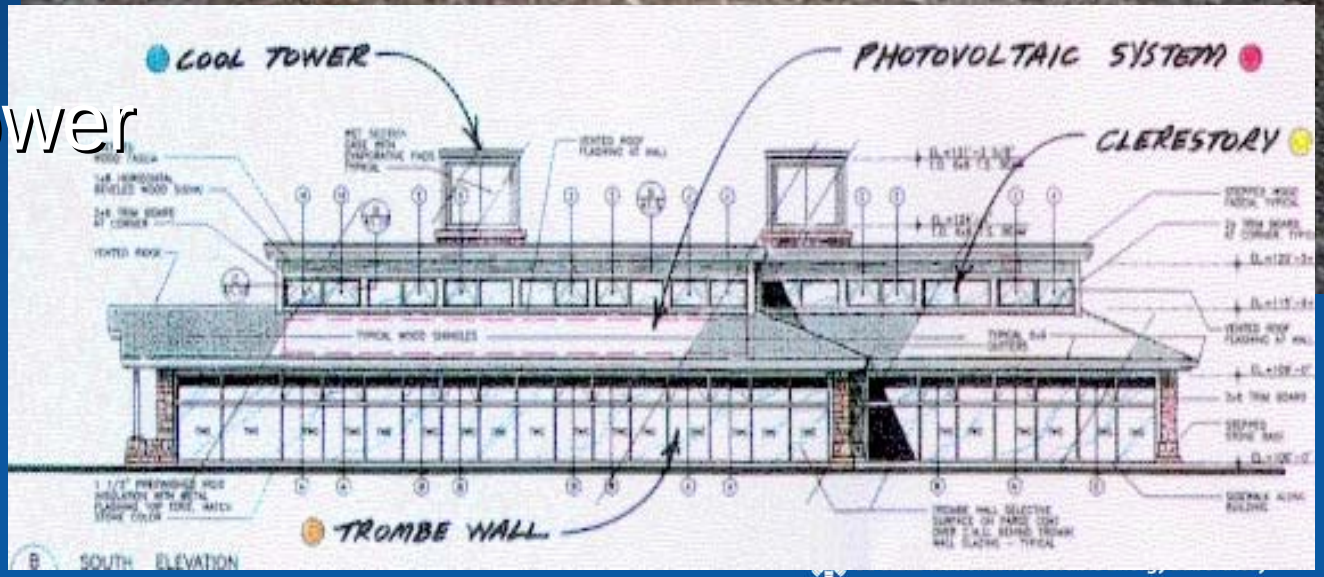
Zero Energy Building



Zion National Park Visitor Center

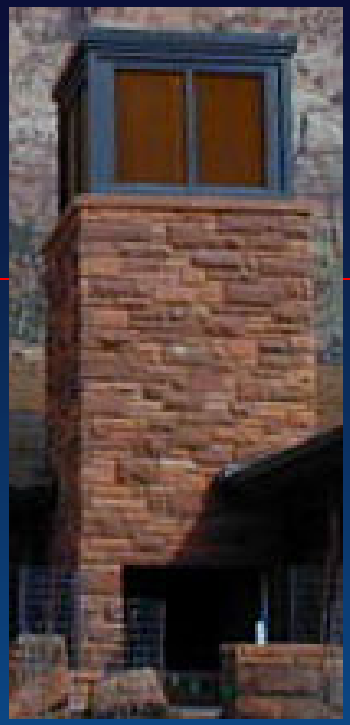
Zion National Park Visitor Center

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



Zion Energy Features

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



What to look for...

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  - Design overhangs to shade surfaces in summer
  - 7 – 12% glass area of building floor area
  - Use high SHGC (>0.50)
- 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 (foam), including below slab
- Energy Star Appliances, minimize “ghost” loads
- No incandescent lights
- 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.

What to look for… and how to accomplish

- Low Maintenance design (Stucco, Masonry, clad windows, metal roof, etc.)
- Use simulations to design building
- Low water use design
- Who else can help you with the design?
- How will project be funded?
- Consider solar electric – PV
  - $4.50 Xcel Rebate
  - 30% Federal Tax Credit ($2000 cap residential)
- Consider solar hot water

Discussion & Questions

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