

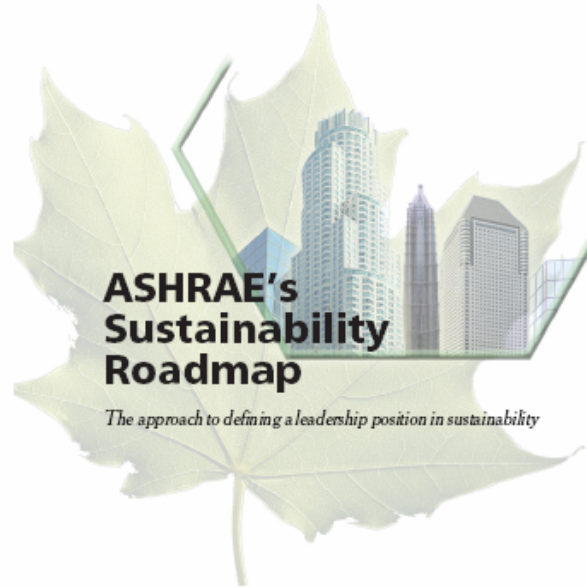
The Energy Design Process for High Performance Buildings

Richard B. Hayter
Kansas State University





American Society of Heating, Refrigerating
and Air-Conditioning Engineers, Inc.



ASHRAE's Sustainability Roadmap

The approach to defining a leadership position in sustainability



ASHRAE
Engineering
for
Sustainability

Approved by ASHRAE Board of Directors
January 22, 2006





ASHRAE
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Sustainability*

www.engineeringforsustainability.org



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A new roadmap adopted by ASHRAE will help members lead the march toward a sustainable built environment through use of advanced technologies.

[Read Roadmap Here»](#)

Tax Incentives



Consumers

Home Shell: *Insulation, Windows, Sealing*
Heating & Cooling Equipment
Passenger Vehicles
Solar Energy Systems
Fuel Cells

Businesses

Commercial Buildings
Commercial Vehicles
Solar Energy Systems
Fuel Cells & Microturbines

Builders/Manufacturers

New Homes
Appliances

General Information

About TIAP
Events
For Program Implementers
State & Utility Incentives
Legislation
TIAP Recommendations
F.A.Q.s & Contact Us

TIAP www.energytaxincentives.org

The Tax Incentives Assistance Project (TIAP), sponsored by a coalition of public interest nonprofit groups, government agencies, and other organizations in the energy efficiency field, is designed to give consumers and businesses information they need to make use of the federal income tax incentives for energy efficient products and technologies passed by Congress as part of the Energy Policy Act of 2005.

- ◆ New- Frequently Asked Questions
- ◆ New- Updated Information on Vehicle Incentives



Tax Incentives

TIAP Business Incentives

What is the tax incentive for commercial buildings?

A tax deduction of up to \$1.80 per square foot is available to owners or tenants (or designers, in the case of government-owned buildings) of new or existing commercial buildings that are constructed or reconstructed to save at least 50% of the heating, cooling, water heating, and interior lighting energy cost of a building that meets ASHRAE Standard 90.1-2001. Partial deductions of up to \$.60 per square foot can be taken for comparable reductions from any one of three building systems—the building envelope, lighting, or heating and cooling system—that meets goals consistent with achieving the 50% savings for the entire building. An interim system-specific goal for lighting is provided directly in the legislation and is valid until and unless the IRS issues a different final regulation. The interim lighting provision allows prorated deductions from 30 cents to 60 cents per square foot for lighting systems as described below.

These deductions are available for buildings or systems placed in service from January 1, 2006, through December 31, 2007.

Who is eligible for the incentives?

The person or organization that makes the expenditures for construction is generally the recipient of the allowed tax deductions. This is usually the building owner, but for some HVAC or lighting efficiency projects, it could be the tenant. For government-owned buildings, the deduction may be taken by the building or system designer.





Summary of Energy Efficiency Tax Incentives in Energy Policy Act of 2005

Product	Eligibility Level	Units	Amount of Incentive	Years Covered	Notes
Existing homes and other non-business applications					
Central air conditioners	15 12.5	SEER EER	\$300 for AC if meet SEER & EER	2006 & 2007	\$500 per taxpayer cap for existing home credits
Heat Pumps (air cooled)	15 13 9.0	SEER EER HSPF	\$300 for HP if meet SEER, EER & HSPF	2006 & 2007	
Group-source heat pumps					
Closed loop	14, 12.5	EER/COP	\$300	2006 & 2007	System must also provide water heating
Open loop	16, 20.6	EER/COP	\$300	2006 & 2007	System must also provide water heating
Direct expansion (DX)	15, 5.5	EER/COP	\$300	2006 & 2007	System must also provide water heating
Water heaters (non-business applications)					
Electric	2.0	EF	\$300	2006 & 2007	
Gas and oil	0.8	EF	\$300	2006 & 2007	
Gas and oil furnaces and boilers					
High combustion efficiency equipment	95%	AFUE	\$150	2006 & 2007	Can earn either one or both incentive with the same unit.
High electric efficiency equipment	Meets CEE spec		\$50	2006 & 2007	CEE spec requires electricity use to be <=2% of site use.
Envelope improvements to existing homes					
Insulation, exterior doors, duct sealing and infiltration reduction	Meet 2003 IECC + supplements		10% up to \$500	2006 & 2007	Duct sealing and infiltration reduction probably included but final determination depends on detailed rules.
Windows and skylights	Same as above		10% up to \$200	2006 & 2007	
Pigmented metal roofs	Meet Energy Star spec		10% up to \$500	2006 & 2007	
Appliances					
Refrigerators					
Save 15-19.3% relative to federal standard	Look to left		\$75	2006	All appliance incentives go to manufacturer, not consumer; manufacturers are expected to reduce prices accordingly.
Save 20-24.9% relative to federal standard	Look to left		\$125	2006 & 2007	
Save 25% or more relative to federal standard	Look to left		\$175	2006 & 2007	
Clothes washers	2007 Energy Star		\$100	2006 & 2007	DOE has proposed 1.72 MEF and 6.0 WF for Energy Star.
Dishwashers	2007 Energy Star		TBD -- based on final Energy Star	2006 & 2007	Incentive likely to be around \$30.
New homes					
Site-built or manufactured homes	50%	savings	\$2,000	2006 & 2007	Incentives go to the builder, not the homeowner. Savings relative to 2004 IECC.

Commercial buildings						
Whole building	50%	savings	Deduction of \$1.80/sq. ft.	2006 & 2007		Deductions are not additive -- maximum is \$1.80/sq. ft.
Lighting, HVAC or envelope	50%	savings	Deduction of \$0.60/sq. ft. per system	2006 & 2007		Savings relative to ASHRAE 90.1-2001.
Lighting savings of at least 25%	25-50%	savings	Sliding scale: \$.30/sq. ft. for 25% svgs	Unclear		Term of this provision depends on Treasury rulemaking.

Motorbikes (only business credit)	20%	efficiency	10% up to \$200kW	2006 & 2007	efficiency requirements for individual credit: Systems < 2000 kW.
Passenger vehicles	Complicated formula -- see http://acesee.org/press/0505HybridIncentive.htm				
Heavy-duty vehicles	Complicated formula -- a description of the credit will be put on www.acesee.org shortly.				

Key: AC= air conditioner; AFUE= annual fuel utilization efficiency; ASHRAE= American Society of Heating, Refrigerating & Air-Conditioning Engineers; CEE= Consortium for Energy Efficiency; COP= coefficient of performance; EER= energy efficiency ratio; EF= energy factor; HP= heat pump; HSPF= heating season performance factor; IECC= International Energy Conservation Code; kW= kilowatt; MEF= modified energy factor; SEER= seasonal energy efficiency ratio.

Prepared by the American Council for an Energy-Efficient Economy, December 23, 2005.



www.acesee.org/press/Tax_incentive05.pdf

“Design and build buildings that do not deplete the earth’s natural resources nor harm global environment or jeopardize the ability of future generations to meet their needs.”

**Don Holte,
ASHRAE President 1996-97**



The Future World

- A world population of 6B, increasing to perhaps 10B by 2050
- Rising expectations of developing countries
- Escalating demand on (finite) resources
- Political and economic instability
- Preservation of environment

Jim Schultz



Influences on HVAC&R Applications

If every centrifugal chiller had an efficacy of 0.48 kW/Ton vs. 0.56, annual power plant emissions would be reduced by:

- Nearly 17 billion pounds of CO₂**
- Over 64 billion grams of SO₂**
- Over 27 billion grams of No_x**

**Jim Wolf,
ASHRAE President 2000-01**



Influences on HVAC&R Applications

Which is equivalent to:

- **Removing over 2 million cars from the road.**
- **Planting nearly 500 million trees each year.**



Building Energy Consumption (U.S.)

- 35% of total energy used in U.S.
- 65% of total electrical consumption
- 48% of energy used in buildings in U.S. is used for comfort cooling & refrigeration.
- 50% of all U.S. homes have A/C.
- 81% of all new homes have central air-conditioning.



Environmental Impact of Buildings in the U.S.

114 million tons of CO₂ produced due to energy consumption in U.S. buildings.

67,000 tons of SO_x

35,000 tons of NO_x



Four Components Critical to the Creation of a Sustainable Building

- 1. The occupant**
- 2. The design team**
- 3. The building as a system**
- 4. The design process**



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Annual Operating Costs

- Energy: \$2.00 to \$4.00/ft²



Annual Operating Costs

- Energy: \$2.00 to \$4.00/ft²
- Maintenance: \$2.00 to \$4.00/ft²



Annual Operating Costs

- **Energy: \$2.00 to \$4.00/ft²**
- **Maintenance: \$2.00 to \$4.00/ft²**
- **Owning or Leasing: \$10.00 to \$40.00/ft²**



Annual Operating Costs

- **Energy: \$2.00 to \$4.00/ft²**
- **Maintenance: \$2.00 to \$4.00/ft²**
- **Owning or Leasing: \$10.00 to \$40.00/ft²**
- **Personnel: \$200.00 to \$400.00/ft²**



Indoor Design Conditions

3.2

2003 ASHRAE Applications Handbook

Table 1 General Design Criteria^{a, b}

General Category	Specific Category	Inside Design Conditions		Air Movement	Circulation, air changes per hour
		Winter	Summer		
Dining and Entertainment Centers	Cafeterias and Luncheonettes	70 to 74°F 20 to 30% rh	78°F ^d 50% rh	50 fpm at 6 ft above floor	12 to 15
	Nightclubs and Casinos	70 to 74°F 20 to 30% rh	74 to 78°F 50 to 60% rh	below 25 fpm at 5 ft above floor	20 to 30
	Kitchens	70 to 74°F	85 to 88°F	30 to 50 fpm	12 to 15 ^e
Office Buildings		70 to 74°F 20 to 30% rh	74 to 78°F 50 to 60% rh	25 to 45 fpm 0.75 to 2 cfm/ft ²	4 to 10

**General Design
Conditions**

Office
Buildings

70 to 74°F
20 to 30% rh

74 to 78°F
50 to 60% rh

25 to 45 fpm
0.75 to 2 cfm/ft²

4 to 10



Indoor Design Conditions

Notes to [Table 1](#), General Design Criteria

^aThis table shows design criteria differences between various commercial and public buildings. It should not be used as the sole source for design criteria. Each type of data contained here can be determined from the *ASHRAE Handbooks and Standards*.

^bConsult governing codes to determine minimum allowable requirements. Outside air requirements may be reduced if high-efficiency adsorption equipment or other odor- or gas-removal equipment is used. See *ASHRAE Standard 62* for calculation procedures. Also see [Chapter 45](#) in this volume and Chapter 13 of the 2001 *ASHRAE Handbook—Fundamentals*.

^cRefer to [Chapter 47](#).

^dFood in these areas is often eaten more quickly than in a restaurant; therefore, turnover of diners is much faster. Because diners seldom remain for long periods, they do not require the degree of comfort necessary in restaurants. Thus, it may be possible to lower design criteria standards and still provide reasonably comfortable conditions. Although space conditions of 80°F and 50% rh may be satisfactory for patrons when it is 95°F and 50% rh outside, inside conditions of 78°F and 40% rh are better.

^eCafeterias and equipment and rooms are generally air-conditioned.

^fIn some nightclubs, the temperature is low so patrons are comfortable.

^gUsually determined by the design.

^hPeak kitchen conditions, although in lunch and dinner dining areas, peak kitchen conditions are higher.

ⁱMethods for reducing humidity are discussed in [Chapter 47](#).

^jAlso includes spaces for storage.



Fundamentals of Thermal Comfort

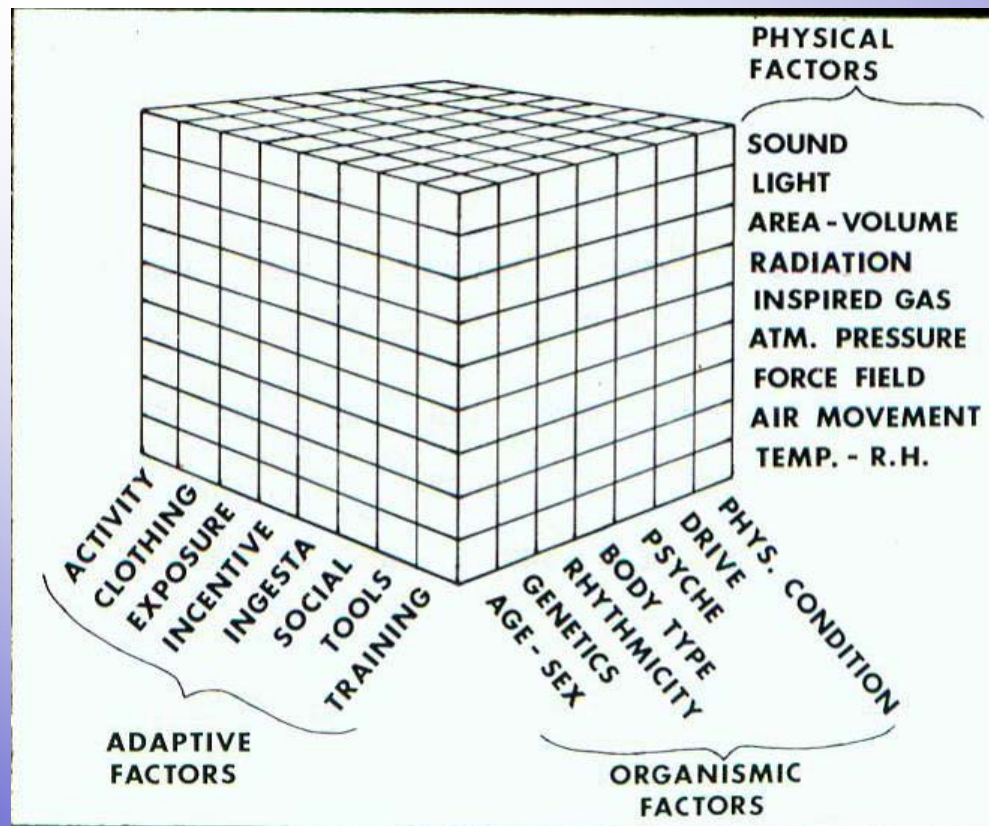


“Thermal Comfort:

*That condition of mind
which expresses
satisfaction with the
thermal environment.”*



Variables Affecting Comfort



Principles of Heat Transfer

- **Humans transfer sensible heat by conduction, convection and radiation.**
- **Humans transfer latent heat by evaporation from the skin (evaporation of perspiration) and through respiration.**



Metabolism

- **Ranges from approximately 340 Btu/Hr (sedentary) to 3400 Btu/Hr (strenuous).**
- **Metabolic capacity of trained athlete can reach 20 times their sedentary rate.**
- **More typical maximum is 12 times sedentary for age 20 and 7 times sedentary for age 70.**



Thermal Equilibrium

Is achieved when the metabolic rate equals rate of heat loss less work.*

* Thermal equilibrium does not necessarily mean comfort.



Physiological Responses

- **Sweating = Increased Evaporation (little benefit from dripping sweat)**

Note: If heat production is greater than heat loss, first mechanism is vasodilatation which can double or triple heat loss.

- **Shivering = Increases Metabolism**



Thermal Neutrality

- That condition where no physiological response is needed other than vasomotion to maintain a normal body temperature.
- Normally achieved between $T_o = 73^\circ\text{F}$ to 81°F for clothed sedentary and 84°F to 88°F unclothed.



Discomfort

- **Localized discomfort will overshadow comfort even under conditions of thermal neutrality.**
- **Causes of localized discomfort include asymmetric radiation, drafts, contact with cold or hot floors, vertical temperature differences.**

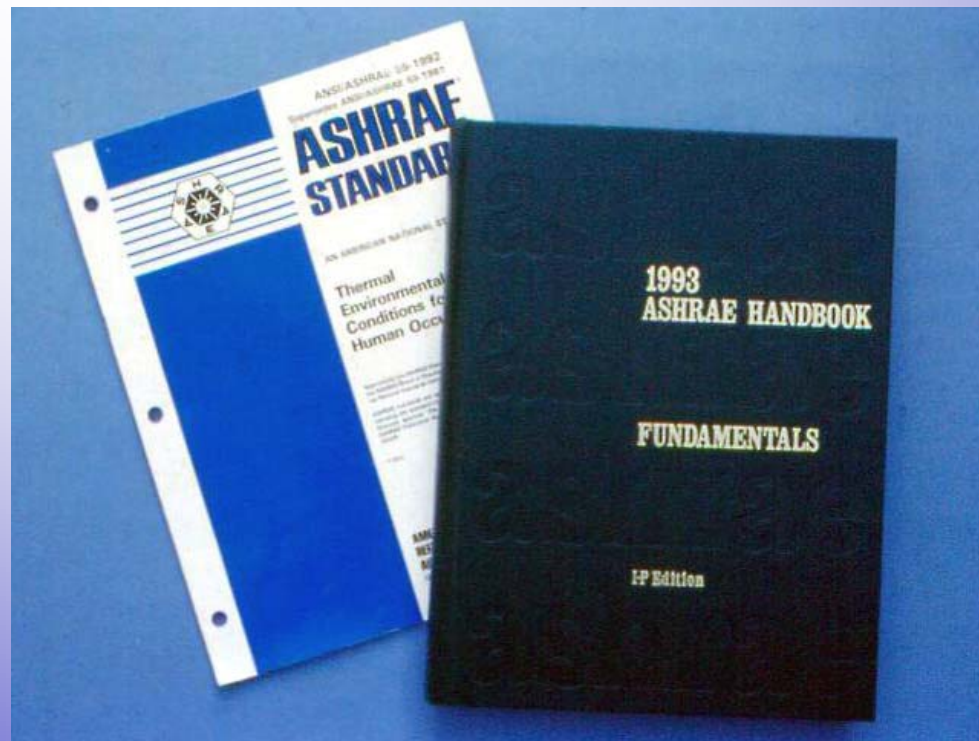


Discomfort Continued

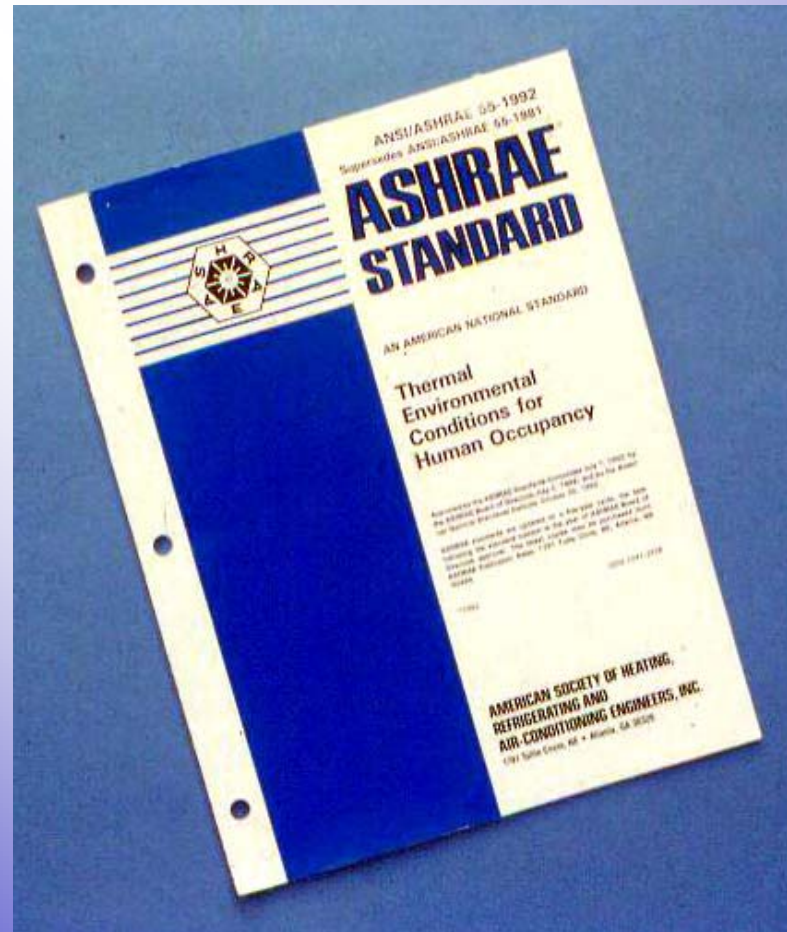
- Drafts have a disproportionate effect on comfort based on heat transfer.
- Dissatisfaction with the environment grows exponentially as air turbulence increases.



ASHRAE Design Tools



ASHRAE Standard 55



ASHRAE Standard 55

Purpose:

“...to specify the combinations of indoor space environment and personal factors that will produce thermal environmental conditions acceptable to 80% or more occupants within the space.”



Handbook of Fundamentals

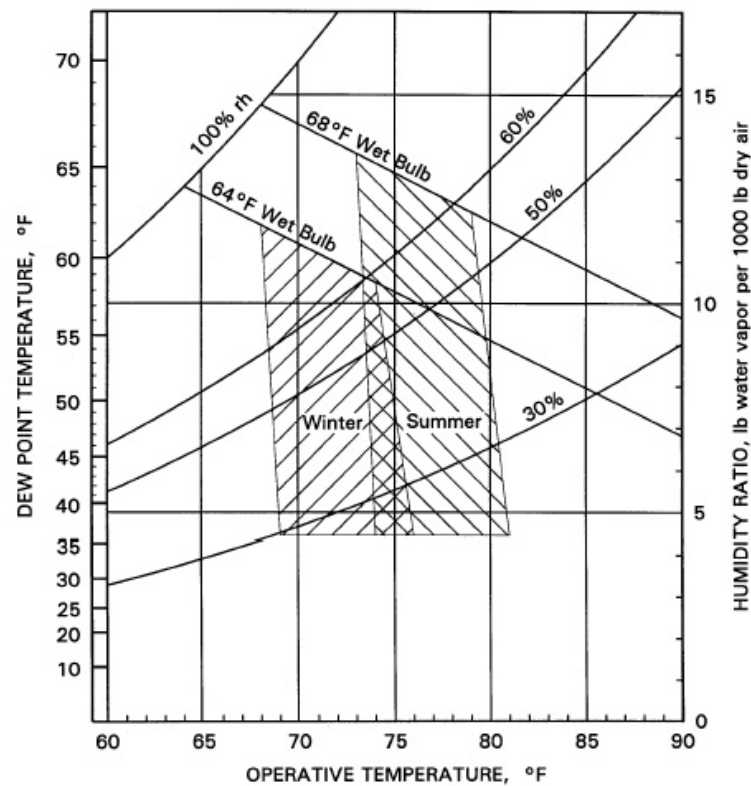


Fig. 5 ASHRAE Summer and Winter Comfort Zones



ASHRAE Design Software

ASHRAE Thermal Comfort Program - Untitled

File Options Help

Basic Thermal Comfort Model Parameters

Environmental Conditions		Results	
Air Temperature	25.0 °C	ET*	25.0 °C IN ASHRAE
MRT <input checked="" type="checkbox"/> Link with Air	25.0 °C	SET*	24.0 °C
Air Velocity	0.10 m/s	TSENS	-0.1 █
Relative Humidity	50 %	DISC	-0.1 Comfortable
<input checked="" type="radio"/> Summer <input type="radio"/> Winter		PMV	-0.40 IN ISO
Activity		PPD	8 %
ASHRAE Standard 55		PD	10 %
Metabolic Rate	1.0 met	PS	40 % Not enough air movement
Clothing		TS	0.0
ASHRAE Standard 55 Summer		Tneutral	21.9 (Humphreys)
Clothing level	0.50 clo	Tneutral	23.3 (Auliciems)



Four Components Critical to the Creation of a Sustainable Building

1. The occupant
- 2. The design team**
3. The building as a system
4. The design process



The Design Team

***“This requires cooperation . . .
among equal partners of
architects, engineers,
contractors, building users
and others.”***

**Richard Rooley
President, ASHRAE**



At a Minimum the Team Must Include

- Building Owner
- Project Manager
- Building Designers
 - ✓ HVAC&R Engineer
 - ✓ Structural Engineer
 - ✓ Architect
- Builder/Contractor
- Equipment Suppliers
- Building Operator



Additional Design Team Members

- **Lighting Designer**
- **Interior Architect**
- **Landscape Architect**
- **Lifts and Controls Engineer**
- **Energy Utilities Provider**
- **Code Official**
- **Financial Institution**
- **Insurer**
- **Educational Institution**



What will the Future Bring?

- ***“It is probable that within a very few years companies of designers, manufacturers and contractors who operate as they did in the latter part of the 20th century will be looked upon as a living museum”***

Rooley

- ***“During your professional lifetime you may well serve on a design team of members you will never meet on a project you will never see in a country you never visit.”***

Hayter



Four Components Critical to the Creation of a Sustainable Building

1. The occupant
2. The design team
3. **The building as a system**
4. The design process



The Building as a System



The Building as a System



The Building as a System



The Building as a System



Four Components Critical to the Creation of a Sustainable Building

1. The occupant
2. The design team
3. The building as a system
4. **The design process**



The Design Process

Critical Initial Steps

- **Agree to a vision for the performance goals**
- **Form an all-inclusive project team**
- **Agree to the process for making design, construction and occupancy decisions.**
- **Hold design charrette.**



“The design charrette is the mechanism that starts the communication process among the project team members, building users and project management.”

Sheila Hayter





U.S. Department of Energy

Office of Energy Efficiency and Renewable Energy

Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable



DOE supports the development of commercial buildings that are energy efficient, healthy and comfortable places to learn, work, and play.

High Performance Buildings

An Initiative of the U.S. Department of Energy Building Technologies Program

Related Topics

[Performance Metrics](#)

See [Residential building information](#)

Building industry's technology roadmap [\(PDF 1.0 MB\)](#)
[Download Acrobat Reader.](#)

www.highperformancebuildings.gov

and benefits

▶ Toolbox

Design guidelines, software, weather data, papers, brochures, and resources

▶ Technologies

Methods, materials, and equipment

research projects, and contact information

▶ Process Change Research

Design and technologies that target 50% energy cost savings

▶ Performance Metrics Research

Standardized metrics and procedures for measuring building performance



Near real-time weather data archive is now available.

Search Our Buildings Database

For environmental features and energy use in buildings



High Performance Saves the Bay...

A global model of energy conservation and sustainable building techniques



DOE/NREL is announcing the availability of a (near) real-time weather data archive with

August 2003 • NREL/BK-710-33425

A Handbook for Planning and Conducting Charrettes for High-Performance Projects

www.highperformancebuildings.gov

[/charrette_handbook.html](http://www.highperformancebuildings.gov/charrette_handbook.html)

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NREL

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The Design Process

1. **Pre-design**: Evaluate building functions, size, site & local conditions.
2. **Base-case Building Model**: Meet prescriptive energy and building functional requirements
3. **Parametric Analysis**: Develop sensitivity analysis



The Design Process

4. **Create Design Options**: Consider building geometry, envelope, systems, energy sources, etc.
5. **Simulate Options**: Investigate variants of base-case building using options from previous step including effect of interactions.



The Design Process

- 6. Conceptual Design: Integrate energy features into architectural design. Refine based on simulation. Optimize envelope for energy use.**
- 7. Design Development: Simulate options for HVAC system & controls. Investigate envelope & system trade-offs.**



The Design Process

8. **Bid Documents & Specifications:** Assure that compromises are avoided such as thermal bridging, poor equipment efficiency, code violations. Simulate any modifications.
9. **Construction:** Simulate change orders. Hold regular design reviews. Maintain communications.



The Design Process

10. Commissioning & Post Occupancy Evaluation: Test subsystems including controls. Simulate any building-use changes from original intent to make needed system adjustments. Educate building owner/operator. Provide sufficient instructions for future users.



The Design Process

LANL Sustainable Design Guide



www.highperformancebuildings.gov

[/lanl_sustainable_guide.html](http://lanl_sustainable_guide.html)



Zion National Park Visitor Center

www.highperformancebuildings.gov/zion/



Edit View Go Communicator Help

Back Forward Reload Home Search Netscape Print Security Shop Stop

Location: http://www.eren.doe.gov/buildings/highperformance/zion/zion.html

High Performance Buildings
Zion Visitor Center

BTS Home Home

Choose a View of the Zion Visitor Center Go!



Upper Canyon Map

Park Entrance

Pedestrian Bridge

Visitor Center Map

Lower Canyon



Head straight to the QuickTime™ panoramas that feature the Visitor Center's technologies ▼

- Clerestory Windows
- Cooltowers
- Daylighting
- Energy-Efficient Landscaping
- Insulation
- Overhangs
- Photovoltaic System
- Thermal Mass Flooring
- Transportation
- Trombe Wall
- Ventilation

Canyon Area Map

Visitor Center Map

Upper Canyon Map

Site Navigation Tips

Guided Tour

Welcome to Zion!

Covering 229 square miles in southwestern Utah, Zion National Park was established in 1919 to preserve the area's natural beauty. At that time, the park welcomed 1,000 visitors a year.



Today, with nearly 2.5 million visitors, the National Park Service has worked with the U.S. Department of Energy to minimize impact on Zion's environment while saving energy and reducing costs. The new Visitor Center, opened in May 2000, was designed

QuickTime Get 4.

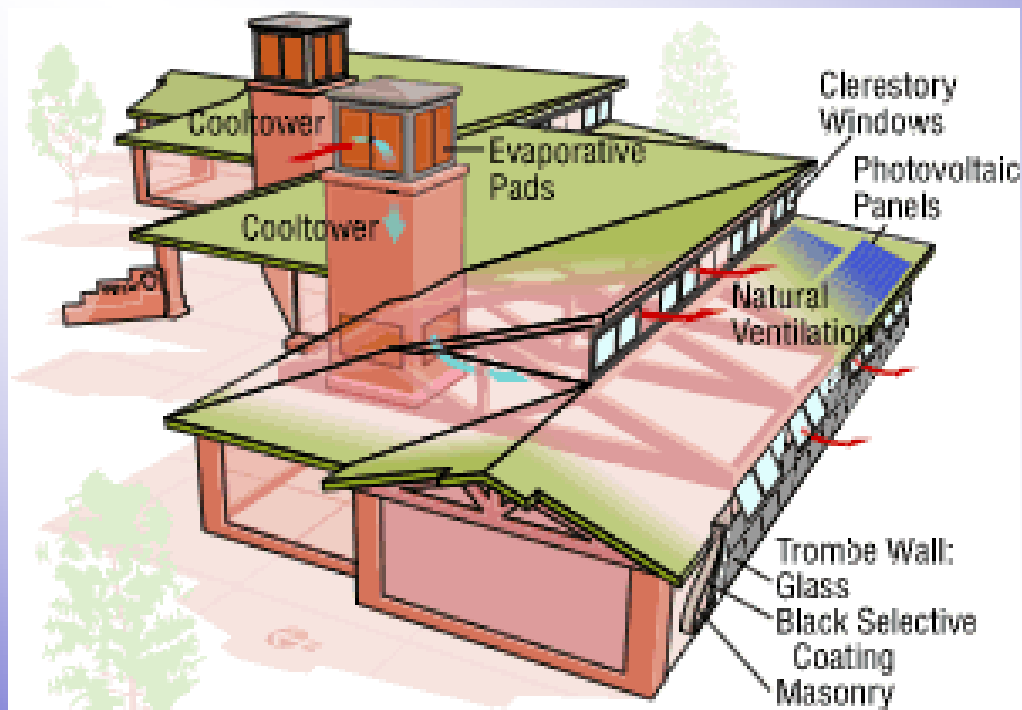
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Zion National Park Visitor Center – The Conditions

- Hot & Dry Climate (100°F daytime high)
- Night temperatures in wider areas of canyon will drop to 59°F
- Slot canyon (2000' deep)
- Canyon provides significant shading
- Wet canyon walls provide evaporative cooling



Zion National Park Visitor Center – Design Features



Goal – Use 70% less energy than ASHRAE Standard 90.



Zion National Park Visitor Center – Dwindraft Cool Towers



Zion National Park Visitor Center – 7.2-kW PV System



PV provides 30% of daytime electrical load & 100% of basic functional requirements.



Zion National Park Visitor Center - Construction

- **Construction costs 30% less than planned for conventional building.**



Zion National Park Visitor Center – Lessons Learned

- **Cooltowers with natural ventilation work best when serving open spaces. Offices with closed doors tend to overheat.**
- **White-washed ceiling less reflective than original design.**
- **No task lighting in original plan. Added later.**



Conclusion

So what is your vision for a sustainable future?



or



Conclusion

" Vision without action is merely a dream and action without vision just passes the time, but vision with action can change the world."

Joel Barker

