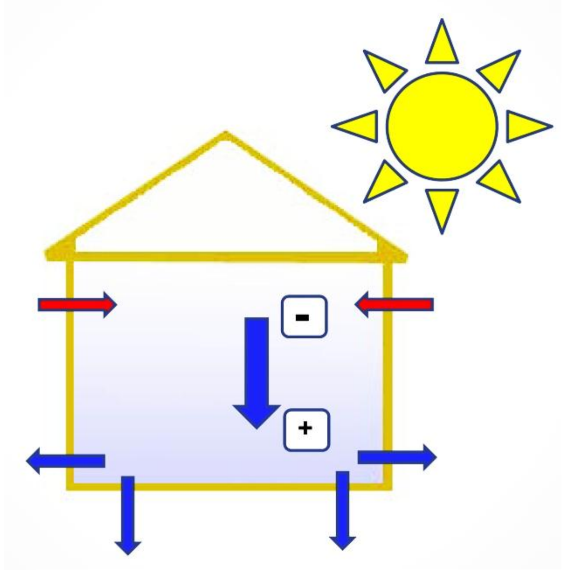
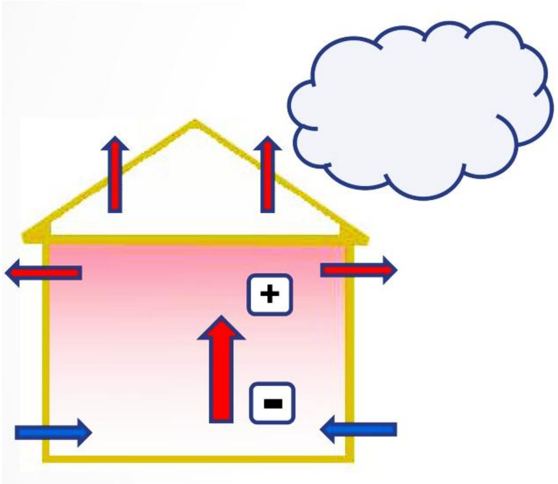
Energy Efficient Homes:

Tight and Healthy

Sponsored by AIA Housing Knowledge Community

www.aia.org/housing





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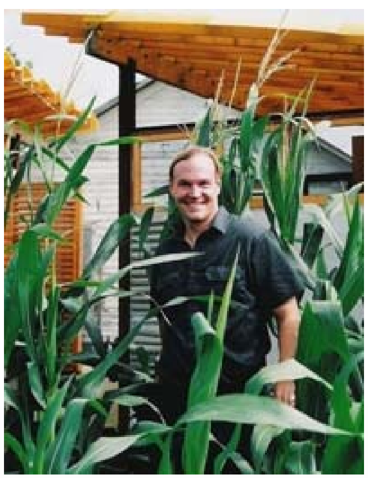


Public Interest Design is a quickly growing sector of the practice of Architecture. The SEED Evaluator provides Public Interest Design with a professional standard of ethical practice through a clear mission and step-by-step process.

Bryan Bell, the Design Corps founder, will present on his current project "Public Interest Design," funded through the 2011 AIA Latrobe Prize.

Level: Intermediate

Re-View the Research Series on YouTube

All past webinars are available on the AIA Housing Knowledge Community playlist including:

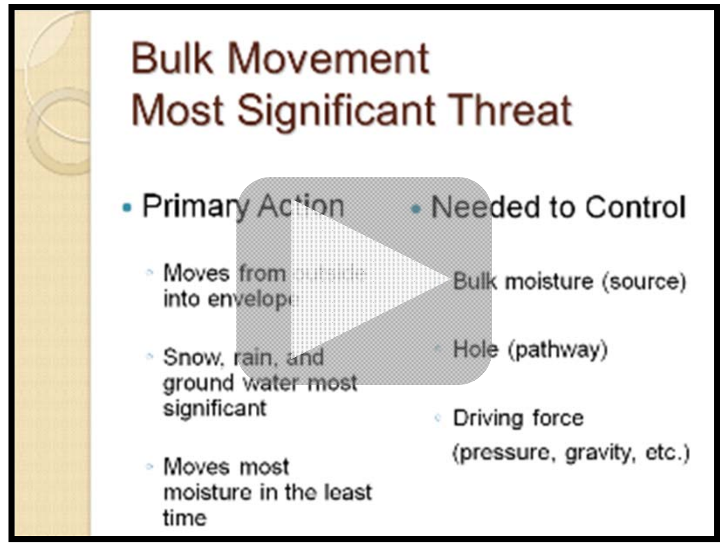
Form Follows Energy

Research, Building Science and Architecture

Detailing for Durability

Healthy Homes Research

Researching Resiliency



http://network.aia.org/hkc/home/WebinarSeries

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Course Description

This presentation focuses on the new energy guidelines and how to make tight houses meet the ASHRAE Health Based Standard 62.2 related to fresh air requirements.

Speakers Camilo Parra, AIA, and Polly Ledvina, PhD, LEED AP Homes, discuss different climatic regions and passive design strategies for these regions. They outline the energy guidelines that apply to new house construction in the United States and review how some of the guidelines are not region specific. They discuss problems associated with achieving the energy guidelines with a house's mechanical system and how these problems can be overcome. Lastly, they explain the ASHRAE Standard relative to fresh air. Stephen Schreiber, FAIA, moderates.

Learning Objectives

1. Identify the different climatic regions of the United States and learn about passive design strategies for these regions.
2. Review the new energy codes that pertain to new house construction.
3. Understand how energy guidelines affect the residential mechanical system.
4. Learn how to achieve the ASHRAE Standard related to fresh air requirements.

Camilo Parra, AIA
Parra Design Group, Ltd.

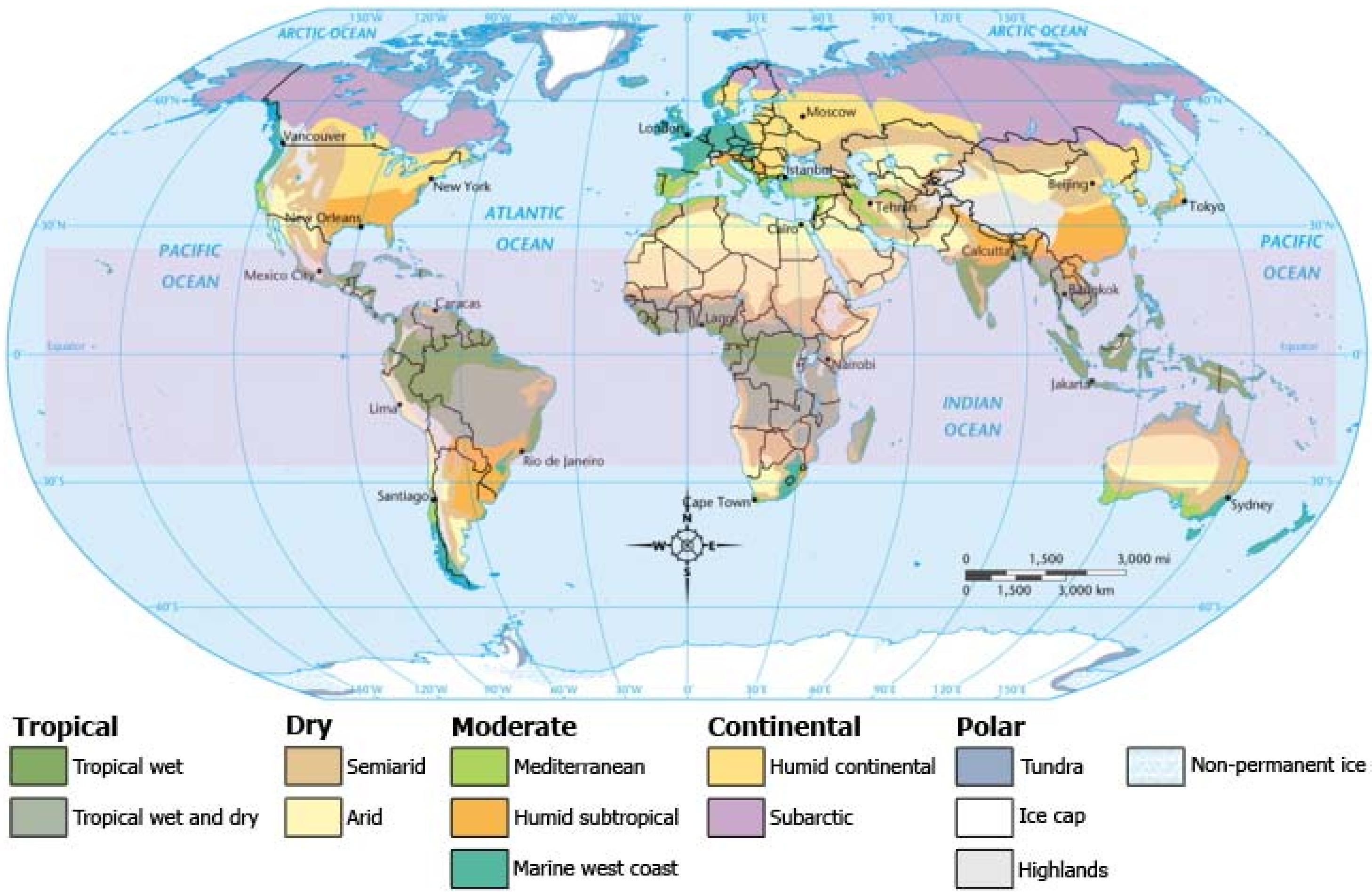
Polly Ledvina, PhD, LEED AP Homes
PSL Integrated Solutions

Stephen Schreiber FAIA
University of Massachusetts Amherst
Moderator

Submit a question to the moderator via the Chat box. They will be answered as time allows.

Part I

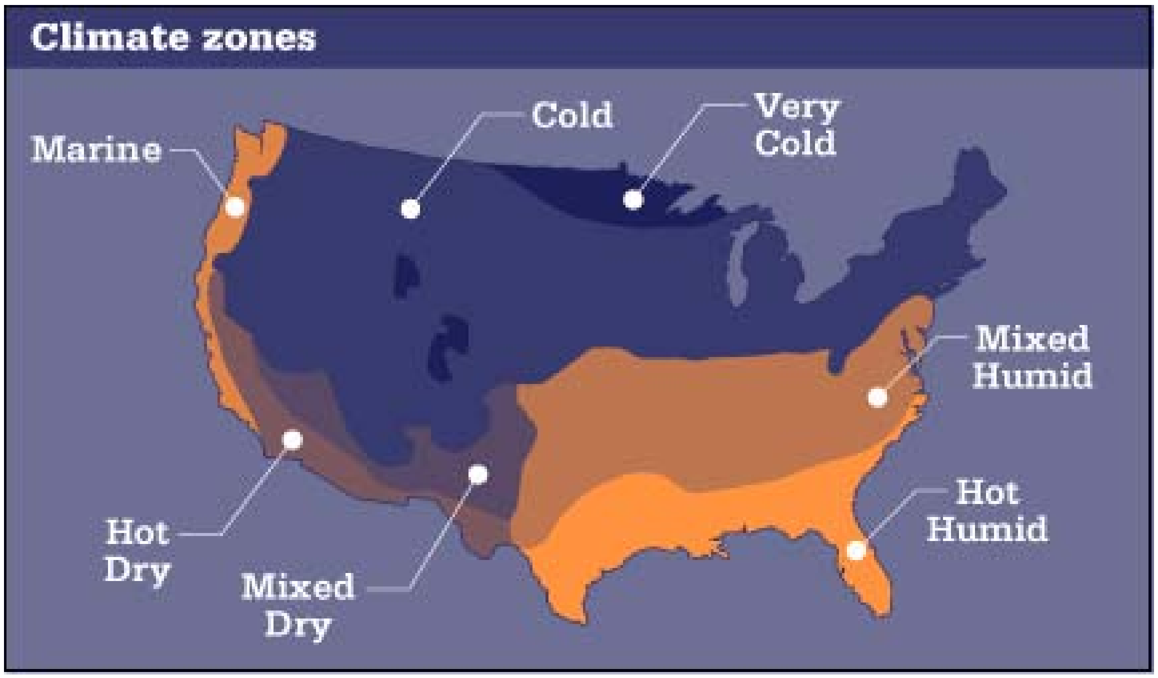
I. Overview of climatic regions of United States/ World
II. Passive design strategies for these different climatic regions
III. Problems of passive design strategies in urban areas/ mechanical system
IV. Overview of residential mechanical system
V. Energy guidelines: IECC /LEED for Homes/Energy Star v 3.0
VI. Examples of how some of these guidelines are not regions specific
VII. Energy guidelines & the residential mechanical system
VIII. Problems with the tight house
IX. How to achieve the ASHRAE 62.2 standard in the tight house
X. Conclusion

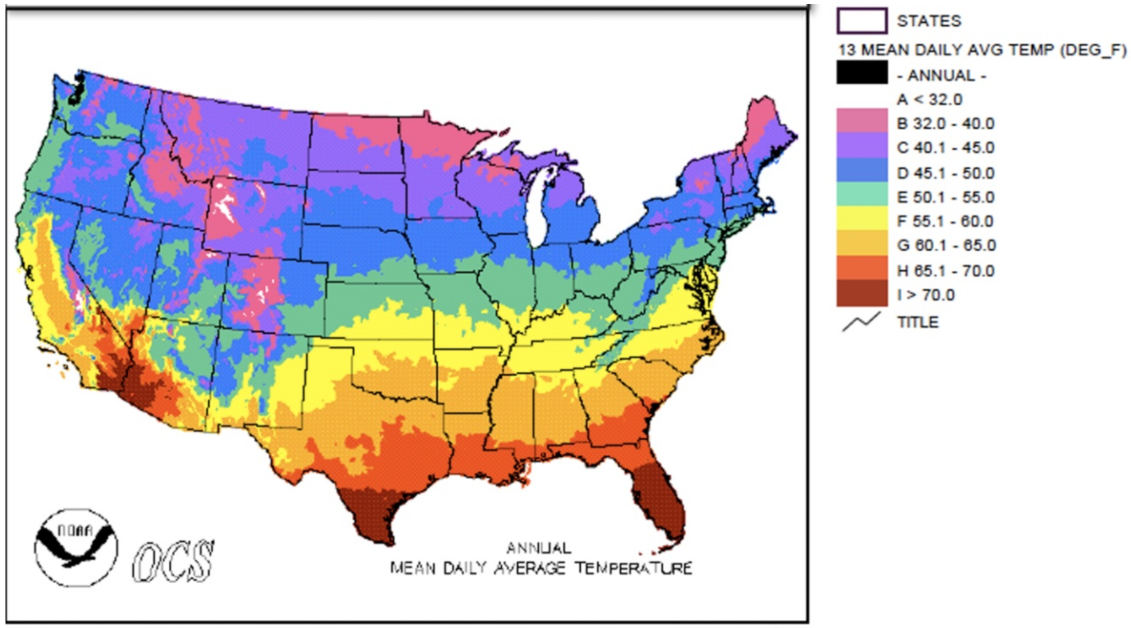

ARCTIC OCEAN
ATLANTIC OCEAN
PACIFIC OCEAN
PACIFIC OCEAN
INDIAN OCEAN
Vancouver
New York
New Orleans
Mexico City
Caracas
Lima
Rio de Janeiro
Santiago
London
Moscow
Istanbul
Tehran
Cairo
Lagos
Nairobi
Cape Town
Beijing
Tokyo
Calcutta
Bangkok
Jakarta
Sydney
Equator
N
S
E
W
0 1,500 3,000 mi
0 1,500 3,000 km
Tropical
Tropical wet
Tropical wet and dry
Dry
Semiarid
Arid
Moderate
Mediterranean
Humid subtropical
Marine west coast
Continental
Humid continental
Subarctic
Polar
Tundra
Ice cap
Highlands
Non-permanent ice

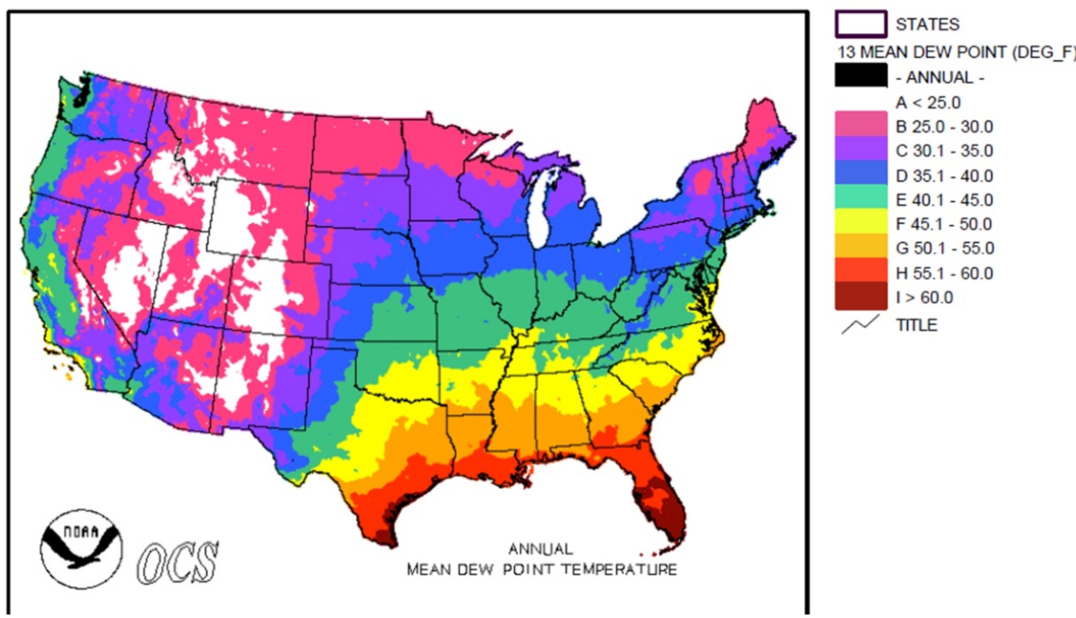
(van Lengen, 1981, The Barefoot Architect)

Three basic climate types:

1. Humid tropical (warm temperatures, little variation between day and night, heavy precipitation)
2. Dry tropical (hot temperatures, large differences between day and night, little precipitation)
3. Temperate (very cold season and cold nights)


Climate zones
Marine
Cold
Very Cold
Mixed Humid
Hot Humid
Hot Dry
Mixed Dry


STATES
13 MEAN DAILY AVG TEMP (DEG_F)
- ANNUAL -
A < 32.0
B 32.0 - 40.0
C 40.1 - 45.0
D 45.1 - 50.0
E 50.1 - 55.0
F 55.1 - 60.0
G 60.1 - 65.0
H 65.1 - 70.0
I > 70.0
TITLE
OCS
ANNUAL
MEAN DAILY AVERAGE TEMPERATURE


STATES
13 MEAN DEW POINT (DEG_F)
- ANNUAL -
A < 25.0
B 25.0 - 30.0
C 30.1 - 35.0
D 35.1 - 40.0
E 40.1 - 45.0
F 45.1 - 50.0
G 50.1 - 55.0
H 55.1 - 60.0
I > 60.0
TITLE
OCS
ANNUAL
MEAN DEW POINT TEMPERATURE

Hedrick & Shirey, Development of Humid Climate Definition (1998)

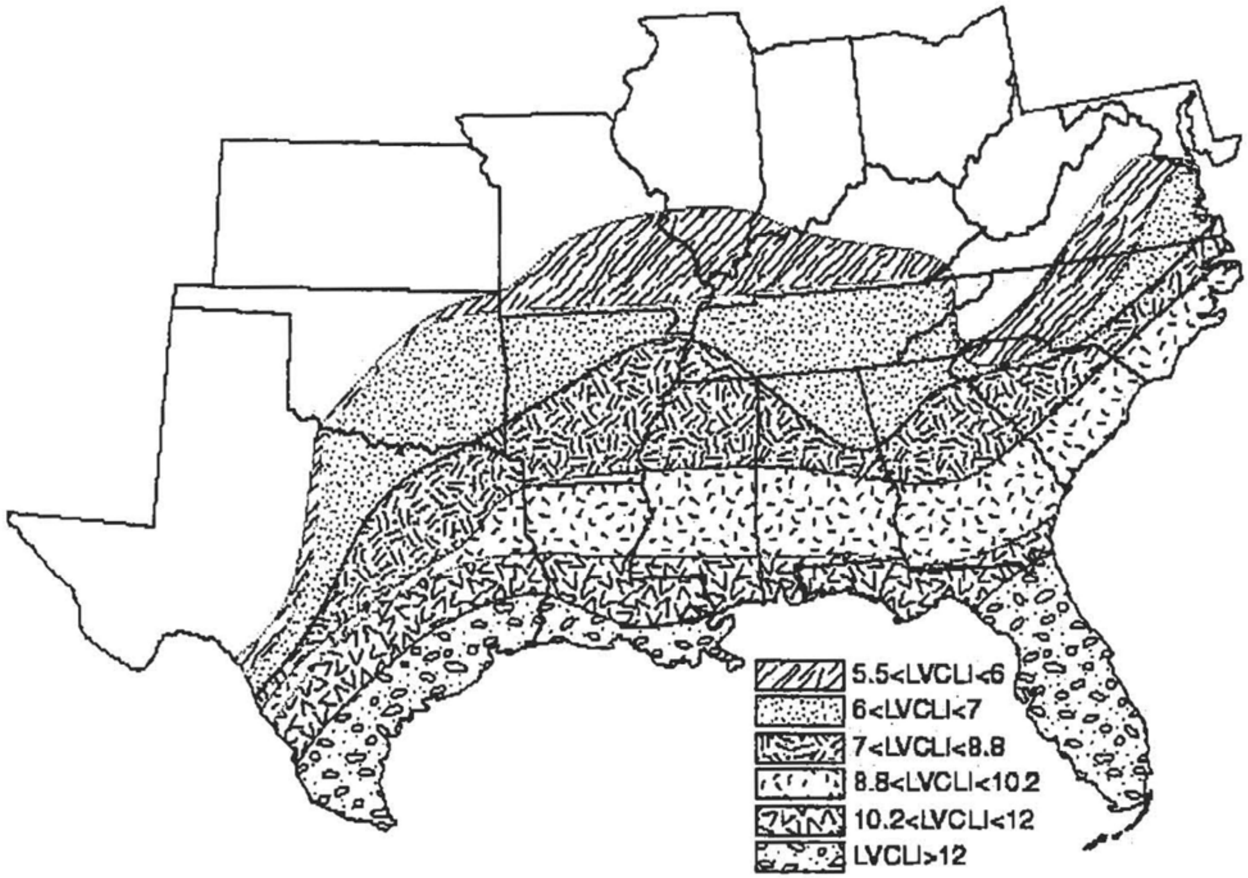
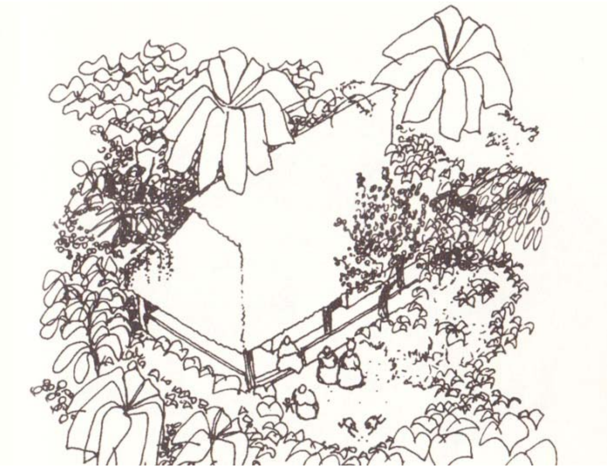


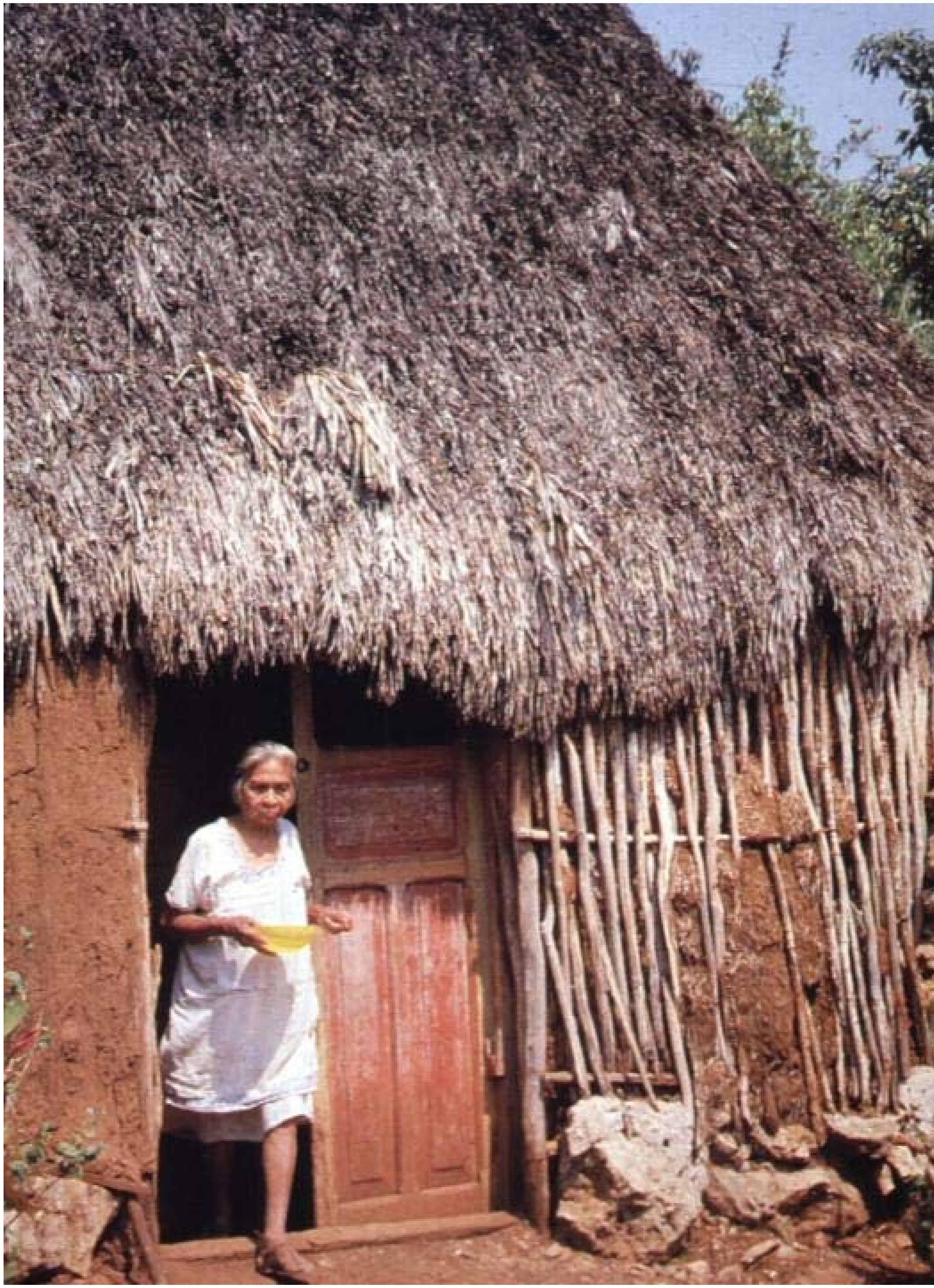
Figure 5. Zones of constant latent ventilation load index.

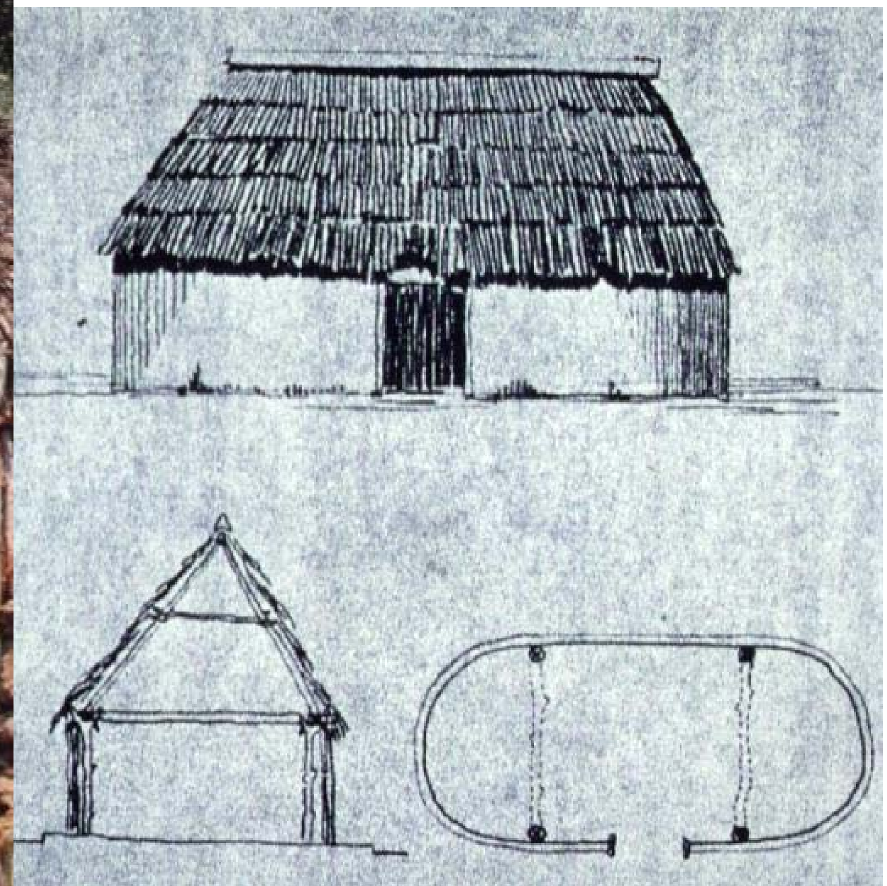
HUMID TROPICAL CLIMATE

van Lengen, 1981, The Barefoot Architect

- Build houses close to hills or elevated sites where there is more air circulation.
- Build thin walls so humidity does not accumulate.
- Build sloped roofs to evacuate rainwater.
- Use materials such as wood, bamboo, and reeds.
- Install large windows to improve ventilation.
- Separate houses to allow cool breezes to circulate.
- Build verandas around the house to protect it from rain.
- Elevate the ground floor to avoid the earth's humidity.







Mayan Hut, Mexico, 500s-present
(drawing from Schoenhauer, 6,000 Years of Housing)

Aborigine House

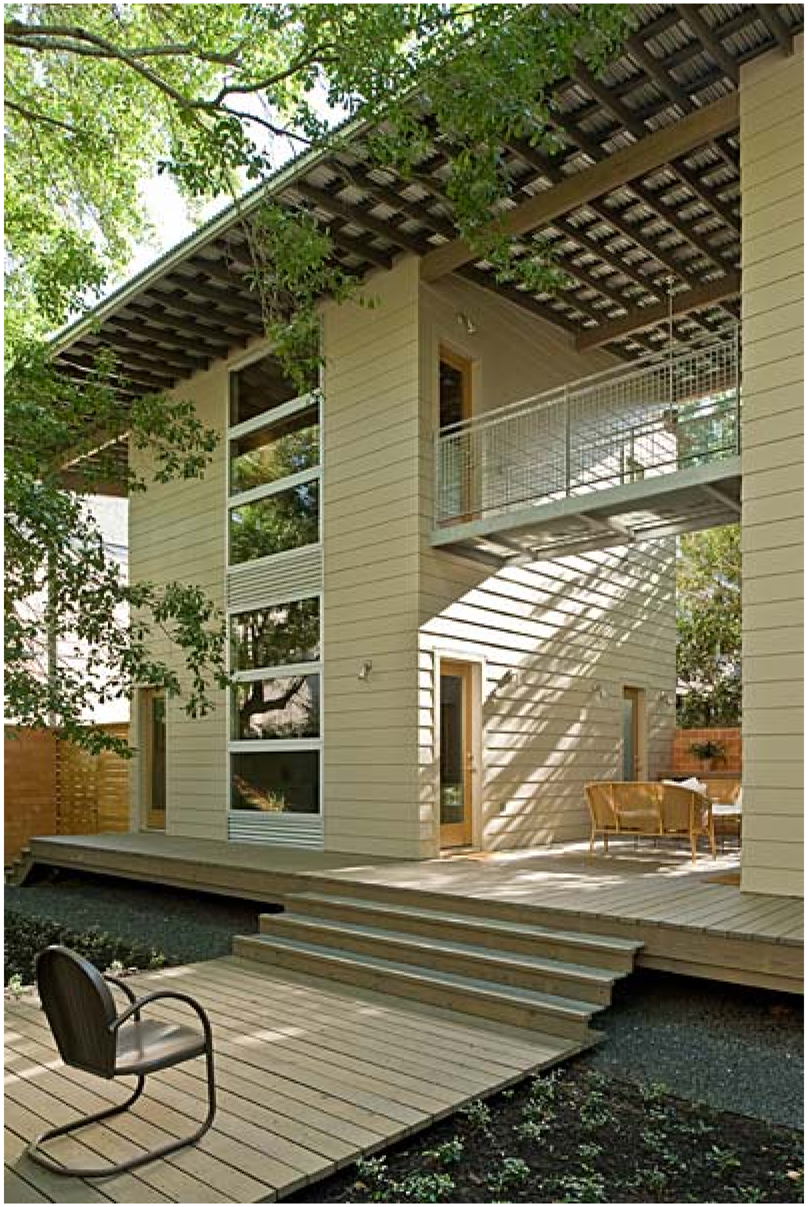
Shihsanhang Museum

Of Archeology

Taiwan

1500s-present

House El Refugio, Punta Uva, Costa Rica
Camilo Parra, AIA
2001

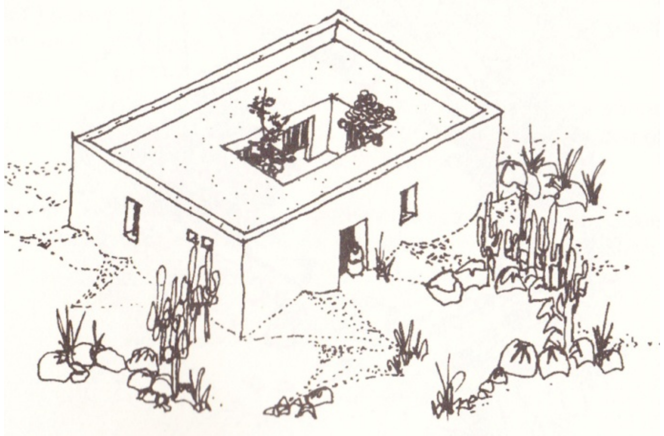


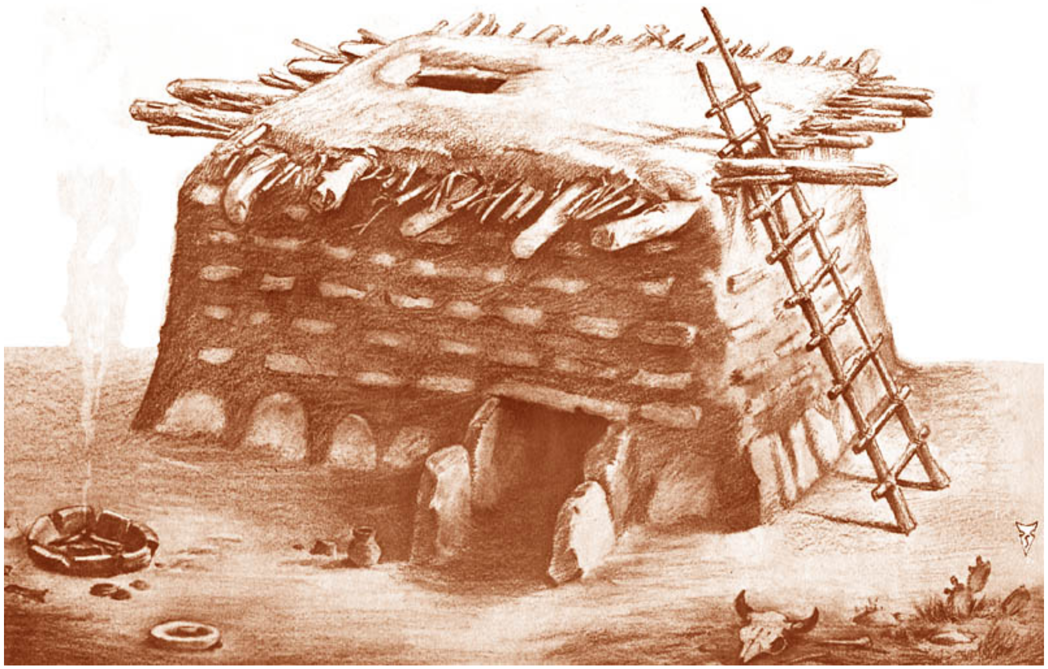
Grenader House, Houston, Texas, Nonya Grenader, FAIA, 2010

DRY TROPICAL CLIMATE

van Lengen, 1981, The Barefoot Architect

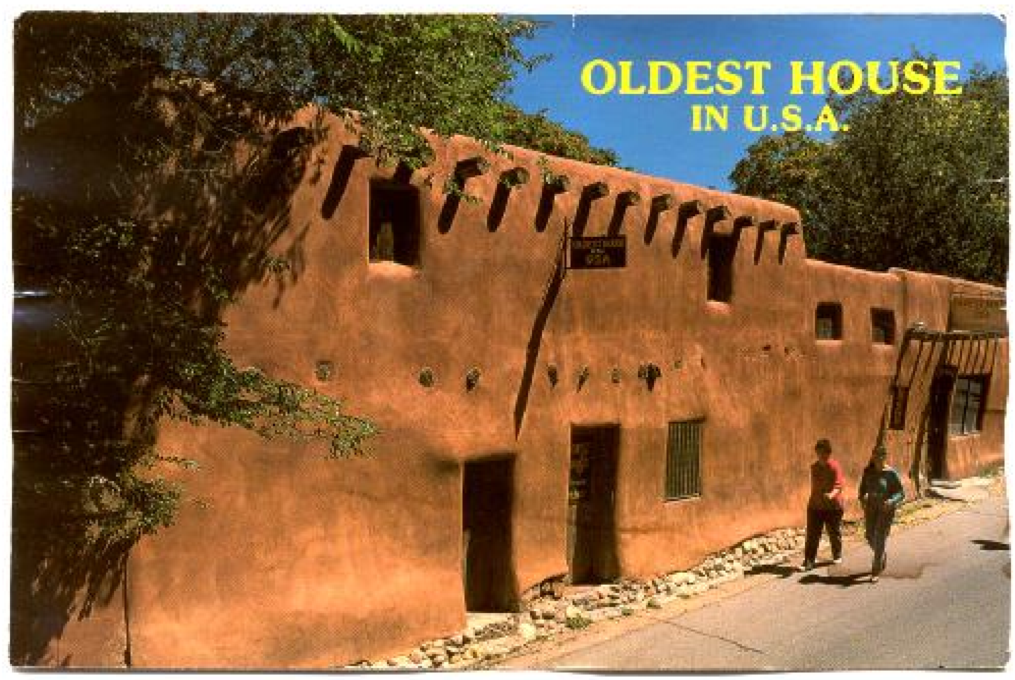
- In regions with hills, build houses in the high areas where there is more air circulation.
- Use thick walls to decrease the penetration of the heat during the day and the cold at night.
- Use materials such as stones, adobe, bricks and blocks.
- Install small windows to prevent the entry of dust and wind.
- Join houses to expose as few walls as possible to the sun. The houses then shade each other.
- Build interior courtyards to ventilate the rooms.
- Build the ground floor on the earth's surface to take advantage of the cool ground temperature.





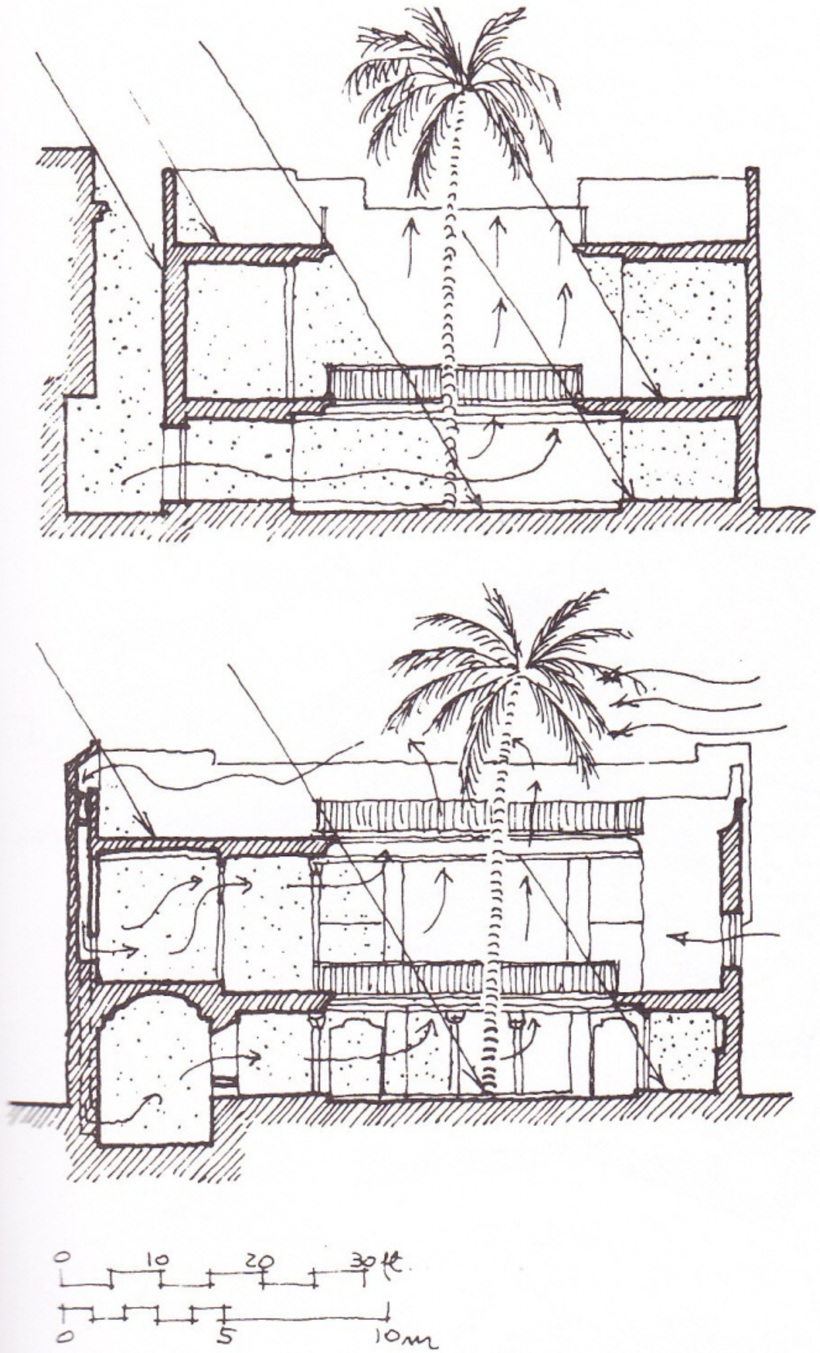
Antelope Creek House, Studer,
Panhandle-Plains Historical Museum
Canyon, Texas
1100-1450

Oldest House In USA Postcard
Santa Fe, New Mexico
1541

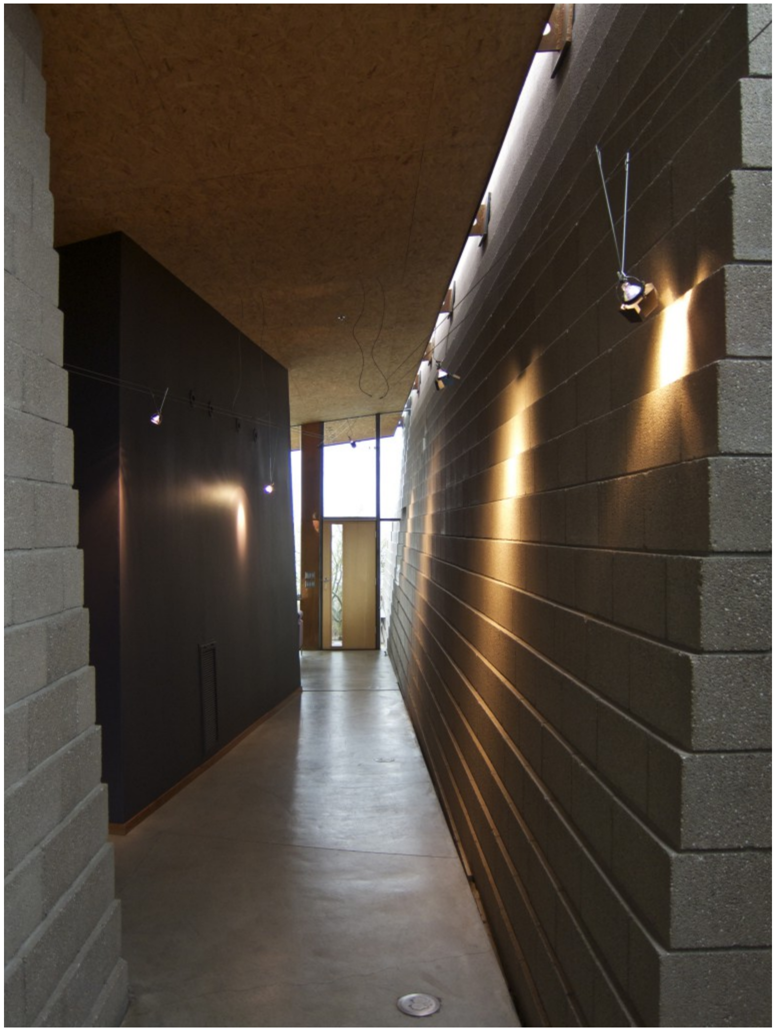


Climate Control in Islamic Dwellings

(Schoenhauer, <u>6,000 Years of Housing</u>)



Santa Fe House
Santa Fe, New Mexico
Lake / Flato, 1990



Byrne Residence
Scottsdale, Arizona
Will Bruder Architects
1999

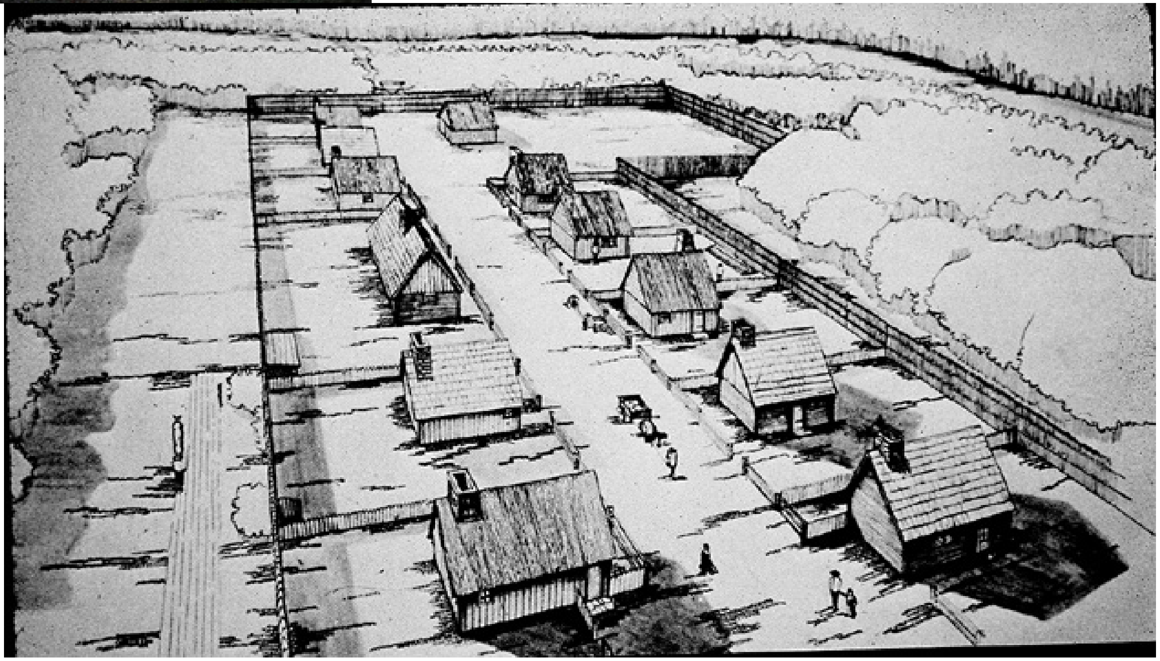
TEMPERATE CLIMATE

van Lengen, 1981, <u>The Barefoot Architect</u>

- Build houses in areas with exposure to the sun.
- Build thick walls that prevent the heat from escaping.
- Build roofs with an average pitch.
- Use materials such as wood, adobe, bricks and blocks.
- Install large windows on the south side and small windows on the north side. This applies to the Northern Hemisphere; do the opposite on the Southern Hemisphere.
- Protect the house from winds with vegetation and earth berms.
- Use the sunlight to heat the rooms. Insulate the floor from the cold ground.

Photograph by
Gail Albert Halaban
on houses Hopper painted
Gloucester, Massachusetts
circa 1920s

Early New England Settlement

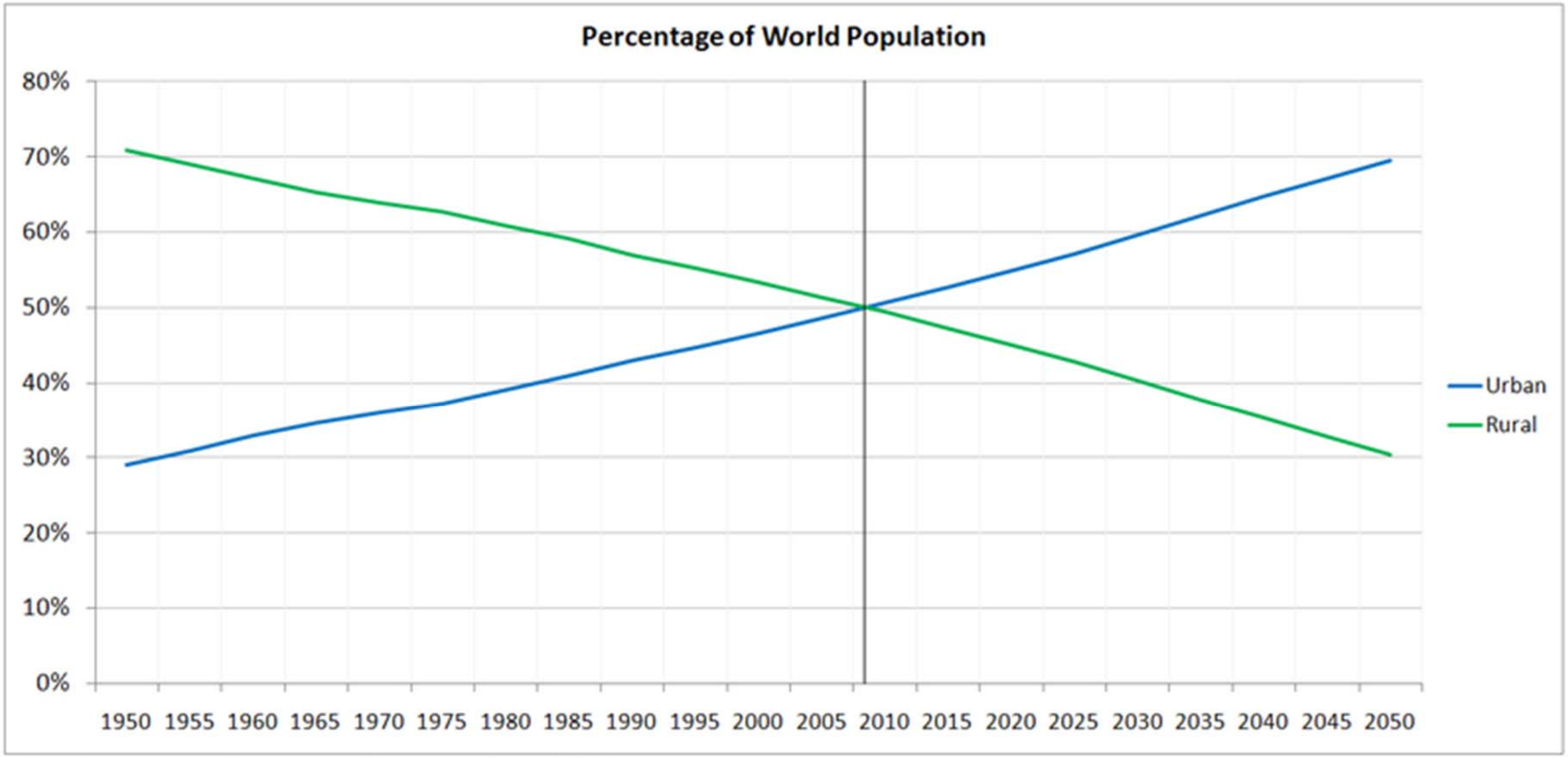


Vernacular Norwegian Architecture

Meribel Les Allues
Savoy, France
Charlotte Perriand
1961

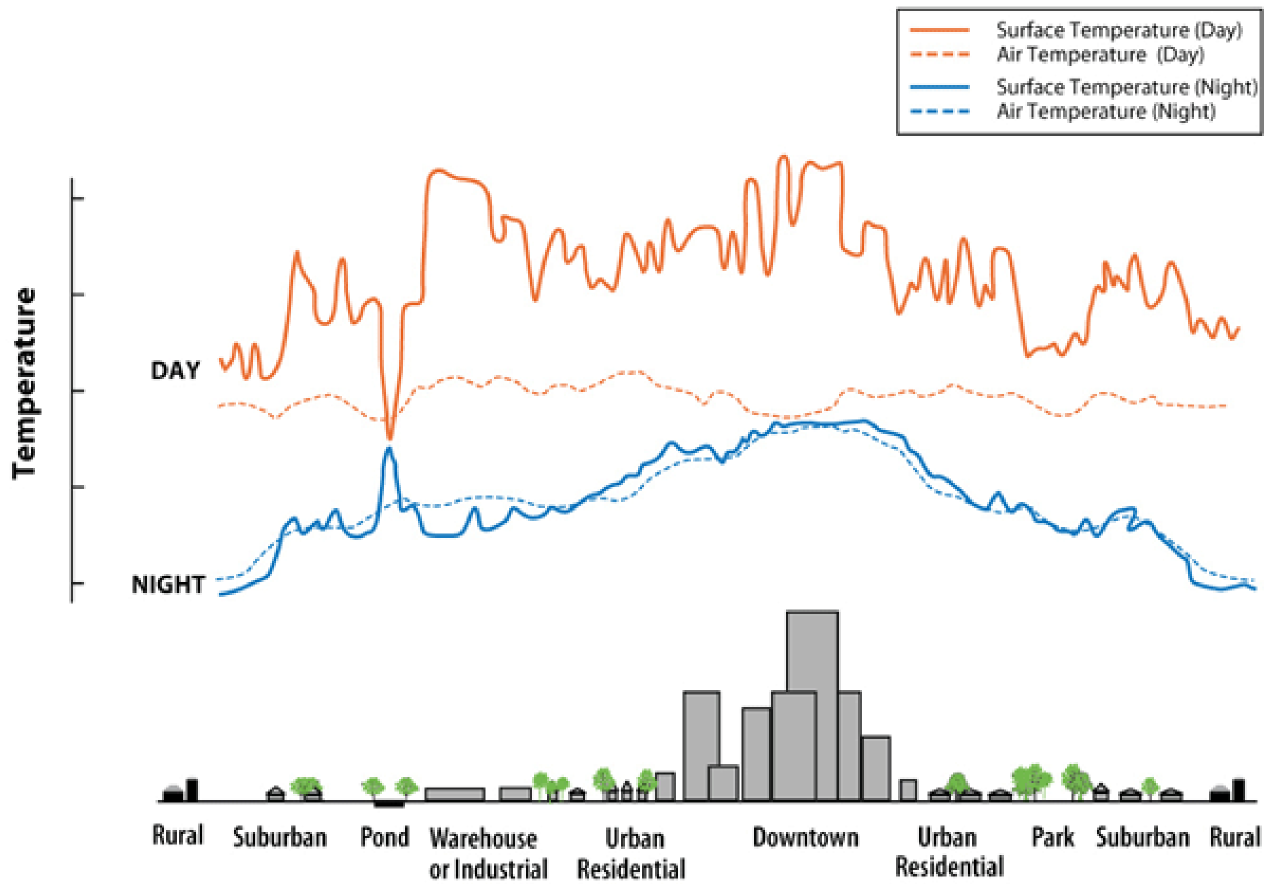
Cutler Anderson Architects
Lopez Island, Washington
2003


養生堅果.進口食品
堅果
永康
黑糖
粉圓
鮮奶
台南担仔

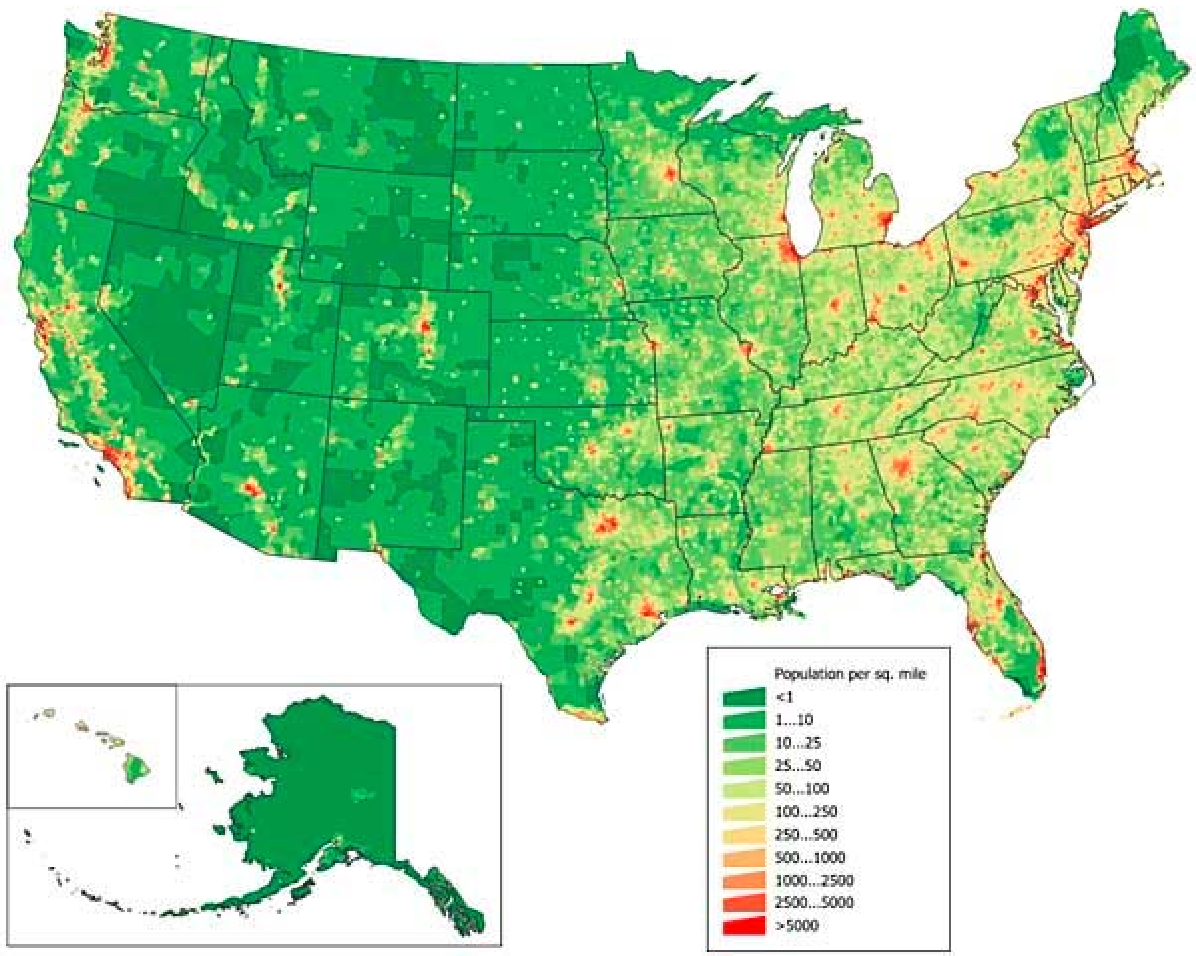


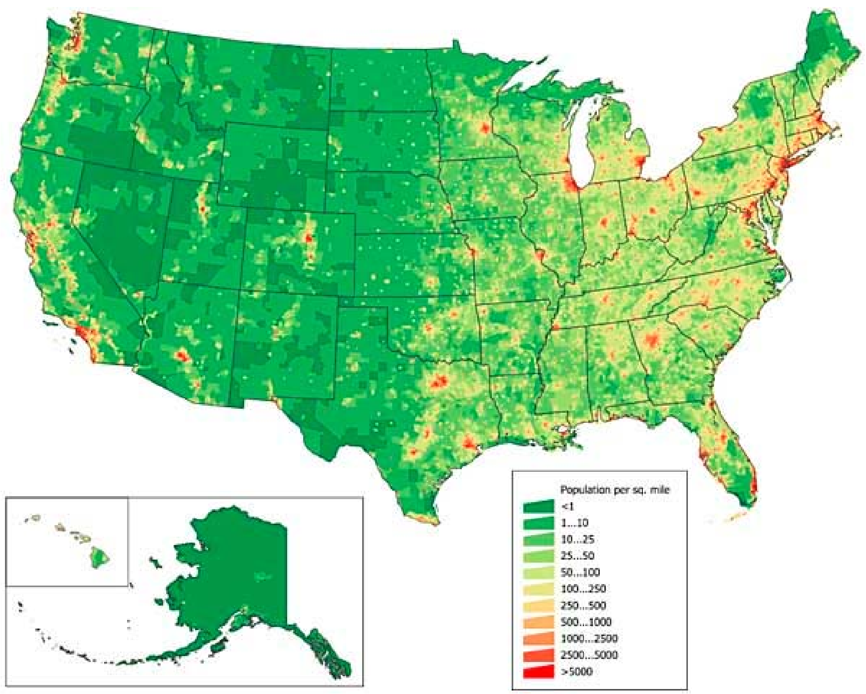
Data Source: United Nations, http://esa.un.org/unup/p2k0data.asp

U.S. Environmental Protection Agency, Urban Heat Island Basics (modified from Voogt, 2002)



U.S. population density based on Census 2010 data





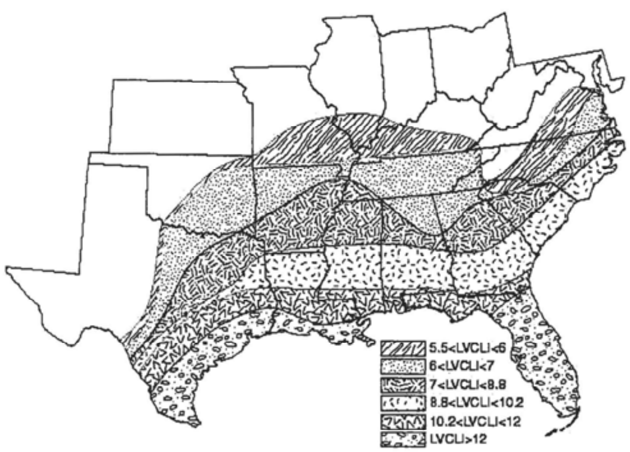
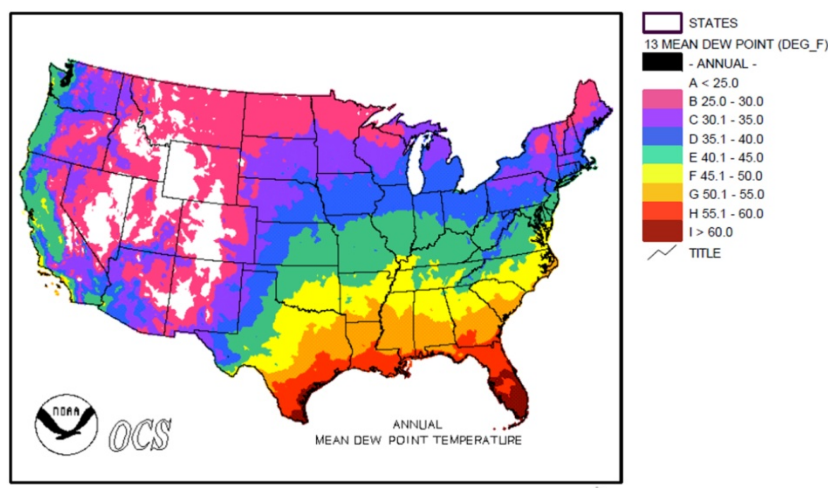


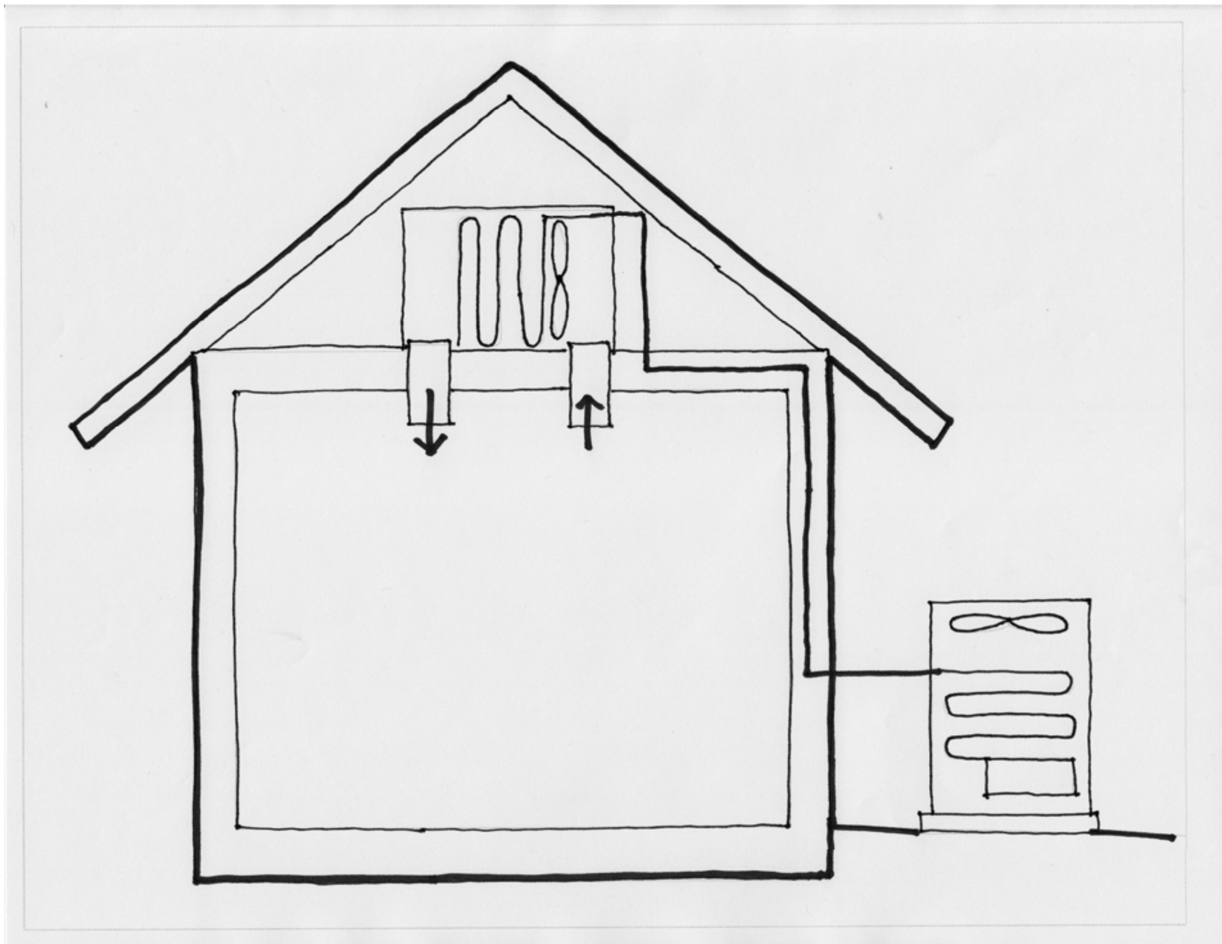
Figure 5. Zones of constant latent ventilation load index.



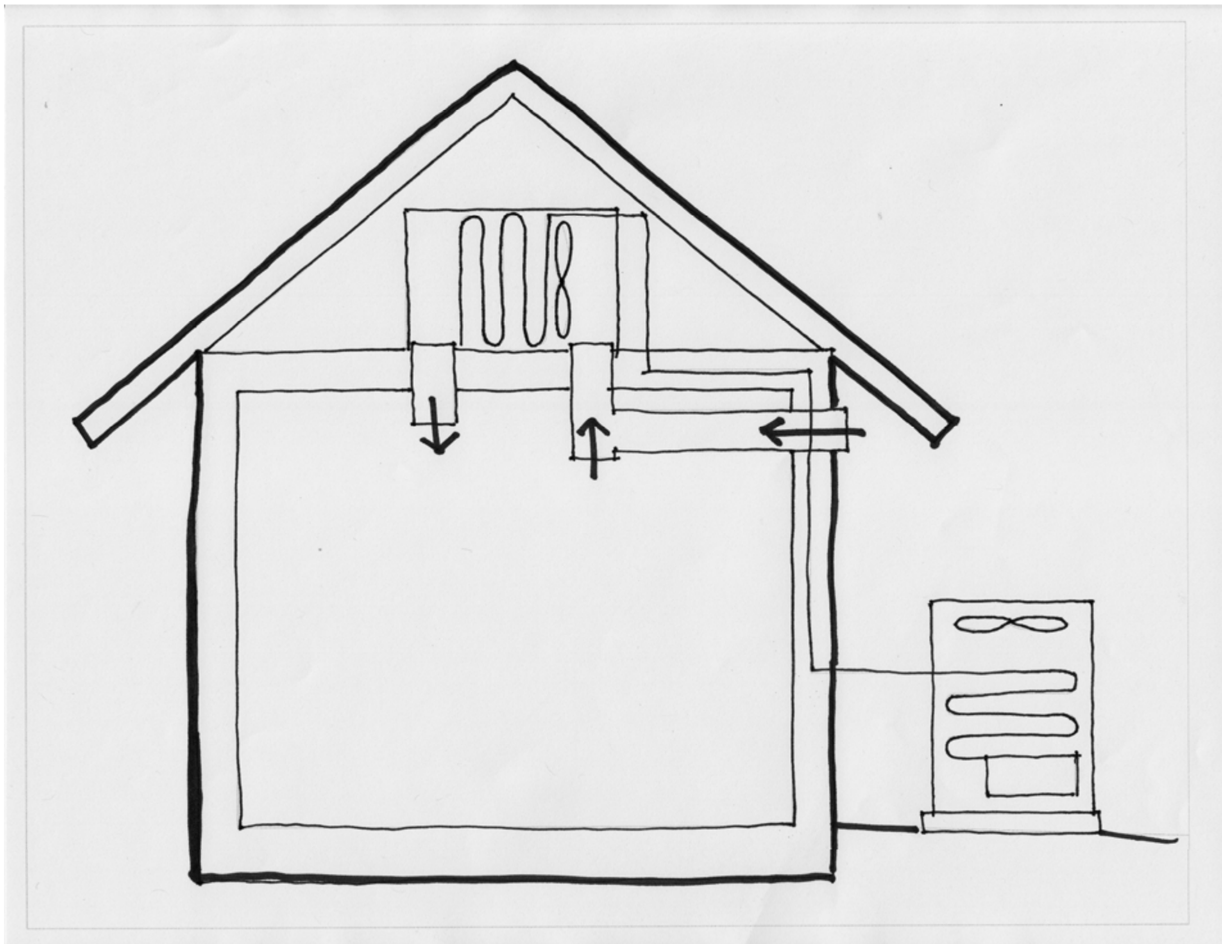

6391-RG

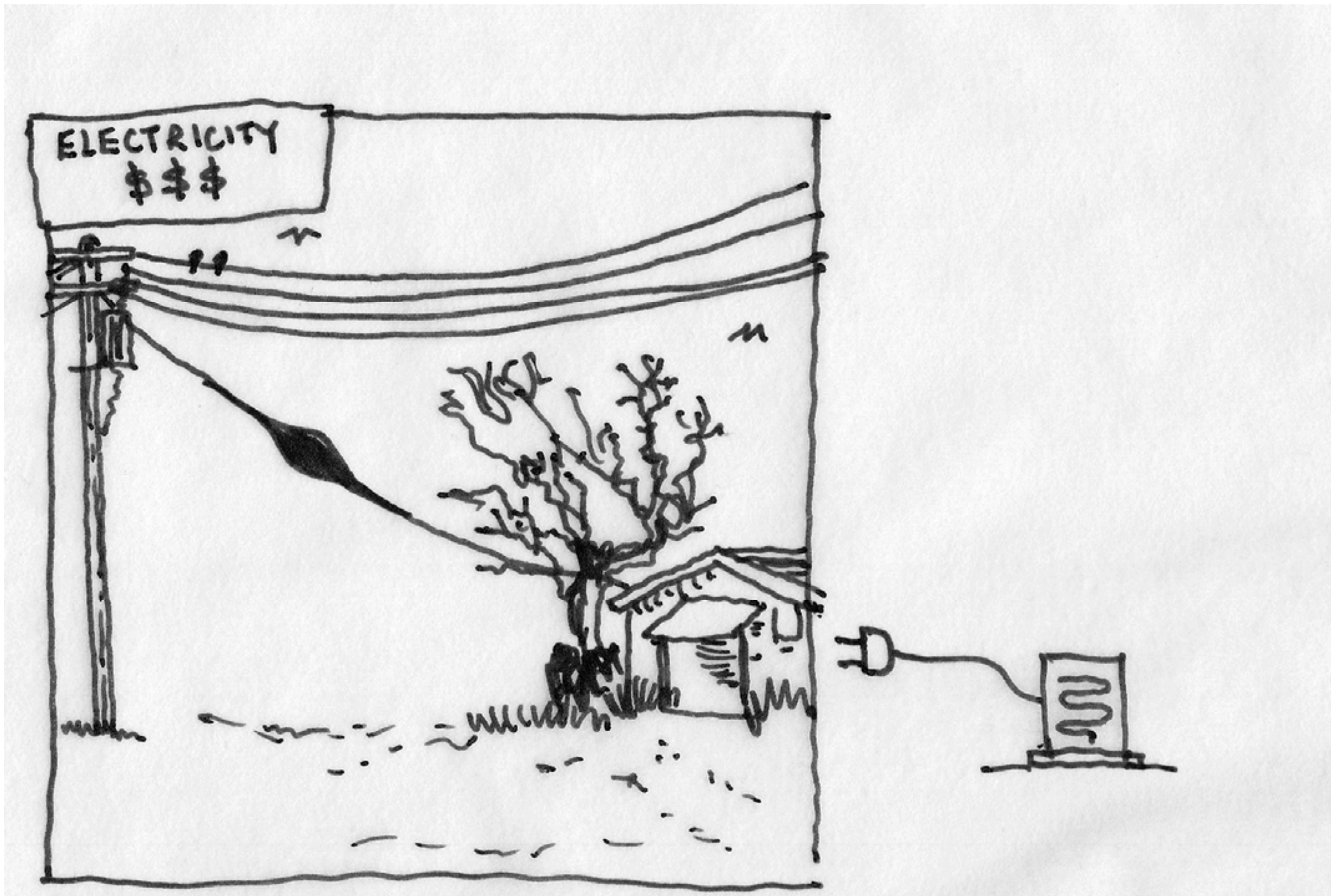

榮華三路
RongHua 3rd Rd.
出入口請勿

RESIDENTIAL HVAC SYSTEM



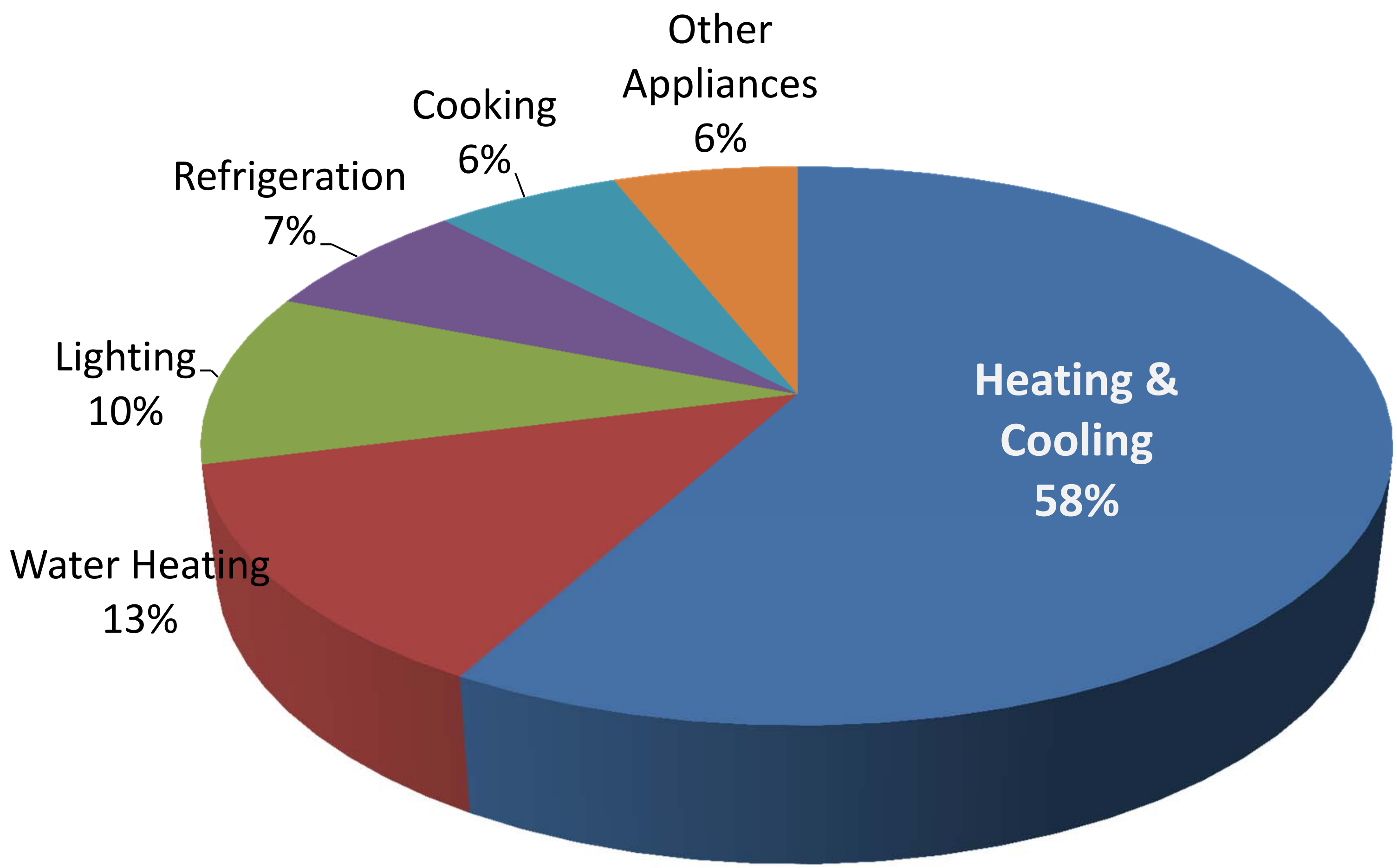
RESIDENTIAL HVAC SYSTEM (FRESH AIR INTAKE)





Adapted from Robert Crumb, The Adventures of Onion Head

Home Energy Use



Part II

I. Overview of climatic regions of United States/ World
II. Passive design strategies for these different climatic regions
III. Problems of passive design strategies in urban areas/ mechanical system
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V. Energy guidelines: IECC /LEED for Homes/Energy Star v 3.0
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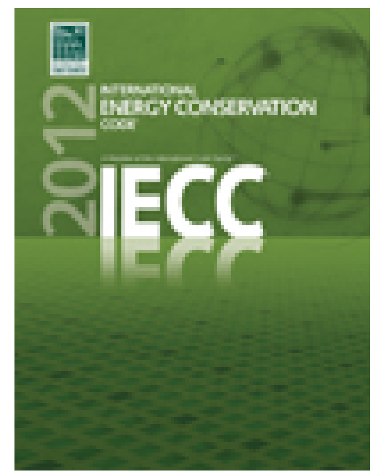
V. Energy guidelines:
IECC /LEED for Homes/Energy Star

2012 IECC: “The 30% Solution”

- America’s primary residential energy code is the International Energy Conservation Code or IECC.
- 2012 IECC-regulated features will use 30% less energy compared to those that comply with the 2006 IECC
- Regulated features:
  - Insulation & Fenestration
  - Infiltration limits
  - Duct insulation, sealing, and testing
  - HVAC controls
  - Equipment sizing
  - Dampers
  - Lighting



Insulation and Fenestration Requirements

Minimum R-values

- Roofs
- Walls
- Foundations

R-value indicates resistance to heat flow; higher in cold climates

Maximum U-values

- Windows
- Skylights

U-value = 1/R-value; lower in cold climates

Maximum SHGC

- Skylights
- Windows

Solar Heat Gain Coefficient; lower in warm climates

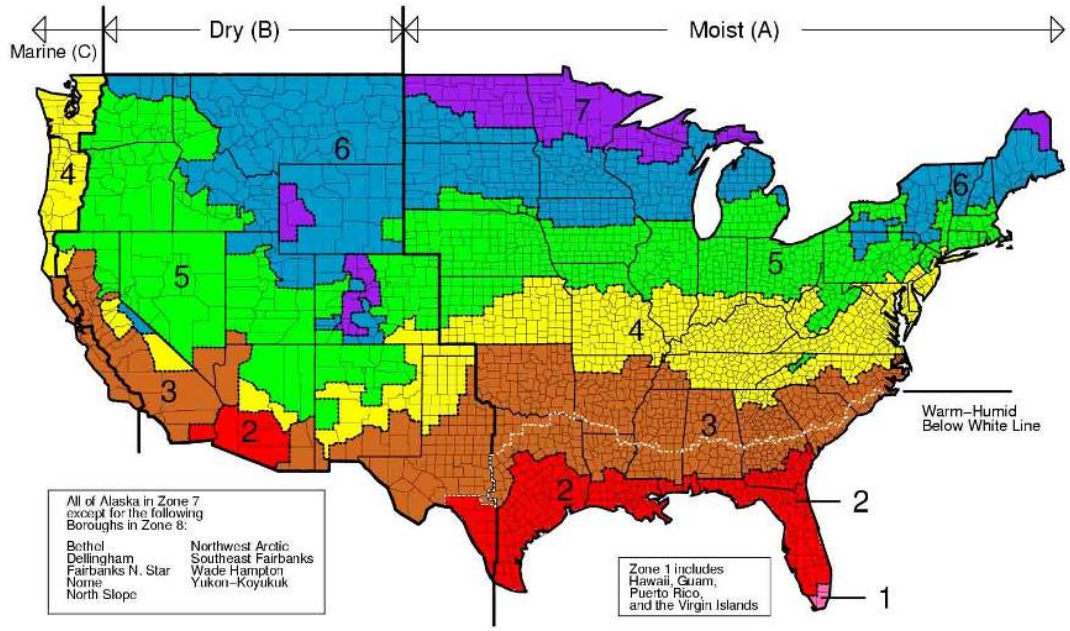


TABLE R402.1.1
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT[a]

CLIMATE ZONE	FENESTRATION U-FACTOR[b]	SKYLIGHT[b] U-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING R-VALUE	WOOD FRAME WALL R-VALUE	MASS WALL R-VALUE[i]	FLOOR R-VALUE	BASEMENT[c] WALL R-VALUE	SLAB[d] R-VALUE & DEPTH	CRAWL SPACE[c] WALL R-VALUE
1	NR	0.75	0.25	30	13	3/4	13	0	0	0
2	0.40	0.65	0.25	38	13	4/6	13	0	0	0
3	0.35	0.55	0.25	38	20 or 13+5[h]	8/13	19	5/13[f]	0	5/13
4 except Marine	0.35	0.55	0.40	49	20 or 13+5[h]	8/13	19	10 /13	10, 2 ft	10/13
5 and Marine 4	0.32	0.55	NR	49	20 or 13+5[h]	13/17	30[g]	15/19	10, 2 ft	15/19
6	0.32	0.55	NR	49	20+5 or 13+10[h]	15/20	30[g]	15/19	10, 4 ft	15/19
7 and 8	0.32	0.55	NR	49	20+5 or 13+10[h]	19/21	38[g]	15/19	10, 4 ft	15/19

“Above Code” Programs

Energy Star v 3. Guidelines set by the U.S. Environmental Protection Agency (USEPA) to attain and independently verify new homes built to be at least 15% more energy efficient than homes built to the 2009 International Energy Conservation Code (IECC)

Leadership in Energy and Environmental Design (LEED). Guidelines set by US Green Building Council (USGBC) to attain and independently verify improved performance in areas of sustainable site development, water savings, energy efficiency, materials selection and indoor environmental quality.

Comparison of Insulation Requirements IECC vs "Above Code" Programs

(Climate Zone 5 used for all values)	IECC 2009	IECC 2012	ENERGY STAR v3	LEED FOR HOMES
Ceiling insulation	R38	R49	R38	Credit
2x6 ext. studs or 1" rigid insulation (R13 + 5)	x	x	x	Credit
Foundation wall insulation R-value (continuous or cavity)	10/13	15/19	10/13	Credit
Windows U-value	< 0.35	< 0.32	< 0.30	< 0.35

http://www.alliancees.org

Energy Efficient Homes: Tight and Healthy (Part II)

VI. Examples of how some of these guidelines are not region specific

Residential Tax Incentives for Ground Source Heat Pumps (GSHPs)

Federal Income Tax Credit:

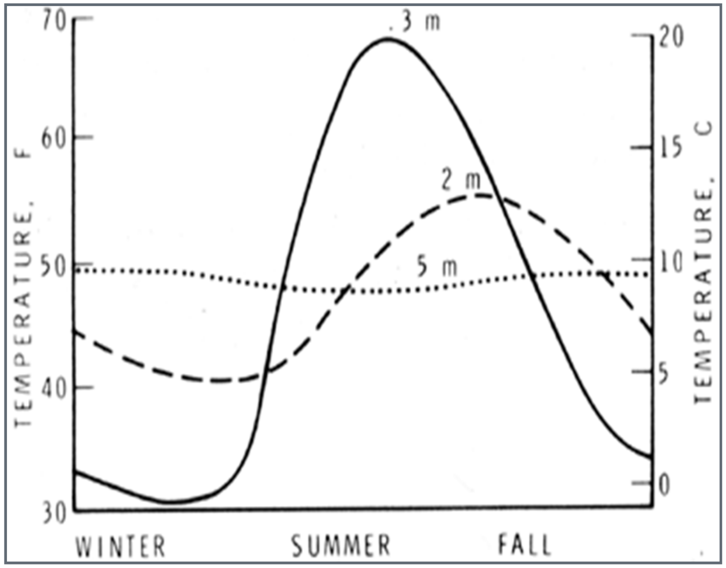
- 30% of total GSHP system cost
- No cap on maximum credit
- Can be used to offset AMT tax
- Can be combined with other tax credits
- Can be used in more than one year

LEARN MORE AT energystar.gov

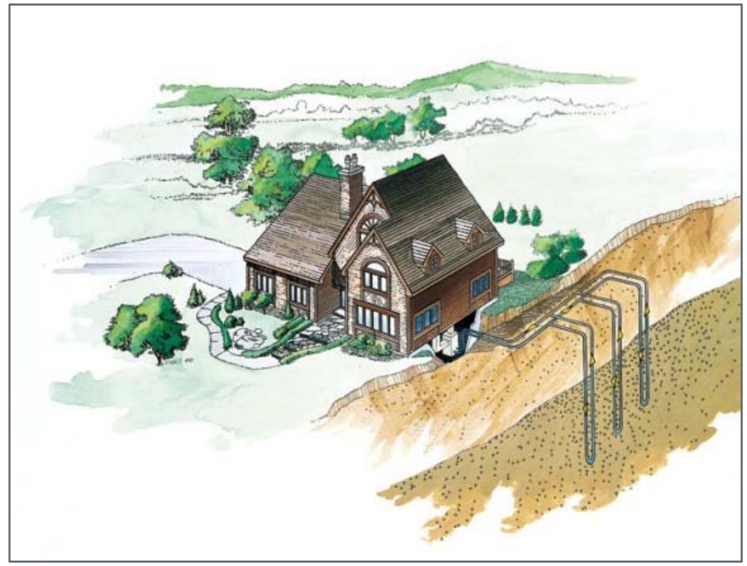
Eligibility:

- Home must be located in the U.S.
- Includes houses, condos, mobile homes
- Does not have to be your main home
- GSHP must meet Energy Star requirements
- Placed in service before 2017

Ground Source Heat Pump (GSHP): Ground Temperature as "Free Energy"



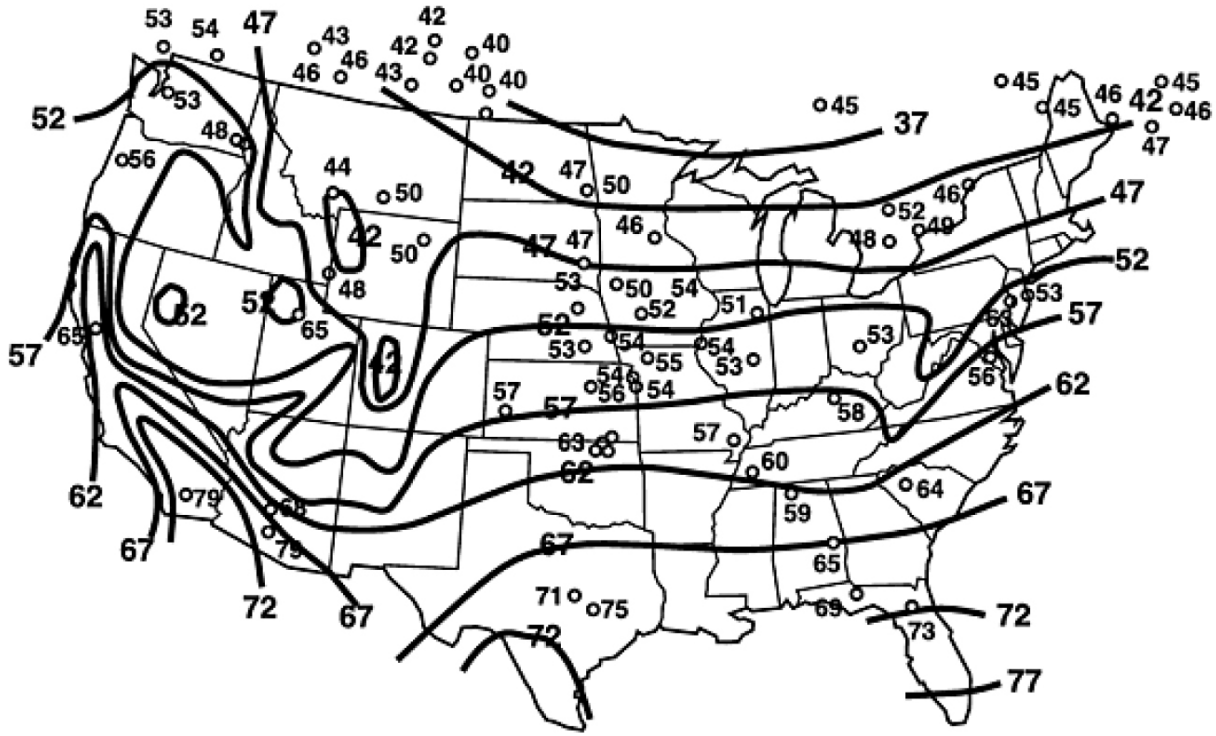
Graphic: Canadian Building Digest



Graphic: www.geoexchange.org

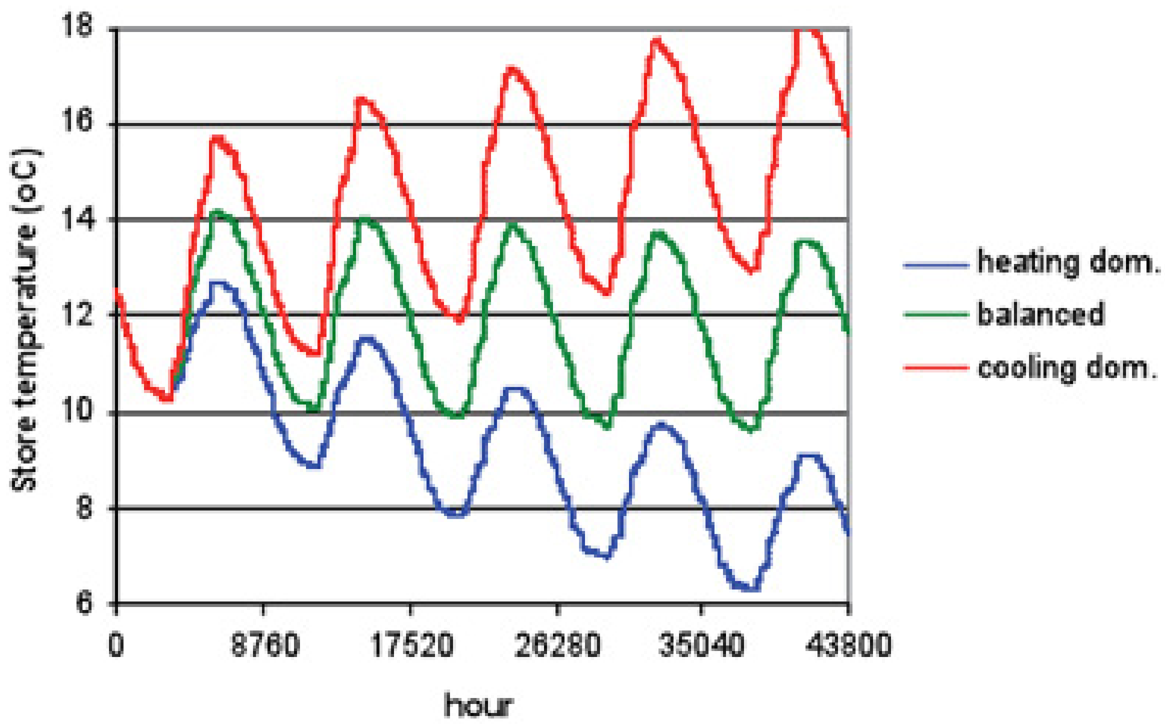
- Ground absorbs about half of sun's incident energy
- Local ground temperatures depend on climate, ground & snow cover, slope, soil properties, etc.
- Temperature variation decreases with depth

Mean Earth Temperatures



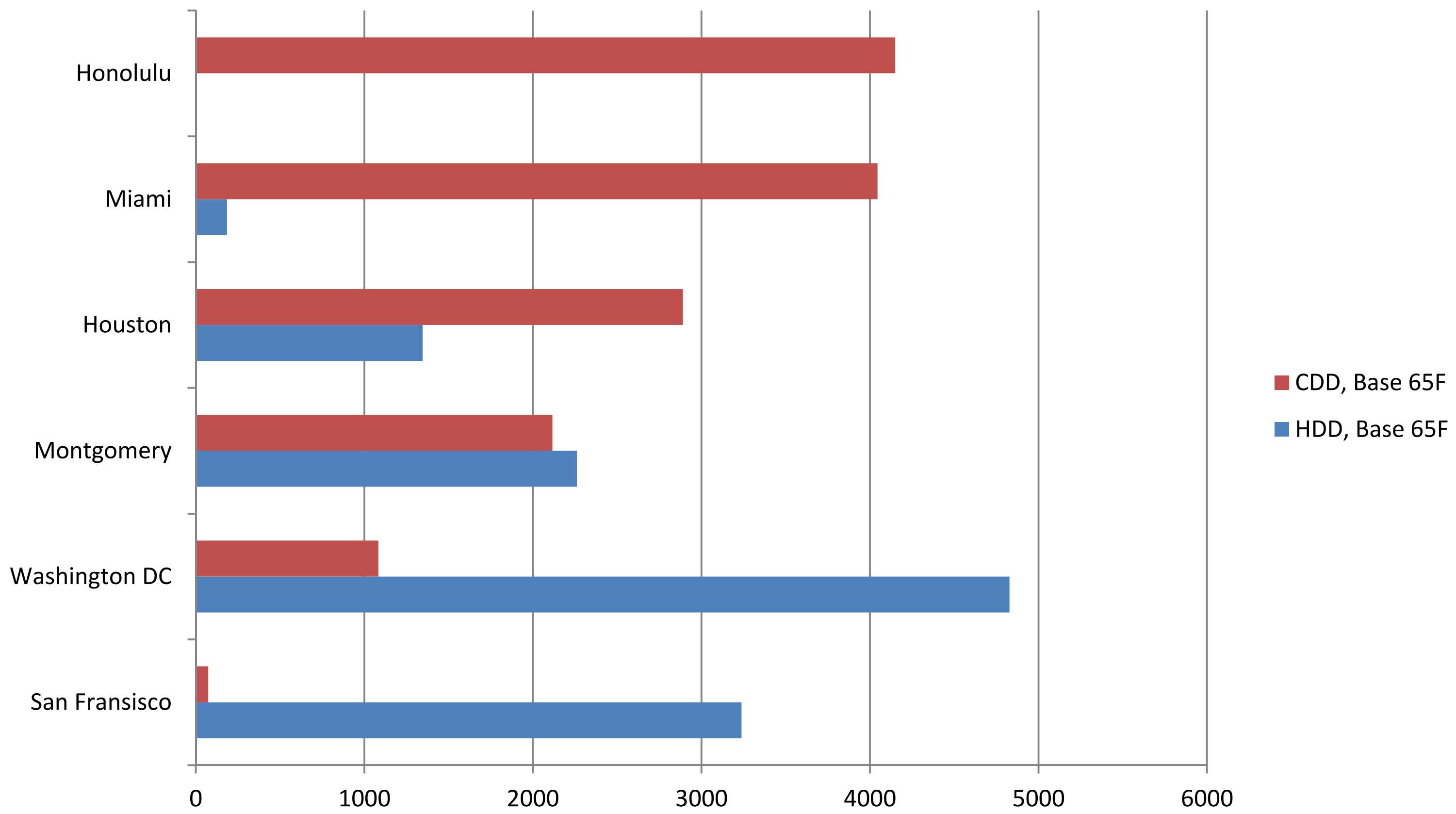
Mean annual earth temperature observations at individual stations, superimposed on well-water temperature contours.

Long Term Temperatures in a Borehole Heat Exchanger



http://www.geodrillinginternational.com/

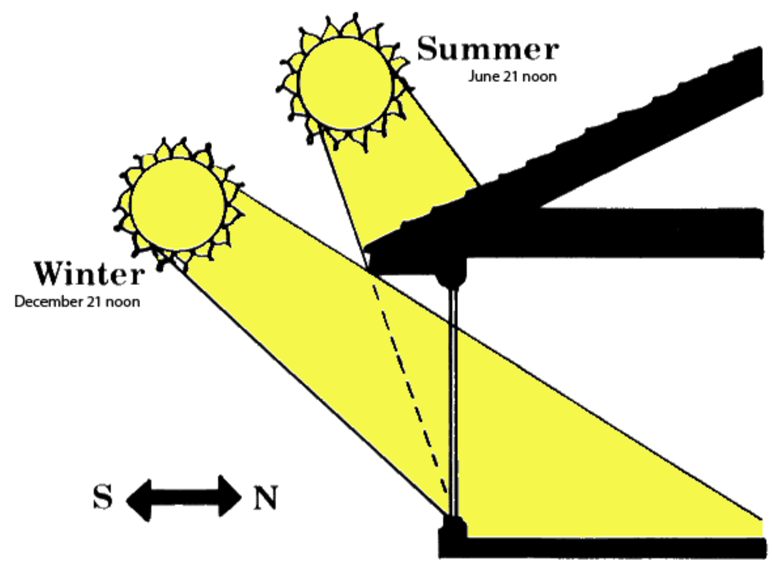
Annual CDD & HDD for Representative US Cities



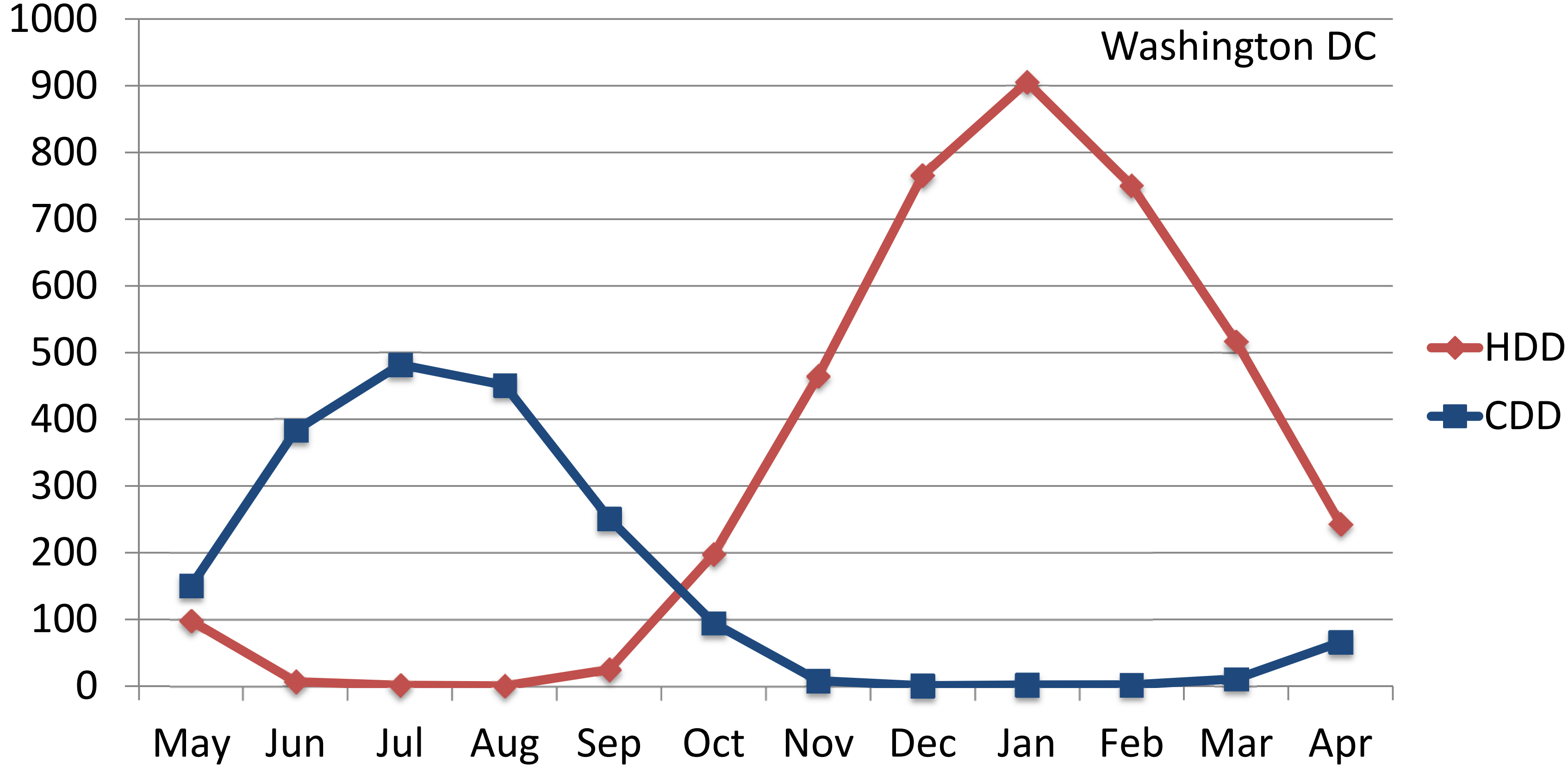
LEED for Homes

ID1.5 Building Orientation for Solar Design

d) At least 90% of the glazing on the south-facing wall is completely shaded (using shading, overhangs, etc.) at noon on June 21 and un-shaded at noon on December 21.



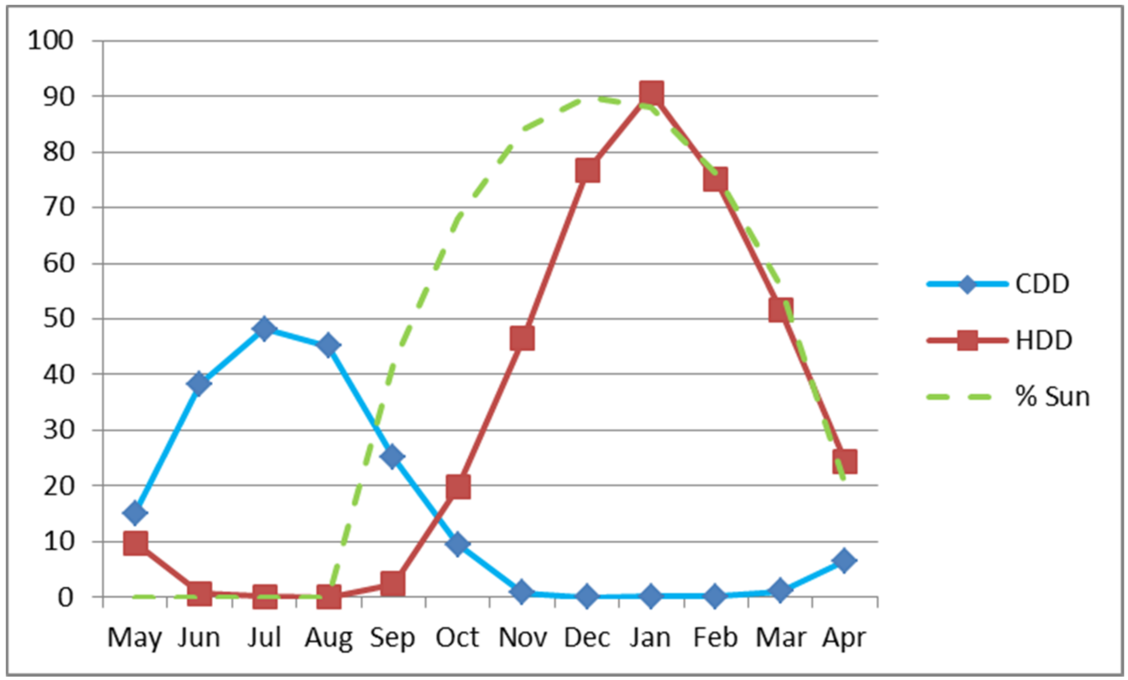
Cooling and Heating Degree Days



Percent Sun on Window

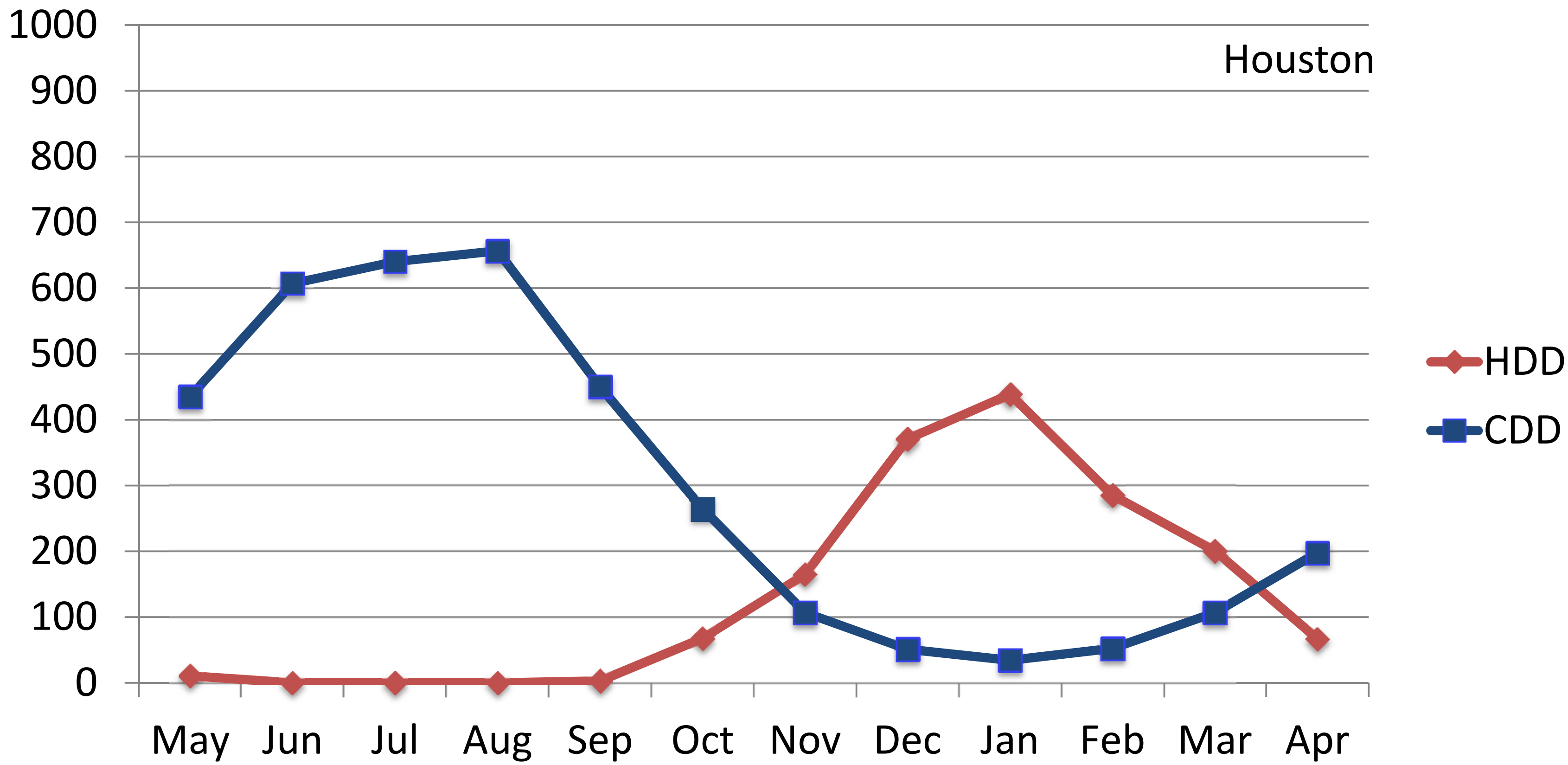
Shown with Monthly Cooling and Heating Degree Days

Washington DC	
	% Sun at Noon
May	0
Jun	0
Jul	0
Aug	0
Sep	42
Oct	68
Nov	84
Dec	90
Jan	88
Feb	76
Mar	56
Apr	20
Overhang depth (ft)	2.8



Degree Days are shown at 1/10 scale

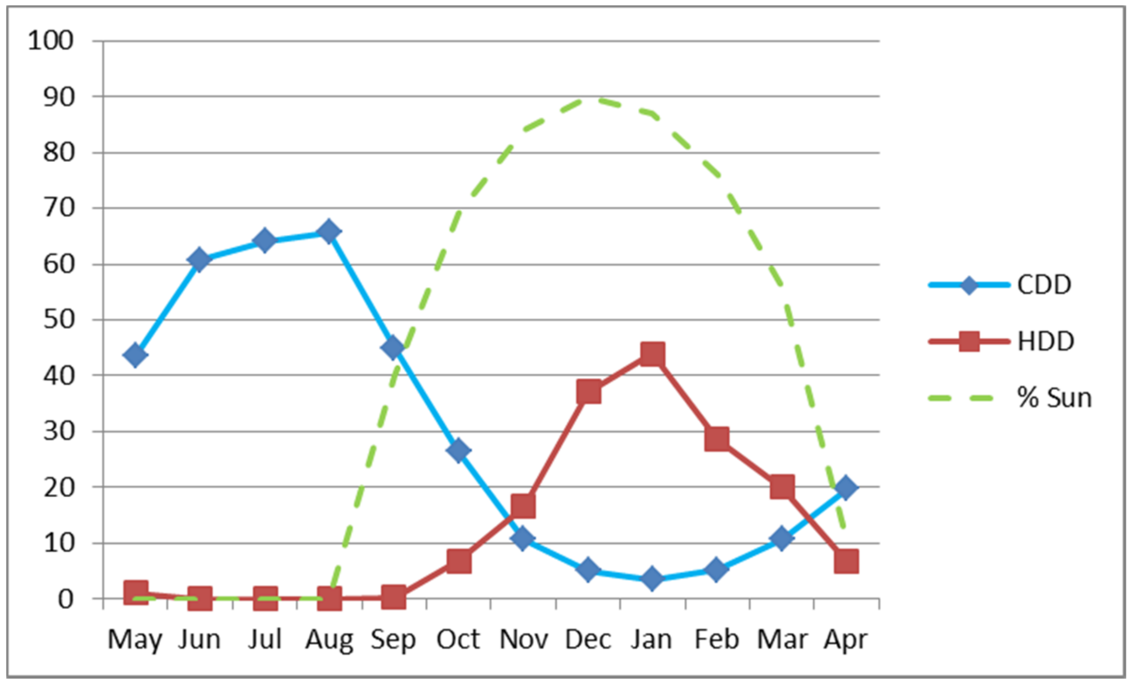
Cooling and Heating Degree Days



Percent Sun on Window

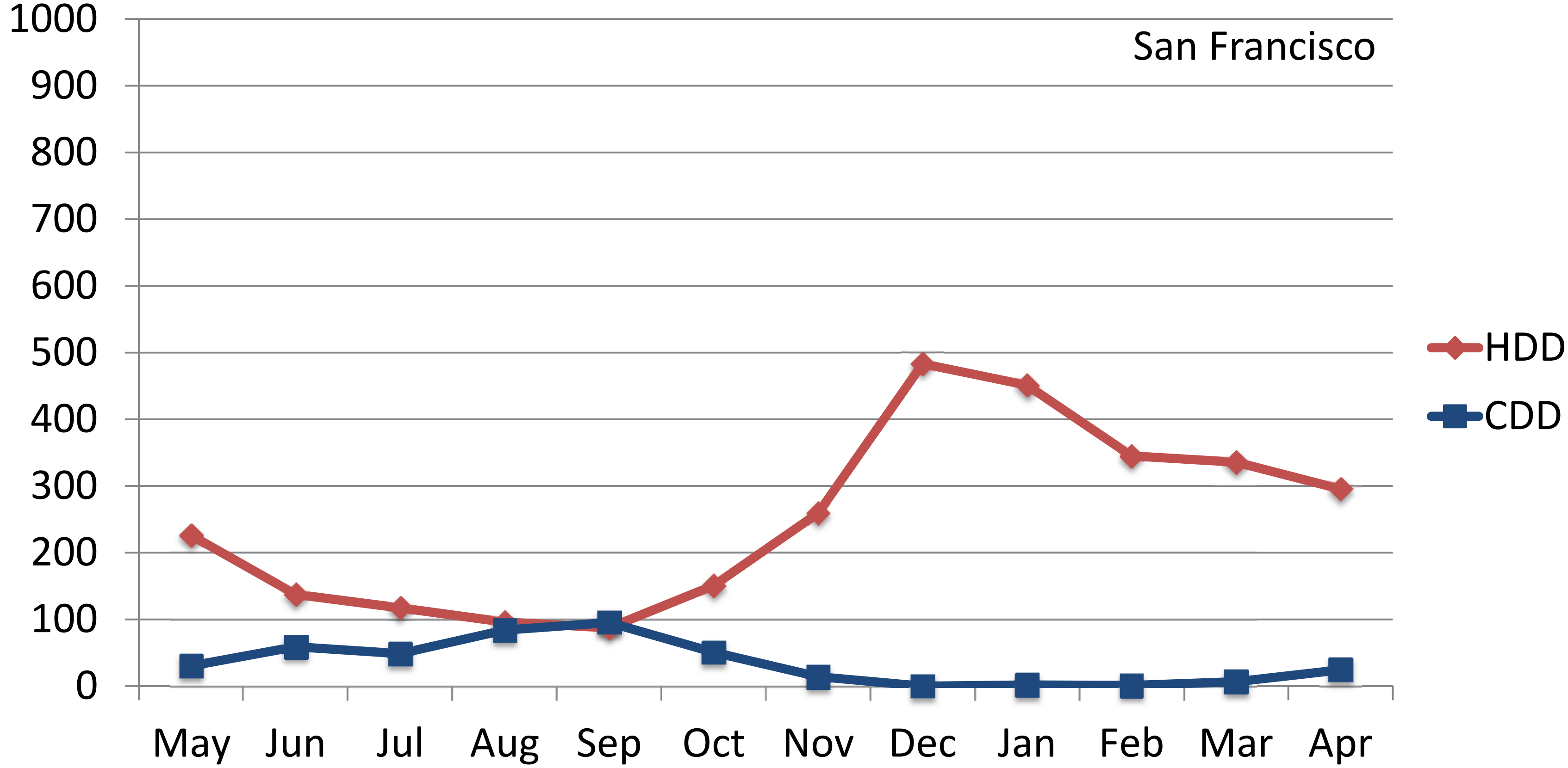
Shown with Monthly Cooling and Heating Degree Days

Houston	
	% Sun at Noon
May	0
Jun	0
Jul	0
Aug	0
Sep	40
Oct	69
Nov	84
Dec	90
Jan	87
Feb	76
Mar	56
Apr	10
Overhang depth (ft)	2.0

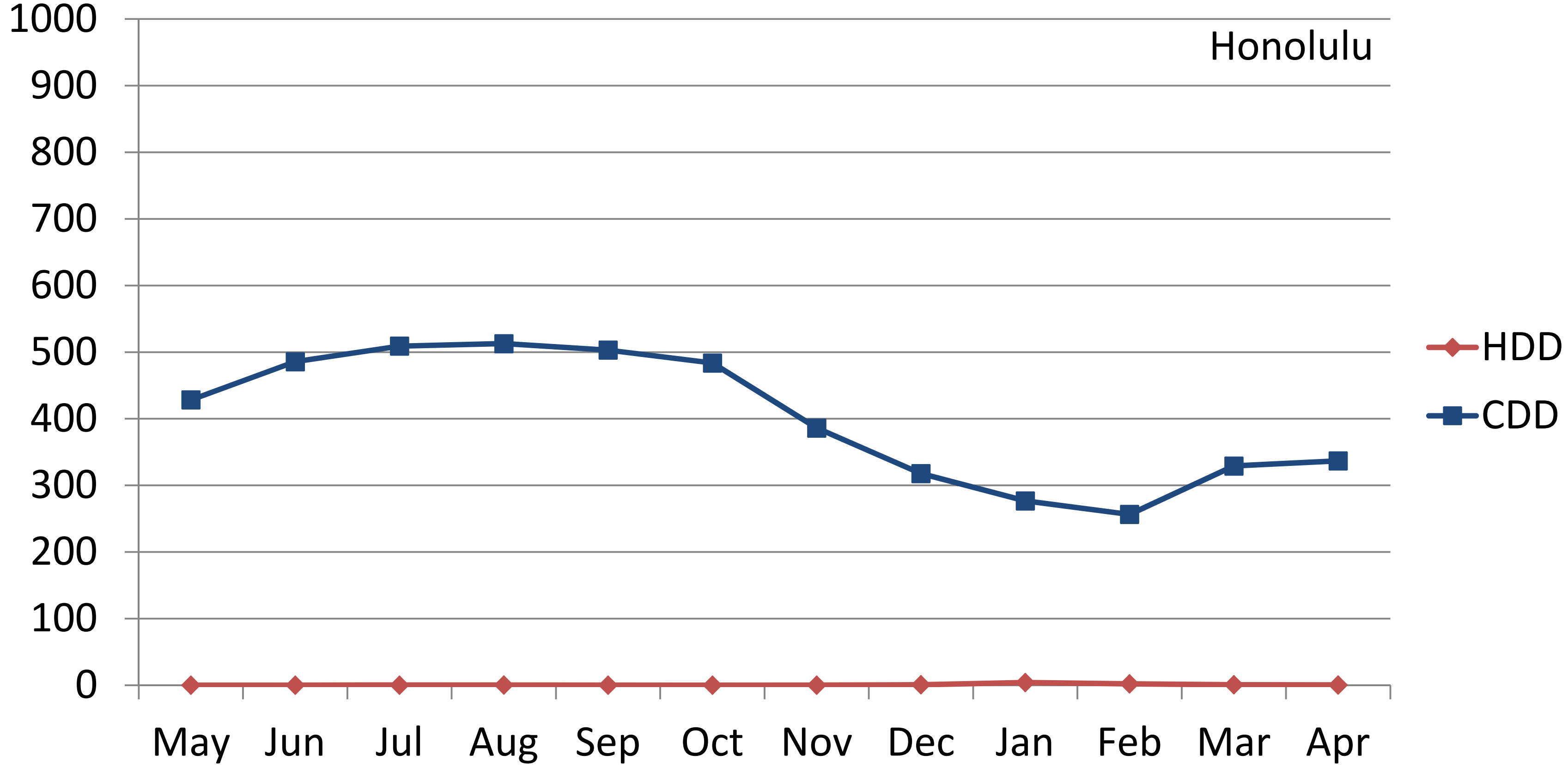


Degree Days are shown at 1/10 scale

Cooling and Heating Degree Days



What Percent Sun is Needed Here?



Energy Efficient Homes: Tight and Healthy (Part II)

VII. Energy guidelines & the residential mechanical system

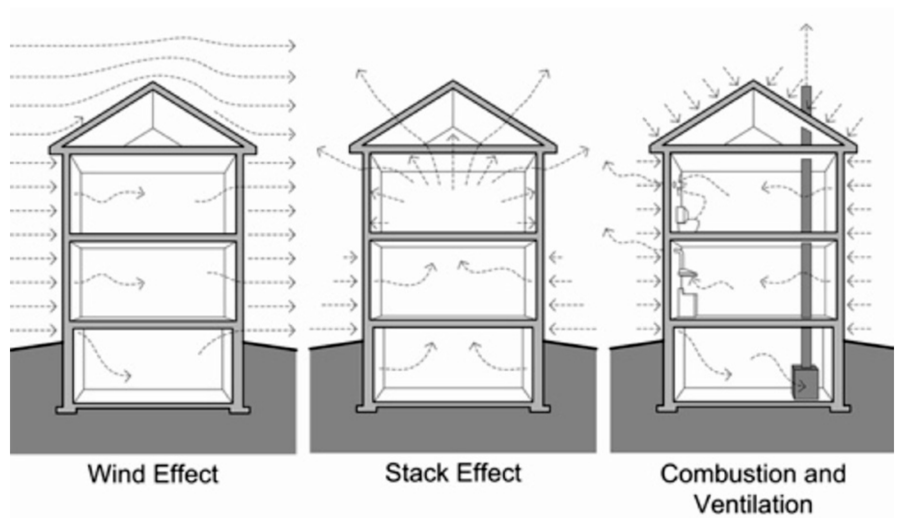
Comparison of HVAC Requirements IECC vs "Above Code" Programs

System Feature	2009 IECC	2012 IECC	Energy Star	LEED for Homes
Manual J room-by-room calculation of load	X	X	X	X
Proof of proper refrigerant charge required			X	X
Total duct leakage limit (CFM/100 sf)	12	4	8	na
Duct-leakage-to-outside limit (CFM/100 sf)	8	< 4	4	4
Duct system tested to be balanced			X	credit
Room pressure differentials minimized			X	credit
Programmable thermostat required	X	X	X*	credit
Mechanical ventilation system required		X	X*	X*

*According to the requirements of ASHRAE Standard 62.2

Infiltration / Exfiltration

- **Infiltration** -- unintentional leakage of outside air into a building
- **Exfiltration** -- unintentional leakage of inside air out of a building
- Caused by pressure differences across the building envelope
  - Wind
  - stack effect
  - mechanical equipment

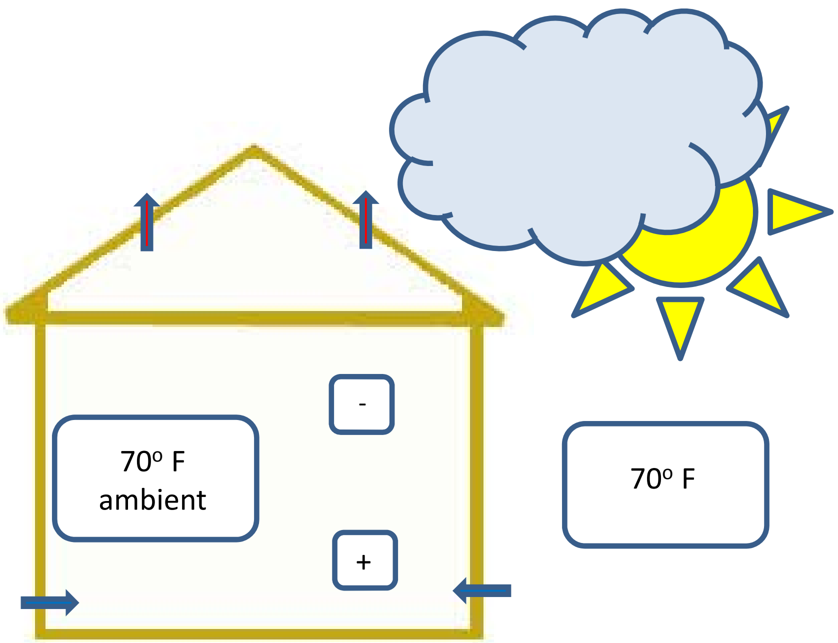


Building Science Corporation
www.buildingscience.com

Infiltration Due to Stack Effect

in non-conditioned spaces

Spring / Fall
Minimal Stack Effect



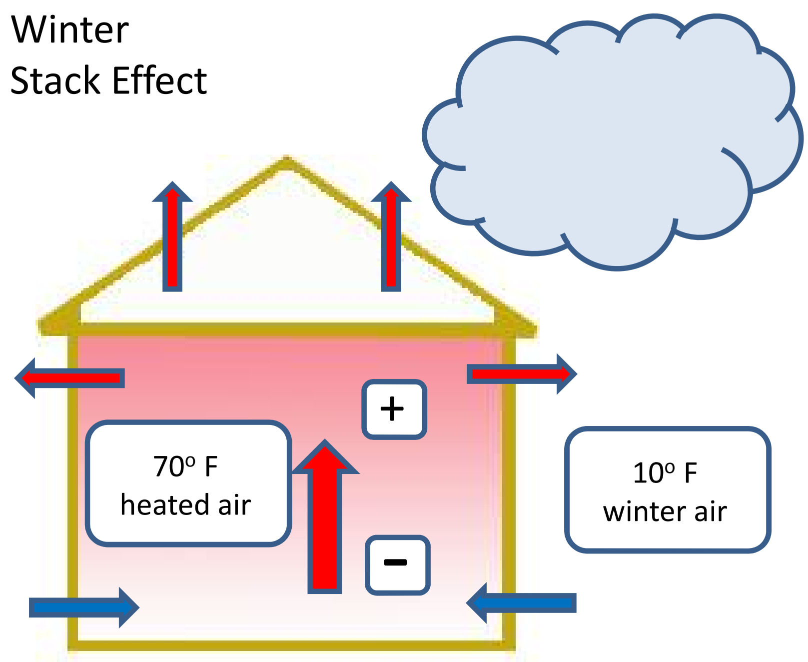
Typical Leakage Rates of 1980-1990 Florida Homes

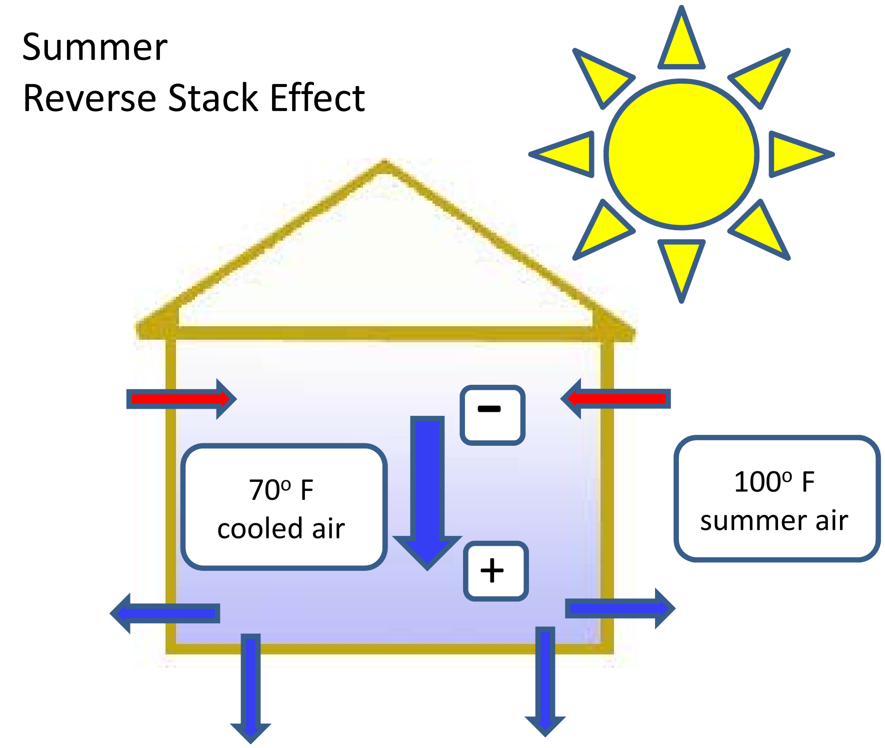
Spring / Fall (no HVAC): 0.1 – 0.2 ACH

Summer / Winter (with HVAC): 0.5 – 1.2 ACH

Air Leakage Due to Stack Effect

in climate-controlled spaces

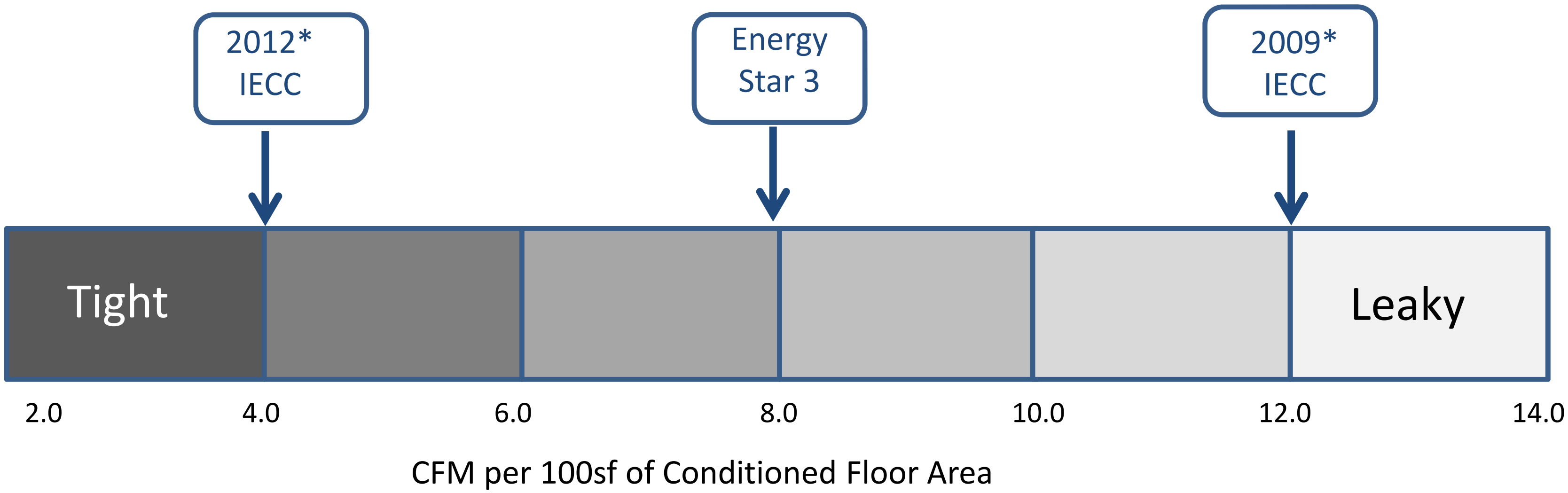




Typical Leakage Rates of 1980-1990 Florida Homes

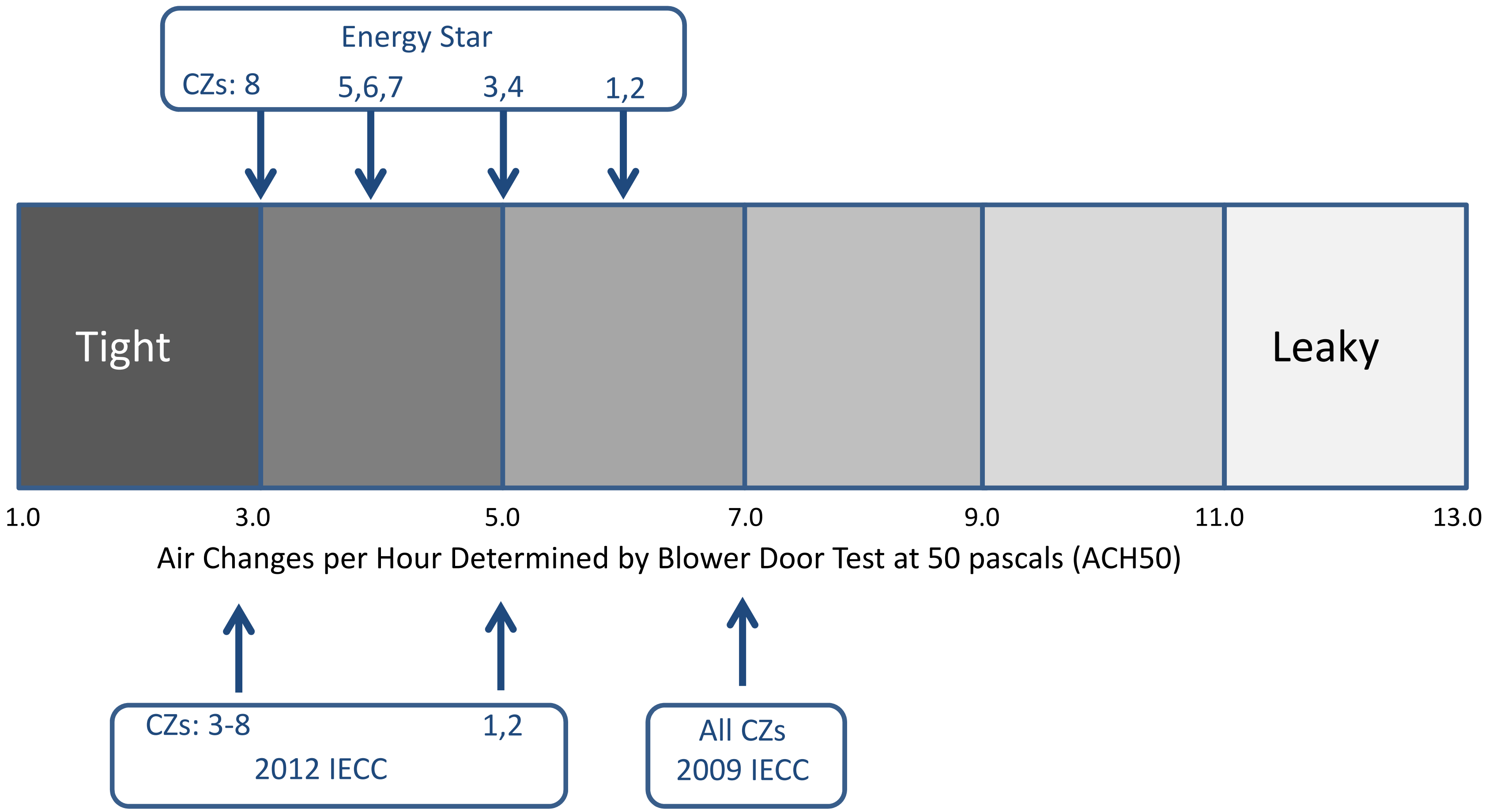
Spring / Fall (no HVAC):	0.1 – 0.2 ACH
Summer / Winter (with HVAC):	0.5 – 1.2 ACH

Total duct-leakage Limits



*Duct tightness test is not required if the air handler and all ducts are located within building thermal envelope.

Building-leakage Limits



Advantages of a Tight House

A tighter house will have:

- Lower energy bills
- Fewer drafts
- Reduced chance of mold/rot from interstitial condensation
- Reduced heating and cooling loads
- Reduced capacity needed for heating and cooling equipment

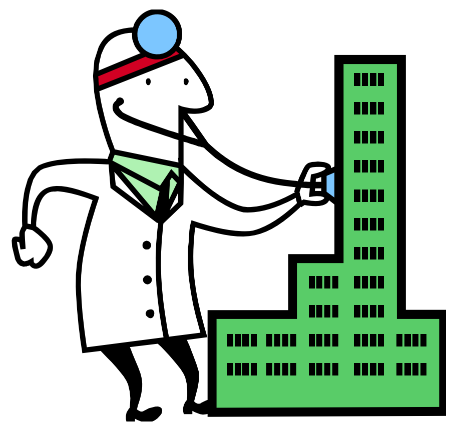
Energy Efficient Homes: Tight and Healthy (Part II)

VIII. Problems with the tight house

High Levels of Chemical Contaminants in Indoor Air

According to the EPA, indoor air pollutants may be two to five times -- occasionally more than 100 times -- higher than outdoor pollution levels.

Increased Susceptibility to “Sick Building Syndrome”



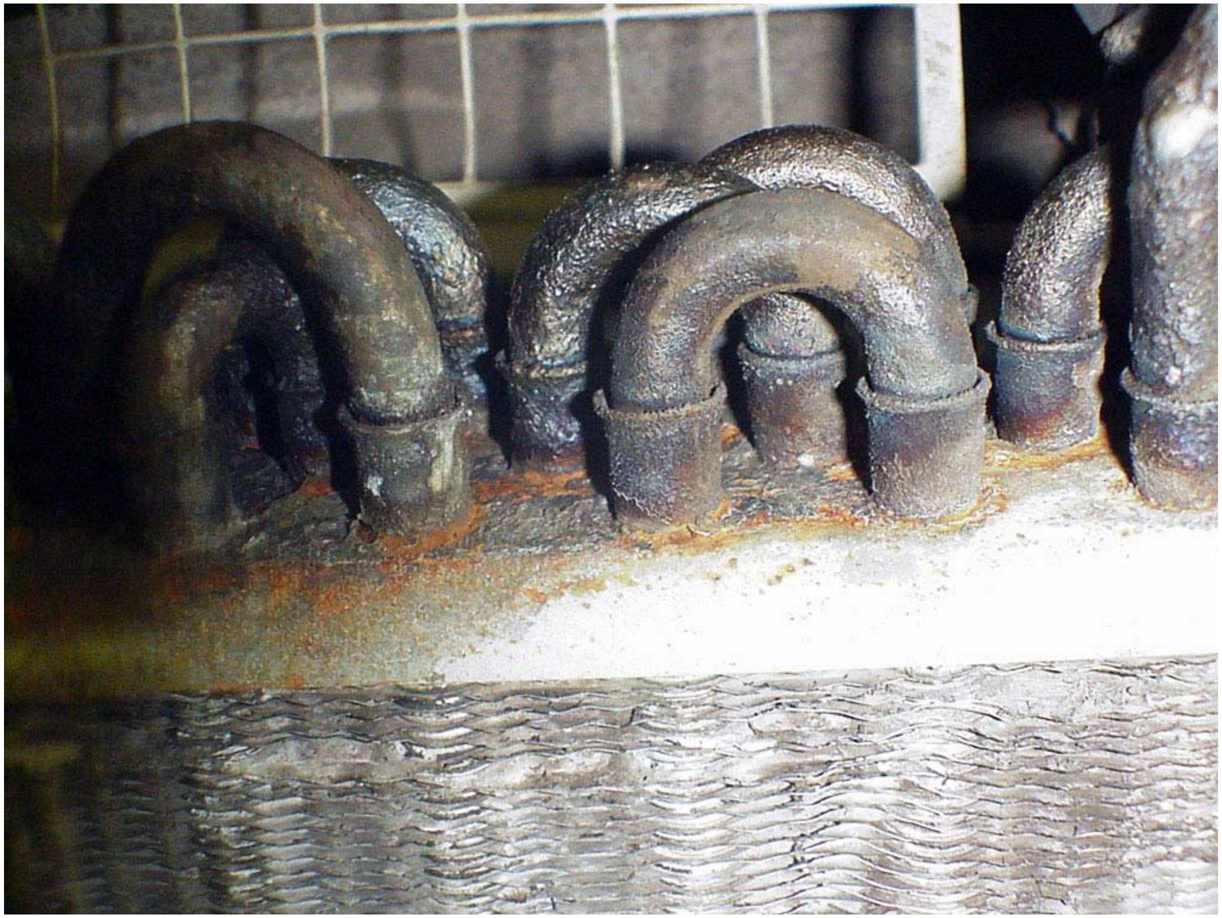
- Building occupants complaints include
  - eye, nose, or throat irritation
  - headache
  - dry cough
  - dry or itchy skin
  - dizziness and nausea
  - difficulty in concentrating
  - fatigue
  - sensitivity to odors

- The specific cause of the symptoms is not known.

- Most of the complainants report relief soon after leaving the building.

  http://www.epa.gov/iaq/pdfs/sick_building_factsheet.pdf

Indoor Air Pollutants Linked to HVAC Coil Corrosion

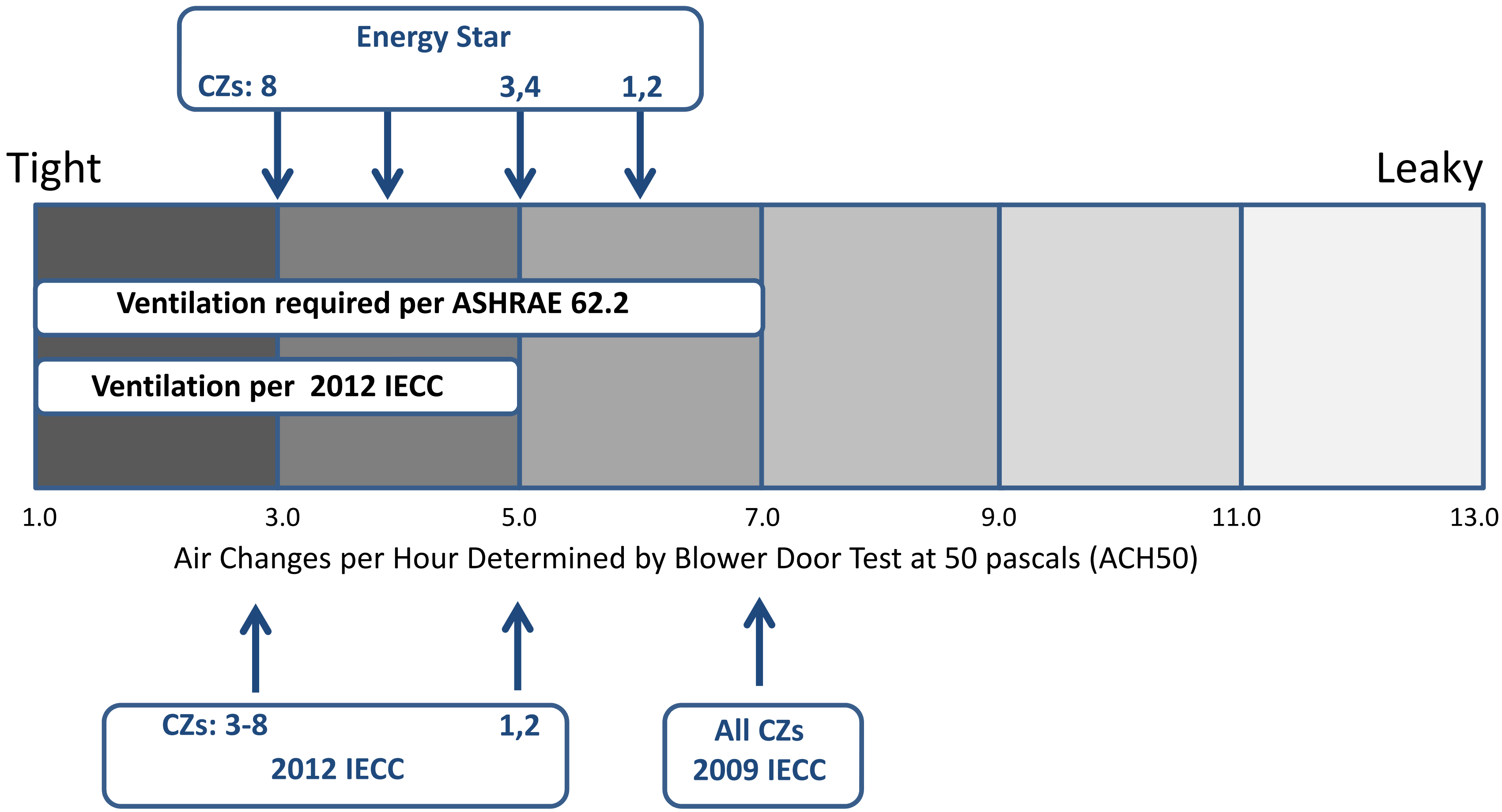


http://www.gpmaintenancesolutions.com

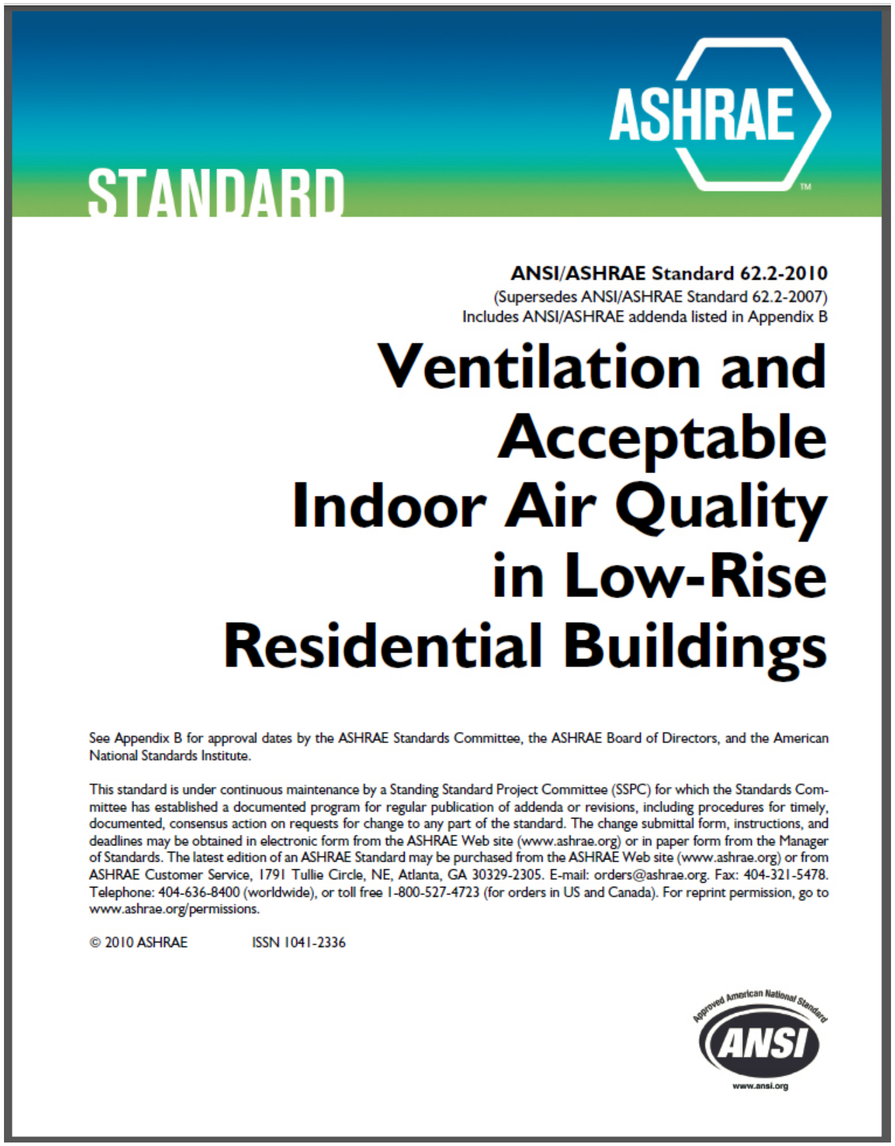
Contributors to “Sick Building Syndrome”

- Use of synthetic building materials and furnishings
- HVAC system-induced problems
- Indoor humidity levels which are too high or too low
- Use of chemically formulated personal products , cleaning agents, and tobacco smoke

Building-leakage Limits – How Tight is too Tight?



ASHRAE Standard 62.2 for Ventilation


STANDARD

ANSI/ASHRAE Standard 62.2-2010
(Supersedes ANSI/ASHRAE Standard 62.2-2007)
Includes ANSI/ASHRAE addenda listed in Appendix B

Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings

See Appendix B for approval dates by the ASHRAE Standards Committee, the ASHRAE Board of Directors, and the American National Standards Institute.

This standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the standard. The change submittal form, instructions, and deadlines may be obtained in electronic form from the ASHRAE Web site (www.ashrae.org) or in paper form from the Manager of Standards. The latest edition of an ASHRAE Standard may be purchased from the ASHRAE Web site (www.ashrae.org) or from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: orders@ashrae.org. Fax: 404-321-5478. Telephone: 404-636-8400 (worldwide), or toll free 1-800-527-4723 (for orders in US and Canada). For reprint permission, go to www.ashrae.org/permissions.

 ISSN 1041-2336

- Provides guidance on ventilation and acceptable indoor air quality in low-rise residential buildings.
- Specifies mechanical ventilation for houses with a natural infiltration rate less than 0.35 ACH.
- Specifies local exhaust from kitchens and bathrooms
- Specifies safety requirements regarding combustion appliances, adjacent space concerns, and location of outdoor air inlets
- Standard is referenced in Indoor airPLUS, Energy Star, LEED for Homes, but not the IECC

Energy Efficient Homes: Tight and Healthy (Part II)

IX. How to achieve the ASHRAE 62.2 standard in the tight house

How Much Outside Air?

According to ASHRAE Standard 62.2, the required amount of outdoor air to be continuously introduced into the home is:

CFM_{fan} = 0.01 CFA + 7.5(Nbr +1)

CFM_{fan} = fan flow rate, CFM

CFA = conditioned floor area, ft2

Nbr = Number of bedrooms

TABLE 4.1a (I-P)
Ventilation Air Requirements, cfm

Floor Area (ft^2)	Bedrooms 0–1	2–3	4–5	6–7	>7
<1500	30	45	60	75	90
1501–3000	45	60	75	90	105
3001–4500	60	75	90	105	120
4501–6000	75	90	105	120	135
6001–7500	90	105	120	135	150
>7500	105	120	135	150	165

There are also provisions in ASHRAE 62.2 that allow ventilation to be delivered on a non-continuous basis as long as the total fresh air delivered to the space is equivalent.

Spot Ventilation / Local Exhaust

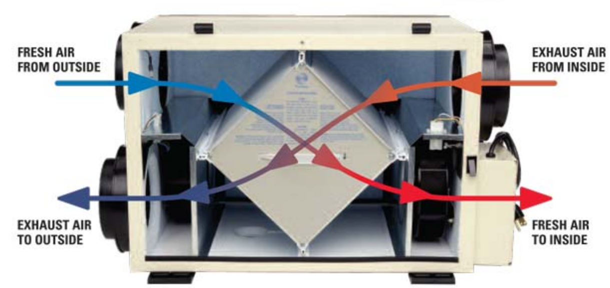
Localized exhaust fans remove humidity and odors at their source

- Exhaust air is to be ducted directly to the outside (exhausting to attics or interstitial spaces is not permitted)
- Recommended flow rates:
  - Bathrooms
    - 50 CFM intermittent
    - 20 CFM continuous
  - Kitchens
    - 100 CFM intermittent
    - 25 CFM continuous

Whole-house Ventilation Strategies

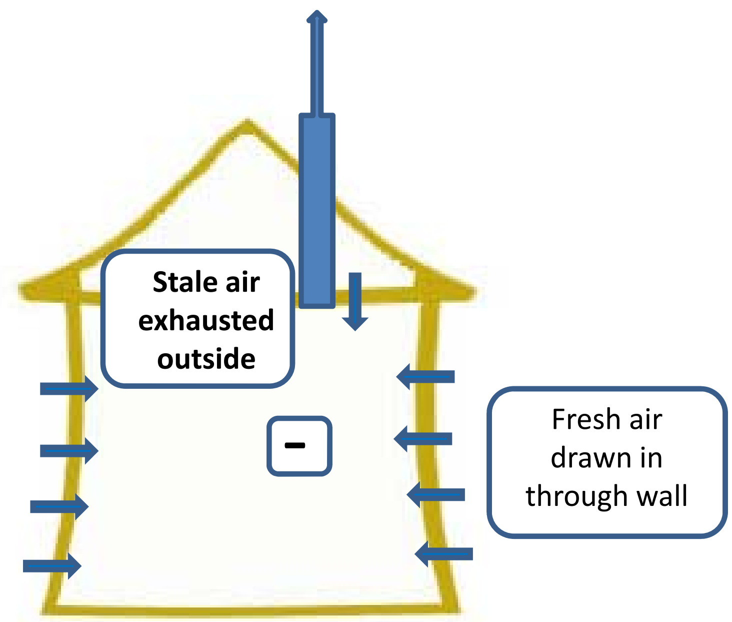

- Exhaust-only ventilation systems
  - Force stale inside air out of the home
  - Outside fresh air enters passively


- Supply-only ventilation systems
  - Force outside fresh air into the home
  - Inside stale air leaves passively



- Balanced plus energy recovery ventilation (ERV) systems
  - Force stale air out and fresh air in
  - Transfer heat/humidity from incoming or outgoing air to “precondition” outside air and minimize energy loss.

Mechanical Ventilation Strategy: Exhaust Only



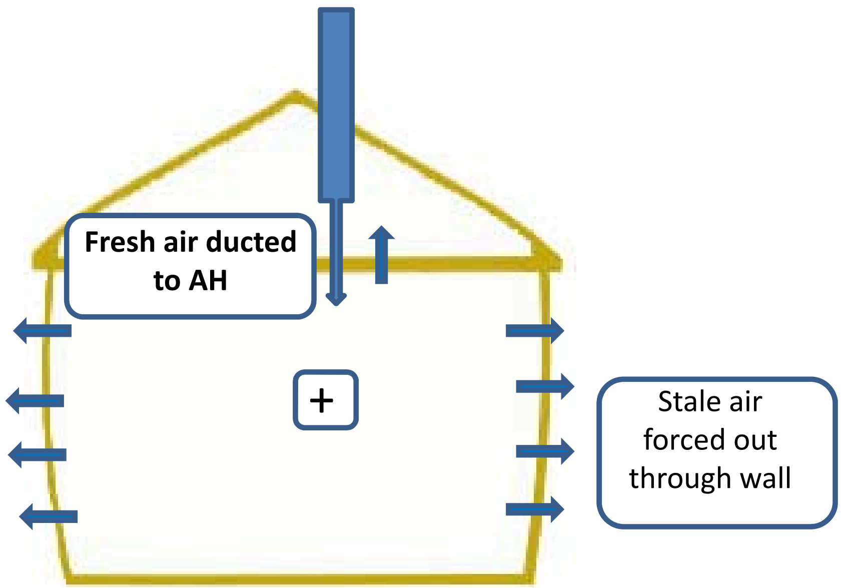
Pros:

- Inexpensive
- In northern climates keeps humid air out of wall cavity

Cons:

- In southern climates draws humid air into wall cavity
- Requires make-up air for combustion products

Mechanical Ventilation Strategy: Supply Only



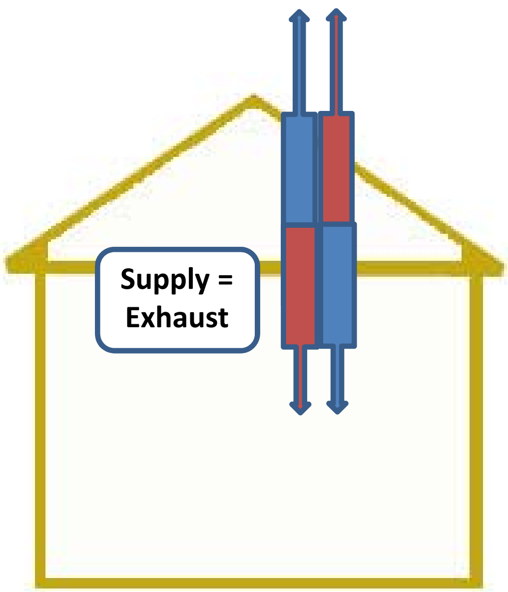
Pros:
- Outside air is conditioned
- Outside air source is known
- In southern climates keeps humid air out of wall cavity

Cons:
- Typically higher fan wattage
- In northern climates pushes humid air into wall cavity

Mechanical Ventilation Strategy: Energy Recovery Ventilation

Heat-recovery ventilators (HRVs)

Energy-recovery ventilators (ERVs)



Pros:

- Fresh air is conditioned and of known source
- Humid air is kept out of wall cavity
- Some energy is recovered

Cons:

- May have greater front-end or operational costs
- Installation errors are common

Energy Efficient Homes: Tight and Healthy (Part II)

X. Conclusion

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PSL Integrated Solutions

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Moderator

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