Holistic HVAC

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INTRODUCTIONS

Gary Beck, P.E., SECB, LEED AP

BSE (Civil, Duke (1976)

- Texas P.E. (1981) LEED AP (2003)
- Structural & Civil Engineering
- Forensic Inspections
- *Design Consulting - Green Building, Shelter-In-Place, Aging-In-Place, Solar Arrays, Wind Generators, Rainwater Harvesting, HVAC Condensate Harvesting*

Eco-Holdings LLC

Register Texas Engineering Firm F-7395

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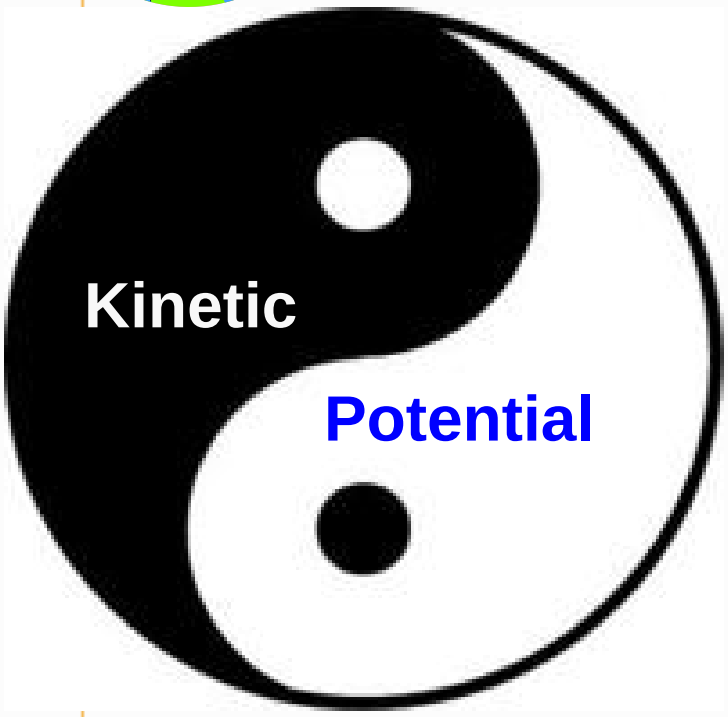
TODAY'SJOURNEY

1. Designing for Low HVAC Usage
2. When the HVAC Quits

Energy 101



1. *Either In Use Or Stored*

Atomic Energy Commission' s Symbol

2. *Small Amounts Good Big Amounts Bad*

Energy 201

Energy is Important

1. ENERGY
2. WATER
3. FOOD
4. ENVIRONMENT
5. POVERTY
6. TERRORISM & WAR
7. DISEASE
8. EDUCATION
9. DEMOCRACY
10. POPULATION

"Humanity's Top Ten Problems for the next 50 years"

Dr. R. E. Smalley, (1943-2005) 1996 Nobel Prize Winner

Slide Information from 2005 Energy Presentation - Rice University

Energy 301

$ x η = $$$$$$ $$$$$$ $$$$$$

Your Money x Your Design = Your Life Quality

Energy Final

Q1: Energy is? ***A1: Really Important***

Q2: Water is? ***A2: Darn Important***

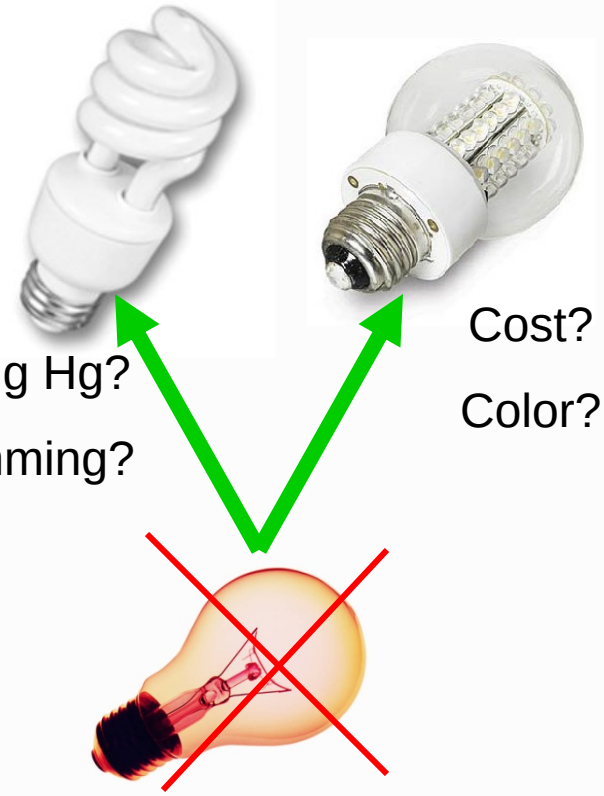
Q3: η X $ = ? ***A3: $+$+$+$+$+$+$.....***

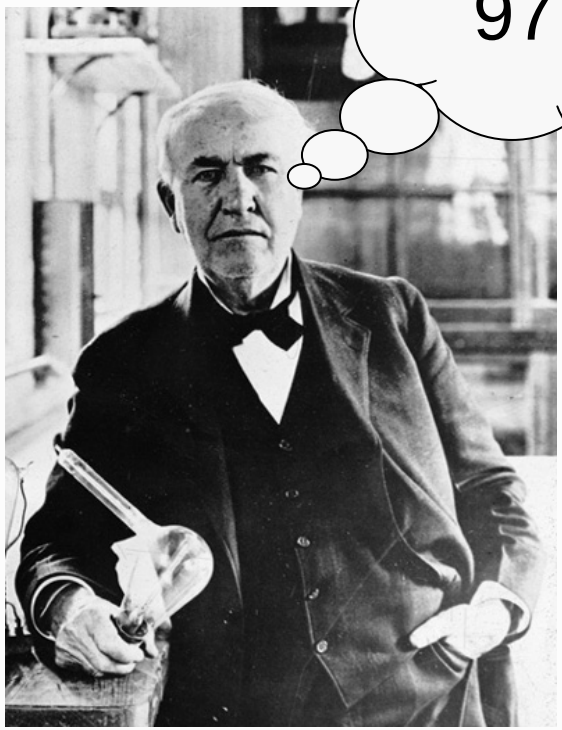
Your Grade: 66

Man, you passed,
…Let's Party!

Design Vs Technology

New light bulbs?





Big wow,…
it only took
97 years

I have seen the (Day) Light…

Day Lighting considerations using windows, skylight, or solar-tube must consider energy performance (online tools like REScheck*)

Consider light access tubes for small areas

Images from Solatube.com

* www.energycodes.gov/rescheck/downloads

Too Much Thinking Involved!

DESIGN

- ARCH. DESIGN

- SITE
- SIZE
- USE

COMPONENTS

- FOUNDATION
- WALLS/ROOF
- WINDOWS
- DOORS
- HVAC

FEATURES

- ENERGY
- WATER
- LIGHTING
- VENTILATION
- FINISHES

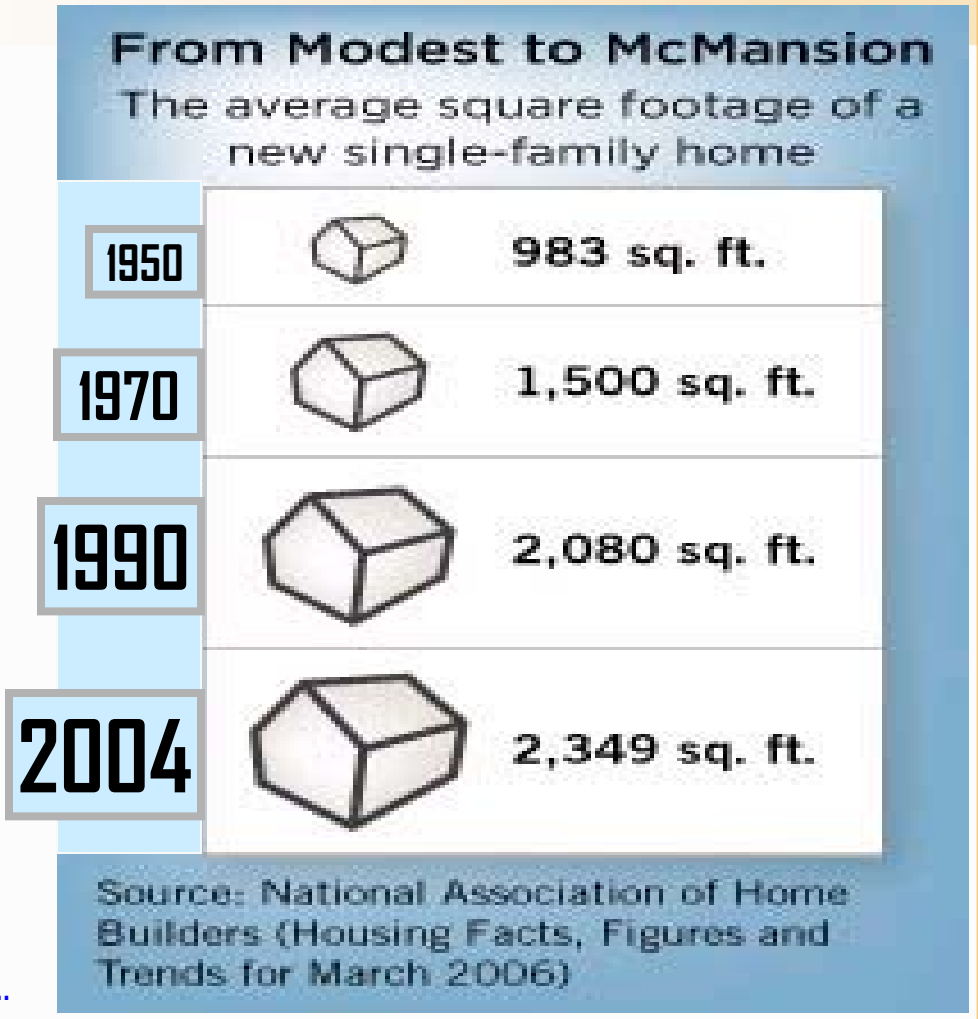
Ahh,... Less is Better!

- ARCH. DESIGN
- SITE
- **SIZE**
- USE

- FOUNDATION
- **WALLS/ROOF**
- **WINDOWS**
- DOORS
- HVAC

- ENERGY
- WATER
- LIGHTING
- **VENTILATION**
- FINISHES

The average US Home is now about **2500 sq. ft.***



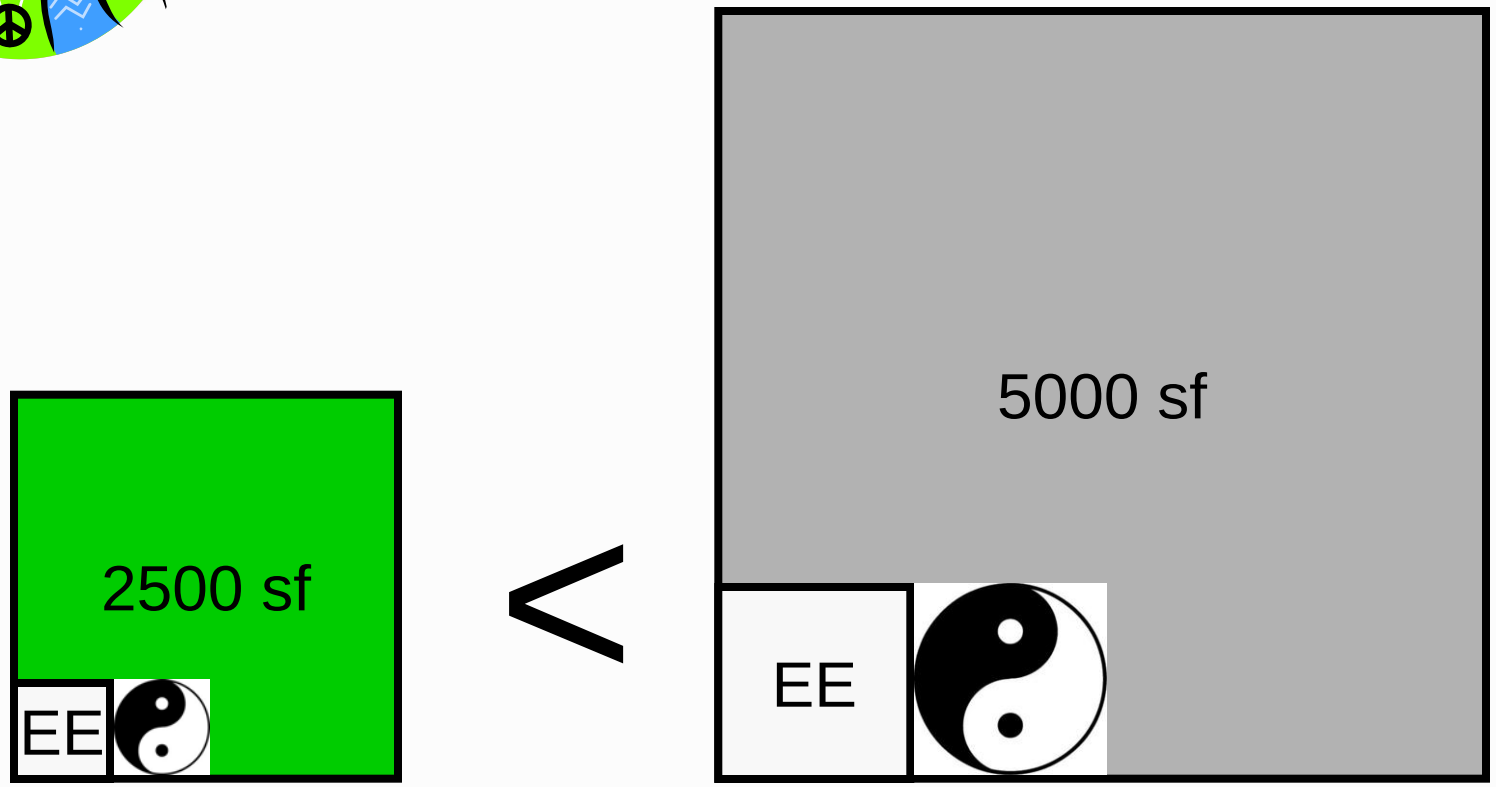
*NHBA: 2004-2350 sf, 2005-2400 sf ...

Design Size

2500 sf is NOT a McMansion

Nor is it a McShack

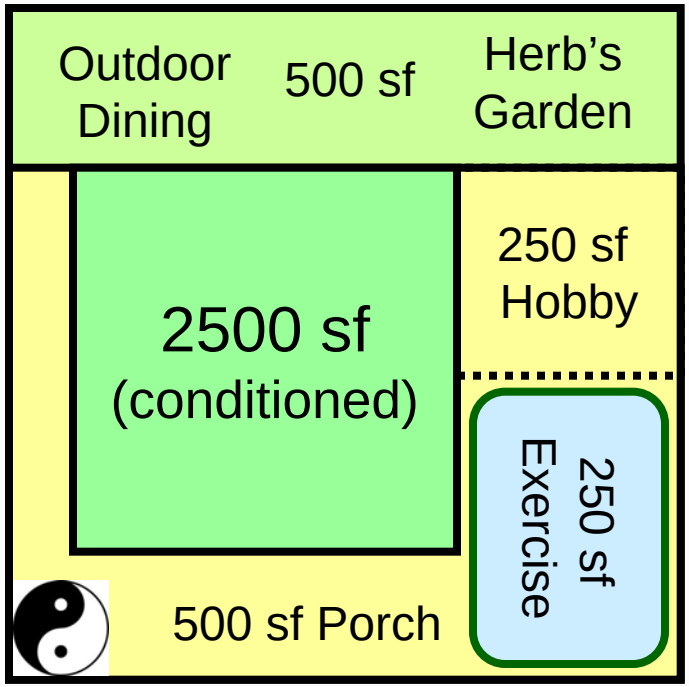
I get it,…small stuff uses less energy…

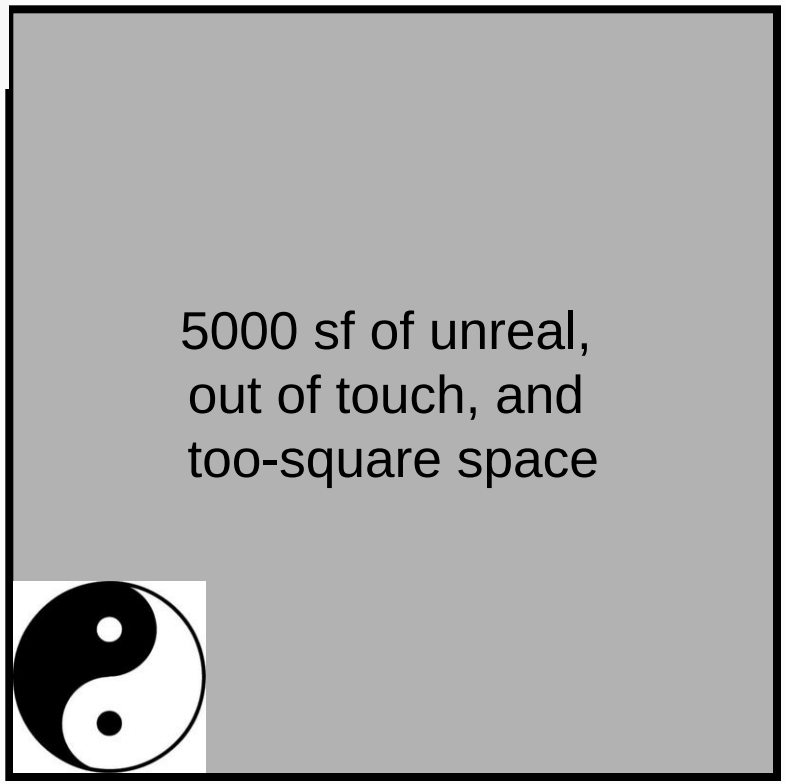


EE = Embodied Energy of a Building System (AWF, SIP SCIP, ICF, AAC)
LCA = Life Cycle Assessment (cycle/years) is the same for the same building system

But we like green stuff.

4000 ‘gsf’ is > 5000 sf





- ✓2001 Avg Annual Home Energy $1,600
- ✓2006 Avg Annual Home Energy $1,900
- ✓2010 Avg Annual Home Energy $2,500?
- ✓Green Homes Save 30% to 50%

30% can easily equal…

Yeah that green stuff…

$80/MONTH SAVED BY EFFICIENT SPACE DESIGN

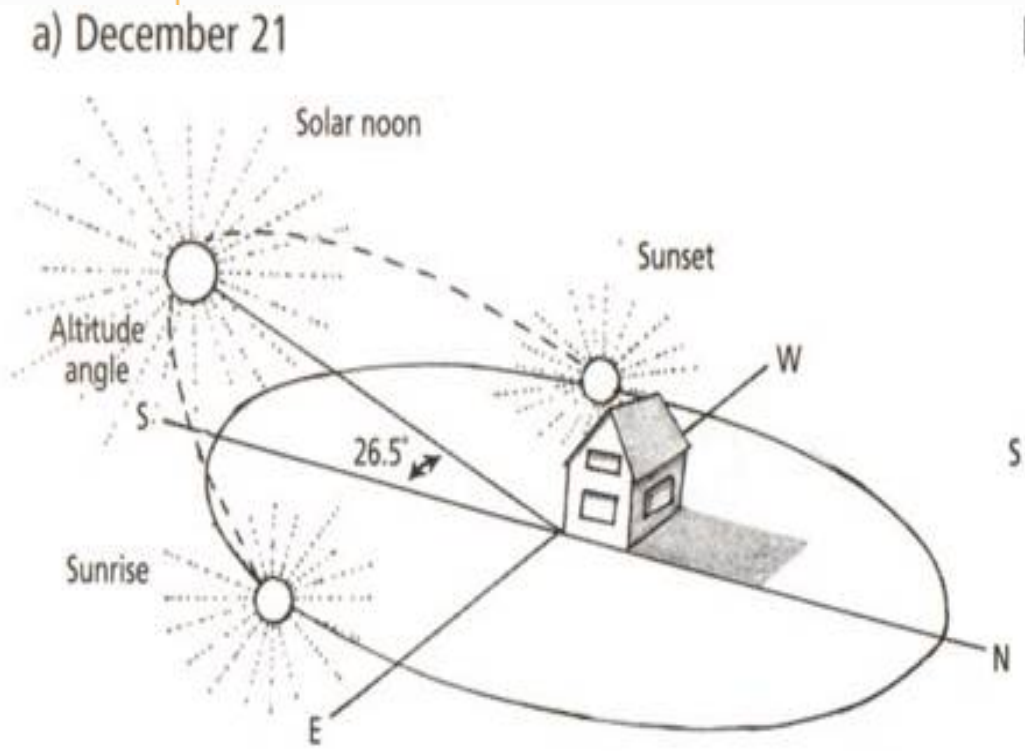
$80/MONTH SAVED IN ENERGY (SUPER INSULATED)

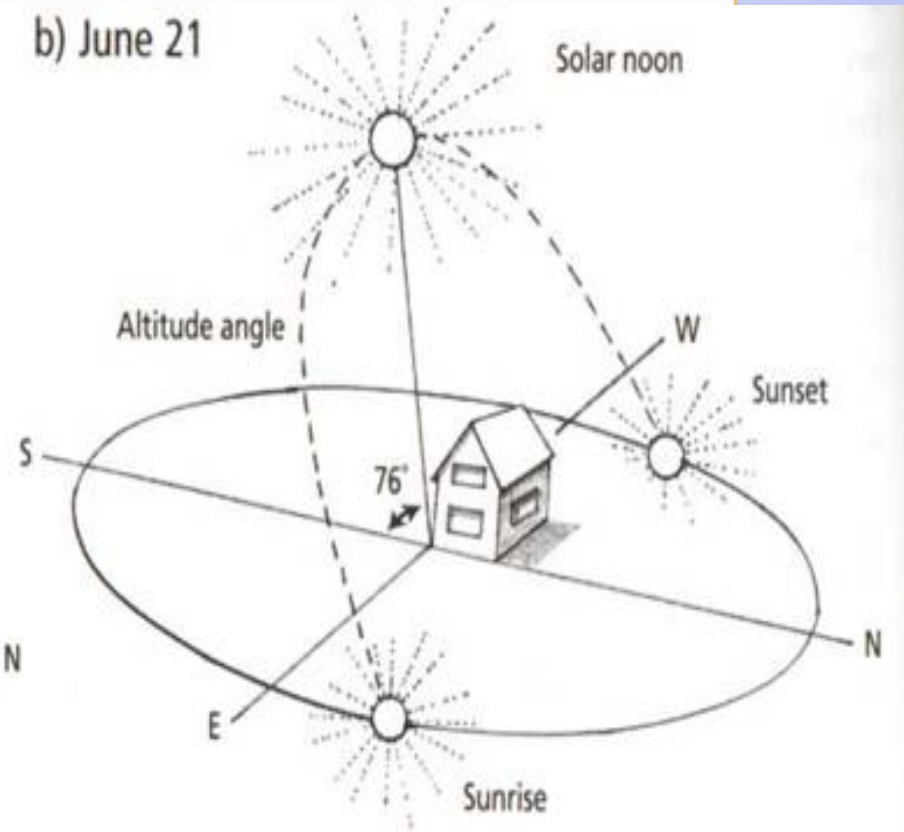
$80/MONTH SAVED BY SOLAR HW & PV SYSTEM

AT 7% FOR 30 YRS = $300,000

Walls/Roof

Winter Solar Heat + Summer Solar Power





Solar is in, just like in the 70's,... except Cheaper!

10 Watt/sf =3 kW system?

(10W/sf x 30' x 10' = 3000W)

Zero, None, Nada, Not Possible.

or pay twice later?

Solar Energy Performance and Costing is simple due to online tools

http://www.kyocerasolar.com/products/pv_calculator.html
http://sharpusa.cleanpowerestimator.com/default.aspx
http://www.findsolar.com/index.php?page=rightforme

A 3000 Watt System @30°S = **3,976 kWh/year**
System Cost $24,000
- Incentives ($7,200)
NET COST WAS $16,800 – on sale now for?

& Solar PV Cost Getting Lower

TRENDS	1998	2002	2006	2010	2012 ?
Number of Systems	39	2,500	8,800	36,000	60,000 ?
Capacity (MW)	1	16	90	470	1,000 ?
Avg. Cost ($/WATT)	$11	$10	$8	$6	$ 5 ?

Dude,…costs differ by region, system size, installation type, installer, and existing home vs. new home construction

Sorry Man.. I lost my focus…

Where was I ?….,

oh yeah,… Roofs/Walls,

Windows, & Ventilation

The Roof

- Huge impact on energy performance
- Can produce energy & collect water
- Can provide shade for outdoor living

I can fill my hot tub with rain?

Easy & Cheap to Harvest Rainwater

Follow City of Houston Code Section 13.04 on Low Impact Design (LID)

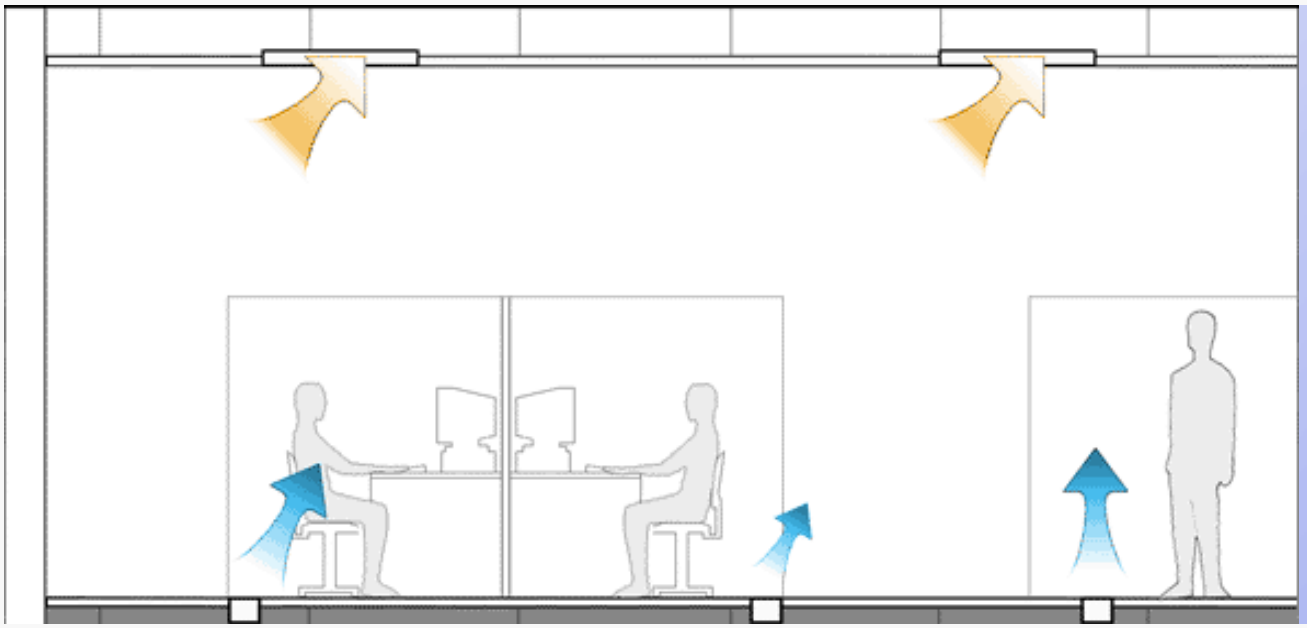
Roof & Attic as a 'System'

My Attic

Your Next Attic

- Insulate at the rafter line
- HVAC & Ducts in semi-conditioned volume

UFAD? I think I saw one in the '60's



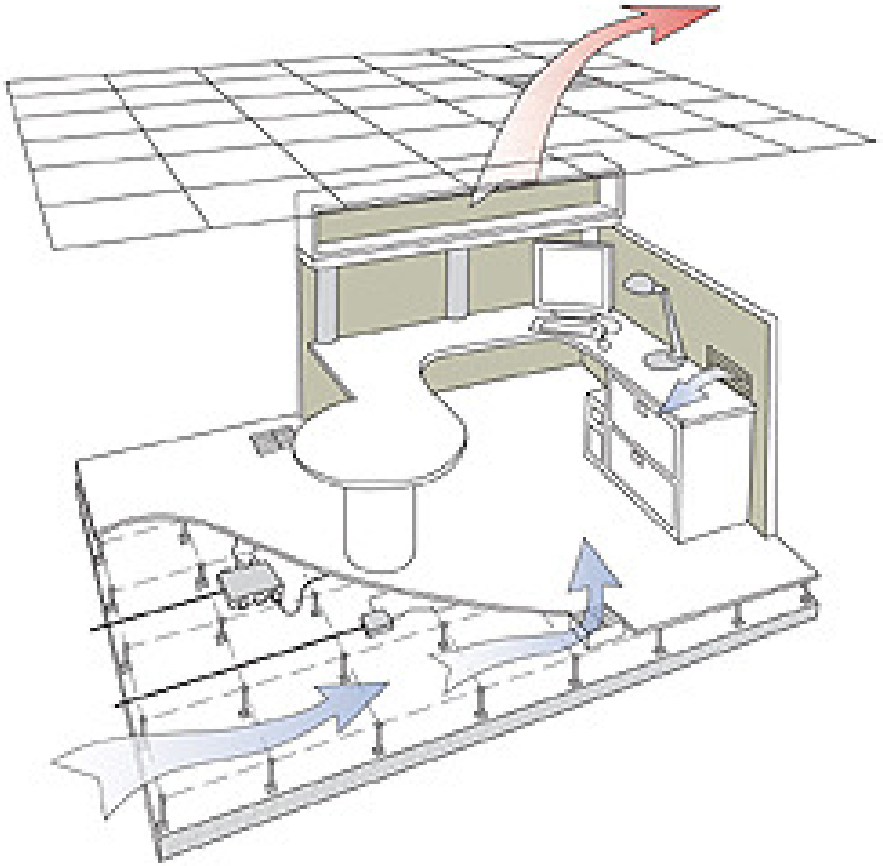
- UFAD air can be 8 to 10° warmer than ceiling delivered air
- 68F air (vs. 58F) saves HVAC BTUs and energy

UFAD = Under Floor Air Delivery

http://www.cbe.berkeley.edu

Ducts inside a slab?,... You are so out there!

- Thermally couple slab to 70°F to 75°F soil
- Air in contact with concrete slab uses thermal mass as energy reservoir.
- Control R.H. at 50%, and the ducts and surface can remain cool or warm but always dry



Crawl Space Foundations

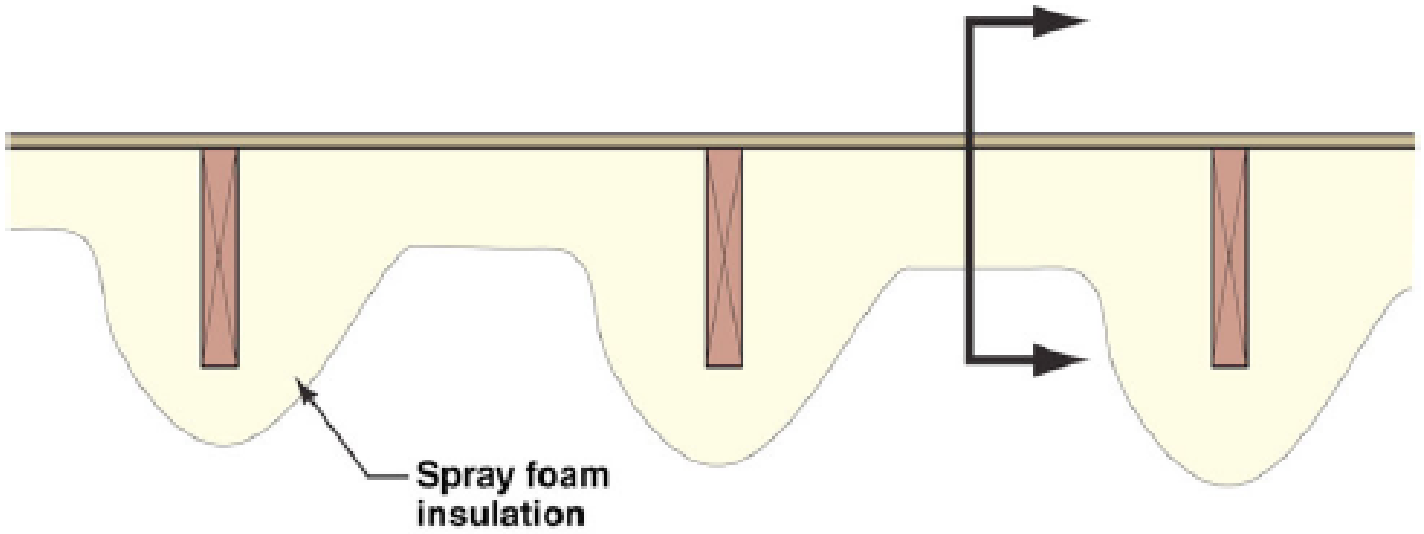
Many schools of thought

- Vent or Conditioned No Vent?
- Frame & Foam Insulate, or Use SIPs?

SIP subfloor combines structure and insulation

The Floor as a System

Crawl Space:



"Wrapping the floor framing in foam insulation lowers the equilibrium moisture content of the wood. Warm wood is dry wood. Warm wood is happy wood." – Building Science Oct 2008

http://www.buildingscience.com

Crawl Space Foundations

Crawl Space: Conditioned No Vent

- Additional cost & multiple steps
- HVAC must control humidity & temperature
- Need detailed drainage plan

Design should include MEP coordination… if it's ever needed

(Latest house in my neighborhood)

My walls were straw bales,... my goat loved 'em!

Wood + Proven Wall Alternates

Wood: Flexible, Strong, Cost Effective

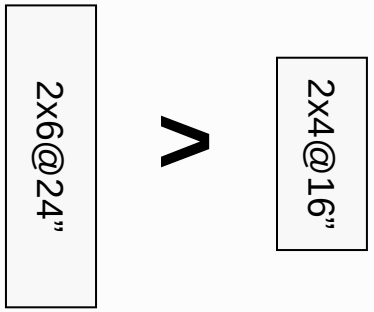
Panels: (SIP) Structural Insulated Panel

Masonry: ICF (Insulated Concrete Forms)
AAC (Aerated Concrete)

Metal: Cold Formed Steel with EPS

Wood Exterior – 2x6 is Best

- **2x6@24 is stronger than 2x4@16**
- 2x6@24”section area per lf is higher than 2x4@16” (4.16 vs. 3.93 si)
- 2x6@24” Bending Stress Md/2(I*) > 2x4@16”



**(Moment of Inertia ‘I’ for rectangle is I=Width*H^3/12; H for 2x6 is 5.5” but 3.5” for 2x4. 2x6@24” is still 2.5 times that of 2x4@16” Note: This is not a comprehensive ‘strength’ comparison!)*

Wall Insulation Systems

ACH (Air Changes per Hour)
Measurement of air infiltration compared to total volume of air in a home per hour.

Older poorly sealed homes	~ 2.5 ACH
Typical wood frame home	~ 1.75 ACH
Tightly constructed	~ 0.35 ACH
Extreme Tightly constructed	~ 0.1 ACH

1.2 ACH measured @ -50 Pascal = ~ 0.1 ACH

Wall Insulation Systems

Wood Framing Energy Performance

2x4 AWF: R-11 typ., R-15 possible

2x6 AWF : R-19 possible w/Batts

2x6 AWF: R-20 is easy
+ 0.1 ACH* tight !
Spray Foam (R 3.6/in.)

* *Theoretical value* Spray foam w/ vapor barrier can reach 1.2 ACH @-50 Pa. vacuum=~ 0.1 ACH

Structural Insulated Components

SIP

- Structural Insulated Panel
- 2 pcf EPS inside, OSB outside
- Jumbo OSB = 8’ x 24’ SIP
- Can be used for walls, roofs, cantilevers, and floors.
- Invented in 1930’s
- Structural Insulated Panel Association (SIPA; sips.org) was formed in 1990

Structural Insulated Components

SIP Energy Performance

2x6 SIP: R-25 to R-22
2x8 SIP: R-29

SIP homes regularly reach 0.5 ACH

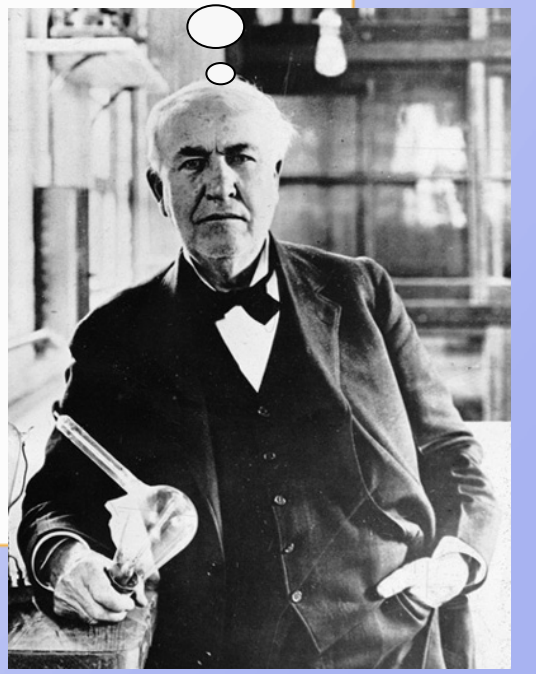
Older poorly sealed homes	~ 2.5 ACH
Typical wood frame home	~ 1.75 ACH
Tightly constructed	~ 0.35 ACH
Extreme Tightly constructed	~ 0.1 ACH

Structural Insulated Components

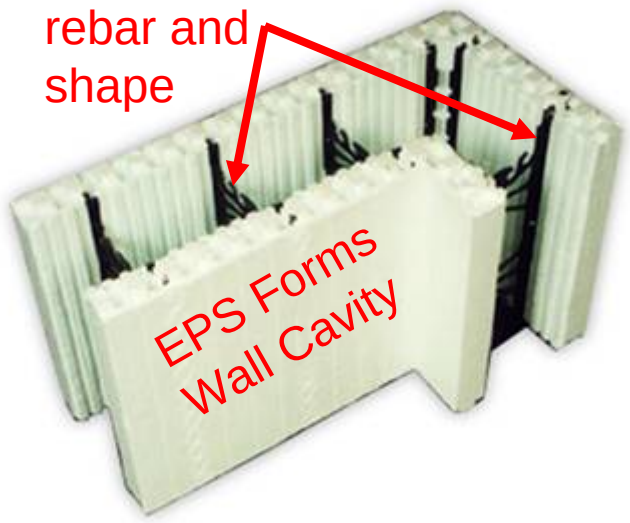
ICF

- **I**nsulated **C**oncrete **F**orms
- Many OEM block systems
- ICF listed by the IRC in 2003

Inventing ICFs would have been a no-brainer,… if I just had invented EPS first



Stiffeners hold rebar and shape



Structural Insulated Components

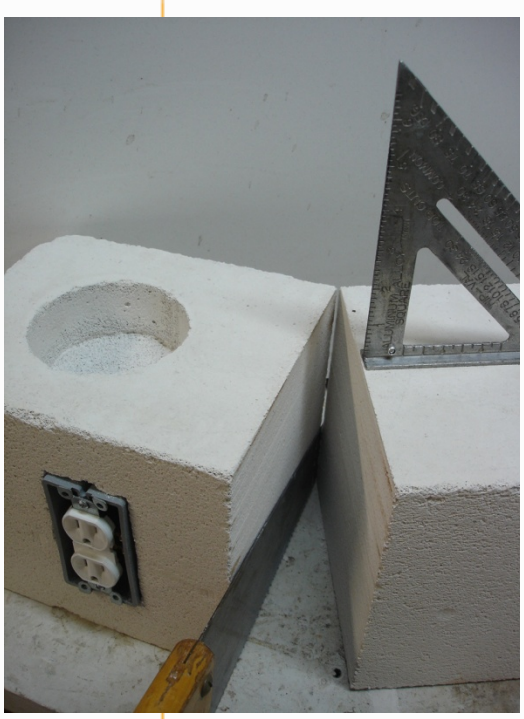
ICF Know Negative Issues

- Must be securely braced and tightly aligned
- Interior and exterior cladding is still required
- No pitched roof system
- Concrete and steel price sensitive
- “Inverted Oreo” Thermal mass is ‘backwards’

ICF is very strong – maybe *a little over-designed?*

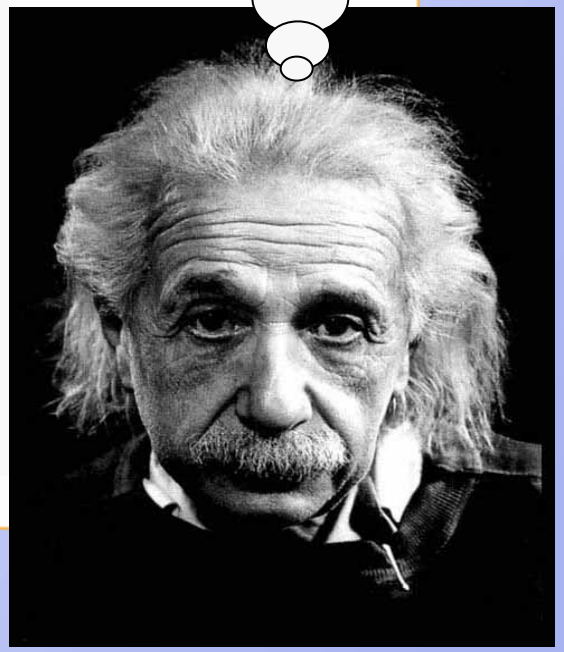
Structural Insulated Components

AAC: Autoclave Aerated Concrete



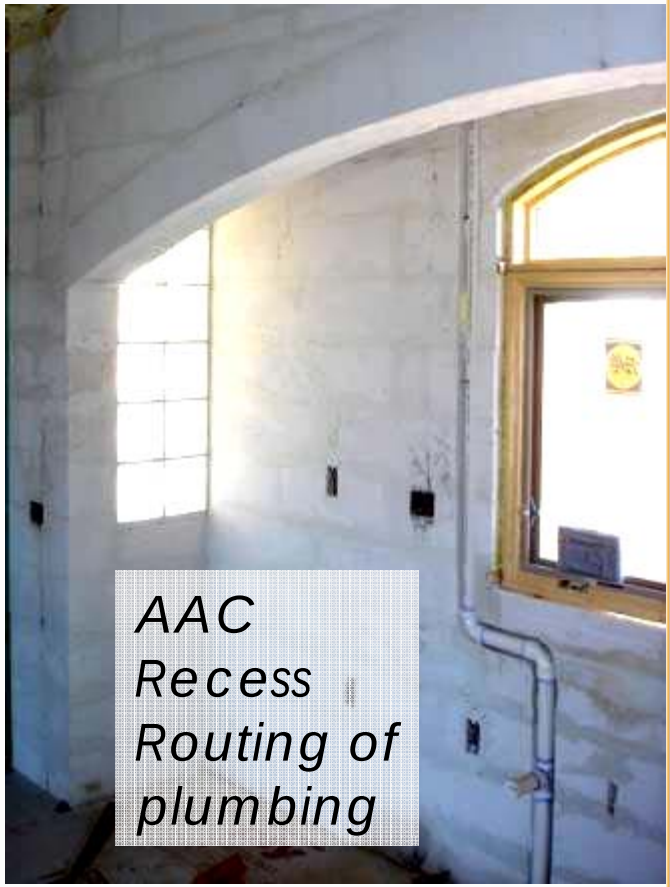
- AAC was invented in Sweden in 1920 and sold in 1940 by Josef Hebbel
- The ‘AAC’ name is used for the class of aerated monolithic concrete building systems – even those that are not autoclave produced.

Another smart Hippy idea from the 20’s



AAC Know Negative Issues

- *Lack of experienced AAC masons mean on the job training is common*
- *Electricians, Plumbers, and HVAC trades less familiar.*
- *Blueprints should include all structural detailing*
- *Special fasteners needed*



AAC Recess Routing of plumbing

Structural Insulated Components

SCIP/ICF/AAC 'ACH' Performance

Must Use 'Equivalent' R Value
Expect to reach 0.5 to 0.1 ACH

Older poorly sealed homes	~ 2.5 ACH
Typical wood frame home	~ 1.75 ACH
Tightly constructed	~ 0.35 ACH
Extreme Tightly constructed	~ 0.1 ACH

No straw bales?,... get with it man!....

MY SCORECARD	WF	SIP	SCIP	ICF	AAC
Industry Experience (5 High, 1 Low)	2	2	1	2	2
Energy Performance (to Code=1, Best=5)	3	4	5	5	5
Relative Strength (5 High, 1 Low)	3	4	5	5	4
Design Flexibility (5 High, 1 Low)	5	3	3	4	5
Direct Labor Cost (5 Low, 1 High)	4	5	1	3	4
MEP & Finish Cost (5 Low, 1 High)	5	3	2	2	3
Speed of Construction (5 High, 1 Low)	4	5	2	3	3
Relative Material Cost (5 Low, 1 High)	5	3	5	2	2
TOTAL	31	29	24	26	28

Windows? For once we agree!

☑ Buy the Best ***Operable*** Windows

Windows →ASHRAE 90.1 or IEEC*

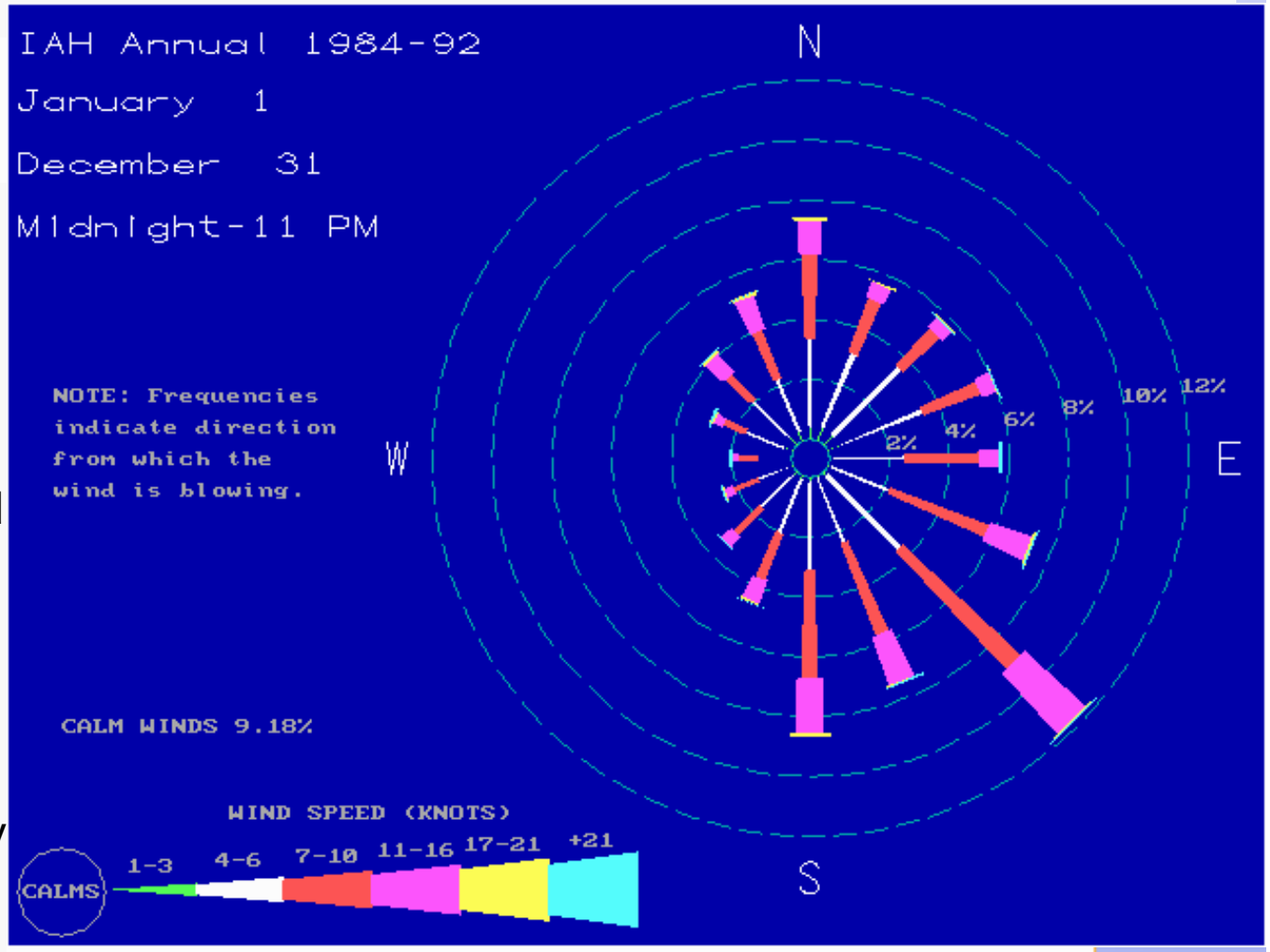
*www.efficientwindows.org/codes/TX-NewWindow.pdf

SHGC: 0.40	Solar Heat Gain Coefficient
U-COG: 0.52	25% Area U-Factor at center of glass
U-COG: 0.75	15% Area U-Factor at center of glass

Other Factors - Variable Transmittance, Shading Coefficient, Air Leakage, Pressure Resistance, all vary by specific climate and local application requirements

We're just dust blowin' in the wind

1. Locate operable windows to catch prevailing winds
2. Use casement windows on upper levels to scoop wind at corners
3. Use transom or hopper windows at high wall levels
4. Include a clear-story window area for chimney venting and late daylight

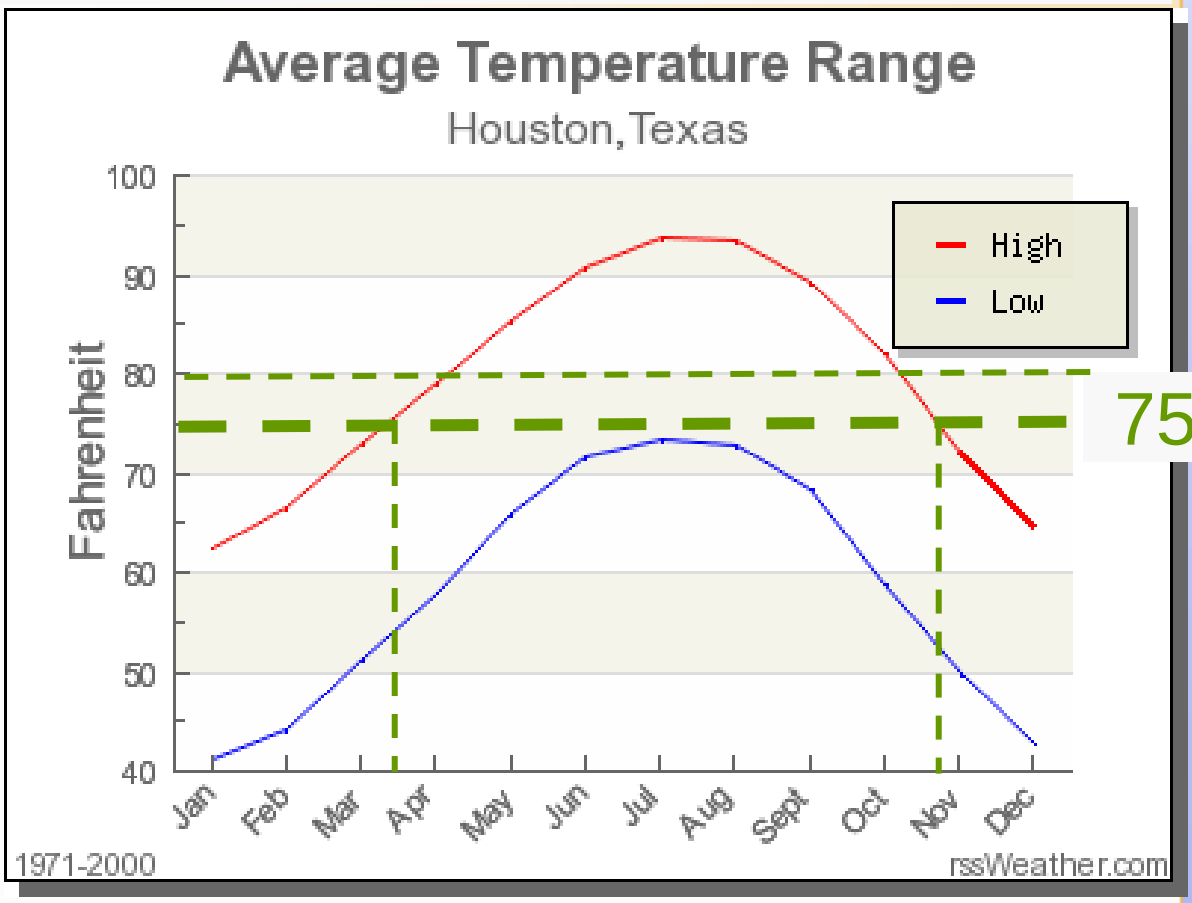


http://www.tceq.texas.gov/airquality/monops/windroses.html

Open Windows in Houston?

>4½ months when the Max. Daily Temp. is below 75F!

>6 Months below 80F! That's > 50%



Ventilation? to clear the haze?

Old home @ ~2 ACH ‘breath’ to vent humidity, gases/vapors, molds/pollens,...

But

New tight homes ‘breath’ only 5% to 10% as much as older homes.

Ventilation is critical for new homes

Here is how to find HVAC and Ventilation resources online

ASHRAE www.ashrae.org
(American Society of Heating, Refrigerating & Air-Conditioning Engineers)

HERS ™ www.natresnet.org
(Residential Energy Services Network)

Manual-J ™ www.acca.org and www.manualj.com
(Air Conditioning Contractors of America)

Ventilation For Comfort

- ☑ Great Architectural Design, Orientation, Views, Breezes
- ☑ Tight Roof, Walls, Efficient lighting, Sunlight, Energy-Star Appliances
- ☑ Operable Windows & Doors
- ☒ People Living Inside (=Humidity, a need for Clean Air, etc.)

Humans Create Moisture

- Family of 4 Each day: Cooking can add 4.5 lbs, showering 2 lbs, dishwashing 1 lb, 'being-human' 6 lbs to 8 lbs,...
- Added H_20 wastes energy
  - Condensing 1 lb H_2O requires 970 BTUs = 0.28 kWh.
  - HVAC must add kWhs for fans & motors so ~.35 kWh?
  - 16 lbs/day = ~ 2 Gallons requires ~5.6 kWh?
  - Equals ~2000 kWh/yr or 20% avg annual BL kWh

Why Not Harvest that Moisture?

- 2500 sf in humid climate = 10 gal/day
- 2,500 gal to 5000 gal clean water/yr

New Home Ventilation Critical

- Good - 15 min timers + 250 cfm vent fans in bathroom showers + range top exhaust fan
- Better - Add humidity controlled ventilation to all ‘wet’ rooms (Broan QTXE110S, Panasonic WhisperGreen, etc.)

New Home Ventilation Critical

- Better – > 0.35 ACH or 15 CFM/person per ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers, www.ashrae.org)

- **Best – Follow Latest ASHRAE 62.1-2010** with new minimum requirements for ventilation and also new natural ventilation procedures.

Whew…Intense session,…
I learned to spell
'A-S-H-R-A-E'

Okay,…We're in the home stretch,…

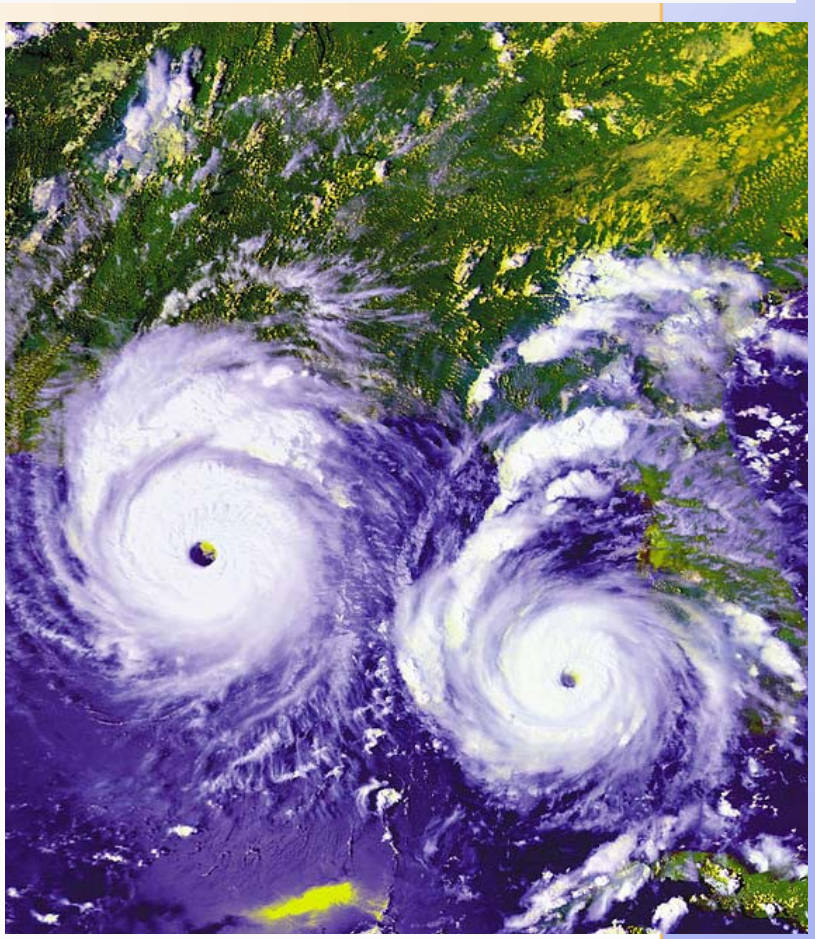
"When the HVAC Quits'

3. When the HVAC Quits

...We've learned a hard few lessons

Katrina- 1/2 million refugees

Rita- choked TX highways



Okay Mister Engineer,…

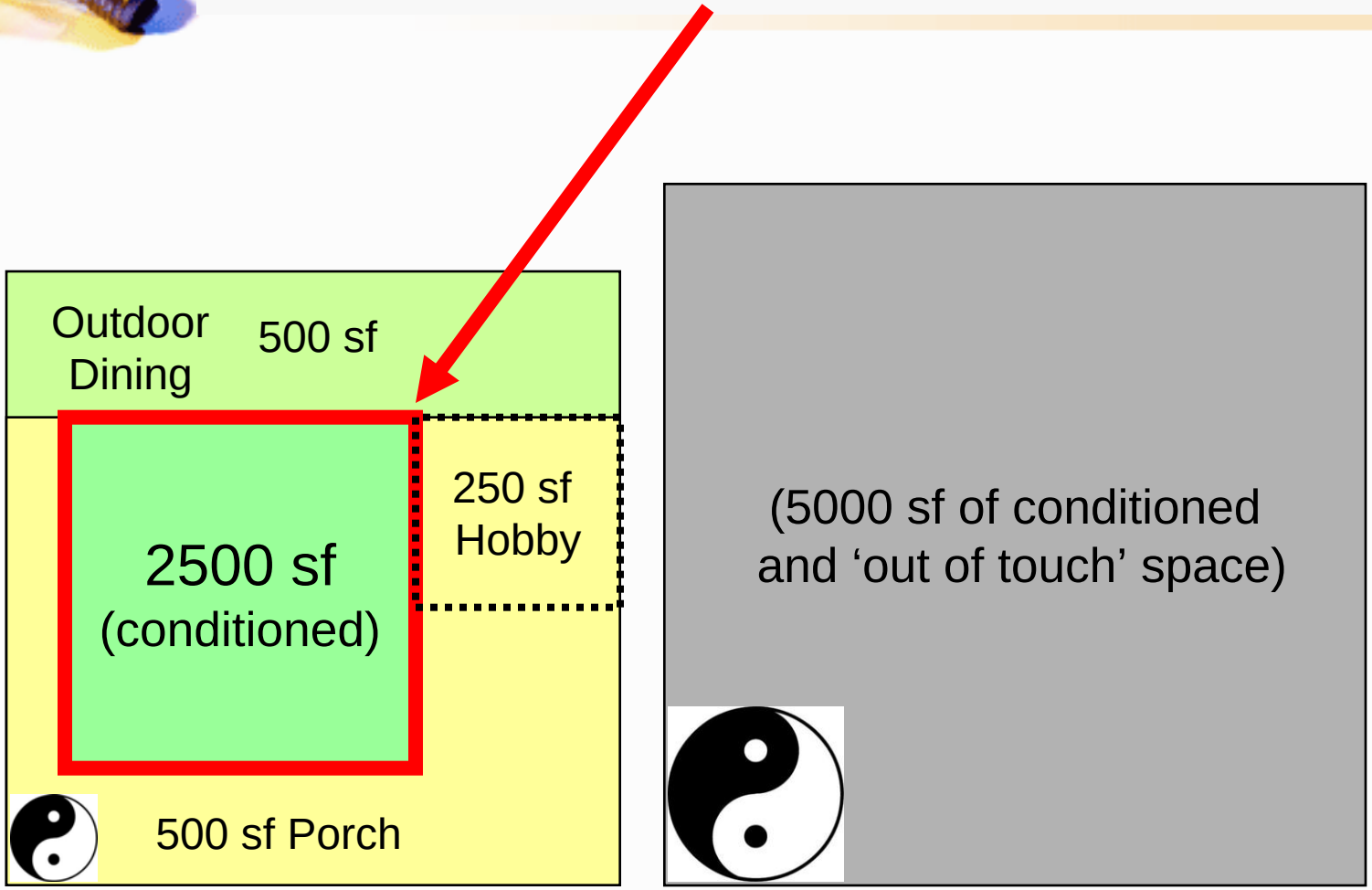
Assuming the 'MAN' says we don't need to leave,…

With my luck the power will still go out,…

Then what do we do?

Make 'Shelter-In-Place' your residential <u>design</u> requirement

Remember This?



Your Energy Target ?

AVG HOME = 2500 sq.ft.

- BL = 4 kWh/sf x 2500 sf = 10,000 kWh
- ES = 3.5 kWh/sf x 2500 sf = 7750 kWh
- GP = 3 kWh/sf x 2500 sf = 7500 kWh

SI = 2 kWh/sf x 2500 sf

= 5000 kWh (BL - 50%)

Your Energy Target ?

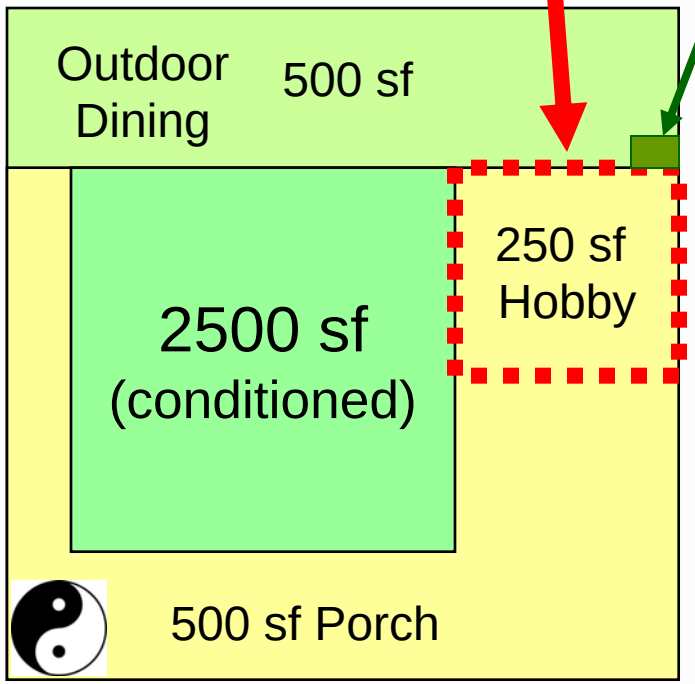
- Our 2500 sf super insulated home at 50% of BL ~2 kWh/sf may need ~5000 kWh/yr
- Our HVAC will require ~50% of this total power or ~2500 kWh/yr
- 3000W Solar Array could ~4000 kWh/yr
- **Net Zero Energy Homes Have Already Been Built in Texas**

Bingo! Finally Off The Grid! …except for night time

- **Not quite, even during the day**
- HVAC + appliances require more power than solar can provide.
- Cloudy days also limit solar power
- Solar array don't store power
- **But we do have a solution…**

Remember This?

5000 to 6000 BTU Window AC Unit (like Frigidaire FAA067P7A or GE ASM05LK) @ 1000 Watts ...



S-I-P Appliances	Wattage
Room Air conditioner	1,000
Ceiling Fan	120
Table Fan	150
Freezer (stand-alone)	600
Lights CF	25
Laptop	25
Television 20“ LCD	65
Total	**1920 Watts**

Generators

Craftsman 30250 – 2500 Watts

Briggs&Stratton EM7 – 5000 Watts

Intermittent Usage	Wattage
Toaster oven	1,225
Whole house fan	500
Microwave oven	925