Auditor I

DAY ONE

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MaineHousing

Logistics

- Class times/breaks/lunches/etc.
- Introductions
- What we will try to give you: (not necessarily in order!)
    - A historical perspective
    - A different way of looking at buildings
    - An understanding of how energy moves in buildings
    - The "tools" to diagnose complex energy related problems.
    - A world of possibilities!
- Do you have any specific questions/issues for us?

1st Day Agenda

- Logistics
- Why Audit?
- Comfort & Climate
- Relative Humidity
- BTU/Square Foot/Heating Degree Day
- Basic Audit formats
- Asbestos & Lead

A Hint Up Front !

If it’s in red,
REMEMBER IT !

World Energy = World Power

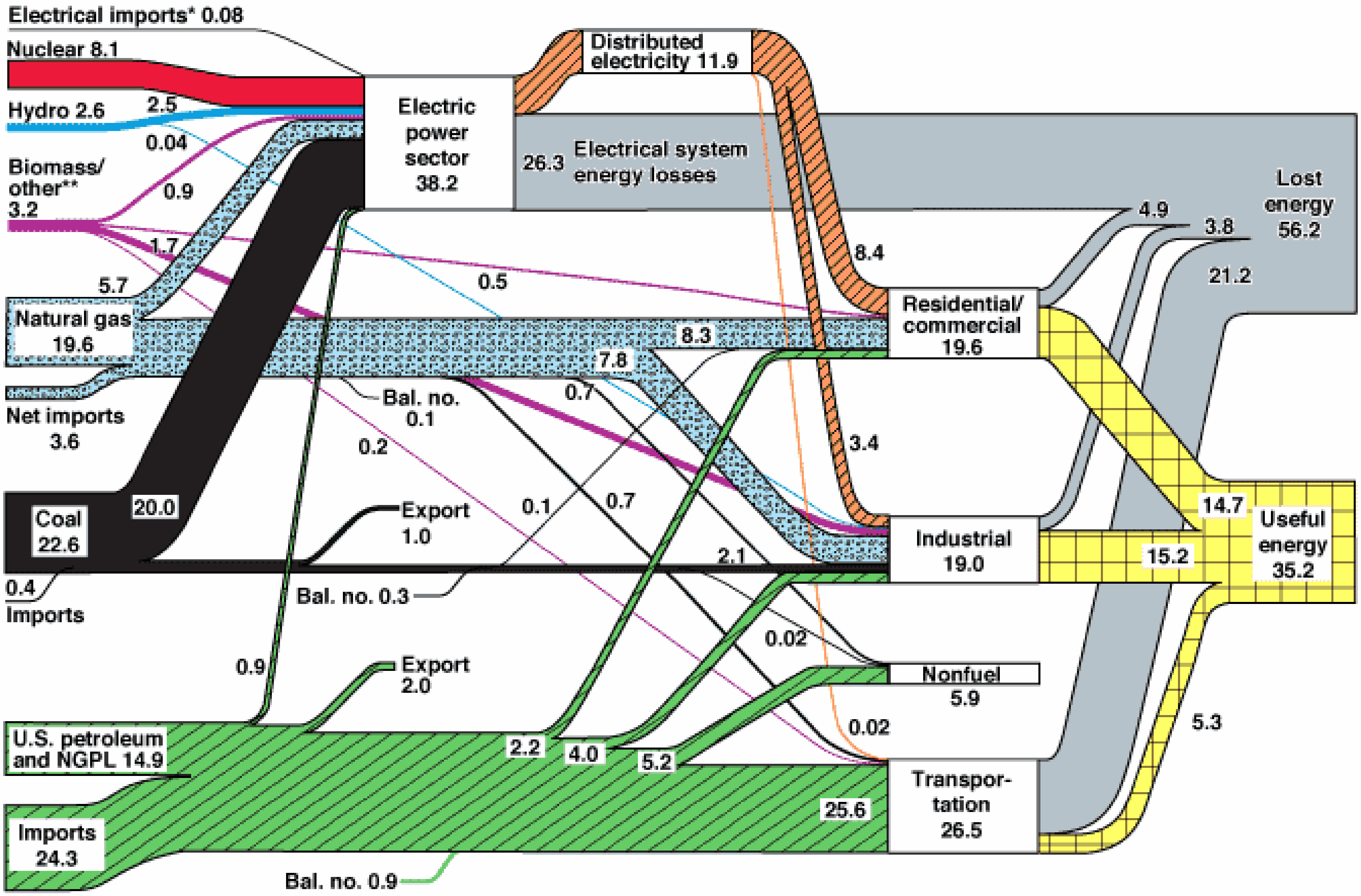
- Years ago we were told, “Knowledge is Power”, the implication being the educated prevail.
- Cynics paraphrased, “Wealth is Power.”
- Energy is power, too – in more ways than one.
- There is huge struggle going on in the world to determine which form of power/wealth – dollars vs. oil & gas reserves – will prevail.

Energy in the US :

Where does it come from ?

Where does it go ?

U.S. Energy Flow Trends – 2002
Net Primary Resource Consumption ~97 Quads



Source: Production and end-use data from Energy Information Administration, *Annual Energy Review 2002*.
*Net fossil-fuel electrical imports.
**Biomass/other includes wood, waste, alcohol, geothermal, solar, and wind.

June 2004
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http://eed.llnl.gov/flow

USA Energy Flow Trends: 2002

- 97 Quads* consumed
- 56.2 Quads wasted
  - 36.3 by electrical system losses
  - 21.2 by transportation losses
  - 4.9 by residential/commercial heat & utilities inefficiency
- 35.2 Quads go to useful energy
  - 14.5 to residential/commercial heat & utilities
  - 15.2 to industry
  - 5.3 to transportation
- 5.9 Quads – mostly oil – go to non-fuel uses
  - Fertilizers & plastics

* Quad: A Quadrillion BTUs is 10 BTUs to the 15th power – 10 with 15 zeros beside it

The BIG Picture

With the exception of solar & a little hydropower (2.6 Quads), every source of energy the US has depends to some degree on oil:

For coal, you need fuel for the mining machinery & diesel to transport it.

For wood, you need gas for the chainsaw & diesel for the truck.

For corn - to eat or burn - you need oil based fertilizer, gas for the tractor, diesel for the truck, etc.

Even with nuclear, there’s transporting & storing spent fuel.

The Even BIGGER Picture

Oil permeates the entire modern world economy:

- It’s not just industrial power, heat & transportation; it’s fertilizer & plastics & cosmetics & so on.

Oil & natural gas are finite resources:

- The question isn’t if they will run out, but when.

There are several forces at play:

  - Reserves (& who has them)
  - Capacity: wells, pipelines & refineries
  - Supply & demand
  - Politics

PEAK OIL ??

- Peak oil proponents contend that world production capacity will soon be exceeded by increased demand from Russia, China & India driving the price of crude to unheard of levels within the next few years.
- Get the facts & decide for yourself.

HTTP://www.nyswda.org/ Link to: Peak Oil

http://www.bloomberg.com/apps/news?pid=20601109&sid=aoCSD7m5zHhA&refer=home

What are the practical applications?

- At some point energy as we know it will become unaffordable.
- Conservation is <u>always</u> the cheapest way to extend a resource.
- The 5 quads of space heat energy wasted each year represents a tremendous opportunity.

Knowledge <u>is</u> Power !

Mars Hill !

Why do an Energy Audit ?

Powerful tool for informed decisions

It’s a “Win-Win” (except for the energy vendors!)

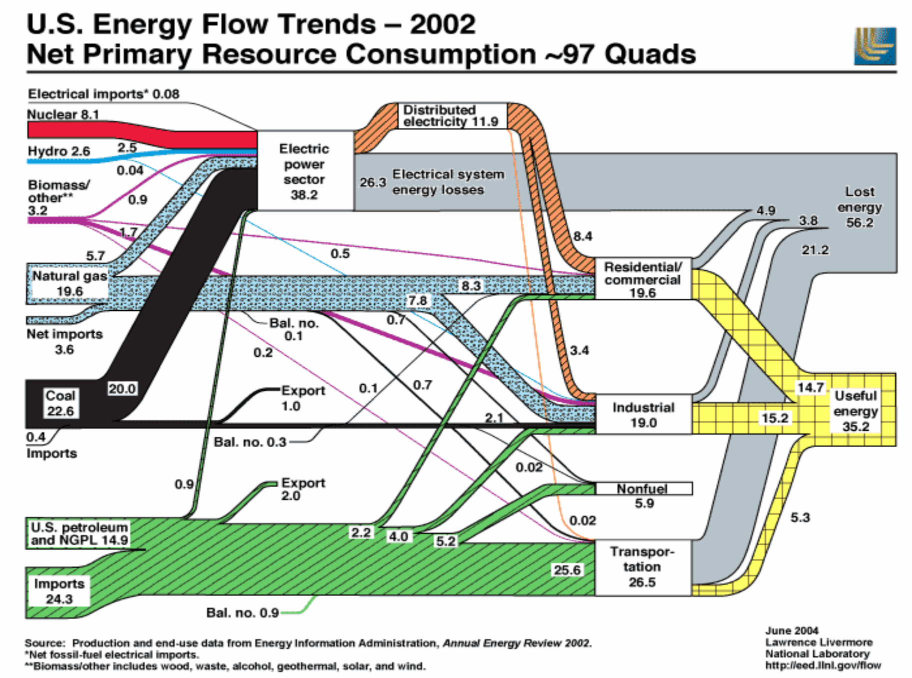
- Save energy
- Improve indoor air quality
- Promote building durability
- Increase comfort

Why do an Energy Audit ?

Save Energy:

≈ 20% of US consumed energy goes to residential & commercial space heat.

≈ ¼ of that is wasted.



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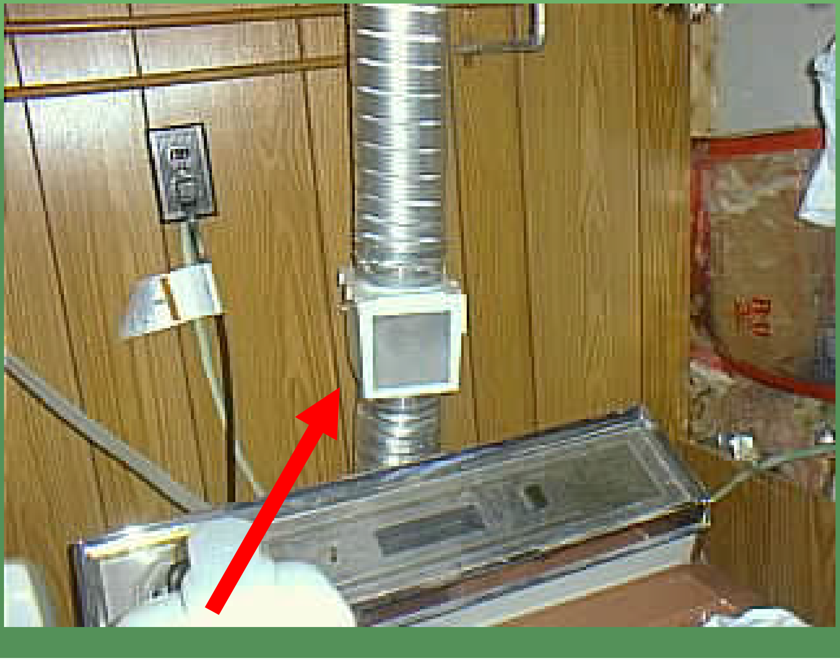
A 5 quad savings opportunity !

Why do an Energy Audit ?

Improve IAQ:

- Prevent mold/mildew
- Eliminate odors
- Reduce respiratory ailments.

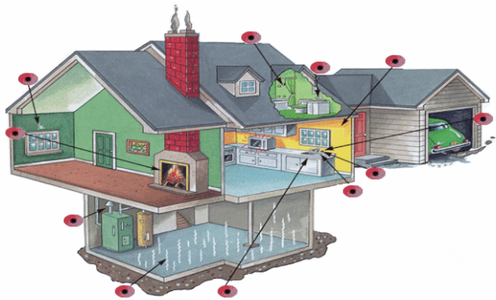


The homeowner installed this device to save energy.
Why is it a bad idea?

In this home it was a Particularly Bad Idea!

- The moisture will condense on cool surfaces causing mold.
- All the chemicals from the wash are delivered to the living space for the occupants to inhale.
- The homeowner's asthmatic son sleeps here.

Dehumidifier for son's breathing.



Indoor Air Quality

A lot of culprits!

- Moisture
- Stored Toxic Materials
- Radon
- Sewer Gas
- Other

Why do an Energy Audit ?

Extend building life:

The same conditions that lower IAQ can reduce building durability.

What's bad for you is usually bad for your home!

Why do an Energy Audit ?

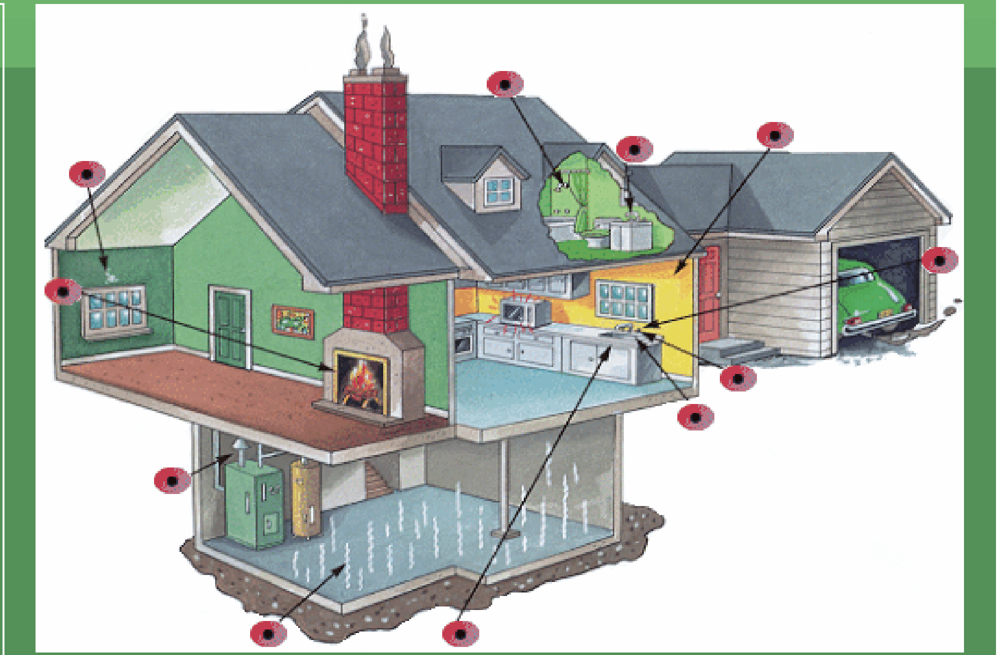
Increase comfort:

- No drafts
- No cold floors
- No hot or cold rooms
- No fogged windows

Tight, well insulated houses not only save energy, they simply feel better !

Sell what your customer wants to buy….

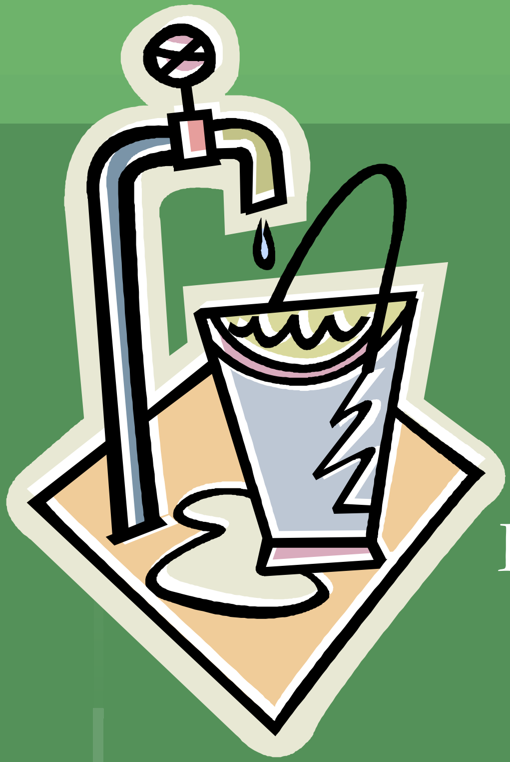
- Energy Conservation
- Good indoor air quality
- Building durability
- Increased comfort



You'll deliver all four !

Done right, they're inseparable.

Heat IN always equals heat OUT



Heat in fills the bucket:

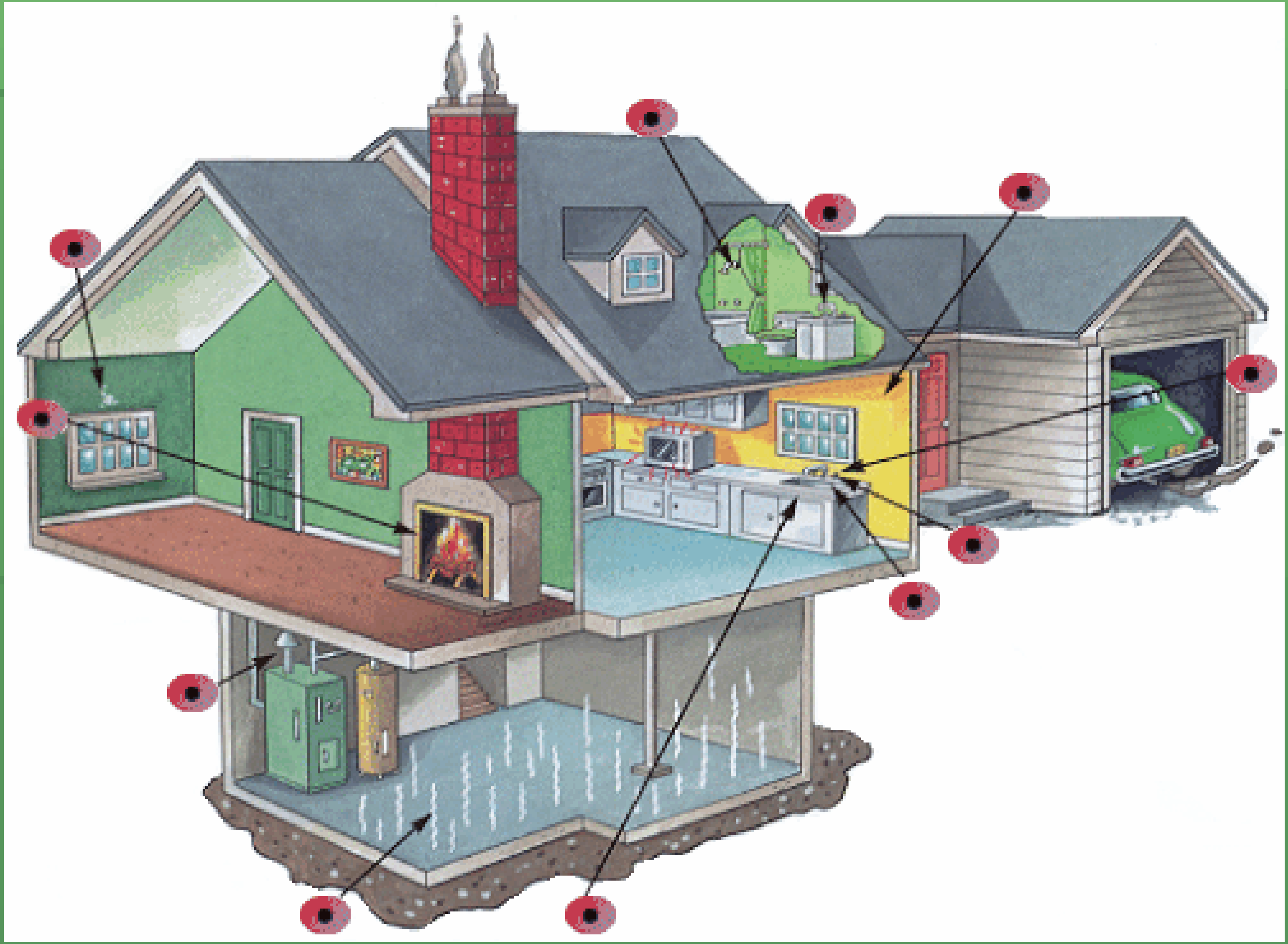
- Heating system
- Solar gain
- Internal gain

Heat out empties it:

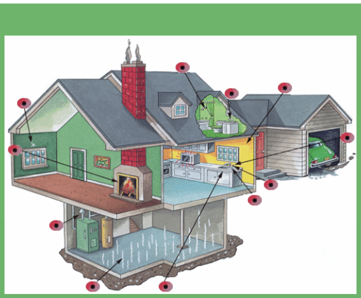
- Air leakage
- Poor insulation
- Occupant activities
- Time

A little about….

HOUSE As a SYSTEM



HOUSE As A SYSTEM



Buildings are systems…Period.

Everything in a building has the potential to interact with everything else.

The tighter a building is, the stronger the interaction will be.

Codes that control trades practices were, for the most part, written when this potential was essentially insignificant.

YOU are the only people currently being trained in House as a System Science!

HOUSE As a SYSTEM

in the Attic…

- Small holes in the attic floor – at pipes, wires, the chimney chase - allow heated air from the living space to enter the attic.
- The entering air will be relatively warm & wet.
- Moisture from the warm-wet air condenses on the first cold surface it contacts - typically the most northerly walls & the underside of the roof deck.

HOUSE As a SYSTEM

in the Basement….

- Without a vapor retarder in-on-below the concrete floor ground moisture is constantly radiated into the basement.
- Even with a vapor retarder, ground moisture will find cracks & holes through which to enter the basement.
- Soil gasses will enter with the moisture.
- Mechanical appliances can produce air borne pollutants.
- Anything stored in the basement can off-gas
- and then there are dirt floors & crawl spaces!
- Basements are typically well connected to the living space.

HOUSE As a SYSTEM

more in the Basement….

- Duct leaks can have many consequences:
  - Heat wasted warming an area you don’t want heated.
  - Cold air pulled into the heating system from the basement.
  - Heated air forced out of the home.
  - Cellar pollutants delivered to the living space.

Remember: Basements are typically well connected to the living space.

Catch that lint !

Spauling

HOUSE As a SYSTEM

In the Garage....

- The garage floor has the same moisture characteristics as the basement floor.

- Garages are even more likely than basements to contain stored "off-gassers".

- Garages typically have a low "air-feed" – the lower edge of the overhead door – and high "relief" – pipe & wire penetrations near the ceiling – or are totally open to the living space attic.

- Garages often contain **AUTOMOBILES!**

HOUSE As a SYSTEM

In the Kitchen & Bathroom….

- Showering creates large amounts of airborne moisture.
- ….as does cooking without using pot lids.
- Existing vent fans are typically underpowered & noisy.
- Often they're not vented to the exterior.
- When they are, the ducts often leak or restrict airflow.
- What about gas ranges?

Are fans used?

HOUSE As a SYSTEM

In the Living room....

- Fireplaces “net cool” all but the smallest spaces.

HOUSE As a SYSTEM

In the Living room….

And then there are

VENT FREE fireplaces !

& kerosene heaters

& home made stuff

HOUSE As a SYSTEM

In the Living room….

And then there are

VENT FREE fireplaces

& kerosene heaters

& home made stuff

HOUSE As a SYSTEM

Outside….

- Roof leaks
- Gutters (or lack of)
- Poor landscaping
  - Ground slope
  - Vegetation
- Poor building design

HOUSE As a SYSTEM

Mechanical ventilation

All exhaust appliances "suck" on the house

- Bathroom & kitchen fans
  - Jenn-aire
- Clothes drier
- Central vacuum
- Whole-house ventilation
- Heating system

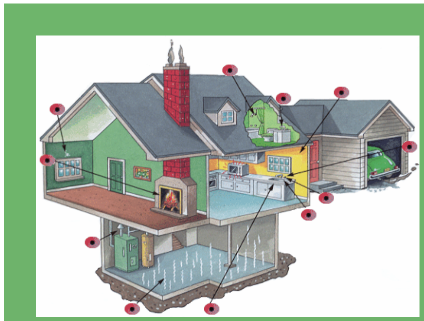
HOUSE As a SYSTEM

Occupant behavior

- Storing firewood inside
- Air drying clothes inside – *even if it's in the basement.*
- Numerous plants
- Animals
- Energy saving(?) gadgets (drier diverter)
- Life style
  - Sleeping in cold rooms
  - Under or over dressing.

Occupant behavior

- The most arbitrary energy use factor in all dwellings.
- As an auditor, you must assess the impact of occupant behavior on what you will recommend.
  - It is extremely difficult to get someone to change a habit!
  - What makes sense to you, may not to your client!



Something to think about !

Houses:

- are tighter.
- have more exhaust appliances.
- have "weaker" natural draft combustion appliances.
- have less drying potential.

With thanks to John Tooley

Houses are:

Tighter

- Plywood & drywall vs. boards & plaster
- Platform vs. balloon framing
- Concrete vs. granite slabs or rubble stone & brick
- Concrete vs. dirt floors
- Vinyl thermo pane windows vs. wood sash & storms
- Insulated doors vs. wooden doors
- Modern caulks

Houses have:

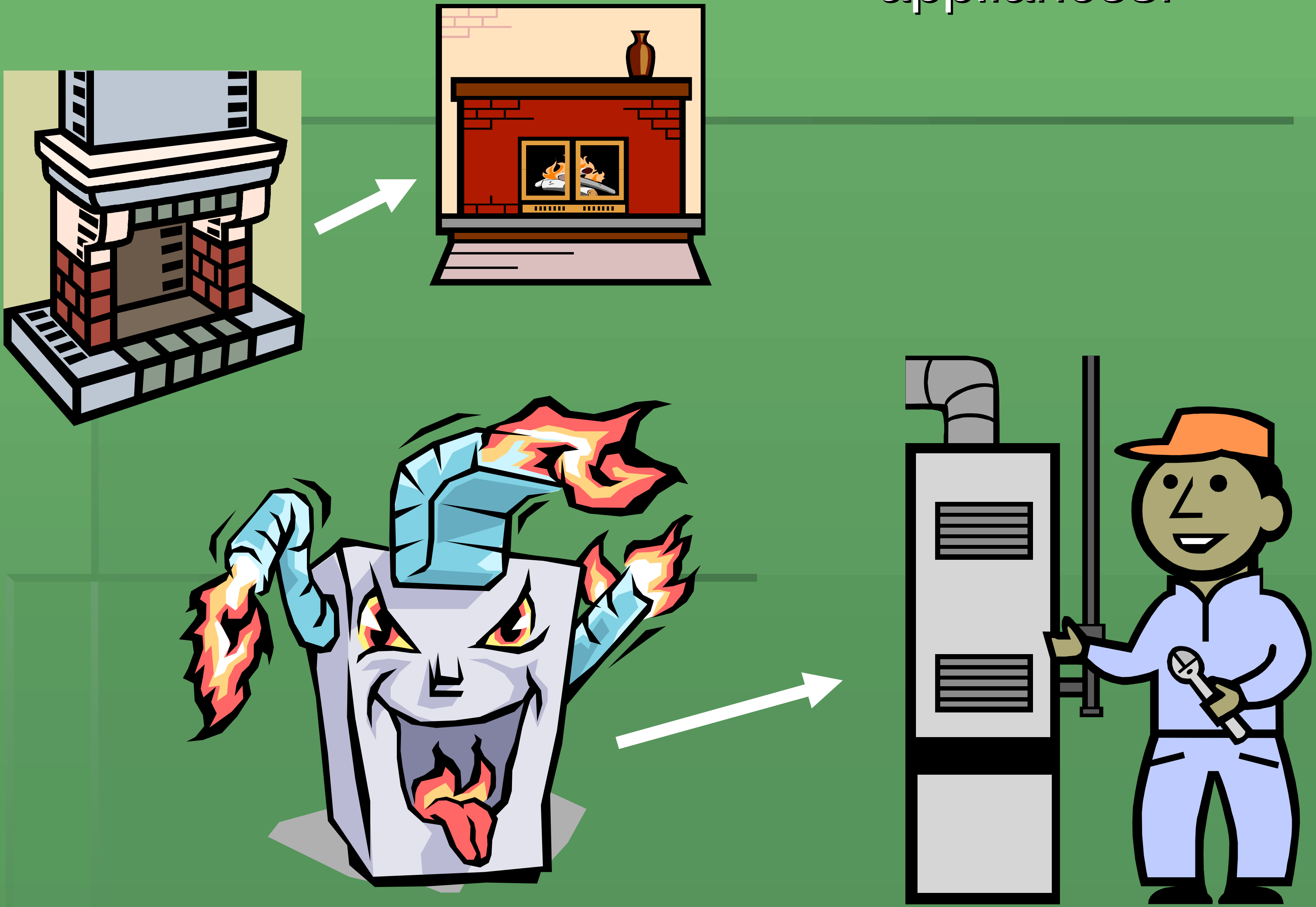
More & stronger exhaust appliances

- Jenn-aire™ vs. 50(?) CFM kitchen paddle fan.
- Clothes driers vs. drying rack or clothes line.
- Central vacuum
- Air handlers
  - Central AC
  - Stronger furnace fans
- Whole house ventilation fans

- More powerful fans in general.

Houses have:

Weaker draft heating appliances:



Houses have:

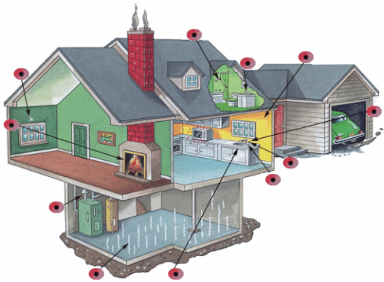
Less drying potential;

- Cavities filled with insulation.

  [“Cellulose rots buildings!” ???]
- Better caulks & sealants.
- Tighter construction details.
- Man made materials.

Lifestyle changes:

- Daily showers vs. weekly baths.
- Water “sports”
    - Hot tubs
    - Multiple shower heads
    - Saunas
    - Indoor pools
- More leisure time
    - More time in the house.
    - Plant enthusiasts.
    - Animal collectors.
    - Hobbyists.
- Anti-bacterial everything !



Something ELSE to think about !

Houses:

- are tighter.
- have more exhaust appliances.
- have “weaker” natural draft combustion appliances.
- have less drying potential.

The majority of the present trades codes were written before drywall, plywood & platform framing were commonly used!

Where does this put us?

- Buildings are much less forgiving: simply, there is less room for error.
- Altering a building or its mechanicals can have unexpected consequences.
- Right now, Auditors are the only persons formally trained in House as a System science.

IN THE DRIVER’S SEAT !

Comfort & Climate

What defines Thermal Comfort ?

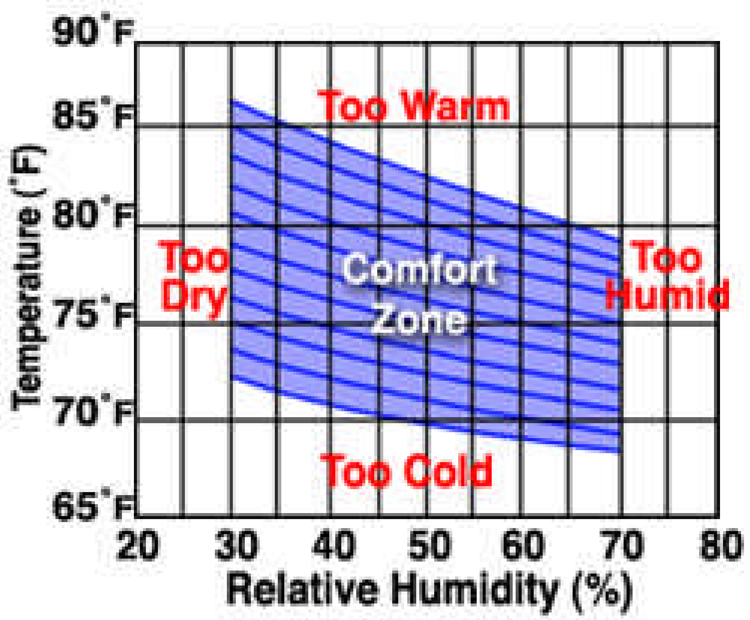
Six Variables:

Environmental:

1. Air Temperature
2. Relative Humidity
3. Air Motion
4. Mean Radiant Temperature

Personal:

1. Clothing Insulation Value (clo)
2. Metabolism Rate (met*)



Touchstone Energy® Cooperatives of Indiana, Illinois, Michigan and Missouri

*1 met = 360 BTU/hr = seated person

Air Temperature

- Most familiar with.
- It’s intuitive; if we’re surrounded by air that’s at a substantially different temperature than our comfort zone*, we’ll be uncomfortable.

  - Humans are generally comfortable between 68° & 82° F.

  - Relative humidity is a big factor.

Relative Humidity

- The most complicated of the comfort issues.
- Broadly speaking, humans adapt well to extremes of humidity.
- 15% to 75% is tolerable by most.
- Tolerance to the upper limit drops with activity level. (75% is ok when sitting but not when running.)
- Below 15%, medical issues arise.
- Humidity above 75% interferes with our body’s natural cooling system.

Relative Humidity

(So what’s it relative to, anyway?)

Relative Humidity (RH) is the amount of water vapor contained in a given volume of air *relative* to the total amount of water vapor it is capable of containing expressed as a percentage.

At 100% relative humidity, condensation happens on <u>all</u> hard surfaces.

No hard surface; no condensation. Every raindrop has a speck of dust inside it.

Sling Psychrometers

A sling psychrometer has two thermometers side by side, one with a wetted wick around the bulb and one with a dry bulb.

Because of heat absorbed by evaporation, the wet bulb will register a lower temperature than the dry bulb. Spinning it speeds the stabilization process.

The point where the wet bulb temperature stabilizes is the wet bulb temperature.

Plotting the two temperatures on a Psychrometric chart gives us dew point & relative humidity

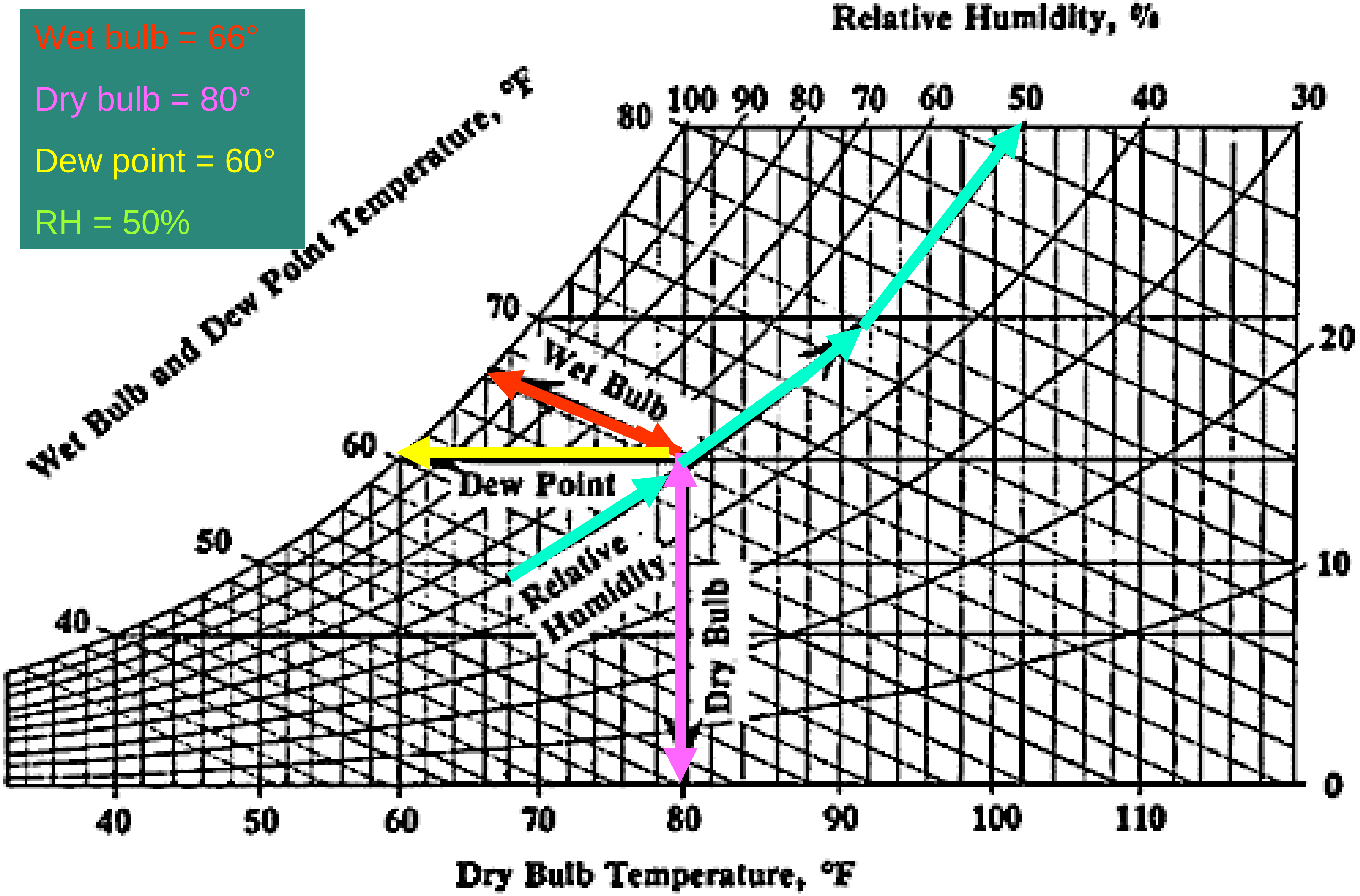
Psychrometric Chart

Wet bulb = 66°

Dry bulb = 80°

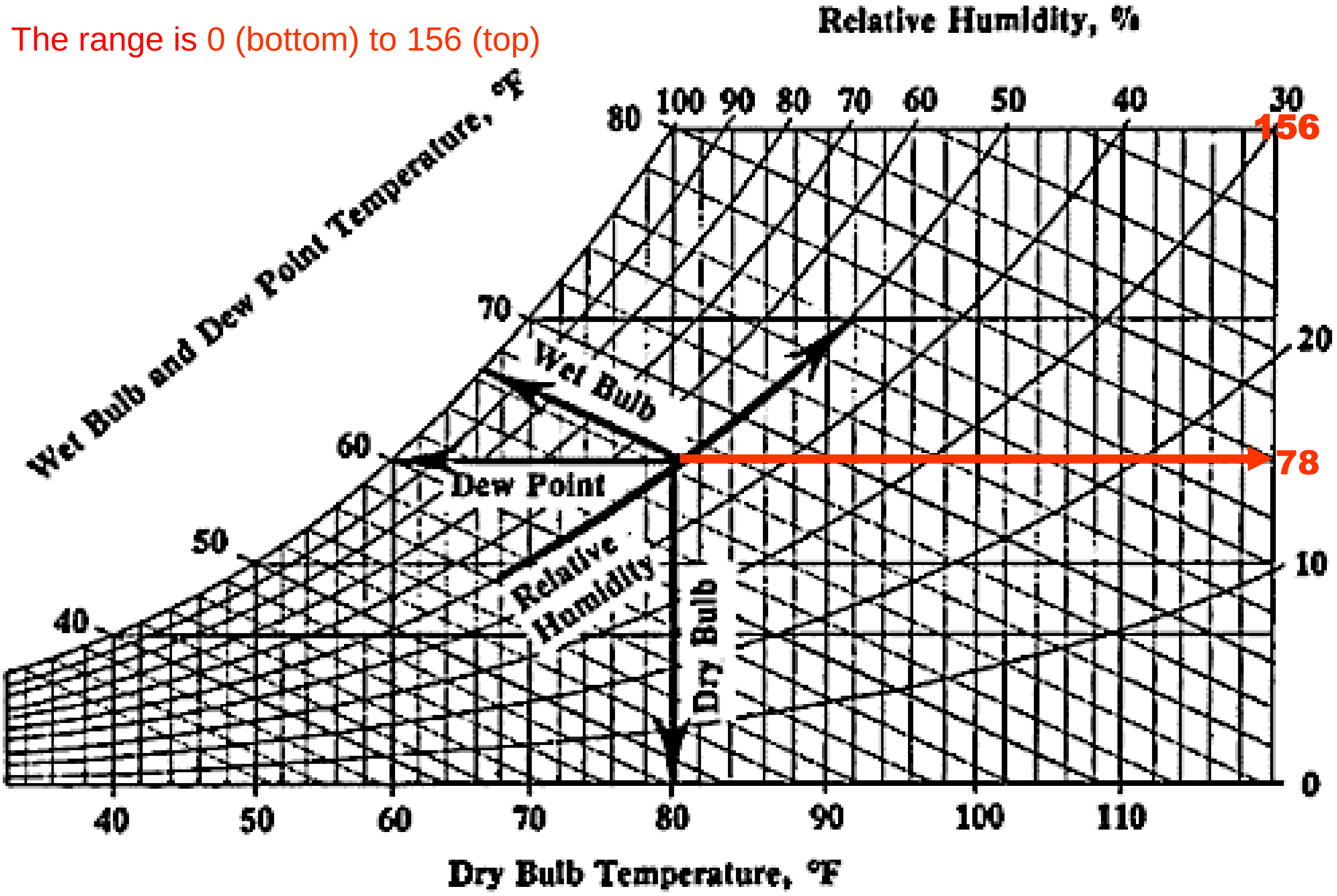
Dew point = 60°

RH = 50%



Following the dew point line to the right, gives the Absolute Humidity or grains of water per lb of dry air. *That number doesn't change unless water is added or removed.*

The range is 0 (bottom) to 156 (top)

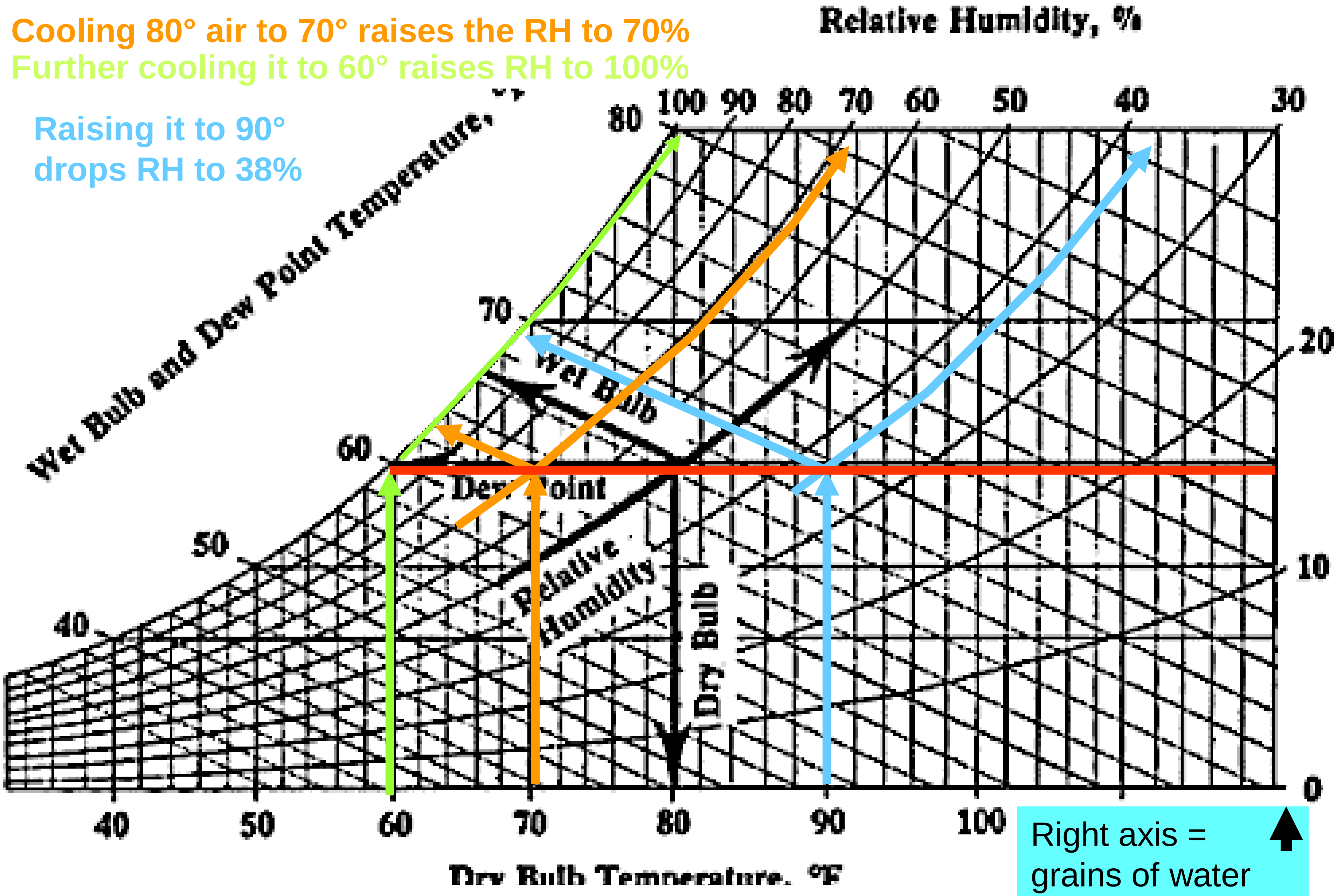


See: Krigger pp294-295

Cooling 80° air to 70° raises the RH to 70%

Further cooling it to 60° raises RH to 100%

Raising it to 90° drops RH to 38%



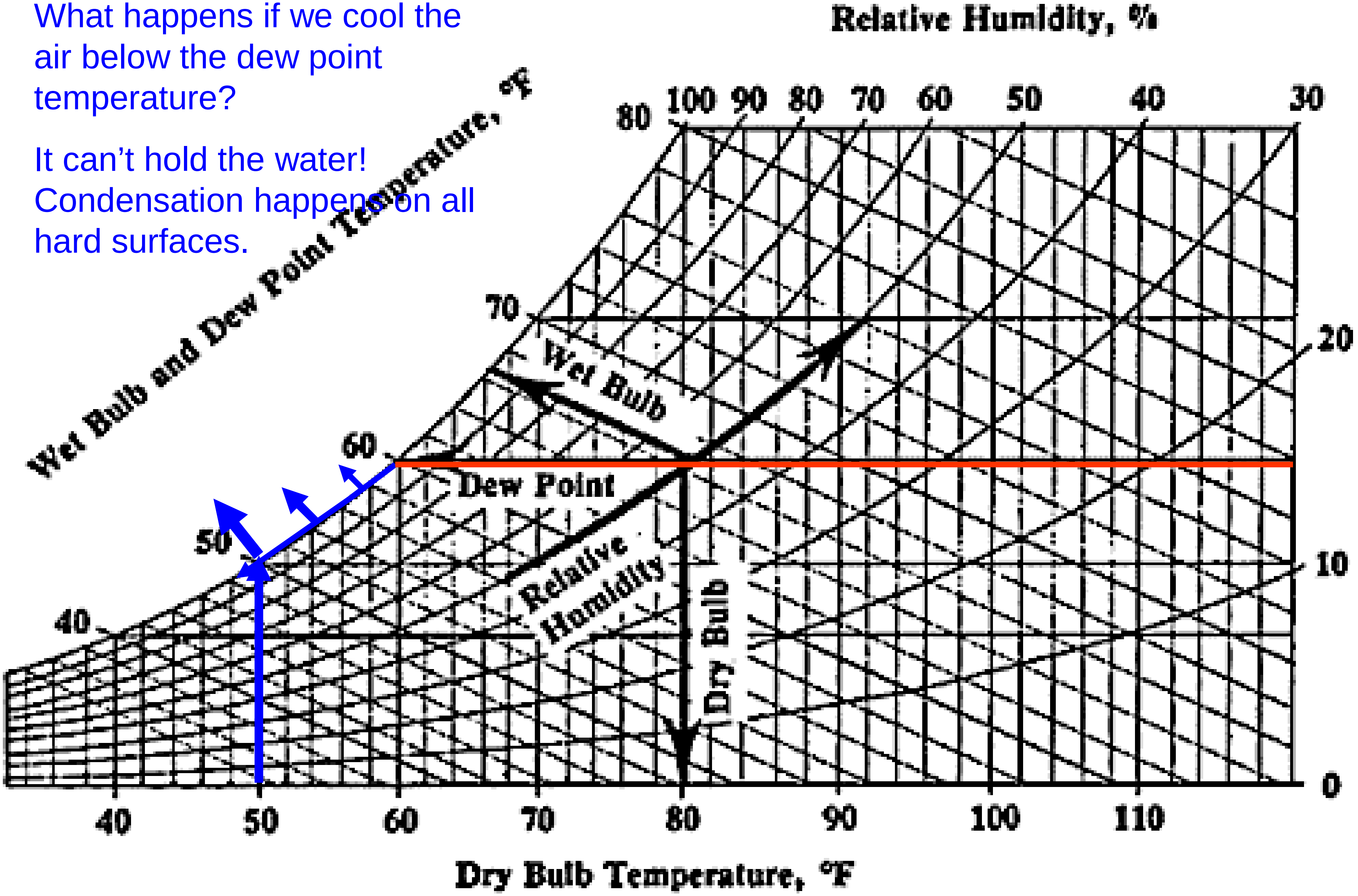
Right axis = grains of water per pound/dry air

Notice that the water content – grains/lb – stays constant !

Psychrometric Chart

What happens if we cool the air below the dew point temperature?

It can't hold the water! Condensation happens on all hard surfaces.



What’s important ?

- Relative Humidity (RH) is the amount of water vapor contained in a given volume of air *relative* to the total amount of water vapor it is capable of containing expressed as a percentage.
- 100% RH = totally saturated air.
- At 100% RH, condensation occurs on hard surfaces.
- Winter air is typically very low humidity. When heated it expands, dropping its RH further.

What's going on ?

Heavy condensation on center window.

No condensation on side windows.

Why?

What is the likely moisture source?

What should we do?

What should we do?

1. Add a storm window
2. Replace the entire window unit.
3. Advise the homeowner to run the ceiling fan.
4. Get rid of the plants.

It Depends !

Besides RH, what matters?

- Air movement
- Mean Radiant Temperature
- Activity level
- Conditioning

Air Movement

- Air movement simply speeds heat transfer.
- If air is moving over us, our evaporative cooling system works better, making us feel cooler at the same absolute temperature.

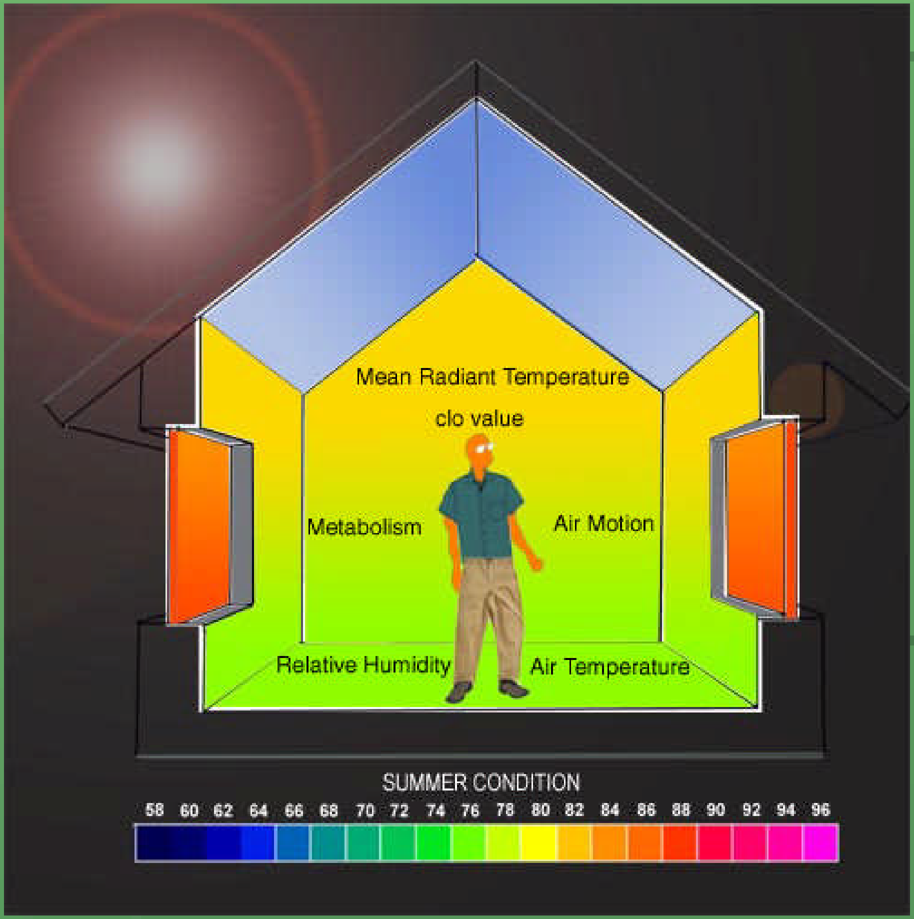
Mean Radiant Temperature

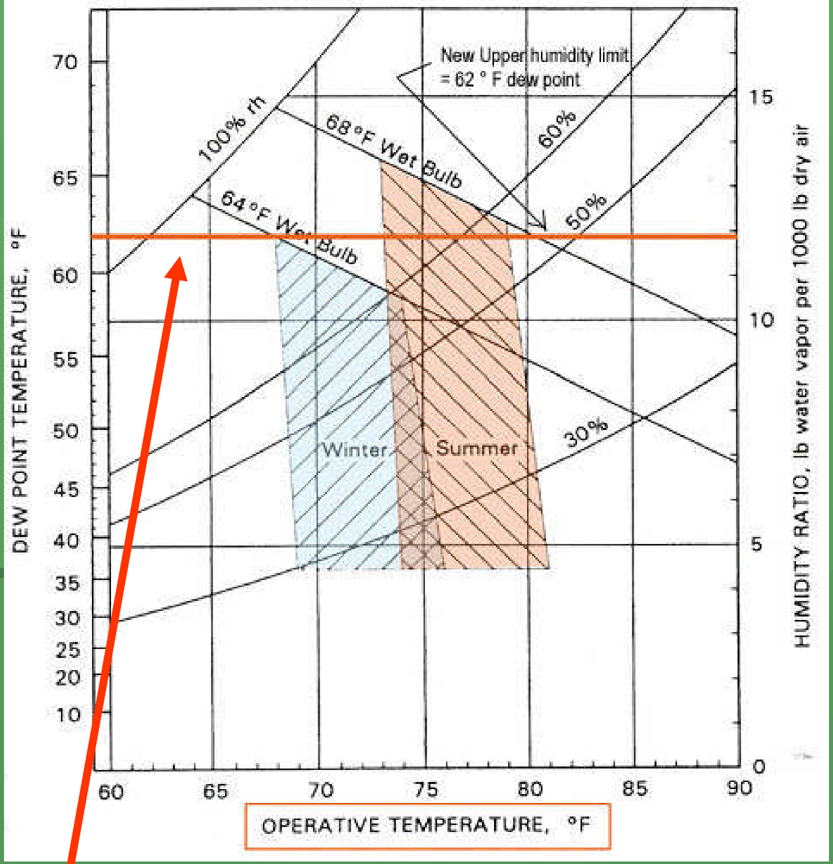
- Radiant heat transfer happens without a medium – air isn’t necessary! More importantly, the temperature of the air surrounding us doesn’t matter!
- If our body surface temperature is higher than that of surrounding surfaces, we will radiate heat to them regardless of the air temperature. It’s why windows seem cold.
- The inverse also happens. (Why a wood stove feels so good on a cold day.)

How does it all relate to comfort ?

- Our bodies try to maintain a core temperature of 96°F (or so) by either burning fat or “dumping” heat.
- Because the fat burning never really stops we’re not comfortable unless we’re losing some heat – but not a lot - to our surroundings.

Visualizing Thermal Comfort

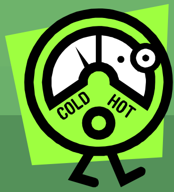




Notice the orange line: Per ASU, the 62°F dew point (not RH) is key to comfort.

See: http://www.design.asu.edu/radiant/01_thermalComfort/thermalC_main.htm

Comfort Defined?



- It’s situational.
- A sedentary person is typically more comfortable at higher & more humid temperatures than an active person would be.
- Older people often prefer higher temperatures.
- Conditioning – what we’re used to - plays a major role.
- High humidity - >60% - is uncomfortable for most.
- People are often more comfortable at higher temperatures when the humidity is lower.
- Most acceptable = 68° to 76°F @ 20% to 40%RH.

Energy Efficient Comfort Summary

- Keep heating RH between 20% & 40%
- Keep cooling RH below 60%
- Heat to 68°F
- Cool to 75°F
- Control drafts
- Minimize temperature swings
- Be very aware of Mean Radiant Transfer

Audit purpose

- Space heat energy load:
  - To size heating systems
- Total household energy audit:
  - To provide household energy conservation options
- Program specific weatherization audit:
  - To prioritize space heat conservation measures by SIR
- HERS/EEMS audit:
  - To justify financing for energy conservation measures

Audit Formats

- Simple Payback
- Life Time Savings
- Life Cycle Costing
- Annual Rate of Return (ARR)
- Savings to Investment Ratio (SIR)

Simple Payback (How long before I break even?)

Initial cost divided by annual savings

Example:

Insulate 20’ x 40’ attic with 12” cellulose @ $1.20 sq’

20’ x 40’ x $1.20sq’ = $960

Annual savings = 100 gal #2 fuel oil @ $4.25 = $425/yr

$960/$425. = 2.26 years

Strength: Simple concept

Lifetime savings
(How much money will I save?)

- Lifetime savings is the annual savings times the number of years the measure is expected to last.
- Example:

Cellulose lifetime is generally accepted to be 30 years.

30yrs x $425/yr = $12,750

Strength: Mental math !

Life Cycle Costing
(What will it cost me to do nothing?)

Life cycle costing compares the cost of acting with that of not acting.

Formula: Annual savings times expected life minus installed cost.

Example: $425 x 30yrs = $12,750 - $960 = $11,790.

Looked at this way, the cost of <u>not</u> insulating the attic over 30 years is $11,790!

Strength: Easily understandable motivator

Annual Rate of Return
(Should I borrow money to do this?)

- ARR calculates return on investment expressed as a percentage.
- Formula: Annual savings divided by initial cost times 100
- Example: \$425/\$960 x 100 = 44%

(I will have 44% of my money back in one year; or, if I borrow to finance the activity at < 44% annual interest, I'll save money from day one.)

Savings to investment ratio (SIR)

(Do I buy stock or insulate the attic?)

SIR is the most sophisticated method. It is typically required by federally funded programs as a justification for taxpayers.

Formula: Projected lifetime savings divided by installed cost. (True SIR calculations include factors for inflation & projected future fuel costs. A computer is needed. Result ≥1 is positive)

In our example: $12,790/$960 = 13.32

Strengths: (1) Lenders accept it.

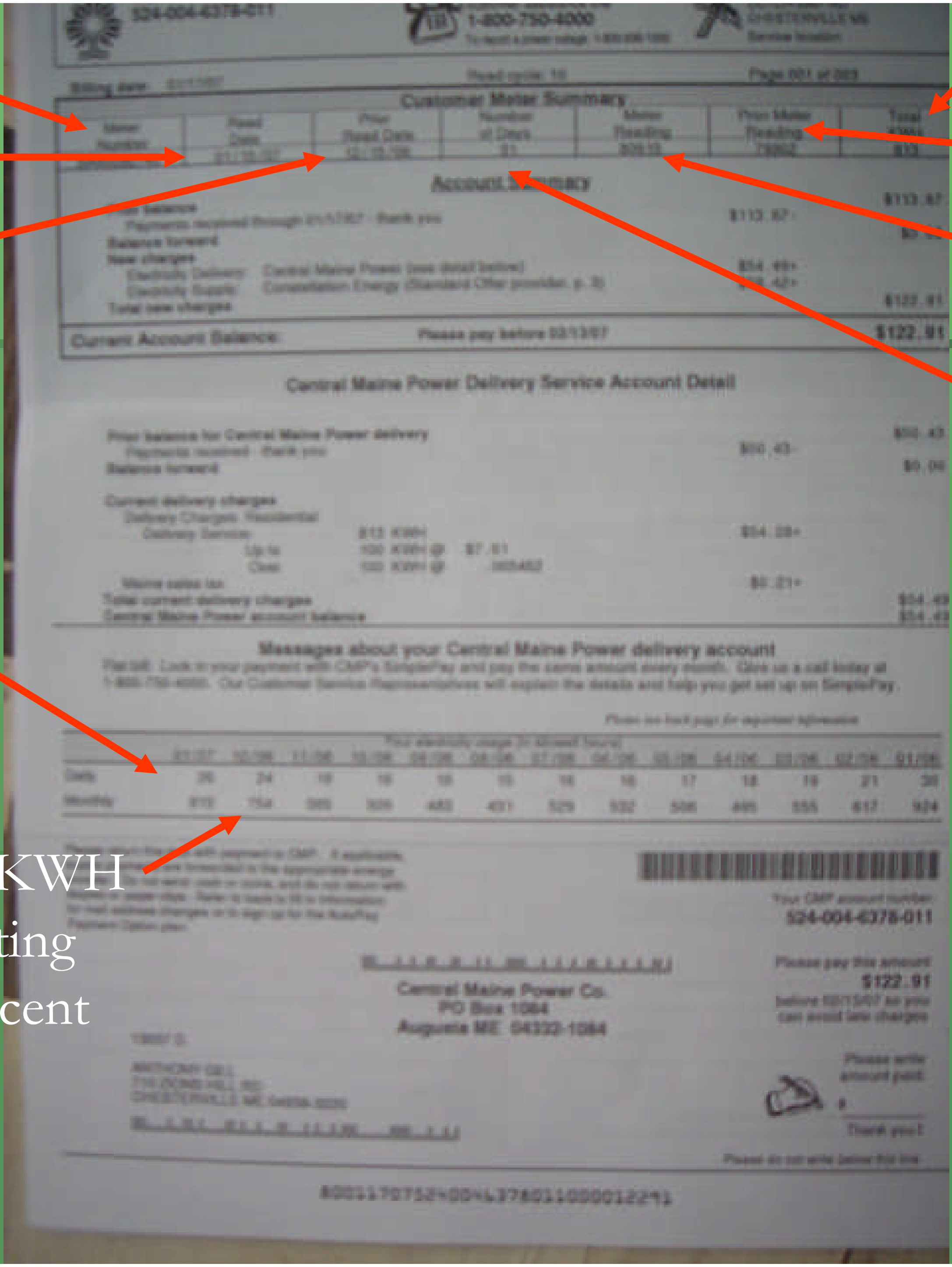
(2) Will prioritize measures.

Electric Auditing

- Reading the electric bill
- Space heating
  - Baseload calculation
- Water heating
- Refrigeration
- Lighting
- Other

Electrical audit equip

- Circuit tester
- “Live wire” tester
- Fuse stats
- Watt/volt Meters
- AC/DC



Meter #

Read date

Prev read date

Av daily KWH

Actual monthly KWH Rolling year starting with the most recent

Total KWH

Prior reading

Present reading

Days

Determining Baseload

1. Average the three lowest use months
2. Multiply the average by 1.1 to account for shorter winter days (lights on longer)
3. Mulitply by 12 to annualize
4. Result is annual baseload use
5. Subtract baseload from total to isolate annual space heat use.

1/07	12/06	11/06	10/06	9/06	8/06	7/06	6/06	5/06	4/06	3/06	2/06	1/06
7489	6201	6003	3092	852	737	648	878	1969	3861	4946	6613	7531

Twelve month total kWh used = 43,289 kWh

$$12 \text{ x } 1.1 \text{ x } \left(\frac{852 + 737 + 648}{3}\right) = 9{,}843 \text{ kWh annual baseload}$$

43,289 kWh – 9,843 kWh = 33,446 kWh per year for space heat.

See Krigger: pp269

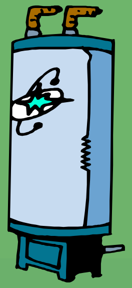
Electric Heat

- Generally has "bad rep"
- Until recent oil price hikes cost was about three times, BTU for BTU, of #2 fuel oil
- $4.25 gallon #2 ≈ $3.00/therm*
- $.15kWh ≈ $4.40/therm
- #2 ≈ 72% seasonal efficiency = $4.25/therm
- Electric heat *in the house* is 100% efficient
- Virtually equal! (& it's very easy to "zone")

*** Therm = 100,000BTU**

Domestic water Heating

Electric water heating



Between the generation plant & the house <u>three fourths</u> of the energy is lost!

<u>In the house</u> 100% of the purchased energy actually goes into the water. (no chimney)

<u>But</u>, in the house standby & distribution losses can rob another 60% of the delivered energy.

The net effect is <u>up to 90%</u> of the total electrical energy generated is often wasted!

What else is there?

- Freestanding tank
  - Electric
  - Propane & gas
  - #2 fuel oil
  - Kerosene
  - Wood!
- Off the boiler (It's not free!)
  - Immersion coil (Fmly of 4 ≈ 15 gal #2/month)
  - Water maker (Family of 4 ≈ 10 gal #2/month)

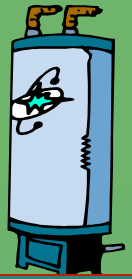
Cost factors:

Cost determined by:

1. Temperature of incoming water
2. Delivery temperature set point
3. Tank “R” value
4. Ambient temperature (Where’s the tank?)
5. Water usage

1 BTU will raise the temp of 1# of water 1°F

What can we do ?



1. Preheat the incoming water
2. Turn down the tank temperature
3. Wrap the tank
4. Move the tank to a warmer location
5. Educate homeowner re water conservation

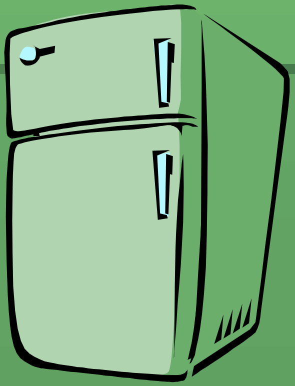
1 BTU will raise the temp of 1# of water 1°F

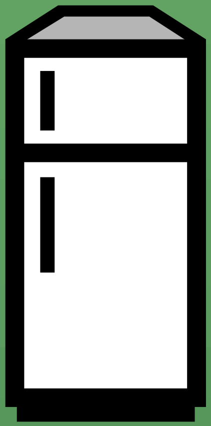
What else ?

1. Insulate the pipes.
2. Install low-flow shower heads & aerators
3. Shorten the pipe runs.
4. Change the pipe diameter!
5. Convert to localized instantaneous heaters.
6. Install a continuous loop.
7. Fuel switch.

SOLAR !

Refrigeration





- A typical pre 1996 refrigerator uses > 1,200 kWh/yr.
- A typical post 1996 refrigerator, ≈ 400kWh/yr.
- At $.15 kWh, the annual difference = $120!
- AHAM* listing

*Association of Home Appliance Manufacturers

Lighting:

CFLs use 25% of the power needed by an incandescent bulb to produce equal light.

CFL average life = 10x incandescent bulb.

CFLs contain minute amounts of mercury.

LEDs = Light of the future!

Other Considerations:

Leaks to ground
Forgotten equipment
Stolen service

Electrical Audit tricks

Conservation:

- Use the meter to find high use circuits.
- Those little transformers add up!

Safety:

- Use IR to spot overloaded circuits.
- Circuit Tracers
- Circuit Analyzers

Analyzing Energy Costs*

- Estimate electrical baseload:
  - Average 3 lowest months x 1.1 = average monthly baseload
  - Multiply by 12 = annual baseload
- Calculate domestic H^2O:
  - Typical family of 4 uses <65 gallons/day
  - Average household use ≈ 40-45 gallons/day
  - 40 gal/day ≈ 3500 kWh/yr or 230 therms/yr or 180 gal #2 fuel oil/yr (120 gal/yr with HeatStor™)

* See Krigger pp269

Comparing Fuels

#2 fuel oil	139,000 BTU/gal	$4.25 gal = $3.06 Therm
Propane	91,000 BTU/gal	$1.50 gal = $1.65 Therm
Nat’l gas	1,000 BTU/cu ft	$0.015 cu ft =$1.50 Therm
Electricity	3412 BTU/KWH	$.15KWH = $ 4.40 Therm

The math: 1 therm = 100,000BTU

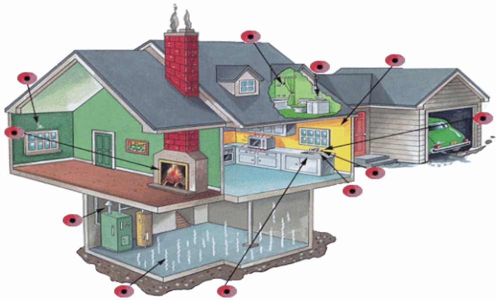
#2 - 100,000/139,000 = .72 x $4.25 = $3.06/therm

PPn - 100,000/91,000 = 1.1 x $1.50 = $1.65/therm

N gas - 100,000/1,000 = 100 x $.015 = $1.50/therm

Elec - 100,000/3412 = 29.31 x $.15 = $4.40/therm

See: Krigger: pp282



Illegal Activities

Protect yourself first!

After that, let your conscience be your guide.

Think !

Lead Paint

Bruce Mathews – MaineHousing

Asbestos

Bruce Mathews – MaineHousing

Some technical stuff :

- BTU = British Thermal Unit = the amount of heat required to raise 1 lb of water 1°F ≈ One wooden kitchen match.
- Energy = A measurable quantity of heat, light or work – a BTU, a Joule*, a foot-pound
- Potential Energy = Stored energy – a can of gasoline – Snow pack on a mountaintop.
- Kinetic energy = Moving energy – a running engine – an avalanche.
- Power = energy divided by time – the *rate* of energy release – BTU/hr, kWh, f-p/minute

* Joule = international energy unit – 1BTU = 1,000 jules

& a little more !

- Sensible heat = The sensible result of adding heat to water – Adding a BTU to a lb of water raises its temperature 1°F (by definition) *until the boiling point is reached* .
- Latent Heat = the amount of heat added per pound (970 BTU/lb – the latent heat of evaporation) to boil water or subtracted (144 BTU/lb - the latent heat of fusion) to freeze it.

Note: @ 32°F, ice contains 0 to 144 BTU/lb water. When it drops below 32°F, ice is considered *Subcooled* . Theoretically its *Enthalpy* or energy content then equals zero, however there is still some energy present in it.

British Thermal Unit (BTU)

- A BTU is the amount of heat required to raise 1 pound of water 1 degree Fahrenheit
- 1 BTU is approximately equal to the amount of heat given off by 1 wooden kitchen match
- One gallon of #2 fuel oil contains approximately 139,000 BTUs

Heating Degree Days

- Formula: $HDD = 65°F - \left(\frac{temp_H + temp_L}{2} \right)$
- In “people speak” HDD are determined by adding the high & low temperatures for the day, dividing that number by two and subtracting the result from 65°F*
- Annual Heating Degree Days are determined by summing all the degree days accrued over the heating season.

*Why 65°F? 65°F is the *balance point* at which *internal gain* will no longer maintain 72°F in the heated space. *Internal gain* is heat from appliances & occupants.

Home Heating Index

- Cars have miles per gallon stickers.
- Electrical appliances have annual kWh use stickers.
- What would we have to consider to create a building fuel use efficiency rating ?
  - How much fuel is being used over what time period ?
  - How large an area is being heated ?
  - What is the temperature difference ?

BTU/Square foot/Heating Degree Day

Home Heating Index

Main house: 28’ x 40’ - 1½ story

Ell (heated): 18’ x 24’ - 1 story

7800 HDD - 700 gallons #2 fuel oil (incl. water maker)

How many sq’ heated floor area?

How many BTU per year?

What is the BTU/Sq’/HDD ?

Home Heating Index

Main house: 28’ x 40’ - 2 story

Ell (heated): 18’ x 24’ - 1 story

7800 HDD - 700 gallons #2 fuel oil (has water maker)

(28’ x 40’ x 2 stories) + (18’ x 24’) = 2672 sq’ heated floor area

(700gal/yr) – (10gal/mo x 12 mo) = (580gal/yr) x (139,000 BTU/gal) = 80,620,000 BTU/yr

(80,620,000 BTU/yr)/2672 sq’/7800 HDD =

3.87 BTU/Sq’/HDD

Another one!

800 gallons # 2 fuel oil – Immersion coil

28’ x 40’ 1.5 story cape

7400 HDD

(800gal/yr) – (12mo x 15gal/mo) = (620 gallons/yr) x (139,000BTU/gal) = 86,180,000 BTU/yr

28’ x 40’ x 1.5 = 1680 sq’ heated floor area

(86,180,000 BTU/yr)/(1680 sq’)/(7400 HDD) = 6.9 BTU/sq’/HDD

Tomorrow’s Teaser !

The second law of thermodynamics

HIGH GOES TO LOW

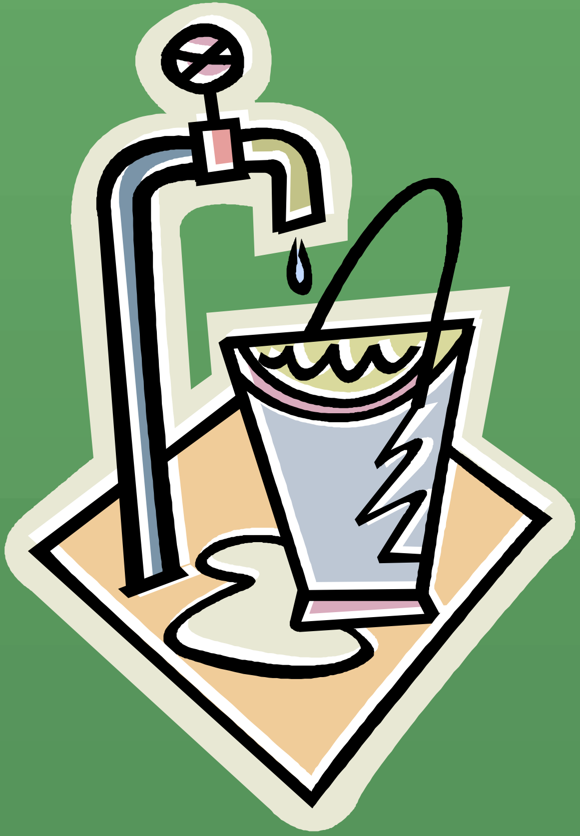
WET GOES TO DRY

HEAT GOES TO COLD

Keeping Heat In!

There are two broad categories of controllable heat loss:

- Surface heat loss
  - Conduction, convection & radiation moving heat through solid surfaces.
- Air transported heat loss
  - Conditioned air escaping the building through holes & cracks & being replaced by outside – unconditioned – air.



Homework:

For Sample House #1, calculate*:

- How many square feet of heated space?
- How many gallons for domestic hot water?
- How many BTU for space heat?
- What is Home Heating Index rating ?

Reading: Krigger PP 1- 119 + Chapter 9

*Krigger – Chapter 9 & pp 269 might help !

Sample House #1

- 20’ x 30’ ranch on full concrete basement
- Average 2’ exposed concrete basement wall
- 7500 HDD - Open, rural area
- Garage, boiler, washer & drier in basement
- 8’ Ceilings - main floor & basement
- 700 gallons #2 fuel oil – HW baseboard
- 3.5” Fiberglass walls
- 6” Fiberglass attic
- Continuous ridge & soffit venting
- DHW by immersion coil in boiler

Day Over !