Heating, Ventilation & Air Conditioning (HVAC)

A training module for Practical Energy Training
by Dr. Joe Davis PE, CEM+CEA (energy)
for
low-cost energy solutions that provide high payback
by
saving energy in all facilities such as
retail businesses, manufacturers, offices, etc.

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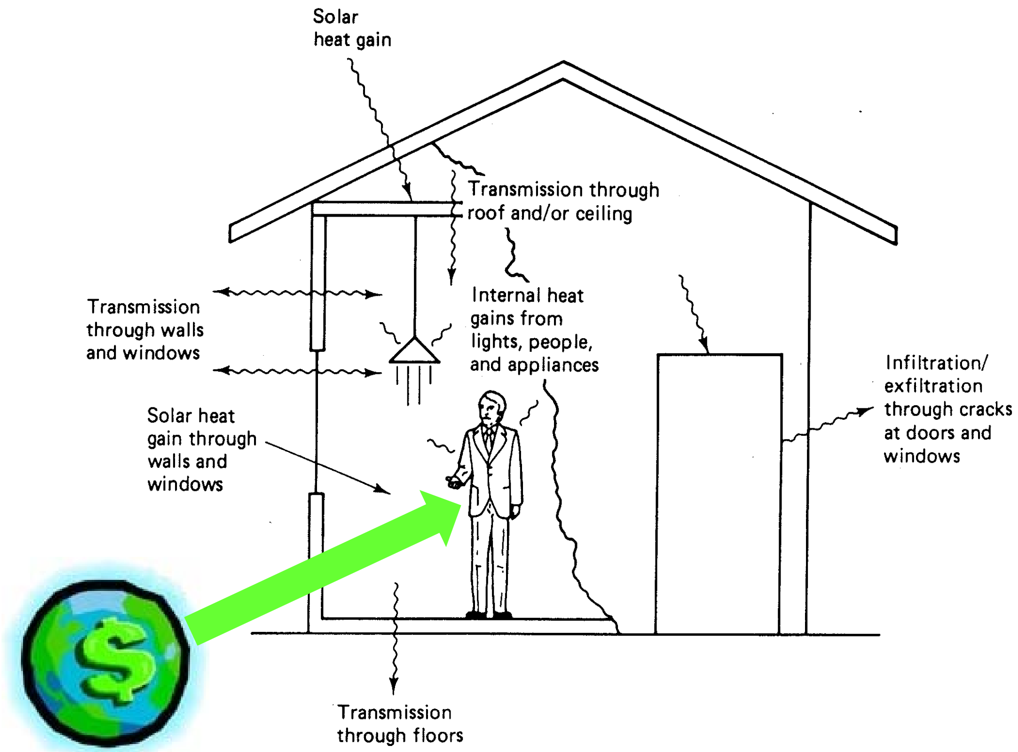
Why Care About HVAC?

- Nearly every building has HVAC systems, so we have <u>big opportunities to save energy</u>
- HVAC systems provide heating, cooling, humidity control, filtration, fresh air (indoor air quality), building pressure control, and comfort control
- Properly operating HVAC systems are essential for employee productivity and product quality
- HVAC is largest energy expenditure (~ 50% of energy $) in most buildings (retail, offices, commercial, etc.)

Why Care About HVAC?

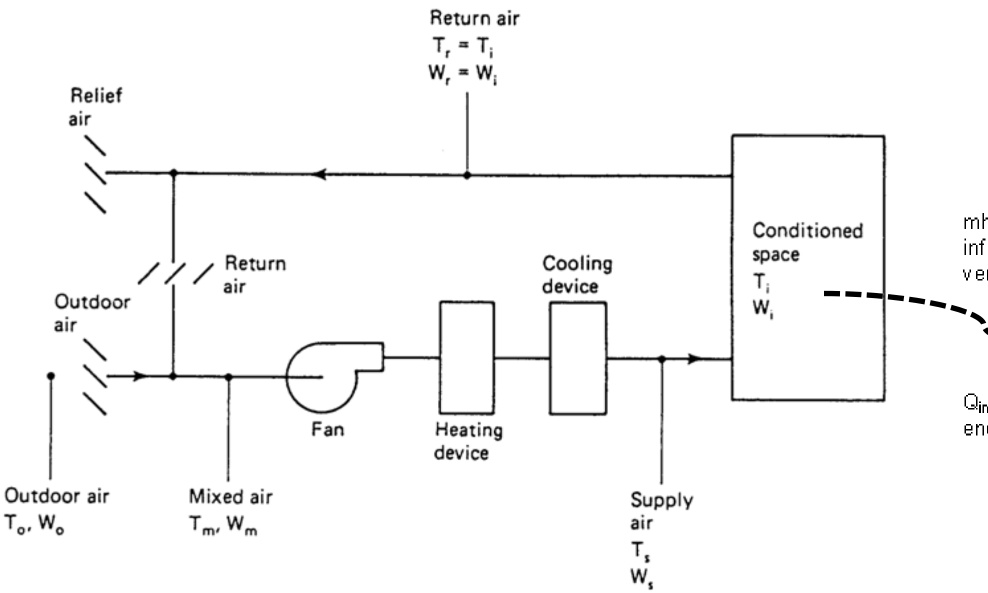


Heat Transfer & Heat Generation in Buildings

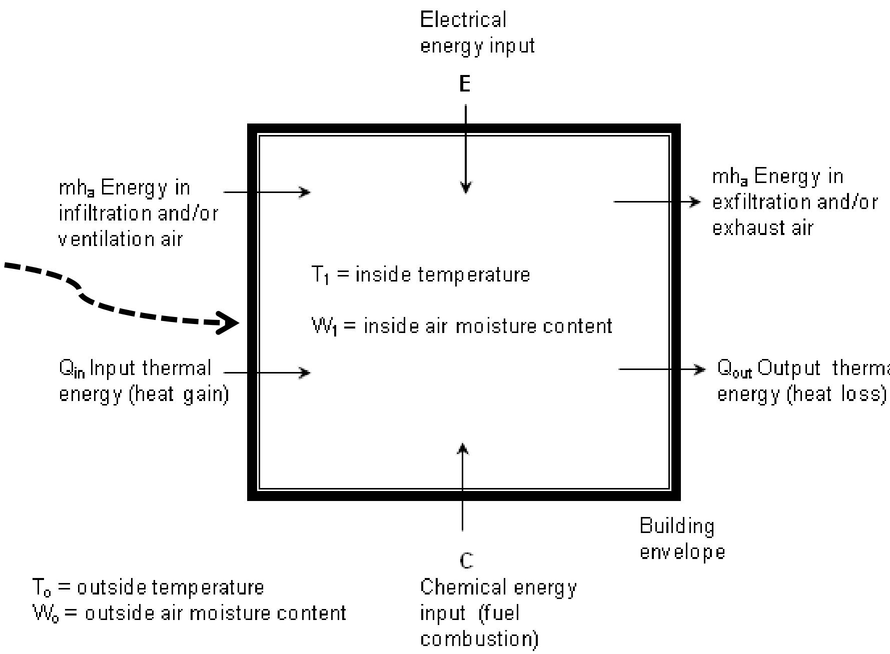
- Big energy savings can be achieved by you (people) monitoring, adjusting, and controlling HVAC systems
- First, will explain HVAC. Then, will do hands-on demo.

HVAC System Analysis

Schematic of HVAC System



Building as a Thermodynamic System



Note: As you can see (above), HVAC is typically presented/analyzed in a complicated way, but after a few more introductory concepts (next few slides), we will focus on practical energy-saving opportunities that are easy to understand.

Fundamental HVAC Parameters

Density, D = mass per unit volume = lb_m / ft^3

Specific Volume, V = volume per unit mass = 1/D = ft^3 / lb_m

Pressure, P = atmospheric pressure 14.7 psia = 29.921" Hg at 59 °F at sea level

Humidity Ratio, W = ratio of (mass of water) / (mass of dry air) in an air sample

Specific Humidity, u = (mass of water) / (total mass of air + water) in an air sample

Relative Humidity, RH = ratio of (mass of water in a given air sample) divided by (mass of water in air saturated with water at same pressure & temp as the sample)

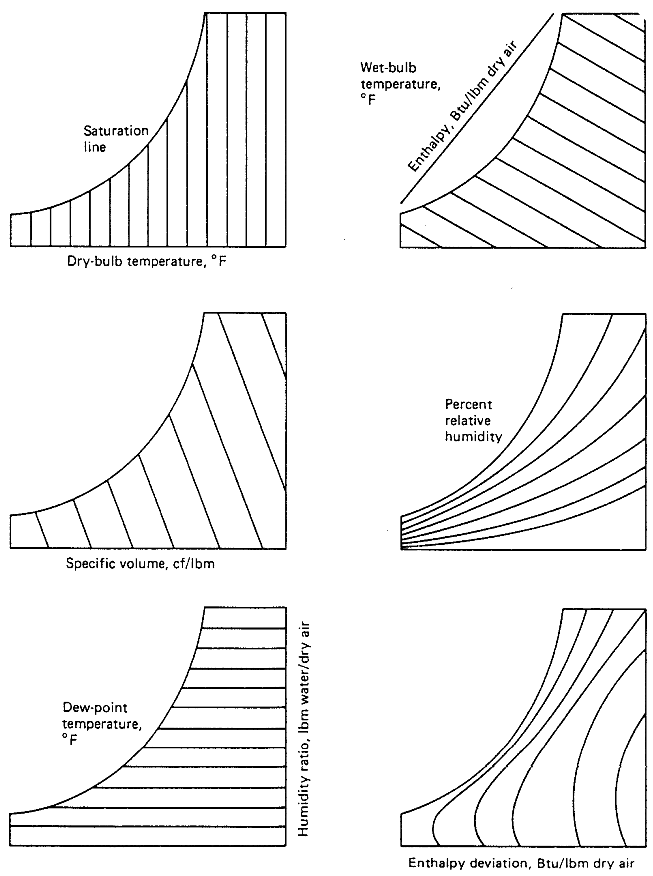
Dewpoint Temperature, T_d = °F temperature at which "dew" or condensation occurs

Wet Bulb Temperature, T_{wb} = °F on a wetted thermometer over which air flows

Dry Bulb Temperature, T_{db} = °F on a dry thermometer over which air flows

Enthalpy, h = heat content of air at a given temperature & pressure = BTU / lb_m

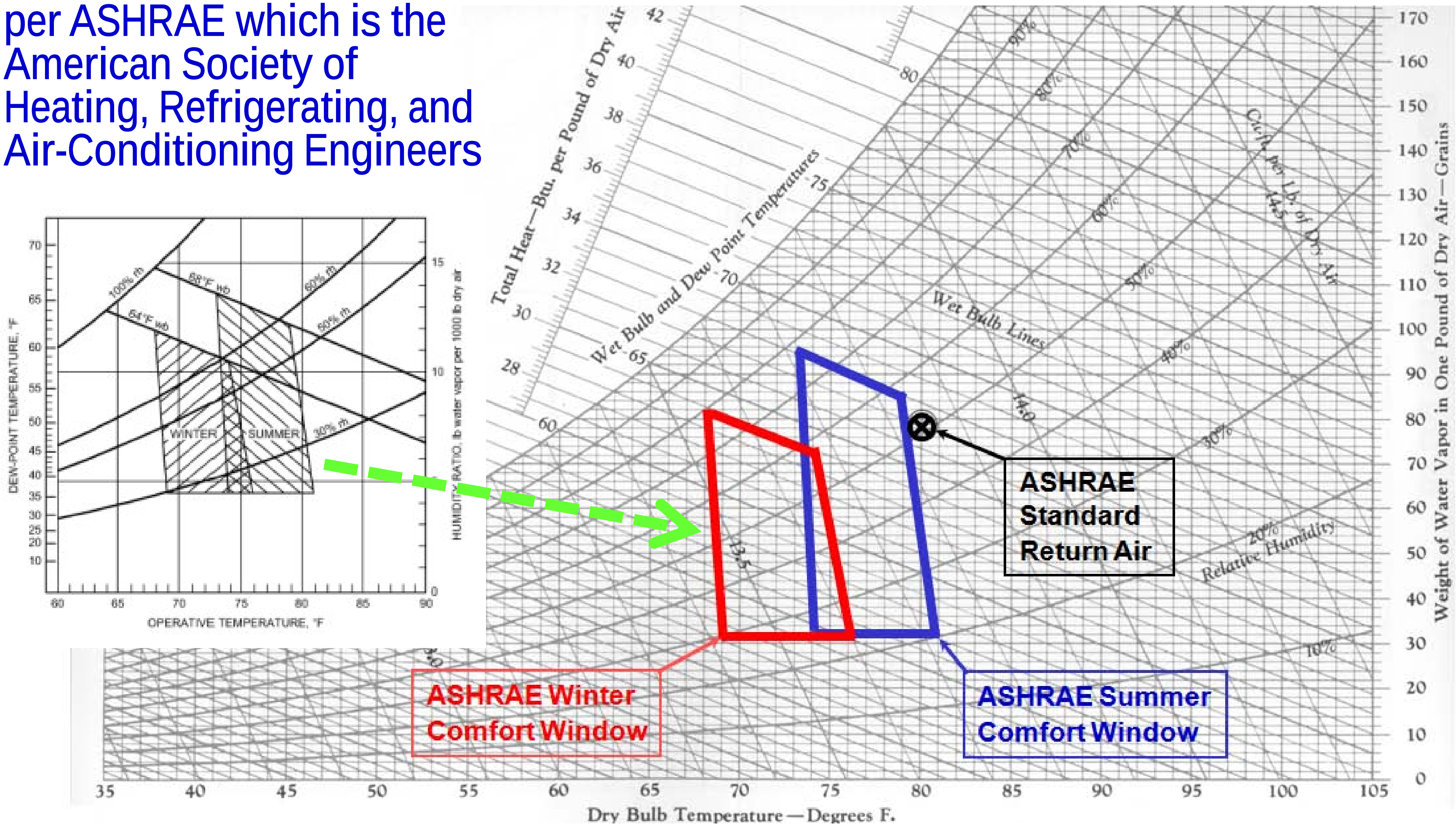
All HVAC Parameters are on a Psychrometric Chart



- A “point” defines HVAC air properties
- A “line” between 2 points is graphical representation of HVAC process such as heating, cooling, etc.
- HVAC can be complicated (see chart next page), but we will concentrate on practical energy-saving solutions

Psychrometric Chart

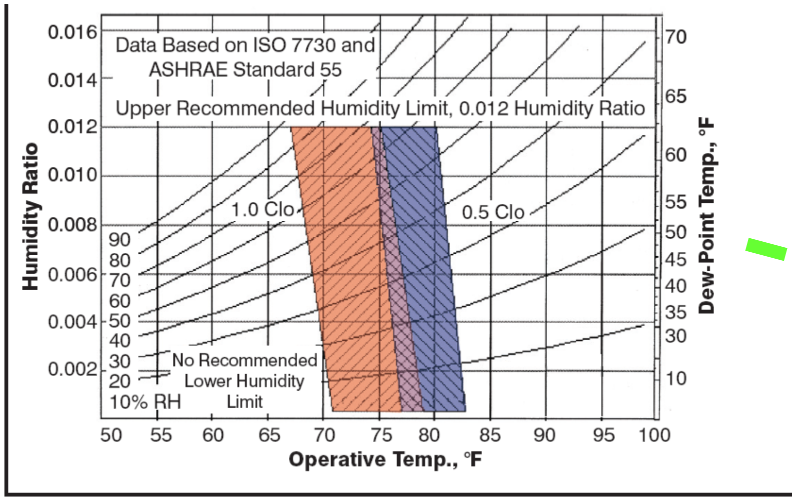
Indoor Comfort Conditions per ASHRAE which is the American Society of Heating, Refrigerating, and Air-Conditioning Engineers



Note: See tighter comfort windows on next slide based on ASHRAE survey of people.

Psychrometric Chart

Tighter recommended conditions for indoor comfort based on survey of people per ASHRAE Standard 55 Thermal Environmental Conditions for Human Occupancy



Acceptable range of operative temperature and humidity

In the figure above:

Clo = Clothing worn by building occupants
0.5 for summer (blue zone when need cooling)
1.0 for winter (red zone when need heating)

Summarize as a Table of Indoor Comfort Conditions

Summer Temp (T_{db} °F)	Summer % RH	Winter Temp (T_{db} °F)	Winter % RH
74	65	68	60-80
75	50-65	69	40-80
76	40-65	70	20-78
77	30-60	72	10-75
78	10-60	74	10-65
79	10-55	76	10-55
80	10-55	77	10-35

Note: End of HVAC intro. Now we concentrate on energy-saving opportunities.

Energy-saving Opportunities

Can use practical easy-to-understand table (below) instead of psychrometric chart. The table is per ASHRAE Standard 55-2004 Thermal Environmental Conditions for Human Occupancy.

- Set thermostats to broadest comfort range which is 76 F summer and 70 F winter indoor setpoint. This automatically creates a 6 degree dead-band within neither heating or cooling is required, and thus saving significant energy.

Summer		Winter	
Temp (T_{db} °F)	% RH	Temp (T_{db} °F)	% RH
74	65	68	60-80
75	50-65	69	40-80
76	40-65	70	20-78
77	30-60	72	10-75
78	10-60	74	10-65
79	10-55	76	10-55
80	10-55	77	10-35

70° winter
76° summer
example on next slide

Energy-saving Opportunities

- OPPORTUNITY: Reduce energy consumption by setting thermostats to 70 (max) for heating & 76 (min) for cooling within broadest comfort windows per ASHRAE (see table prior page).

- SAVINGS: Typical energy savings of 1% per degree. Per DOE EIA (Energy Information Administration), about half (~50%) of the typical commercial office building energy use is related to HVAC, and the typical average building annual HVAC energy cost is at least $2 per square foot.

- EXAMPLE: 50,000 ft^2 building costing $100,000 per year for HVAC with thermostats currently set at 74 (max) heating & 72 (min) cooling. Reset thermostats 4 degrees to 70 (max) heating & 76 (min) cooling. Save 4% of HVAC energy which is <u>$4,000 savings annually</u>.

Note: Calculation methods above are from State of NC Energy Office www.energync.net and next are 4 more energy-saving HVAC examples from State of NC Energy Office.

Energy-saving Opportunities

- OPPORTUNITY: Reduce air flow (slow the fan using variable speed motor or different size pulley) in unoccupied areas of building & during unoccupied periods of time (night, etc).

- SAVINGS: Reducing fan speed to match air flow loads will save energy per relation (see left side of fan curve next page) that fan power is proportional to cube of airflow. So, reducing airflow 10% by reducing fan speed 10% will reduce fan power consumption by about 27% because 100% - 10% = 90% = 0.9 and $(0.9)^3$ = 0.73 = 73%.

- EXAMPLE: 50,000 ft^2 building in Raleigh NC occupied half-time. Assume fan operation only during occupied periods. Typically, fan power usage is 1 kW per 2000 ft^2 of building floor area, so 50,000 ft^2 / (2000 ft^2/kW) = 25 kW present fan power. Reducing fan speed 10% reduces fan power by 27%, so save 27% of 25 kW = 6.7 kW x 365 days x 12 hr/day x \$0.10 / kWh = <u>\$2,900 annually</u>.

  Note: Calculation methods above are from State of NC Energy Office www.energync.net

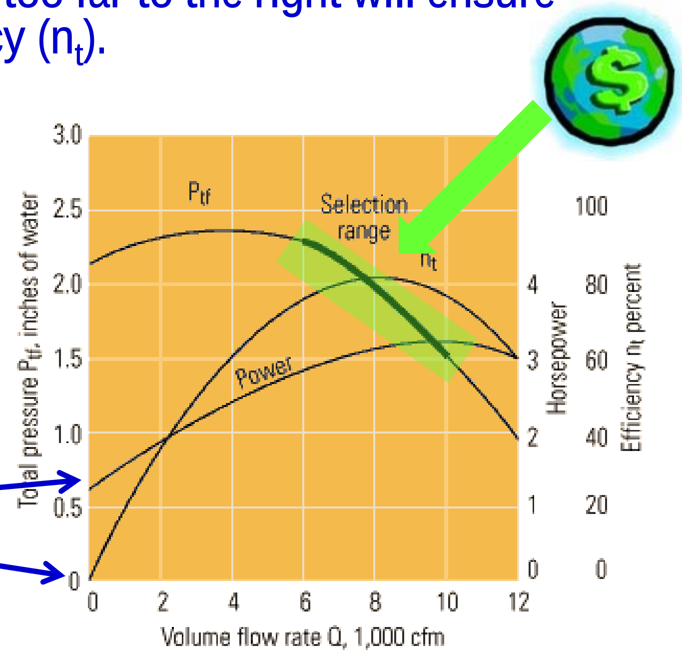
Energy-saving Opportunities

- Fan curves show the relation between quantity of air (CFM) a given fan will deliver and the pressure (P_{tf}) against which it can discharge air. The curves also show horsepower required from the drive motor for the corresponding airflow, and the fan efficiency (n_t).

- We want to operate a fan most of the time near the top (shown by “selection range”) of the efficiency curve. As shown, operating a fan too far to the right will ensure plenty of airflow (CFM), but at a penalty in efficiency (n_t).

- As shown, if HVAC filters/coils become clogged so that the fan operates too far to the left, then efficiency (n_t) drops dramatically until efficiency goes to zero when there is no air flow (CFM = 0).

- An interesting (but counterintuitive) result of totally clogged HVAC filters/coils (CFM = 0) is that the fan motor electrical usage will reduce (not increase) as shown by the power curve, but because CFM = 0, efficiency is 0 so fan is churning air, but not circulating air.



- **So, if you see a change (+ or —) in fan motor** electrical usage of more than 10%, then you should check for clogged filters/coils.

Note: We will do hands-on demo.

Energy-saving Opportunities

- OPPORTUNITY: Save energy in unoccupied periods by using timers to turn-off HVAC compressors, fans, & close outdoor air dampers.

- SAVINGS: For 50% occupancy period, heating savings (BTU/yr) is roughly equal to the building floor area (ft^2) times number of heating degree days (HDDs), assuming a heating system efficiency of 75%. Cooling energy savings (kWh/yr) is roughly equal to the building floor area (ft^2) times number of cooling degree days (CDDs) times 0.00027, assuming cooling system efficiency 1.5 kW/ton.

- EXAMPLE: 50,000 ft^2 building in Raleigh NC occupied half-time. Annual heating energy savings = 50,000 x 3586 HDDs = 179 MMBtu = $5,370 (at $30 / MMBtu fuel cost). Annual cooling energy savings = 50,000 x 1426 CDD x 0.00027 = 19250 kWh = $1925 (at $0.10 / kWh). Total estimated savings = $5,370 + $1925 = <u>$7,295 annually</u>.

Note: Calculation methods above are from State of NC Energy Office www.energync.net

Energy-saving Opportunities

- OPPORTUNITY: Reduce cooling energy consumption by using outside air (when outside air cooler than indoor return air) for "free cooling" by outside air dampers opening between 55F & 65F.

- SAVINGS: Displacing 1000 CFM of return air (at 65Fwb) with 60Fwb outside air will reduce the coil cooling load by 1.3 tons. One "ton" of cooling defined as 12000 BTU heat removal per hour. Calculation is 4.5 x 3.5 x 1000 / 12000 BTUs per ton-hr = 1.3 tons. In Raleigh NC there are roughly 1600 hours during the cooling season between 55 and 65F ambient (average 60F). Assuming efficiency of 1.5 kW / ton, about 3,000 kWh can be saved annually.

- EXAMPLE: 50,000 ft^2 building in Raleigh NC occupied half-time. Typical 1 CFM / ft^2 or 50,000 CFM return airflow. Annual savings per 1,000 CFM is 3,000 kWh (from above). Total annual savings = 50 x 3,000 x ½ = 75,000 kWh at $0.10 / kWh = <u>$7,500 annually</u>.

Note: Calculation methods above are from State of NC Energy Office www.energync.net

Energy-saving Opportunities

- OPPORTUNITY: Reduce cooling energy by increasing supply air temperature (SAT) setpoint from typical/standard setting of 55 F to instead have SAT setpoint to suit actual space conditioning loads.

  Note: Supply air (see schematic of HVAC system already shown) is air going into a room. HVAC systems have a setpoint temperature for supply air that allows the air to absorb energy at exactly the rate at which energy is entering the room from walls, roof, glass, and other sources of cooling load. For cooling, typical/standard SAT setpoint is 55 F.

- SAVINGS: Raising SAT setpoint from 55 to 60F (+5 degrees) saves 1.3 tons of cooling (as shown in prior example). Reset SAT from 55 to 60 when outside air 65 - 75F during 2,000 hrs annually in Raleigh, NC.

- EXAMPLE: 50,000 ft^2 building in Raleigh NC occupied half-time. Typical 1 CFM per ft^2 supply airflow, or 50,000 CFM. Cooling energy savings = 1.3 tons x 50 x 2000 hrs x 1.5 kW / ton-hr = 195,000 kWh at $0.10 / kWh x ½ = <u>$9,750 annually</u>.

Note: Calculation methods above are from State of NC Energy Office www.energync.net

Energy-saving Opportunities

- OPPORTUNITY: Significant HVAC energy can saved simply by reducing the area/volume of indoor space that is heated or cooled.
- SAVINGS: Accomplish savings by making more efficient use of space, consolidating areas and activities in less floor area, and designating rooms/buildings (e.g. storage) that either will have no HVAC or will have minimal HVAC (keep from freezing, etc.). Also, lowering ceilings (put in false ceiling) will reduce heat gains and losses simply by reducing the heat transfer area because there will be less room volume and less wall area between conditioned space and the outdoors. This measure has the added benefit of potentially allowing lighting to be reduced to maintain same level of light at work surfaces, thus saving energy for overhead lights.
- EXAMPLE: 50,000 ft^2 building costing $100,000 per year for HVAC. If only 75% of the building needs to be heated/cooled, then heating and cooling costs will be reduced by 25%, saving $25,000 annually.

Energy-saving Opportunities

- OPPORTUNITY: Add insulation, especially for the ceiling/roof.

- SAVINGS: For sloping roofs, additional insulation can be added to attic spaces relatively easily. Increasing attic insulation from an existing R-19 (typical) to R-30, will reduce heat gain (summer) and reduce heat loss (winter) through the roof by about 30%.

  For flat or low-slope roofs, re-roofing is usually required by adding rigid board insulation to double the insulation factor (thermal resistance). This is typically very cost effective (3-5 year payback) and will reduce heat gain/loss through the roof by about 50%.

- EXAMPLE: 50,000 ft^2 building costing $100,000 per year for HVAC. In a typical building, 35% of heat transfer is through the roof. So, if add insulation to a flat roof to save 50%, then savings could be as much as $100,000 x 0.35 x ½ = <u>$17,500 annual savings</u>.

Energy-saving Opportunities

- Insulation Tips

  - One of the most cost-effective ways to save energy in your building is to add insulation to your top-floor ceiling (attic).

  - Also, attic ventilation helps with moisture control and reducing summer cooling bills. Attic vents can be installed along the entire ceiling cavity to help ensure proper airflow from the soffit to the attic to make a building more comfortable and energy efficient.

  - Use higher density insulation on exterior walls, such as rigid foam boards, in cathedral ceilings and on exterior walls.

  - Recessed light fixtures can be a major source of heat transfer, but you need to be careful how close you place insulation next to a light fixture unless it is marked "ICAT" (insulation contact air tight) so you know it is designed for direct insulation contact and is air tight.

  From DOE: www1.eere.energy.gov/consumer/tips/insulation.html

Energy-saving Opportunities

- Minimum Recommended Insulation R-values

  Ceiling: R-30 which is about 9 inches of fiberglass batts or loose fill

  Walls: R-11 which is about 3.5 inches of fiberglass batts or loose fill

  Floor: R-19 which is about 6 inches of fiberglass batts or loose fill

- Typical Insulation R-values Found in Older Buildings

  Ceiling: R-19 which is about 6 inches of fiberglass batts or loose fill

  Walls: R-11 which is about 3.5 inches of fiberglass batts or loose fill

  Floor: R-11 which is about 3.5 inches of fiberglass batts or loose fill

From DOE: www1.eere.energy.gov/consumer/tips/insulation.html
and http://progress-energy.com/custservice/flares/billtoolkit/rvalues.asp

Energy-saving Opportunities

Insulation Recommendations by Utility (Progress Energy)

- In Carolina:
  - Ceiling: R-30
  - Wall: R-11 to R-15 in frame wall
  - Floor: R-19 in floors
- In Florida:
  - Ceiling: R-19 to R-30
  - Wall: R-11 in fram walls
  - Floor: R-11 in floors

Insulation Type / **Inches Needed For:**

Ceiling Insulation	**R-11**	**R-19**	**R-22**	**R-26**	**R-30**
Batts or Blankets					
• Mineral fiber (rock, slag, glass)	3.5	6	6.5	8	9
Loose Fill					
• Mineral fiber (rock, slag, glass)	5	8.6	10	12	13.6
• Cellulose	3.2	5.6	6.5	7.6	8.8
Frame Wall Insulation	**R-11**	**R-19**			
Batts or Blankets					
• Mineral fiber (rock, slag, glass)	3.5	6			
Rigid Board					
• Polyisocyanurate	.5	.75 *			
• Expanded Polystyrene (molded bead-type)	1.0	1.5			

R-Values Per Inch For Common Insulating Materials

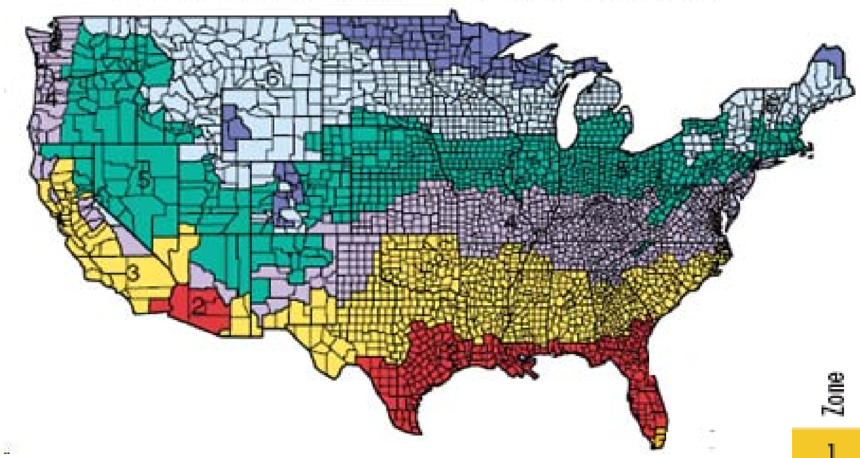
Insulating Material	**Avg. R-Value Per Inch**
Batts or Blankets	
• Mineral fiber (rock, slag or glass)	3.25
Loose Fill	
• Mineral fiber (rock, slag or glass)	2.2
• Cellulose (milled paper and wood pulp)	3.4
• Vermiculite, exfoliated	2.13
• Perlite, expanded	2.7
Rigid Board and Slabs	
• Expanded polystyrene, extruded (cut-cell surface) and molded bead-type	4.0
• Expanded polystyrene, extruded (smooth-cell surface)	5.0
• Expanded polyurethane, refrigerant 31 exp.	6.25
• Polyisocyanurate	7.04
Building Board Sheathing, regular density	2.64

From http://progress-energy.com/custservice/flares/billtoolkit/rvalues.asp

Energy-saving Opportunities

- Insulation Recommendations by U.S. DOE

U.S. Department of Energy Recommended* Total R-Values



North Carolina is in DOE's zones 3 and 4

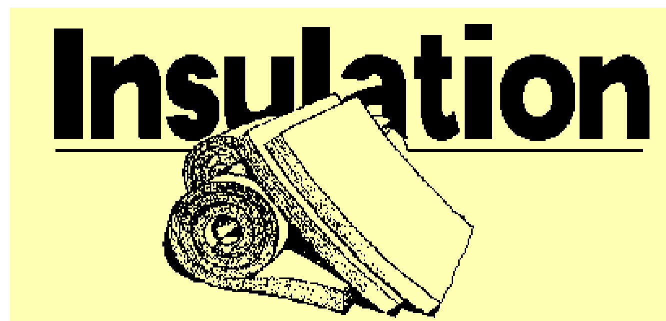
Zone	Gas	Heat Pump	Fuel Oil	Electric Furnace	Attic	Cathedral Ceiling	Wall: Cavity	Wall: Insulation Sheathing	Floor
1	✓	✓	✓	✓	R30 to R49	R22 to R38	R13 to R15	None	R13
2	✓	✓	✓		R30 to R60	R22 to R38	R13 to R15	None	R13
2				✓	R30 to R60	R22 to R38	R13 to R15	None	R19 - R25
3	✓	✓	✓		R30 to R60	R22 to R38	R13 to R15	None	R25
3				✓	R30 to R60	R22 to R38	R13 to R15	R2.5 to R5	R25
4	✓	✓	✓		R38 to R60	R30 to R38	R13 to R15	R2.5 to R6	R25 - R30
4				✓	R38 to R60	R30 to R38	R13 to R15	R5 to R6	R25 - R30

From DOE: www1.eere.energy.gov/consumer/tips/insulation.html

Energy-saving Opportunities

- Insulation Recommendations by U.S. DOE
  - For more customized insulation recommendations, use DOE's Zip Code Insulation Calculator www.ornl.gov/~roofs/Zip/ZipHome.html

Department of Energy
Assistant Secretary
Energy Efficiency and Renewable Energy



Enter first 3 digits of Zip Code:

Start ZipCode

Energy-saving Opportunities

- Window Recommendations by U.S. DOE

Improving the Energy Efficiency of Existing Windows

You can improve the energy efficiency of existing windows by doing the following:

- Adding storm windows
  Reduce air leakage and some heat transfer
- Caulking and weather stripping
  Reduce air leakage around windows
- Using window treatments or coverings
  Reduce heat loss and/or gain

Selecting New Energy-Efficient Windows

When properly selected and installed, energy-efficient windows can help minimize your heating, cooling, and lighting costs.

Achieving improved window performance in your home involves three steps:

- Design
  Consider your home's design and climate in relation to the energy performance of windows.
- Selection
  Find windows that meet your energy performance requirements.
- Installation
  Ensure proper installation of windows to maximize their energy efficiency.

From DOE:
www.energysavers.gov/your_home/windows_doors_skylights/index.cfm/mytopic=13340
www.energysavers.gov/your_home/windows_doors_skylights/index.cfm/mytopic=13480

Energy-saving Opportunities

- Window Treatment Recommendations by U.S. DOE

Window Treatments and Coverings

You can choose window treatments or coverings not only for decoration but also for saving energy. Some carefully selected window treatments can reduce heat loss in the winter and heat gain in the summer. They include the following:

- Awnings
- Blinds
- Draperies
- High-reflectivity films
- Insulated panels
- Mesh window screens
- Overhangs
- Shades
- Shutters
- Storm panels

Typically, the most effective window treatments for retrofitting existing buildings will be via awnings and/or solar control films because these are easy to add to an existing building and these require no action (but drapes/blinds/etc do require action) by the building occupants after initial installation.

Window Awnings

Window awnings can reduce solar heat gain in the summer by up to 65% on south-facing windows and 77% on west-facing windows. You can use an awning to shade one window or have an awning custom-made to shade the entire side of your house.

High-Reflectivity Window Films

High-reflectivity window films help block summer heat gain. They are best used in climates with long cooling seasons because they also block the sun's heat in the winter.

www.energysavers.gov/your_home/windows_doors_skylights/index.cfm/mytopic=13500

Energy-saving Opportunities

- Reflective Roof Saves Energy (up to 20%)

  - Professional installation costs $3.50 to $4.00 per sq.ft. including labor & materials for white or silver tar-like coatings

  - Usually best to wait/do when flat roof needs re-coating anyway

Reflective White Roofing Cuts Energy Costs 20%

Switch to a White Roof Can Reduce Power Bills, Greenhouse Gases

A study released September 9, 2008 by scientists from Lawrence Berkeley National Laboratory in California quantified what traditional builders have known for centuries: that white roofs help deflect the sun's hot rays and reduce the indoor temperature of the building below.

Potential Savings: 20% of Your Annual Energy Use

"White roofs can cut a building's energy use by 20% and save consumers money," says California Energy Commissioner Art Rosenfeld. "The potential energy savings in the U.S. is in excess of $1 billion annually."

While cool roofs significantly reduce a building's cooling load in most climate zones around the world, they can also increase heating costs in winter months by reflecting solar heat back into the air instead of absorbing it as other roofs do. But the energy savings in warm months typically greatly outweigh the extra costs in winter, since less of the sun's heat reaches the earth in winter.

From website:
http://saving-energy.suite101.com/article.cfm/energyefficient_white_roofs_save_money

Energy-saving Opportunities

- OPPORTUNITY: Reduce infiltration (air drafts) of outside air.
- SAVINGS: Identify drafts using velometer (~ $425) or simple "tissue test" (~ $0)

Tissue test: With all doors/windows closed in a building, open just one outside door or window about 1" to 2" and hold a tissue on the inside of the opening. If the tissue blows/waves noticeably, then infiltration is a problem and should be addressed. Also, if HVAC system air flow is unbalanced so it is either pressurizing the building or pulling a slight vacuum on the building, then tissue will blow/wave in that case. In either case (infiltration or air flow imbalance), corrective action is needed.

Note: The two main methods of reducing infiltration are: (1) apply caulking and weatherstripping around outside openings and (2) install entry vestibules. Weatherstripping wears out every 3-5 yrs, so replace. Every wall penetration (window frame, doorframe, louver frame, pipe, etc.) should be caulked airtight. Expansion joints in masonry walls and lap joints in siding (vertical & horizontal) require caulking. Caulking is a recurring requirement, usually every 5-7 years. Entry doors that are used regularly should be equipped with automatic closers and vestibules, particularly if they face northwest, north, or northeast. Vestibules, to be effective, must be as long as possible (at least 7 ft).

- EXAMPLE: 50,000 ft^2 building costing $100,000 per year for HVAC. In a typical building, 15% of HVAC energy cost is due to drafts. So, if add weatherstripping/caulking to save half of that 15%, then savings could be $100,000 x 0.15 x ½ = $7,500 annual savings.

Energy-saving Opportunities

- OPPORTUNITY: Change air filters (inside building) and if extremely dirty air filters, then clean evaporator coils (in unit inside building).
- SAVINGS: Change air filters regularly. Dirty filters cause more load on blower/fan motors and also force air to go around filtration sections so the unfiltered bypass air deposits dirt on HVAC evaporator coils (in air handling unit inside building). Dirty filters/coils will typically reduce efficiency by 10% due to less air circulation in HVAC system and less efficient heat transfer at coils.
- EXAMPLE: $50,000 ft^2 building costing $100,000 per year for HVAC. From above, dirty filters/coils will typically reduce energy efficiency by 10 percent. So, if clean the filters/coils to save that 10%, then the savings could be $100,000 x 0.10 = <u>$10,000 annual savings</u>.

Note: HVAC dirty coil +10% power consumption for example above based on info from U.S. Dept of Energy http://www1.eere.energy.gov/femp/pdfs/om_cooling.pdf

Energy-saving Opportunities

- OPPORTUNITY: Clean condenser coils (in unit outside building).
- SAVINGS: Condenser coils can be cleaned with a vacuum cleaner, washed out with water, blown out with low-pressure compressed air, or brushed (do not use wire brush). Clean outdoor coil annually (or more frequently as required by location or outdoor air conditions). Inspect coils monthly, and clean as required. Fins are not continuous through coil sections; dirt and debris may pass through first section, become trapped between the rows of fins and restrict outdoor airflow. So, use flashlight to see if dirt/debris has collected (& clean out) between fin sections.
- EXAMPLE: $50,000 ft^2 building costing $100,000 per year for HVAC. Typically, 10% of HVAC energy (can be up to 30%) is being lost due to dirty HVAC coils/fins. So, if clean the coils/fins to save that 10%, then the savings will be $100,000 x 0.10 = <u>$10,000 annual savings</u>.

Energy-saving Opportunities

- General recommendations for HVAC energy savings

  - Install an ENERGY STAR (see https://www.energystar.gov/) programmable thermostat that can turn off HVAC at night and turn on HVAC just before you arrive for work. Cost is typically $25 to $150, and it can cut your HVAC costs up to 30%. Add a locking cover to prevent tampering with thermostat settings.

  - Consider installing an energy management system which is especially useful when your HVAC system is too complex to control with time clocks or programmable thermostats. This lets you choose different temperatures for different zones, optimum equipment start/stop times, and control strategies that keep building occupants comfortable while minimizing energy use. Typically save 30 to 40% of your investment annually.

Energy-saving Opportunities

- General recommendations for HVAC energy savings

  - Reduce energy bills by selecting high-efficiency units when HVAC equipment wears out and needs to be replaced. Although high-efficiency units may be more expensive than the average efficiency units, the higher initial payment is recovered through increased energy savings with payback usually in 3 to 4 years.

  - When heat pumps need replacement, install high efficiency units with SEER (Seasonal Energy Efficiency Ratio) at/above 14 which is equivalent to EER (Energy Efficiency Ratio) above 11. Typically save 25% to 35% on your investment annually.

  Note: SEER and EER are explained at https://www.energystar.gov/ and details at http://energystar.custhelp.com/cgi-bin/energystar.cfg/php/enduser/std_adp.php?p_faqid=3041

Energy-saving Opportunities

- General recommendations for HVAC energy savings

  - When HVAC fan/blower V-belts need replacement, then use either cogged belt (can use in same pulley as V-belt) to save 2% or notched “tooth” belt (must replace V-belt pulley) to save 5% of HVAC fan/blower motor energy usage because less slippage. Payback is usually within 6 months.

  - When HVAC fan and pump motors need repair, replace with high efficiency models to save 35 to 45% of investment annually.

  - Reduce solar heat gain in the summer by installing awnings, overhangs (keep high-angle sunlight out in summer but allow in low-angle sunlight in winter), or “e-coated” windows with low solar heat gain coefficient (SHGC) when do renovation or new construction. Also, can use shades/blinds to keep some of the sunlight out. Payback is usually in 3 to 5 years.

Energy-saving Opportunities

- Tune-up HVAC systems by using "HVAC Tune-up Checklist" from State Energy Office website:

  www.energync.net/programs/docs/usi/om/hvac/HVAC Tuneup Checklist.xls

  provided here as:
  HVAC tune-up checklist for Energy Auditor Training by Joe Davis.xls

- HVAC tune-up is usually low-cost (e.g. adjust & clean) and quick payback (< 1 year)

- For HVAC systems, payback typically within 10 months per experience with past HVAC tune-up projects

Energy-saving Opportunities

- Do a "sanity check" for energy $ savings

  - The preceding examples of energy-saving opportunities are not directly additive. If you simply add, all those would add up to save slightly over 100% of HVAC energy which is impossible. Some implementations will change others. For example, if you decide not to heat/cool 25% of your building as shown in the example with potential savings of $25,000 then the $ savings for all other implementations (like adding insulation) must be reduced by 25% because no heating/cooling in 25% of building.

  - It is always important for you to do a "sanity check" after you finish analyzing potential energy $ savings for a company. Among energy experts, it is widely known (but unpublished) of consultants who presented multiple energy-saving ideas that added up to be more than a company was actually spending on energy, so do a "sanity check" to avoid that embarrassing error.

Company's Request

We currently have AC that uses R22. What are requirements and what actions should we be taking to change over ?

- Requirements in the USA (now)

  - All refrigerants cannot be vented into atmosphere during installation, service, or retirement of equipment. So, R22 must be recovered and recycled (for reuse in the same system) or reclaimed (reprocessed to same purity levels as new R22).

- Requirements in Europe (started 12-31-2009)

  - Europe's final phase out date for R22 was Dec 31, 2009 when no R22 can be manufactured or used after this date even for servicing, and even if R22 was purchased before, so stockpiling not an option (for/in Europe).

  - For equipment that was using R22 for air conditioning, R417A (Isceon59) is a drop-in (no equipment changes or oil change needed) replacement except need a slightly larger amount of R417A (about 10% more "charge"). So, <u>R417A looks like the most likely R22 substitute for existing equipment</u>.

(continued on next slide)

Company's Request

We currently have AC that uses R22. What are requirements and what actions should we be taking to change over ? (continued)

Requirements In Europe (USA can watch/learn from Europe's experiences)

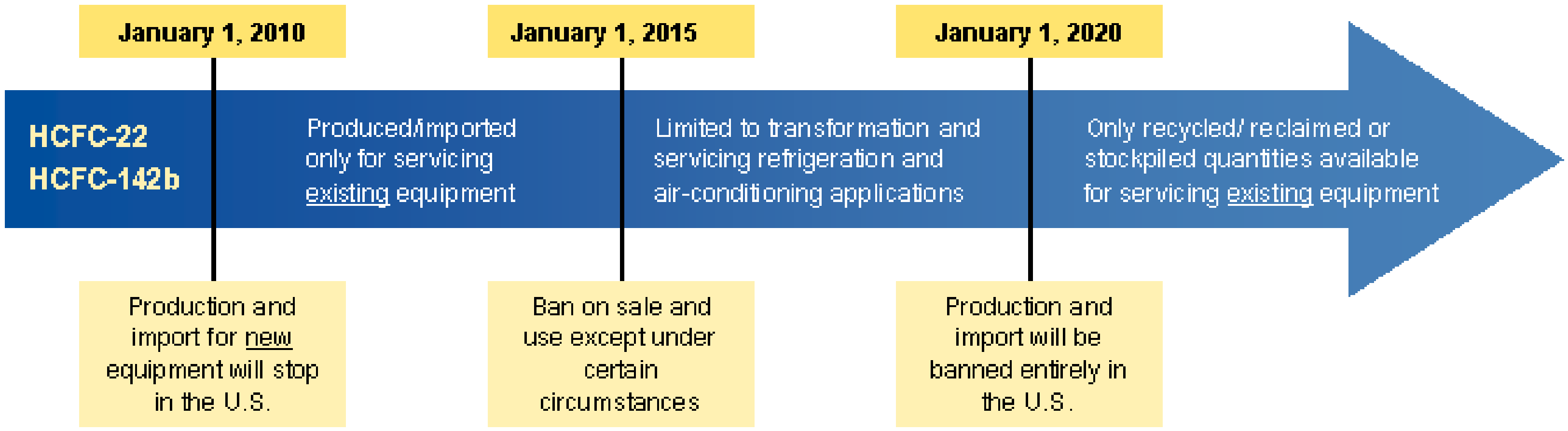
- R417A is expensive, but it will still probably be used for existing equipment because even though other R22 substitutes are less expensive than R417A, there are problems for existing equipment. For example, R410A ($ < R417A) is sold under trade names (GENETRON AZ20, SUVA 410A, & Puron) and <u>R410A seems most popular & likely to be used for new equipment</u>.

- But, R410A requires too much retrofit for existing equipment because:
  - R410A requires different oil than R22, so must flush system & use separate set of test gauges.
  - R410A incompatible with moisture whereas R22 tolerates some moisture, so this will create many problems with open line sets and old lines nearly impossible to totally flush.
  - R410A requires higher pressures than R22, so need to replace coils. Also, equipment for R410A needs coils much larger than R22 coils, so need to replace coils for that reason too.
  - R410A requires much larger fin surface area to generate the same amount of cooling as R22. For example, if you successfully put R410A into a 2-ton coil that previously had R22, you will probably only get about 16,000 to 18,000 BTU/hr instead of the prior 24,000 BTU/hr.

Company's Request

We currently have AC that uses R22. What are requirements and what actions should we be taking to change over ? (continued)

- Requirements in the USA (future)
  from EPA website www.epa.gov/ozone/title6/phaseout/hcfcfaqs.html



- Summary
  - We can still use R22 for servicing existing AC and refrigeration until 2020 but no R22 in new equipment after 1-1-2010

Company's Request

We currently have AC that uses R22. What are requirements and what actions should we be taking to change over ? (continued)

What actions should be we taking in the USA ? (now / soon)

- Keep watching Europe (e.g internet search using "R22 phase out") for what happens about which R22 substitutes are most widely used and work well without problems. Also, keep close contact with your equipment suppliers about what they are doing.

- Ask your company's technicians (or find outside technicians) to identify/select model/etc of new equipment soon so ready when old equipment needs replacement
  - See EPA's *What Technicians and Contractors Need to Know About Phasing Out HCFC* available from www.epa.gov/ozone/title6/downloads/TechniciansBrochure12-08-06.pdf
    Note: HCFC = <u>H</u>ydro<u>C</u>hloro<u>F</u>luoro<u>C</u>arbon (R22, etc.)

- Keep checking USA website for EPA advisories and information
  - Schedule/etc www.epa.gov/ozone/title6/phaseout/22phaseout.html#related
  - Frequently asked questions www.epa.gov/ozone/title6/phaseout/hcfcfaqs.html
  - R22 substitutes by equip. category www.epa.gov/ozone/snap/refrigerants/index.html
  - R22 substitutes list (summary p.11) www.epa.gov/ozone/snap/refrigerants/reflist.pdf

Hands-on Demonstration

- As part of the initial in-class training segment, attendees are trained to use a clamp-on (no need to probe wires) amp meter (hardware tool) to measure electricity for HVAC components such as fan motors, compressors, etc.

- After in-class training, then the attendees and instructor go to a production area (or in-class simulation if no production), to do a walk-thru to look/find & tag HVAC energy savings per checklist such as checking thermostats to see if set in broadest comfort windows per ASHRAE recommendation 70 (max) for heating & 76 (min) for cooling.

- During walk-thru, attendees take turns being the leader while using the HVAC checklist to look/find & tag energy-saving opportunities. Also, can do the simple "tissue test" for infiltration (air drafts) of outside air.

- That tagging would complete the hands-on demonstration, and everyone would return to the on-site classroom for calculating an estimate of economic savings/impact of typically at least 20-to-1 payback by Practical Energy.

Note: Advanced software tools (FSAT, PHAST, CHP) for HVAC system analysis at http://www1.eere.energy.gov/industry/bestpractices/software.html

Hands-on Demonstration

- Detect energy-saving opportunities, tag for correction, calculate $ savings
- A good general purpose (for HVAC, etc.) energy tool is a clamp-on amp meter that allows you to check electrical usage without probing electrical wires/conductors
- For this demo, because we won't know electrical usage history (such as for HVAC fan motor), we can't compare current to past energy usage. So, we will do an in-class demo of using the clamp-on amp meter for a fan/blower.
- Then, we will look/find & tag other HVAC energy savings per the checklist such as the simple "tissue test" for infiltration (air drafts) of outside air.
- Tag with yellow tags
- Calculate $ savings (will show)

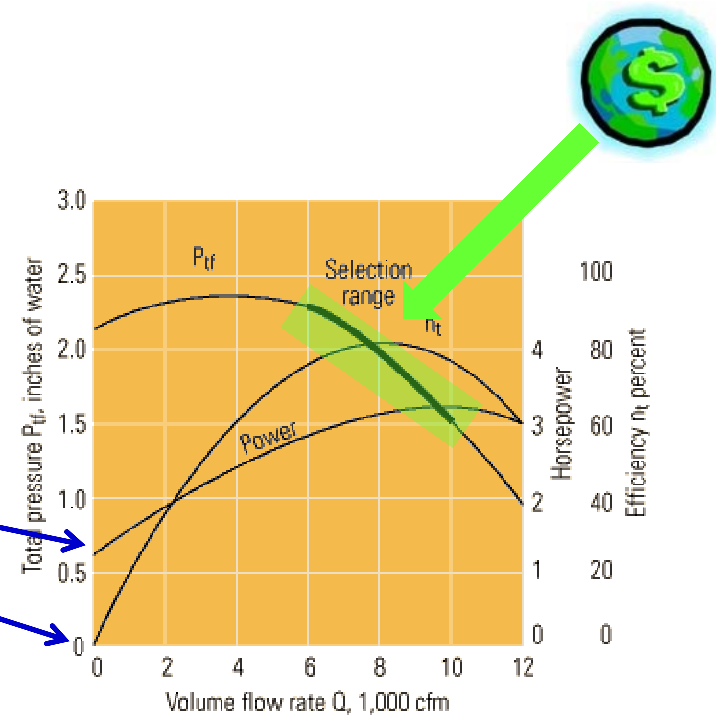
Hands-on Demonstration

- As shown, if HVAC filters/coils become clogged so that the fan operates too far to the left, then efficiency (n_t) drops dramatically until efficiency goes to zero when there is no air flow (CFM = 0).

- An interesting (but counterintuitive) result of totally clogged HVAC filters/coils (CFM = 0) is that the fan motor electrical usage will reduce (not increase) as shown by the power curve, but CFM = 0, so efficiency is 0 and the fan is churning air, but not circulating air.

- **So, if you see a change (+ or –) in fan** motor electrical usage of more than 10%, then you should check for clogged filters/coils.

Recall this info already presented



Hands-on Demonstration

Recall this info
already presented

- OPPORTUNITY: Reduce air flow (slow the fan using variable speed motor or different size pulley) in unoccupied areas of building & during unoccupied periods of time (night, etc).

- EXAMPLE: 50,000 ft^2 building in Raleigh NC occupied half-time. Reducing fan speed 10% saves $2,900 annually

Note: Calculation methods above are from
State of NC Energy Office www.energync.net

- PAYBACK: Achieve over 20-to-1 payback within one year when save $2,900 if the cost is $145 (labor time) to close dampers/vents and change pulley on fan motor to run slower.

Note: After full payback in the first year, will continue to have/enjoy savings of $2,900 (probably more as energy costs rise) per year at no cost in future years.

Hands-on Demonstration

Plus, we achieve additional $ savings if we find/tag other energy-saving opportunities per checklist such as:

- Check thermostats to see if set in broadest comfort windows per ASHRAE recommends 70 (max) for heating & 76 (min) for cooling
- Ask if areas of buildings need no heating/cooling (storage, etc.) or are unoccupied for long periods of time, and then recommend either entirely shutting off HVAC to those areas or using timers to turn-off HVAC compressors, and fans during unoccupied periods
- Do the simple "tissue test" for infiltration (air drafts) of outside air

Tissue test: With all doors/windows closed in a building, open just one outside door or window about 1" to 2" and hold a tissue on the inside of the opening. If the tissue blows/waves noticeably, then infiltration is a problem and should be addressed. Also, if HVAC system air flow is unbalanced so is either pressurizing the building or pulling a slight vacuum on the building, then the tissue will also blow/wave in that case. In either case (infiltration or air flow imbalance), corrective action is needed.

Hands-on Demonstration

Recall this info already presented

- OPPORTUNITY: Reduce energy consumption by setting thermostats to 70 (max) for heating & 76 (min) for cooling within broadest comfort windows per ASHRAE (see table prior page).

- EXAMPLE: 50,000 ft^2 building costing $100,000 per year for HVAC with thermostats currently set at 74 (max) heating & 72 (min) cooling. Reset thermostats 4 degrees to 70 (max) heating & 76 (min) cooling. Save 4% of HVAC energy which is <u>$4,000 annually</u>.

  Note: Calculation methods above are from State of NC Energy Office www.energync.net

- PAYBACK: Achieve over 20-to-1 payback within one year when save $4,000 if the cost is $200 (labor time) to reset thermostats.

  Note: After full payback in the first year, will continue to have/enjoy savings of $4,000 (probably more as energy costs rise) per year at no cost in future years.

Hands-on Demonstration

Recall this info
already presented

- OPPORTUNITY: Significant HVAC energy can saved simply by reducing the area/volume of indoor space that is heated or cooled.

- EXAMPLE: 50,000 ft^2 building costing $100,000 per year for HVAC. If only 75% of the building needs to be heated/cooled, then heating and cooling costs will be reduced by 25%, saving $25,000 annually.

  Note: Calculation methods above are from
  State of NC Energy Office www.energync.net

- PAYBACK: Achieve over 20-to-1 payback within one year when save $25,000 if the cost is $1,250 or turn off heating/cooling in 25% of rooms in the building (storage rooms, etc.).

  Note: After full payback in the first year, will continue to have/enjoy savings of $25,000 (probably more as energy costs rise) per year at no cost in future years.

Hands-on Demonstration

Recall this info
already presented

- OPPORTUNITY: Save energy in unoccupied periods by using timers to turn-off HVAC compressors, fans, & close outdoor air dampers.

- EXAMPLE: 50,000 ft^2 building in Raleigh NC occupied half-time. Total savings = \$5,370 heating + \$1925 cooling = <u>\$7,295 annually</u>.

  Note: Calculation methods above are from
  State of NC Energy Office www.energync.net

- PAYBACK: Achieve over 20-to-1 payback within one year when save \$7,295 if the cost is \$364 or less to buy/install timers.

  Note: After full payback in the first year, will continue to have/enjoy savings of \$7,295 (probably more as energy costs rise) per year at no cost in future years.

Hands-on Demonstration

Recall this info already presented

- OPPORTUNITY: Reduce infiltration (air drafts) of outside air.

  Note: The two main methods of reducing infiltration are: (1) apply caulking and weatherstripping around outside openings and (2) install entry vestibules. Weatherstripping wears out every 3-5 yrs, so replace. Every wall penetration (window frame, doorframe, louver frame, pipe, etc.) should be caulked airtight. Expansion joints in masonry walls and lap joints in siding (vertical & horizontal) require caulking. Caulking is a recurring requirement, usually every 5-7 years. Entry doors that are used regularly should be equipped with automatic closers and vestibules, particularly if they face northwest, north, or northeast. Vestibules, to be effective, must be as long as possible (at least 7 ft).

- EXAMPLE: 50,000 ft^2 building costing $100,000 per year for HVAC. Savings = $7,500 annually.

- PAYBACK: Achieve over 20-to-1 payback recurring every 5 years when save $7,500 x 5 = $37,500 if the cost is $1,875 or less to buy/apply caulking and weatherstripping about every 5 years.

Questions?

If you have questions or want assistance in the future,
feel free to contact me anytime.

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