Energy Efficiency in Industrial HVAC Systems

FACT SHEET

Heating, ventilation and air conditioning (HVAC) constitutes up to 35 percent of energy used in manufacturing facilities. This fact sheet is geared towards energy efficiency in existing equipment and covers common opportunities for facilities to conserve energy and cut costs. The fact sheet contains a checklist to assess existing conditions in order to determine the opportunities available during an HVAC audit.

When the opportunity exists, energy conservation should be a factor in the original equipment selection and system design. The best HVAC design considers the interrelationship of building systems while addressing energy consumption, indoor air quality, and environmental benefit.

What is HVAC?

HVAC stands for heating, ventilation and air conditioning and refers to the equipment, distribution network and terminals used either collectively or individually to provide fresh filtered air, heating, cooling and humidity control in a building.

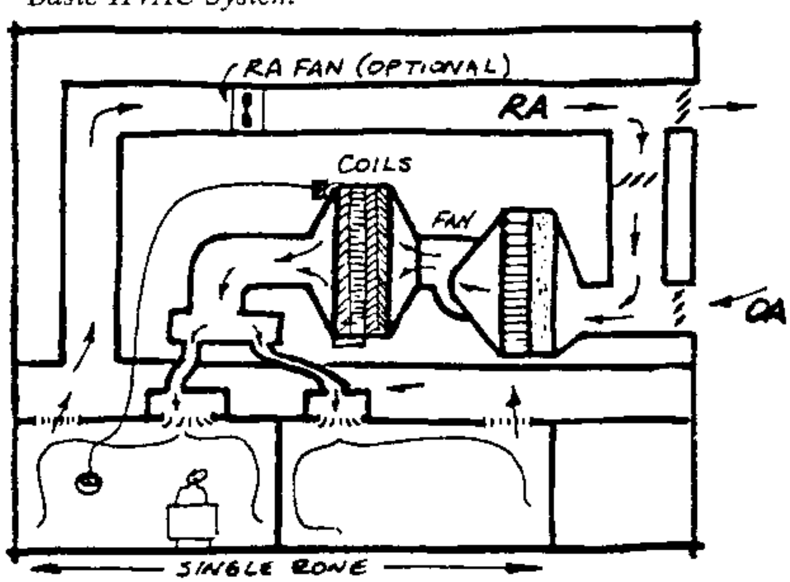
A facility can have any combination of heating and cooling sources to supply the HVAC system. For heating a facility, a gas-or oil-fired boiler or furnace, heat pump, rooftop unit, new technology such as infrared radiation, or electric heat could be employed. Common cooling sources include rooftop units, chillers, heat pumps, air conditioner or some sort of off-peak cooling system.

What is the Basic HVAC Design?

HVAC systems can vary in design and complexity. The following description and diagram represent a simple HVAC system (termed a single-zone constant air volume system). Modifications can be added to the basic system to reach the desired HVAC operation.

Air is taken through an outdoor air intake that is usually a louvered opening on the top or side of the building. Atmospheric pressure pushes the air through a damper, which regulates the amount of outdoor air (OA) taken in by the system. At this point, already conditioned return air (RA) from the system can be mixed with the outdoor air to form "mixed air." The mixed air goes through a pre-filter where larger dust particles, insects, leaves, etc. are caught. A more efficient filter is usually present to address small particles. After the filters, the air enters a centrifugal fan. Once exiting the fan outlet, the air is under positive pressure and being

Basic HVAC System



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pushed towards coils where the air is either heated or cooled, depending on the temperature of the air and the season. Under the coils lies a drain pan to collect any water condensing on the coils. If a humidifier or dehumidifier is needed it is usually incorporated into the cycle at this point. The air travels through ductwork where it reaches a distribution box and may travel through smaller ducts to supply the terminals, registers or diffusers into the workspace. Once the air reaches its destination, it is returned through an air register (usually through a louvered door that opens into a space above the ceiling tiles) in the form of return air that will become mixed air or exit the building.

What is Air Conditioning?

Air conditioning is treating air for temperature, cleanliness and humidity, and directing its distribution to meet requirements of a conditioned space. Comfort air conditioning is when the primary function of the system is to provide comfort to occupants of the conditioned space. The term industrial air conditioning is used when the primary function is other than comfort.

There are three basic types of air conditioners:

- Direct expansion coolers include window air conditioners, heat pumps and packaged or rooftop units. Air is cooled and dehumidified as it moves past a cold, refrigerant-filled coil.
- Chilled water systems use water cooled by a refrigeration machine instead of air. This cool water supplies a coil, which cools and dehumidifies the air.
- Evaporative (or "swamp") coolers are usually only appropriate in hot, dry climates and bring hot air in contact with a water spray or damp surface. The result is evaporation of moisture, which lowers the temperature of the air.

Comfort and productivity

While designing HVAC systems for energy efficiency, it is also good to take into account the design for human comfort. Good working conditions increase productivity and employee satisfaction. The HVAC design should incorporate:

- a determination of indoor conditions and how energy use is affected;
- the impact on equipment selection, ducting and register design; and
- a determination whether certain conditions will be acceptable for comfort criterion.

What is Ventilation?

Ventilation is a process that either supplies or removes air from a space by natural or mechanical means. All air that is exhausted from a building must be replaced by outside air. Outside air must be brought to a certain temperature by makeup air units used throughout the building. Negative building pressure can be a problem during winter heating season and could lead to a number of other problems such as difficulty in opening doors and equipment operation. Air seeps through gaps around windows, doors and ducts. Equations are available to estimate makeup air heating costs in the *Guide to Industrial Assessments for Pollution Prevention and Energy Efficiency*, referenced at the end of this document.

Air is distributed through ducts. Units such as a window air conditioner, distribute air directly from the unit. Other units using baseboards or radiators may deliver heat through water, steam or electric resistance systems. Blowers and registers deliver air in forced air systems.

Where can I find information about energy efficiency requirements?

The American Society of Heating, Refrigerating and Air-Conditioning Engineers Inc. (ASHRAE) writes standards and guidelines for energy efficiency - http://www.ashrae.org/.

Conducting an HVAC Audit

The potential for energy conservation varies depending on the design of the system, the method of operation, operating standards, maintenance of control systems, monitoring of the system, and competence of the operators. General opportunities for energy conservation are discussed below. Please keep in mind that some of these efficiencies will need to be conducted by an expert. Some of these efficiencies will be at no cost, while others will require some investment. Generally, implementing a maintenance plan, installing controls and upgrading equipment when possible are good ways to save on energy costs.

Assess existing conditions
To conduct a HVAC audit you will first need basic HVAC information such as type and number of units, hours of use, etc. to help you understand the current energy use attributed to HVAC systems in your facility. This information will help you understand how much you are currently spending and the potential savings available from HVAC efficiencies. A worksheet is available at the end of this document to assist in the assessment of your current HVAC conditions.

Assess opportunities for increasing HVAC energy efficiency
Determine if the following opportunities exist for a given location. Each checkbox represents an opportunity for energy savings, followed by suggestions on how to best take advantage of the opportunity.

☐ Reduce HVAC system operation when building or space is unoccupied.

- Reduce HVAC operating hours to reduce electrical, heating and cooling requirements.
- Eliminate HVAC usage in vestibules and unoccupied space.
- Minimize direct cooling of unoccupied areas by turning off fan coil units and unit heaters and by closing the vent or supply air diffuser.
- Turn fans off.
- Close outdoor air dampers.
- Install system controls to reduce cooling/heating of unoccupied space.

☐ Reduce HVAC operating hours.

- Turn HVAC off earlier.
- Install HVAC night-setback controls.
- Shut HVAC off when not needed.
- Adjust thermostat settings for change in seasons.
- Adjust the housekeeping schedule to minimize HVAC use.
- Schedule off-hour meetings in a location that does not require HVAC in the entire facility.
- Install separate controls for zones.
- Install local heating/cooling equipment to serve seldom-used areas located far from the center of the HVAC system.
- Install controls to vary hot water temperature based on outside air.
- Use variable speed drives and direct digital controls on water circulation pumps motors and controls.

- ☐ Adjust areas that are too hot or too cold.
  - Adjust air duct registers.
  - Use operable windows for ventilation during mild weather.
  - Use window coverings such as blinds or awnings to cut down on heat loss and to avoid heat gain.
  - Use light-colored roofing material and exterior wall covering with high reflectance to reflect heat.
  - Incorporate outside trees to create shade.
  - Install ceiling fans.
  - Create zones with separate controls.
- ☐ Reduce unnecessary heating or cooling.
  - Set the thermostat higher in the cooling season and lower in the heating season.
  - Allow a fluctuation in temperature, usually in the range of 68˚ to 70˚F for heating and 78˚ to 80˚ for cooling.
  - Adjust heating and cooling controls when weather conditions permit or when facilities are unoccupied.
  - Adjust air supply from the air-handling unit to match the required space conditioning.
  - Eliminate reheating for humidity control (often air is cooled to dewpoint to remove moisture, then is reheated to desired temperature and humidity).
- ☐ Install an economizer cycle

  Instead of operating on a fixed minimum airflow supply, an economizer allows the HVAC system to utilize outdoor air by varying the supply airflow according to outdoor air conditions, usually using an outdoor dry bulb temperature sensor or return air enthalpy (enthalpy switchover). Enthalpy switchover is more efficient because it is based on the true heat content of the air.

  Example of economizer savings

  In an example highlighted in *Guide to Industrial Assessments for Pollution Prevention and Energy Efficiency*, an economizer was installed with outdoor temperature switchover at 56.5˚F on a continuously operating, year-round air conditioning system, with the preheated discharge temperature controlled at 40˚F. Savings from the economizer totaled $2,280 per year. Using the same conditions, an economizer was installed using the enthalpy method and saved $3,520 per year.[1]

- ☐ Employ heat recovery

  A heat exchanger transfers heat from one medium to another. Common types of heat exchangers are: rotary, sealed, plate, coil run-around system, and hot oil recovery system.

  - Install heat recovery ventilators that exchange between 50 and 70 percent of the energy between the incoming fresh air and the outgoing return (conditioned) air.
- ☐ Minimize the amount of air delivered to conditioned space

  The amount of air delivered to a space is dependent upon heating/cooling load, delivery temperature, ventilation requirements and/or air circulation or air changes. On average the air should change every five to 10 minutes.

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[1] Guide to Industrial Assessments for Pollution Prevention and Energy Efficiency. U.S. EPA, Office of Research and Development, National Risk Management Resource Management Resource Library, and the Center for Environmental Research Information, Cincinnati, Ohio. EPA/625/R-99/003. June 2001.

Reducing airflow will reduce horsepower. Occupational Safety and Health Administration (OSHA) and local requirements of air exchange must be maintained.

- Extend the time frame for circulation of air by using a fan discharge damper, fan vortex damper (fan inlet), or fan speed change.

☐ Minimize exhaust and make-up air.
Makeup air depends on the needs of ventilation for personnel, exhaust air from workspaces, overcoming infiltration, machine air needs, and federal, state and local requirements.

- Seal ducts that run through unconditioned space (up to 20 percent of conditioned air can be lost in supply duct run).
- Keep doors closed when air conditioning is running.
- Properly insulate walls and ceilings.
- Insulate air ducts, chilled water, hot water and steam pipes.
- Rewire fans to operate only when lights are switched on, as codes permit.
- Check for damper leakage/ensure tight seals.
- Shut off unneeded exhaust fans and reduce use where possible.
- Reduce air volume lost by reducing exhaust rates to the minimum.
- Review process temperatures.
- Install thermal windows to minimize cooling and heating loss.

☐ Implement a regular maintenance plan.

- Inspect to ensure dampers are sealed tightly.
- Clean coil surfaces.
- Ensure doors and windows have tight seals.
- Check fans for lint, dirt or other causes of reduced flow.
- Schedule HVAC tune-ups (the typical energy savings generated by tune-up is 10 percent).
- Check and calibrate thermostat regularly.
- Replace air filters regularly.
- Inspect ductwork.
- Repair leaks.
- Turn off hot water pumps in mild weather.

Maintenance for an expert

- Reduce fan speeds and adjust belt drives.
- Check valves, dampers, linkages and motors.

- Check/maintain steam traps, vacuum systems and vents in one-pipe steam systems.
- Repair, calibrate or replace controls.

Cooling system maintenance

- Clean the surfaces on the coiling coils, heat exchangers, evaporators and condensing units regularly so that they are clear of obstructions.
- Adjust the temperature of the cold air supply from air conditioner or heat pump or the cold water supplied by the chiller (a 2° to 3°F adjustment can bring a three to five percent energy savings).
- Test and repair leaks in equipment and refrigerant lines.
- Upgrade inefficient chillers.

Fuel-fired heating system maintenance (possible five to 10 percent in fuel savings)

- Clean and adjust the boiler or furnace.
- Check the combustion efficiency by measuring carbon dioxide and oxygen concentrations and the temperature of stack gases; make any necessary adjustments.
- Remove accumulated soot from boiler tubes and heat transfer surfaces.
- Install a fuel-efficient burner.

Control setting maintenance

- Determine if the hot air or hot water supply can be lowered.
- Check to see if the forced air fan or water circulation pump remains on for a suitable time period after the heating unit, air conditioner or chiller is turned off to distribute air remaining in the distribution ducts.

☐ Implement an energy management system (EMS).
An EMS is a system designed to optimize and adjust HVAC operations based on environmental conditions, changing uses and timing.

- Create an energy management system to automatically monitor and control HVAC, lighting and other equipment.

☐ Upgrade fuel-burning equipment.

- Install a more efficient burner.
- Install an automatic flue damper to close the flue when not firing.
- Install turbulators to improve heat transfer efficiency in older fire tube boilers.
- Install an automatic combustion control system to monitor the combustion of exit gases and adjust the intake air for large boilers.
- Insulate hot boiler surfaces.
- Install electric ignitions instead of pilot lights.

☐ Evaluate thermostat controls and location.

- Install programmable thermostats.
- Lock thermostat to prevent tampering.
- Ensure proper location of thermostat to provide balanced space conditioning.
- Note the proximity of the heated or cooled air producing equipment to thermostat.

☐ Evaluate boiler operations.

- Investigate preheating boiler feed water
- Adjust boilers and air conditioner controls so that boilers do not fire and compressors do not start at the same time but satisfy demand.
- Use hot water from boiler condensate to preheat air.

☐ Use existing cooling towers to provide chilled water instead of using mechanical refrigeration for part of the year.

☐ Install water meters on cooling towers to record makeup water usage.

☐ Installed controls on heat pump (if has electric resistance heating elements) to minimize use.

☐ Install a variable air volume system (VAV) with variable speed drives on fan motors. A VAV system is designed to deliver only the volume of air needed for conditioning the actual load.

☐ Employ cool storage to save on electric bills.
The concept behind cool storage systems is to operate the system during off-peak electricity hours, and use the stored coolness to satisfy a building's air conditioning needs. Avoiding peak electricity hours will reduce electric bills.

☐ Upgrade to premium efficiency models when available.
Federal law and some state laws require minimum efficiency levels for energy intensive equipment. Always consider purchasing equipment that exceeds the standards. See the below table for descriptions of different energy efficiency rating for HVAC equipment.

HVAC Equipment Efficiencies - Adapted from *How to Reduce Your Energy Cost.*

Equipment	Efficiency Rating	Measurement of
Window Air Conditioner	Energy Efficiency Ratio (EER)	Cooling output in BTUs per hour for a watt of input power.
Central Air Conditioner	Seasonal Energy Efficiency Ratio (SEER)	Total BTUs of cooling delivered divided by total watt-hours of power used during a representative cooling season.
Electric Chiller	Integrated Part Load Value (IPLV)	Average kW of input power per ton (12,000 BTU/hr) of cooling output.
Heat Pump (Split) – Cooling	SEER	

(table continued on following page)

Heat Pump (Split) – Heating	Heating Season Performance Factor (HSPF)	Total BTUs of heating delivered divided by the total watt-hours of power used during a representative heating season.
Heat Pump (Single Package) – Cooling	SEER	
Heat Pump (Single Package) – Heating	HSPF	
Gas Furnace	Annual Fuel Utilization Efficiency (AFUE)	BTUs of heating output divided by the BTUs of fuel input during a representative heating season.
Gas Boiler	AFUE	
Oil Furnace	AFUE	
Oil Burner	AFUE	

- ☐ Think ahead by investigating prices and availability of components that may fail.
- ☐ Increase duct size to reduce duct pressure drop and fan speed (delivering a large mass of air at a low velocity is more efficient then pushing air through small ducts at a high velocity). Air traveling at lower velocities remains in contact with coils longer.
- ☐ Replace oversized fans to match the load
    - Electronically control the speed of the fan motor to compensate for the changing building load conditions.

Where to get calculations for savings opportunities

The U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, Building Technologies Program Web site has links to many software tools for building simulation that can help guide design and cost decisions. http://www.eere.energy.gov/buildings/index.cfm?flash=yes

Resources

How to Reduce Your Energy Costs: The Energy Efficiency Guide for Business, Industry, Government and Institutions. The Vermont Department of Public Service, Energy Efficiency Division. Third Edition. For a free copy call 1.888.921.5990.

Guide to Industrial Assessments for Pollution Prevention and Energy Efficiency. United States Environmental Protection Agency, Office of Research and Development, National Risk Management Resource Management Resource Library, and the Center for Environmental Research Information, Cincinnati, Ohio. EPA/625/R-99/003. June 2001. http://www.p2pays.org/search/pdfframe.asp?pdfurl=/ref/19/18351.pdf

U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Building Technologies Program http://www.eere.energy.gov/buildings/index.cfm?flash=yes

The American Society of Heating, Refrigerating and Air-Conditioning Engineers Inc. (ASHRAE). http://www.ashrae.org/

Electronic Self-Audit Tools. Waste Reduction Partners, http://landofsky.fp.skyrunner.net/wrp/Other_Resources.htm

Worksheet for Assessing Existing Conditions

The first step is to assess current HVAC conditions. Measuring current conditions against calculated upgrades will present the expected savings (adapted from *How to Reduce your Energy Costs*).

Air conditioning

Number of units:______________________________

Make, type, size and location of each (you may need to look at the model number and check with the manufacturer to determine size): ____

Frequency of service:______________________________

Date of last service:______________________________

Heat pumps

Number of units:______________________________

Make, type, size and location of each (you may need to look at the model number and check with the manufacturer to determine size): ____

Frequency of service:______________________________

Date of last service:______________________________

Do they have auxiliary heating (if yes, do they have controls minimizing use of that heating)?________________________

Central heating plant and system

Location:______________________________

Type of fuel used:______________________________

Type of system (e.g. hot water, steam, warm air):______________________________

Number of zones:______________________________

Age of boiler or furnace:______________________________

Age or burner:______________________________

Steam pressure (___psi) or hot water temperature (___°F).

If you have a steam system, when were steam traps last checked? ______________________________

Type, condition of insulation on boiler:______________________________

Type, condition of insulation on air ducts or on distribution piping:______________________________

Is domestic hot water heated by the boiler? ______________________________

Frequency of testing/cleaning adjustment

Date of last test/service:______________________________

Results of test (e.g. combustion efficiency %):______________________________

Has HVAC system been balanced? ______________________________

Controls/Use

Location(s) and description(s) of thermostats:____________________________________

Location(s) of thermostat(s) that might need to be locked:____________________________________

Location of clock thermostat:____________________________________

Cold weather thermostat setting: (___°F).

When and how much is the thermostat set back:

For the night: _______ For the weekend: _______

Hot weather thermostat setting: (___°F).

When and how much is the thermostat set back:

For the night: _______ For the weekend: _______

How many hours a week is the system used?

_____ hours in hot weather ______ hours in cold weather

Can system be turned down during cleaning hours? ____________________________________

When is system turned on/off in relation to daily occupancy (i.e. before, after, how long)?____________________________________

Which areas are too hot, too cold? ____________________________________

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