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ENERGY SAVING BY MODIFICATION IN HVAC AS A COST SAVING OPPORTUNITY FOR INDUSTRIES

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ABSTRACT: HVAC maintain both comfort and safety of indoor air quality. The challenge of maintaining high product quality while simultaneously reducing production costs can often be met through investments in energy efficient technologies and energy efficiency practices. The greatest opportunities for energy efficiency exist at the design stage for HVAC systems in new industrial facilities. By sizing components of HVAC systems generally include dampers, supply and exhaust fans, filters, humidifiers, dehumidifiers, heating and cooling coils, ducts, and various sensors properly and designing energy efficiency into a new facility, an industry can minimize the energy consumption and operational costs of its plant HVAC systems from the outset. Optimizing system design and operations, such as minimizing laboratory ventilation, can also lead to significant reductions in energy use. Energy efficiency improvement is an important way to reduce these costs and to increase predictable earnings, especially in times of high energy price volatility. There are a variety of opportunities available at individual plants in the industry to reduce energy consumption in a cost-effective manner.

INTRODUCTION:

Heating, Ventilation and Air Conditioning (HVAC) Systems: The components of HVAC systems generally include dampers, supply and exhaust fans, filters, humidifiers, dehumidifiers, heating and cooling coils, ducts, and various sensors. HVAC is very important in industry. [1-3] They consist of four components:

- Controls
- Fuel supply
- Heating or cooling unit
- Distribution system [1-4]

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Each component must be evaluated for its physical and functional condition and its adequacy in terms of the buildings planned reuse. The adequacy of heating and cooling is often quite subjective and depends upon occupant perceptions that are affected by the distribution of air, the location of return air vents, air velocity, the sound of the system in operation, and similar characteristics. For this reason, past energy use should not be used as the basis for estimating future energy use. [4, 5]

These packages include materials, procedures and equipment and are designed to remove some of the guesswork from a builder, contractor, and installer decisions about how best to carry out HVAC changes.

Heating, ventilating, and air conditioning is based on the basic principles of thermodynamics and heat transfer, and to inventions and discoveries made by Michael Faraday, Willis Carrier, Reuben Trane, James Joule, William Rankine, Sadi Carnot, and many others. The invention of the components of HVAC systems goes hand-in-hand with the industrial revolution, and new methods of modernization, higher efficiency, and system control are constantly introduced by companies and inventors all over the world [4-7].

HVAC is sometimes referred to as climate control and is particularly important in the construction of most industrial and office buildings, and in marine environments such as aquariums, where humidity and temperature must all be closely regulated whilst maintaining safe and healthy conditions within [7, 8].

HVAC systems can provide ventilation, reduce air infiltration, and maintain pressure relationships between spaces. The means of air delivery and removal from spaces is known as room air distribution.

HVAC system also use in medical system. The primary requirement of the heating, ventilating and air conditioning (HVAC) systems in a medical facility is the support of medical function and the assurance of occupant health, comfort, and safety. The HVAC system functions not only to maintain minimum requirements of comfort and ventilation, but is an essential tool for the control of infection, removal of noxious odors, dilution and expelling of contaminants, and establishment of special environmental conditions conducive to medical procedures and patient healing. This criterion applies to new and existing medical facilities including hospitals, medical and dental clinics, veterinary clinics, medical supply warehouses, medical training facilities, and medical research laboratories [9].

Natural Ventilation [10, 11]: Natural ventilation is the use of differences in air pressure that exist between the inside of a building relative to the outside of it, across the building envelope, to ventilate a building. These air pressure differences are created by natural forces such as wind and temperature. Air moves into and out of naturally ventilated buildings through windows, doors, vents and other openings incorporated into the building design and via infiltration/exfiltration.

Mechanical Ventilation [12]: Mechanical ventilation is the use of mechanical air handling systems-commonly referred to as heating, ventilation, and air conditioning (HVAC) systems to ventilate buildings. Most commercial buildings use mechanical ventilation, which is more controllable and responsive than natural ventilation in providing adequate indoor air quality. However, mechanical ventilation also can exacerbate infiltration/ exfiltration, which can compromise indoor air quality.

MODIFICATION IN HVAC SYSTEM [13-71]: By sizing equipment properly and designing energy efficiency into a new facility, a manufacturer can minimize the energy consumption and operational costs of its plant HVAC systems from the outset. These changes lead to the cost and energy saving in industries. An energy monitoring and control system supports the efficient operation of HVAC systems by monitoring, controlling, and tracking system energy consumption. Such systems continuously manage and optimize HVAC system energy consumption while also providing building engineers and energy managers with a valuable diagnostic tool for tracking energy consumption and identifying potential HVAC system problems. [13]. Setting back building temperatures (i.e., turning building temperatures down in winter or up in summer) during periods of non-use, such as weekends or non-production times, can lead to significant savings in HVAC energy consumption. Similarly reducing ventilation in clean rooms and laboratories during periods of non-use can also lead to energy savings.[14] Summary of all modification in HVAC was given in **Table 1 and Figure 1**.

Energy efficient system design [16-17]: The greatest opportunities for energy efficiency exist at the design stage for HVAC systems in new industrial facilities. This practice often saves money in the long run, as it is generally cheaper to install energy efficient HVAC equipment at building construction than it is to upgrade an existing building with an energy efficient HVAC system later on, especially if those upgrades lead to production downtime. Later HVAC modification may also require review and approval by the United States of Food and Drug Administration, which can lead to further delays and production downtime.

TABLE 1: SCREENING CHECKLIST OF HVAC [16-77]

MEASUREMENT/ OBSERVATION	POTENTIAL TARGET VALUE	POTENTIAL RETROFIT ACTION
Duct leakage	<10% of air handler flow	Seal ducts: aeroseal/tape/mastic
Duct insulation	R6 (RSI 1) to R8 (RSI 1.4) for all ducts outside conditioned space	Add insulation to ducts
Air flows at registers	Compare to ACCA manual J	Replace registers, open/close dampers, and reduce system flow resistance by straightening existing ducts or replacing them with straight runs of new ducts.
Air handler flow	**Cooling**: >400 cfm/ton in dry climate, or >350 cfm/ton in humid climate **Heating**: 12.5 cfm/kBtu/h	Replace filters, fix duct restrictions, change fan speed, replace fan with high efficient unit, add extra returns in return restricted systems
Filter condition	Clean & atleast MERV 61	Replace with MERV 6 or better. Use 2 or 4 inch filters if possible
Thermostat Setting	Heating: 68°F (20°C) Cooling: 78°F (25°C)	Thermostat rose in summer and lowered in winter to account for better distribution, mixing and envelope improvements.
Spot ventilation	50 cfm each bathroom 100 cfm each kitchen	Replace fans, fix restrictive ducting
Spot Ventilation fan power consumption	2.5 cfm/W (1.2 L/s/W), A good source for these ratings is the HVI directory (www.hvi.org)	Replace with higher efficiency unit, remove/reduce duct flow restrictions, clean fan and ducting
Equipment capacity	Manual S	Replace with correct size
Refrigerant charge	Use superheat or sub cooling tests	Add/subtract refrigerant
Age and Condition of HVAC system	Clean and undamaged. Determine system age.	Clean the system and repair damage or Replace the system if > 15 years old
Location of HVAC system equipment and ducts	Inside conditioned space	Seal and insulates duct locations to make them more like conditioned space, or move system location.

MERV is an industry standard rating system for air filters; it stands for Minimum Efficiency Report Value determined using ASHRAE Standard 52.2.

Window A/C units	Energy Star compliant	Replace with central unit or improved distribution
Multiple systems/zoning	System and controls in good working order and providing good comfort for occupants	Ensure correct damper operation, check capacity of each system/zone matches a Manual J (or equivalent) load calculation
Envelope leakage	Normalized Leakage Area reduction of 0.35	Insulate envelope, seal windows/doors/other openings
Moisture testing	No moisture problems	Source control — better kitchen and bath venting, fix flashing/detailing, seal crawlspaces in high humidity climates, replace windows, add insulation to walls, floors and ceiling
House insulation	Ceiling: R-30 (RSI 5.3) minimum, R-49 (RSI 8.6) in cold/severe cold climate. Floor over crawlspace- 25 (RSI 4.4). Basement walls: R10 (RSI 1.8), Basement Floor or slab usually depends on local codes. Walls: Cavity should be completely filled with insulation.	Add insulation to fill cavity. Add semi-permeable rigid exterior insulation in cold/severe cold climates if the wall is 2×4 construction.

Windows	Double-glazed, low-e. Shaded in cooling dominant climates	Replace windows. Add shading.
Window shading	Located on south and/or west facing windows	Add shading to reduce solar loads
Solar radiation control	Radiant barrier in attic, low absorptivity roof coatings	Add radiant barrier in attic, or low absorptivity roof coatings
Wall, floor and ceiling construction	Space for ducts/vents	-
Occupant survey: Ask occupants to report problems	No problems	Moisture removal strategies, new windows, change register type, airflow and location to improve mixing/remove drafts, add envelope insulation, etc.

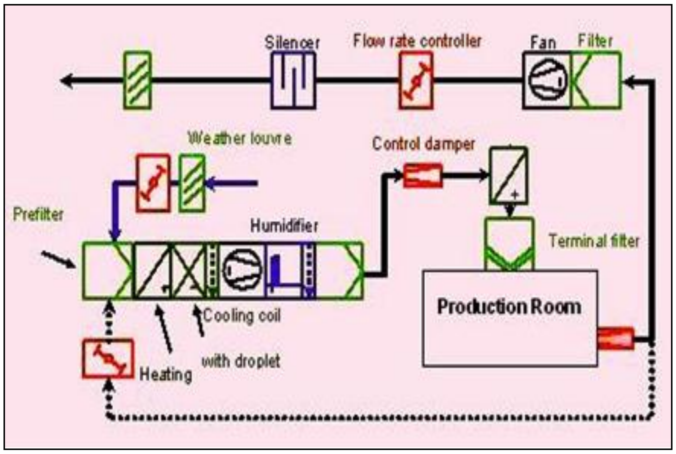

FIGURE 1: MODIFICATION OF HVAC SYSTEM

Energy monitoring and control systems [18-20]**:** An energy monitoring and control system supports the efficient operation of HVAC systems by monitoring, controlling, and tracking system energy consumption. Such systems continuously manage and optimize HVAC system energy consumption while also providing building engineers and energy managers with a valuable diagnostic tool for tracking energy consumption and identifying potential HVAC system problems. Several industrial case studies from the United States indicate that the average payback period for HVAC control systems is about 1.3 years (IAC 2003).

Non-production hours set-back temperatures [21, 22]**:** Setting back building temperatures (i.e., turning building temperatures down in winter or up in summer) during periods of non-use, such as weekends or non-production times, can lead to significant savings in HVAC energy consumption. Similarly, reducing ventilation in cleanrooms and laboratories during periods of non-use can also lead to energy savings. In recent studies of laboratories and cleanrooms in the pharmaceutical and similar industries, HVAC systems were found to account for up to two-thirds of facility energy. Thus, scaling back HVAC energy consumption during periods of non-use can have a major impact.

Discharge Air Temperature Management [23-24]**:** In facilities with make-up air handling systems, energy can be wasted when cooled make-up air must be reheated. By setting higher discharge air temperatures when demand for cooling decreases, unnecessary reheating of the make-up air supply can be reduced. At Genentech's Vacaville facility, a new control system was implemented to reset the discharge air temperature from 55°F to 60°F under periods of low cooling demand. This temperature adjustment prevented overcooling and subsequent unnecessary reheating of supply air, thereby saving chilled water and steam plant energy.

This measure was expected to have annual energy cost savings of around $150,000 per year (CIEE 2000a).

Variable-Air-Volume (VAV) systems [24-26]**:** Variable-air-volume systems adjust the rate of air flow into a room or spaces based on the current air flow requirements of that room or space, and therefore work to optimize the air flow within HVAC ductwork. By optimizing air flow, the loads on building air handling units can be reduced, thereby leading to reduced electricity consumption.

Duct leakage repair [27, 28]**:** Duct leakage can waste significant amounts of energy in HVAC systems. Measures for reducing duct leakage include installing duct insulation and performing regular duct inspection and maintenance, including ongoing leak detection and repair. According to studies by Lawrence Berkeley National Laboratory, repairing duct leaks in industrial and commercial spaces could reduce HVAC energy consumption by up to 30%. One commercial building in Apple Valley, California, adopted a technique called the mobile aerosol-sealant injection system (MASIS) to reduce duct leakage. The application of MASIS resulted in a reduction in overall duct leakage from 582 cfm to 74 cfm, leading to a 34% increase in the overall efficiency of the building's HVAC system (Aeroseal 2013).

Adjustable speed drives (ASDs) [29, 30] Adjustable speed drives can be installed on variable volume air handlers, as well as recirculation fans, to match the flow and pressure requirements of air handling systems precisely. Energy consumed by fans can be lowered considerably since they are not constantly running at full speed. Adjustable speed drives can also be used on chiller pumps and water systems pumps to minimize power consumption based on system demand.

Heat recovery systems [31-33]**:** Heat recovery systems reduce the energy required to heat or cool facility intake air by harnessing the thermal energy of the facility's exhaust air. Common heat recovery systems include heat recovery wheels, heat pipes, and run-around loops. For areas requiring 100% make-up air, studies have shown that heat recovery systems can reduce a facility's heating/cooling cost by about 3% for each degree (Fahrenheit) that the intake air is raised/lowered. The payback period is typically three years or less (Tetley 2001). The efficiency of heat pipes is in the 45-65% range (U.S. EPA/DOE 2003), while the efficiency of run-around loops can be slightly higher, in the 55-65% range (U.S. EPA/DOE 2001a).

HVAC chiller efficiency improvement [34-36]**:** The efficiency of chillers can be improved by lowering the temperature of the condenser water, thereby increasing the chilled water temperature differential. This can reduce pumping energy requirements. Another possible efficiency measure is the installation of separate high-temperature chillers for process cooling (Tschudi and Xu 2003).

Sizing chillers to better balance chiller load with demand is also an important energy efficiency strategy. At Genentech's facility in Vacaville, California, two 1,400 ton chillers and one 600 ton chiller were chosen instead of three equally-sized chillers. This selection was made in an effort to operate the chillers at as close to full load as possible, where they are most efficient. The two larger chillers are run at full load and the smaller chiller is run to supply additionally cooling only on an as-needed basis, reducing energy needs. The cost savings associated with this chiller selection strategy were estimated to be $113,250 per year (CIEE 2000a).

Fan modification [37, 38]**:** Changing the size or shape of the sheaves of a fan can help to optimize fan efficiency and airflow, thereby reducing energy consumption. At a Toyota plant, the sheaves of fans were optimized in lieu of installing ASDs on fans. Toyota found better savings and payback periods with sheave modification than they anticipated to experience from ASDs (Toyota 2002).

Efficient exhaust fans [39]**:** Exhaust fans are standard components in any HVAC system. Mixed flow impeller exhaust fans offer an efficient alternative to traditional centrifugal exhaust fans. Mixed flow impeller fans are typically 25% more efficient that centrifugal fans, and can also be cheaper to install and maintain. The expected payback period for this measure is around 2 years (Tetley 2001).

Cooling water recovery [40, 41]**:** If available, secondary cooling water from municipal sources can be leveraged to reduce chiller energy consumption. In Washington, Boeing partnered with Puget Sound Power and Light and the King County Department of Metropolitan Services to recycle secondary treated cooling water into its chiller system. By doing so, Boeing reduced its water consumption by 48 million gallons per year and projected savings of 20% in its cooling energy consumption (Michaelson and Sparrow 1995). As an additional benefit, Boeing also expected to save on refrigerant and treatment chemicals for its cooling tower water.

Solar air heating [42, 43]**:** Solar air heating systems, such as Solar wall®, use conventional steel siding painted black to absorb solar radiation for insulation. Fresh air enters the bottom of the panels where it is heated as it passes over the warm absorber. Fans distribute the air. Using this technology, Ford Motor Company's Chicago Stamping plant turned the south wall of its plant into a huge solar collector (CREST 2001). Energy savings were estimated to be over $300,000 per year compared to conventional gas air systems. Capital costs were $863,000 ($14.90 per square foot, including installation) resulting in a payback period of less than 3 years. In addition to energy savings, the system provides clean fresh air for its employees, evens out hot and cold spots in the plant and reduces emissions. However, this measure is only of interest for buildings in cold climates, and the potential benefits should be analyzed based on the local conditions of each site.

Building reflection [44, 45]**:** Use of a reflective coating on the roof of buildings in sunny, hot climates can save on air conditioning costs inside. Two medical offices in Northern California used reflective roofs on their buildings; one reduced air conditioning demand by 8%, the other reduced air conditioning demand by 12% (Konopacki et al., 1998). For colder climates, heat lost due to cool roofs (in winter, for example) also needs to be taken into account, and often negates savings. In addition to location and weather, other primary factors influence energy savings, such as roof insulation, air conditioning efficiency, and building age. Reflective roof materials are available in different forms and colors.

Building insulation [46-48]**:** Adding insulation to a facility will nearly always result in the reduction of utility bills. Much of the existing building stock in the United States is not insulated to the best level. Older buildings are likely to use more energy than newer ones, leading to very high heating and air conditioning bills. Even for a new building, adding insulation may save enough through reduced utility bills to pay for itself within a few years (U.S. DOE 2002a). Various states have regulations and guidelines for building insulation, for example, California's Energy Efficiency Standards for Residential and Nonresidential Buildings (Title 24) (CEC 2001).

Low-emittance (Low-E) windows [49]**:** Low-emittance windows are another effective strategy for improving building insulation. Low-emittance windows can lower the heat transmitted into a building and therefore increase its insulating ability. There are two types of Low-E glass, high solar transmitting (for regions with higher winter utility bills) and low solar transmitting (for regions with higher summer utility bills) (U.S. DOE 1997). The U.S. DOE supports the development of new window and glazing technology, while ENERGY STAR provides a selection of rated Low-E windows. New window and glazing technology is being developed continuously around the world.

Add an economizer [50-54]**:** In dry cooling climates an economizer can significantly reduce compressor operation and result in energy savings at the same time as providing ventilation air. If the economizer is connected to the forced air system (as is usually done) it will help to ensure good thermal and fresh air mixing throughout the house. Economizer operation needs to be carefully checked to make sure that the flow control dampers are operating properly including pressure relief dampers.

Separate humidity and air temperature control [55, 56]**:** Separate the temperature control from the humidity control so that they can be optimized independently. Currently residential air conditioning systems are a compromise between high latent (moisture removal) and sensible (cold air) efficiency. A good solution to this problem is to use a dehumidifier to control humidity only, and a separate air conditioning system for temperature control. For optimum system operation it is possible that the dehumidifier be placed somewhere unobtrusive (e.g., in a suitable closet) and a drain line should be permanently installed so as to reduce the servicing burden on the homeowner.

Use improved filters and/or filter slots to eliminate filter bypass and filter slot leakage [57, 58]**:** These filters will have lower pressure drops and will therefore use less air handler fan power and help ensure proper system airflow. The lower pressure drop also means that the return ducts downstream of the filter operate under a lower negative pressure, thus reducing duct leakage effects.

FUME HOODS [59]**:** Fume hoods are commonly installed in R&D laboratory facilities in the pharmaceutical industry. Fume hoods capture, contain, and exhaust hazardous gases generated by laboratory activities and industrial process and therefore protect workers from breathing harmful substances (Mills and Sartor 2004). The energy required to heat and cool make-up air for laboratory fume hoods can account for a significant fraction of laboratory HVAC energy consumption. Fume hoods are often operated at high air exchange rates in an effort to guarantee the safety of occupants in the facility. However, significant energy savings can often be realized by using low-flow fume hoods and variable flow exhaust systems.

There are several benefits are:

- Restriction of sash openings
- Improved storage/housekeeping
- Promotion of a vortex in tops of fume hoods

MOTORS AND MOTOR SYSTEMS [60-63]**:** Motors and drives are used throughout the pharmaceutical industry to operate HVAC systems, to drive laboratory or bulk manufacturing equipment (including mixers, pumps, centrifuges, and dryers), and for transport and equipment operation in the formulation and packaging stages. The energy efficiency measures described in the following section apply to any system that uses motors. Where appropriate, specific examples are listed detailing to which system each measure has already been applied, and to what success. Replacing a motor with a high-efficiency motor is often a better choice than rewinding a motor.

The practice of rewinding motors currently has no quality or efficiency standards. The efficiency of a motor decreases after rewinding; typically by anywhere from 2-25%. Recent case study data show that new motors are not only more energy efficient, but also reduce overall operation costs (CDA 2003).

COMPRESSED AIR SYSTEMS [64-66]**:** Compressed air is required in many applications in the pharmaceutical industry, for example, for the operation of equipment, for use in vacuum cleaning systems, sprays systems, and breathing air, and as instrument air in hazardous areas. In pharmaceutical facilities, compressed air often comes in contact with products, such as in spray coating operations or in packaging. Hence, compressed air is also often fitted with filters to meet strict contamination control standards.

Many opportunities to reduce energy consumption in compressed air systems are not prohibitively expensive; payback periods for some options can be extremely short. Energy savings from compressed air system improvements can range from 20-50% or more of total system electricity consumption.

Adding additional compressors should be considered only after a complete system evaluation. In many cases, it can be managed and reconfigured to operate more efficiently without purchasing additional compressors. Compressed air system service provider offer integrated services both for system assessments and for ongoing system maintenance needs, alleviating the need to contact several separate firms.

PUMPS [67-71]**:** The pumping systems account for about 25% of the electricity used in manufacturing facilities. The pumping of coolants such as glycol or chilled water is common in pharmaceutical manufacturing facilities and is also a source of significant energy consumption. Studies have shown that over 20% of the energy consumed by pumping systems could be saved through changes to pumping equipment and/or control systems (Xenergy 1998).

- **Maintenance:**
  - Replacement of worn impellers, especially in caustic or semi-solid applications.
  - Bearing inspection and repair.
  - Bearing lubrication replacement, on an annual or semiannual basis.
  - Inspection and replacement of packing seals. Allowable leakage from packing seals is usually between 2-60 drops per minute.
  - Inspection and replacement of mechanical seals. Allowable leakage is typically 1-4 drops per minute.
  - Wear ring and impeller replacement. Pump efficiency degrades 1-6 points for impellers less than the maximum diameter and with increased wear ring clearances.
  - Pump & motor alignment check

SUMMARY AND CONCLUSION: By modifying parts or rearranging them in proper manner as describe above the cost in industries due to high energy consumption by HVAC is reduced. Moreover it leads to high performance of HVAC.

Pharmaceutical manufacturing consumes a considerable amount of energy. In 2002, the U.S. pharmaceutical industry spent over $900 million on energy, making energy a significant cost driver for the industry.

Energy efficiency improvement is an important way to reduce these costs and to increase predictable earnings, especially in times of high energy price volatility.

Significant potential exists for energy efficiency improvement in the industry. A focused and strategic energy management program will help to identify and implement energy efficiency measures and practices across an organization. Many companies have already accepted the challenge to improve their energy efficiency due to steadily-rising energy prices; these companies have also begun to reap the rewards of energy efficiency investments. There are a variety of opportunities available at individual plants in the industries to reduce energy consumption in a cost-effective manner. This Energy Guide has identified many energy efficiency practices and energy efficient technologies that can be implemented at the component, process, system, and organizational levels.

Expected savings in energy and energy-related costs have been provided for many energy efficiency measures, based on case study data from real-world industrial applications.

Table 2 summarizes the efficiency measures presented in this Energy Guide & screening check list. For all efficiency measurements, individual plants should pursue further research on the economics of the measures, as well as on the applicability of different measures to their own unique production practices, in order to assess the feasibility of measure implementations.

Thus by sizing components of HVAC systems generally include dampers, supply and exhaust fans, filters, humidifiers, dehumidifiers, heating and cooling coils, ducts, and various sensors properly and designing energy efficiency into a new facility, an industry can minimize the energy consumption and operational costs of its plant HVAC systems from the outset.

TABLE 2: SUMMARY OF MODIFICATION OF HVAC SYSTEM

GENERAL	
ENERGY MANAGEMENT PROGRAMS	**ENERGY MONITORING SYSTEMS**
HVAC Systems	
Energy efficient system design	Recommissioning
Energy monitoring and control systems	Non-production hours set-back temperatures
Duct leakage repair	Discharge air temperature management
Variable-air-volume systems	Adjustable speed drives
Heat recovery systems	Chiller efficiency improvement
Fan modification	Efficient exhaust fans
Cooling water recovery	Solar air heating
Building reflection	Building insulation
Fume Hoods	
Improved storage/housekeeping	Restriction of sash openings
Vortex promotion	Variable-air-volume hoods
Motors	
Maintenance	Properly sized motors
Replacement of belt drives	High-efficiency motors and drives
Pumps	
Maintenance	Monitoring
Pump demand reduction	Controls
High-efficiency pumps	Properly sized pumps
Multiple pumps for variable loads	Impeller trimming
Miscellaneous Measures	
Stand-by power Membranes	Energy efficient office equipment

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