WEBINAR REPORT ON

HVAC DESIGN FOR OFFICE BUILDINGS

HOW TO KEEP AN EAR OUT FOR IT

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INTRODUCTION

Heating, ventilating, and air-conditioning (HVAC systems) account for almost 39% of the energy used in commercial buildings . Consequently, almost any business or client has the potential to realize significant savings by improving its control of HVAC operations and improving the efficiency of the system it uses.

The use of high performance HVAC equipment can result in considerable energy, emissions, and cost savings (10%–40%). Whole building design coupled with an "extended comfort zone" can produce much greater savings (40%–70%). In addition, high-performance HVAC can provide increased user thermal comfort, and contribute to improved indoor environmental quality (IEQ).

HEATING, VENTILATING, AND AIR-CONDITIONING (HVAC)

The term HVAC refers to the three disciplines of Heating, Ventilating, and Air-Conditioning. A fourth discipline, Controls, pervades the entire HVAC field. Controls determine how HVAC systems operate to meet the design goals of comfort, safety, and cost-effective operation.

- Heating can be accomplished by heating the air within a space (e.g. supply air systems, perimeter fin-tube "radiators"), or by heating the occupants directly by radiation (e.g. floor/ceiling/wall radiation or radiant panels).

- Ventilating maintains an adequate mixture of gases in the air we breathe (e.g. not too much CO2), controls odors, and removes contaminants from occupied spaces. "Clean" air helps keep occupants healthy and productive. Ventilation can be accomplished passively through natural ventilation, or actively through mechanical distribution systems powered by fans.

- Air-conditioning refers to the sensible and latent cooling of air. Sensible cooling involves the control of air temperature while latent cooling involves the control of air humidity. Room air is cooled by transferring heat between spaces, such as with a water loop heat pump system, or by rejecting it to the outside air via air-cooled or water-cooled equipment. Heat can also be rejected to the ground using geothermal exchange . The fresh air can be very effectively cooled to a supply air temp of around 28-29 DEG C using geothermal cooling , resulting in huge savings on the fresh air cooling load. The recent example of a massive geothermal system implemented very successfully are 2 campuses of Pathways school in Noida and Gurgaon.

Cool air is not comfortable if it is too humid. Air is dehumidified by condensing its moisture on a cold surface, such as part of mechanical cooling), or by removing the moisture through absorption (desiccant dehumidification). In dry climates, humidification may be required for comfort instead of dehumidification. Evaporative humidification also cools the air. Further, in such climates it is possible to use radiant cooling systems, similar to the radiant heating systems mentioned above.

- Controls ensure occupant comfort, provide safe operation of the equipment, and in a modern HVAC control system enable judicious use of energy resources. HVAC systems are sized to meet heating and cooling loads that historically occur only 1% to 2.5% of the time. It is the function of the controls to ensure that the HVAC systems perform properly, reliably, and efficiently during those conditions that occur 97.5% to 99% of the time.

- Each HVAC discipline has specific design requirements and each has opportunities for energy savings. It must be understood, however, that energy savings in one area may augment or diminish savings in another. This applies to interactions between components of an HVAC system, as well as between the HVAC system and the lighting and envelope systems. Therefore, understanding how one system or subsystem affects another is essential to making the most of the available opportunities for energy savings. This design approach is known as whole building design.

HEATING, VENTILATING, AND AIR-CONDITIONING (HVAC)

- Employing high-performance HVAC equipment in conjunction with whole building design can result in significant energy savings. Typically, a 30% reduction in annual energy costs can be achieved with a simple payback period of about three to five years. And, if the payback threshold is extended to seven years, the savings can be about 40%. These figures apply to buildings that offer conventional comfort (e.g., 70°F in winter, 76°F in summer)

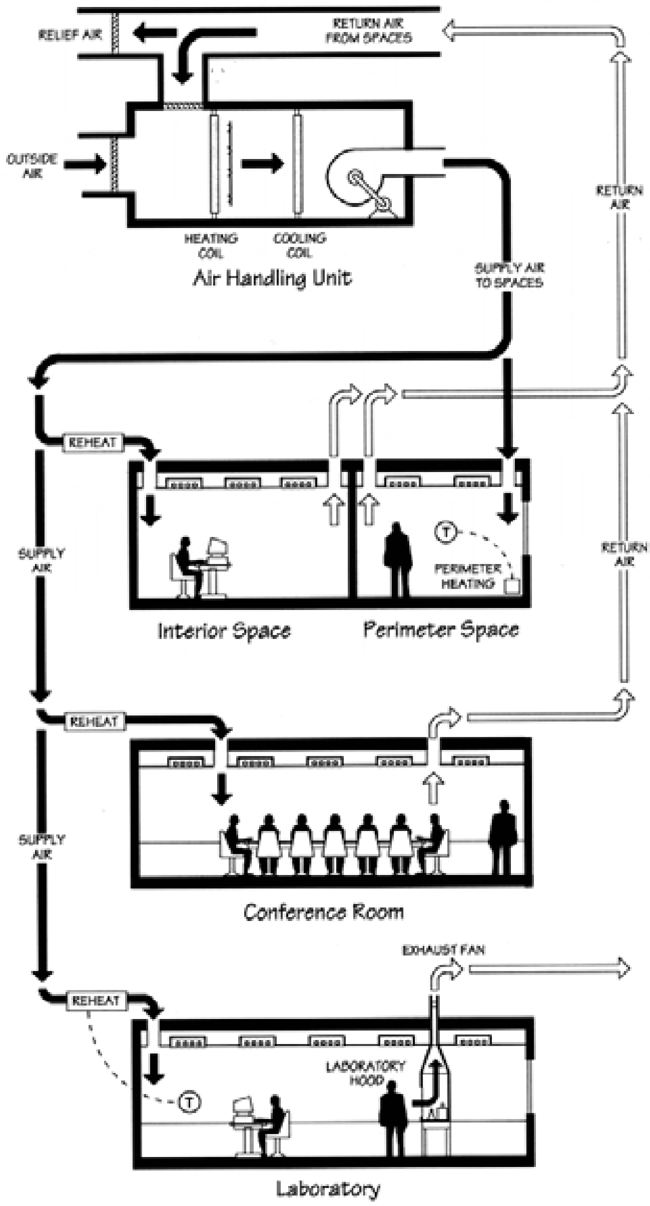

Figure 3-23. Schematic of an air handling unit and the spaces it serves.

- However, note that highly energy-efficient design utilizing high-performance HVAC equipment often requires more effort and more collaboration from the design team than a conventional, sequential approach.

HVAC DESIGN GUIDELINES FOR OFFICE SPACES

1. Design the space to reduce HVAC cooling loads for energy efficiency

- The HVAC system consumes more energy than any other part of your office space. When you're renovating or building a new open plan space, it pays to design the space to reduce HVAC loads and save on energy costs. You'll probably be installing better insulated walls, floors and windows, but here are some additional ideas you may not have considered.

- Adding more daylight is a design consideration that's great for workplace health and wellbeing, and also for reducing heating loads in the winter. However, to avoid solar gain and increased cooling loads in the summer, consider using tinted low-e glass or double glass unit having low heat transfer co- efficient and solar factor. The campuses of Pathways schools have been provided with double glass units with overhang to cut off direct radiation load and thereby drastically reducing the cooling load.

- Another energy-saving idea is lighting systems that dim or turn off when there is sufficient daylight for working in the space. This strategy combined with cooler types of lighting produce less heat waste and reduce the cooling load on your HVAC system. The best example of such lighting is usage of LED lights .

2. HVAC system design and sizing

- Calculating loads for HVAC system design must take into consideration all energy efficiency design features in order to avoid installing an oversized HVAC system.

- Here's something you may not realize: bigger is not better when it comes to HVAC system design. Installing air conditioning equipment that's oversized for the required load of your space will produce inadequate comfort conditions. Here's what happens: the system is constantly turning on and off, and never runs long enough to remove humidity. So your space is clammy and riddled with hot and cold spots.

3. Create zones

- For better energy efficiency as well as comfort, your HVAC system design should include multiple independently-controlled zones within the space. That's because, even in an open office, different areas have different requirements to remain consistently comfortable. For example:

- Perimeter spaces are more affected by weather than interior areas and should be controlled separately

- Some spaces have special needs for temperature and/or humidity control, such as computer rooms from comfort zones, and these must be controlled independently.

- Areas where large numbers of people are gathering, such as big conference rooms, will need more cooling when in use, and less when unoccupied.

- This can be easily done by use of VAV boxes along with the associated controls like back pressure sensors / temperature sensors and VFD drives for the AHU's.

4. Take advantage of sensors

- Sensor technology for smart buildings has come a long way in recent years. Two types of sensors are useful for saving energy by integrating with HVAC system design:

- Temperature and pressure SENSORS : they can sense the temperatures in each individual zones and adjust the air quantity in those zones accordingly with the help of back pressure sensors and VFD drives installed in the ducts and on the AHU's.

- CO2 SENSORS: they can sense the amount of CO2 in each individual zone and in conjunction with demand controlled ventilation can vary the amount of fresh air being inducted into the office areas to keep the indoor CO2 levels at optimum levels and help to improve the indoor air quality while keeping the fresh air load in check.

- LIGHT SENSORS are mentioned above: they can sense the amount of daylight available in the space, and adjust the lighting as needed.

- OCCUPANCY SENSORS track how many people are using the space at any given time, and can send messages to HVAC controls. For example, when sensors detect that a large meeting space is in use, cooling can be increased to accommodate the increased load in the area.

5. Consider under floor air distribution

- Traditionally, office spaces have been cooled with overhead air distribution. However, this HVAC system design can be less than effective (and less energy efficient) in open, modern office spaces with high ceilings.

- Instead, many office spaces with an open plan are using under floor air distribution systems. These systems use diffusers installed under a raised floor to deliver conditioned air to different areas within the space. The systems then take advantage of stratification that moves warm air up toward the ceiling to be replaced by the cooler conditioned air at workers' feet. Under floor air is great for providing consistent comfort levels as well as maintaining indoor air quality.

6. Address indoor air quality with ventilation

- When it comes to the right HVAC system design for a modern office space, it's not only about thermal comfort. It's just as important to control humidity, eliminate odors, and remove contaminants such as dust, carbon dioxide and even bacteria and viruses that can spread illness. Maintaining proper indoor air quality levels is critically important for workforce wellbeing and productivity.

- That means addressing the "V" in HVAC: ventilation. Your HVAC system design must provide for adequate intake and distribution of outside air within the space, as well as well-controlled distribution of conditioned air. This is another are where the expertise of HVAC design professionals makes the difference between getting everything right before building, and having expensive problems to fix later.

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TYPES OF HVAC SYSTEMS IN OFFICE BUILDINGS

1 – DUCTING SYSTEM

A – Exposed ducting system with either exposed elliptical / round ducts or exposed rectangular ducts with grills / diffusers mounted directly on the ducts.

The return air is either ducted or through appropriate boxing in the form of false ceiling at select locations.

2- Normal ducts hidden above the false ceiling with appropriate grills/ slots/ diffusers installed in the false ceiling and connected to the ducts via flexible connections.

3- Server room cooling – Types of cooling methodologies adopted in server rooms:

- Arranging servers in rows so that the cold air comes in the front and is expelled out the back; keeping the doors to the room closed; ensuring that the flow of cold air makes it to the equipment.
- Having redundant AC – if one unit fails, another takes over.
- Avoid using AC systems designed for humans – known as comfort AC. Cooling equipment needs to be specifically designed for computers and have adequate temperature and humidity controls. If you don't control the humidity level you either end up with damaged equipment due to static electricity or servers dripping with water due to condensation. It is therefore recommended to install precision AC units

TYPES OF HVAC SYSTEMS IN OFFICE BUILDINGS

PROS :

- Precise and quick processor-based temperature control, to keep your IT equipment at the precisely right temperature, always.
- Precise humidity control. Electronic devices require a steady level of humidity for proper functioning. Both high/low humidity levels can impede them on the long run.
- Designed for 24 x 7, 365 days continuous operation. Room air conditioners are generally designed to be used for a few hours, that too during summers.
- Precision air conditioners are designed to manage high levels of sensible heat (heat without humidity, emanated by machines) while comfort/standard air conditioners are designed to manage latent heat (heat with humidity, emanated by people).
- Precision air conditioners demonstrate better air distribution. They have higher CFM rates that moves more air volume at higher speeds than standard AC's. That also means that there are less airborne particles due to the AC.
- Precision air conditioners can handle higher heat and AC load densities per each unit.
- For larger premises, several units of precision air conditioners can coordinate with each other and automatically control (increase/decrease) individual AC loads, for efficient cooling.
- Precision air conditioners can deploy new features or enhance existing ones as their software/firmware is regularly updated.
- Precision air conditioners have better, faster support facilities/contracts, as vendors specialized for them understand the critical nature of IT support and maintenance.

CONS :

- Higher per / ton cost vis-à-vis comfort AC units.
- Require greater floor space due to bigger size vis-à-vis comfort AC units.
- Limitations of ref piping length vis-à-vis comfort AC units which can be designed for much higher ref piping length.
- Inability to install the outdoor units at levels below the indoor AC units, which is possible to do in comfort AC units.
- The noise levels are much higher in precision AC units vis-à-vis the comfort AC units.
- Precision air conditioners consume more power/ ton vis-à-vis comfort AC units.
- Precision air conditioners require specialized agencies to install and maintain , usually the manufacturers of the precision AC units supply as well as install and commission the units. Whereas the comfort AC units do not require such specialized agencies and can be installed and maintained by competent third parties as well.
- Precision air conditioners have longer lead times vis-à-vis comfort AC's as they are usually not available ex- stock and are custom made machines, which are manufactured as per the individual project requirement.

COMPARISON OF HOT AISLE AND COLD AISLE CONTAINMENT FOR SERVER ROOMS

HOT AISLE (HACS)	COLD AISLE (CACS)
Avoids mixing of hot and and cold air thereby leading to a more efficient cooling system.	Avoids mixing of hot and and cold air thereby leading to a more efficient cooling system.
Unlike CACS, a HACS does not impact the temperature of the surrounding room. A HACS is, in effect, a room neutral solution. The hot air inside of the HACS is contained from the rest of the room. The HACS does not deliver any hot air to the outside room; therefore the existing cooling system is not rendered less efficient.	When cold aisles are contained, the air in the rest of the room becomes hotter (well above 80° F / 27° C and in some cases as high as 100° F / 38° C), and anyone entering the data center is exposed to unusually high temperatures.For example, if the temperature of the data center is set for 75°F (24° C), and a CACS system is implemented, the room temperatures outside of the cold aisle will rise because hot air will mix in with the air outside of the cold aisle on its way to the intake of the cooling system
May get problematic during a prolonged power shutdown as the heat gets trapped in the hot aisle containment zone.	Lesser problem during power shutdown as the heat gets dissipated over a larger area
Uncomfortable for the IT people working at the rear of the racks, however the issue may be mitigated to some extent by opening the hot aisle containment doors while the IT people are working in the hot aisle.	Easier to work at the rear of the racks as the heat gets dissipated over a larger area.

FUNDAMENTALS OF ENERGY- AND RESOURCE-EFFICIENT HVAC DESIGN

1-Consider all aspects of the building simultaneously:

- Energy-efficient, climate responsive construction requires a whole building perspective that integrates architectural and engineering concerns early in the design process. For example, the evaluation of a building envelope design must consider its effect on cooling loads and daylighting. An energy-efficient building envelope, coupled with a state-of-the-art lighting system and efficient, properly-sized HVAC equipment will cost less to purchase and operate than a building whose systems are selected in isolation from each other.
- The building should incorporate as many features as possible that reduce heating and cooling loads, for example:
- In skin-load dominated structures, employ passive heating or cooling strategies (e.g., sun control and shading devices, thermal mass) and include glazing that has a low U value and solar factor.
- In internal-load dominated structures, include energy efficient lighting and equipment.
- Specify exterior wall constructions that avoid thermal bridging.
- Incorporate the highest R-value wall and roof construction that is cost-effective.
- Design efficient lighting systems.
- Use daylight dimming controls whenever possible.
- Specify efficient office equipment (e.g., EPA Energy Star® Office Equipment).

2-"Right Size" HVAC systems to ensure efficient operation:

- Safety factors for HVAC systems allow for uncertainties in the final design, construction and use of the building, but should be used reasonably.Greatly oversized equipment operates less efficiently and costs more than properly sized equipment. For example, oversized cooling systems may not dehumidify the air properly, resulting in cool but "clammy" spaces.It is unreasonable and expensive to assume a simultaneous worst-case scenario for all load components (occupancy, lighting, shading devices, weather) and then to apply the highest safety factors for sizing.
- Applying safety factors to a reasonable baseline. It is unreasonable to assume that on the hottest clear day if no shades are drawn and all lights are on that each room is occupied by the maximum number of people the room has been designed to accommodate (thus, far in excess of the maximum number of people that can be expected in the building), and then apply safety factors. Safety factors should be applied to a baseline that was created using reasonable assumptions.

3- Consider part-load performance when selecting equipment:

- Part-load performance of equipment is a critical consideration for HVAC sizing.Most heating and cooling equipment only operate at their rated, peak efficiency when fully loaded (that is, working near their maximum output).

However, HVAC systems are sized to meet design heating and cooling conditions that historically occur only 1% to 2.5% of the time. Thus, HVAC systems are intentionally oversized at least 97.5% to 99% of the time. In addition, most equipment is further oversized to handle pick-up loads and to provide a factor of safety. Therefore, systems almost never operate at full load. In fact, most systems operate at 50% or less of their capacity.

- Select systems that can operate efficiently at part-load. For example:Variable volume fan systems and variable speed drive controls for fan motors along with VAV boxes;
- Variable capacity cooling plants (e.g., modular chiller plants, multiple compressor equipment, and variable speed chillers);
- Variable capacity cooling towers (e.g., multiple cell towers with variable speed or two speed fans, reset controls);
- Variable capacity pump systems (e.g., primary/secondary pump loops, variable speed pump motors); and,

4-Commission the HVAC systems:

- Commercial HVAC systems do not always work as expected. Problems can be caused by the design of the HVAC system or because equipment and controls are improperly connected or installed.A part of commissioning involves testing the HVAC systems under all aspects of operation, revealing and correcting problems, and ensuring that everything works as intended. A comprehensive commissioning program will also ensure that O&M personnel are properly trained in the functioning of all systems.

5- Establish an Operations and Maintenance (O&M) Program:

- Proper performance and energy-efficient operation of HVAC systems can only be ensured through a successful O&M program. The building design team should provide systems that will perform effectively at the level of maintenance that the owner is able to provide. In turn, the owner must understand that different components of the HVAC system will require different degrees of maintenance to perform properly.
- Specify systems that can be properly maintained by the owner, based on the owner's stated resources.
- Provide as part of construction, contract system interfaces to allow personnel to easily monitor and adjust system parameters.
- Make systems control, operation, and maintenance training part of the construction contract.
- Include complete documentation regarding operation and maintenance of all equipment and controls systems as part of the construction contract.
- Establish a written, comprehensive operation and maintenance program, based on the requirements of the facility, equipment, and systems installed.

AIR-CONDITIONING EQUIPMENT CONTROLS

- Controls that significantly affect the energy efficiency of chillers include:

- Variable speed drives achieve good part-load performance by matching the motor output to the chiller load, and by cycling off at a lower fraction of capacity than constant-speed chillers.
- Multiple compressor achieves a closer match of the load than single-compressor chillers by sequencing the compressors as needed.
- Water temperature reset controls raise the water temperature as the demand decreases, allowing for more efficient chiller operation.

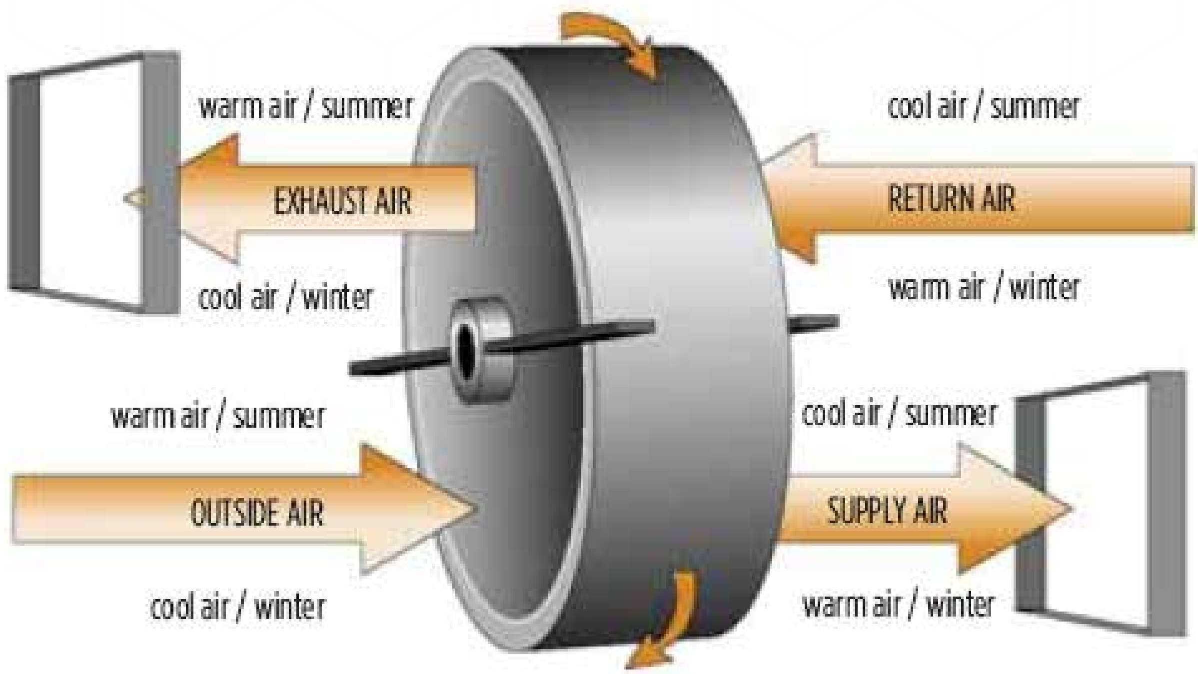
- Strategies that significantly affect the energy efficiency of cooling towers include the use of:

- Variable-speed or multiple-speed fans
- Wet-bulb reset strategies, where the temperature of the cooling water is adjusted according to the temperature and humidity of outside air (instead of maintaining it constant)
- Fans and pumps that use variable frequency drive (VFD) controls to reduce energy use at part-load

- Integrated chiller plant controls use monitoring and computational strategies to yield the minimum combined energy cost for the chillers, cooling towers, fans, and pumps.This approach can be significantly more effective (though more difficult to implement) than optimizing the operation of each piece of equipment independently.

HEAT RECOVERY

- Heat recovery ventilation (HRV) or Energy recovery ventilation (ERV) is the energy recovery process of exchanging the energy contained in normally exhausted building or space air and using it to treat (precondition) the incoming outdoor ventilation air in residential and commercial HVAC systems. During the warmer seasons, the system pre-cools and dehumidifies while humidifying and pre-heating in the cooler seasons. The benefit of using energy recovery is the ability to meet the ASHRAE ventilation & energy standards, while improving indoor air quality and reducing total HVAC equipment capacity.



Thermo wheels *[courtesy Munters Corporation, Des Champs Products]*

ENHANCE INDOOR ENVIRONMENTAL QUALITY (IEQ)

• When constructing cost-effective buildings, it is easy to forget that the success or failure of a project may rest on its indoor environmental quality (IEQ). Healthy, comfortable employees are often more satisfied and productive. Unfortunately, this simple truth is often lost, for it is easier to focus on the first-cost of a project than it is to determine the value of increased user productivity and health. Facilities should be constructed with an appreciation of the importance of providing high-quality, interior environments for all users.

• IEQ encompasses indoor air quality (IAQ), which focuses on airborne contaminants, as well as other health, safety, and comfort issues such as aesthetics, potable water surveillance, ergonomics, acoustics, lighting, and electromagnetic frequency levels. IEQ improvements to an existing building can occur at any point during the use of a building.

During the facility/renovation design and development process, projects must have a comprehensive, integrated perspective that seeks to:

- Facilitate quality IEQ through good design, construction, commissioning, and operating and maintenance practices;
- Value aesthetic decisions, such as the importance of views and the integration of natural and man-made elements;
- Provide thermal comfort with a maximum degree of personal control over temperature and airflow;
- Supply adequate levels and quality of ventilation and outside air for acceptable indoor air quality;
- Prevent airborne bacteria, mold, and other fungi, as well as radon, through building envelope design that properly manages moisture sources from outside and inside the building, and with heating, ventilating, air-conditioning (HVAC) system designs that are effective at controlling indoor humidity;
- Use materials that do not emit pollutants or are low-emitting;
- Assure acoustic privacy and comfort through the use of sound absorbing material and equipment isolation;
- Control disturbing odors through contaminant isolation and removal, and by careful selection of cleaning products. Pursue energy efficient strategies to remove harmful odors while recovering the energy used in conditioning the interior environment;
- Create a high-performance luminous environment through the careful integration of natural and artificial light sources; and
- Provide quality water.

ENHANCE INDOOR ENVIRONMENTAL QUALITY (IEQ)

Recommendations for improving the IEQ for a facility / office building vis-à-vis the HVAC system are listed below:

- Design the ventilation system to meet or exceed ASHRAE Standard 62.1: Ventilation for Acceptable Indoor Air Quality.
- Implement a construction management program that ensures key ventilation components are protected from contamination during construction. Ensure that construction filters placed in ductwork and mechanical equipment are routinely inspected and replaced as needed. Do not install high efficiency filters until all construction work, including dry wall and painting, has ceased.
- Commission HVAC systems to validate and document design performance intent. Review commissioning report to ensure that adequate ventilation rates have been achieved prior to initial occupancy. One Commissioning technique that can be employed over the life of the building is the use of a well maintained carbon dioxide monitoring system that will continually provide diagnostic feedback on the actual amount ventilation provided in the most densely occupied spaces
- Consider a building design with a natural ventilation or hybrid component to both reduce energy consumption and to make some provisions for ventilation even if external power were not available (a measure of resiliency). Use of natural ventilation component is dependent on relative humidity being within an acceptable range.
- Use of separate outside air and conditioned air distribution systems.
- Ensure fresh air intakes are located away from loading areas, exhaust fans, and other contamination points, preferably on roofs.
- If building is close to a large roadway source, consider the location of the fresh air intakes or possible breaks that may help reduce impact of the outdoor air on the indoor environment.
- During operation, either develop a plan for identifying needed filter media replacement or replace filter media on a regular schedule.
- Provide Energy Recovery Ventilation systems for needed ventilation air as a standard feature in new construction which is typically highly insulated and extremely airtight.