Comparison of Energy Efficient Air-Conditioning Systems

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Abstract. The purpose of this paper is to provide a comparison of energy-efficient air-conditioning systems in an office building in a warm, tropical climate. Miami, Florida was the city used for the demonstration. A typical office building from the coast of Miami was selected and to do a proper assessment of the energy efficiency of different air-conditioning units, we designed the shell of the office building and simulated the energy usage in eQUEST software. The software then generated the results for examining the energy usage of each air-conditioning systems and allowed us to determine which would be the most energy efficient based on the results received.

1. Introduction

With its subtropical climate and intimate ties to Latin America, Miami is like no other city in the United States. Situated at the southern tip of the 500-mile-long Florida peninsula, the city of Miami is in Southeast Florida, in Miami-Dade County on the Miami River, with the Atlantic Ocean to the east and the Florida Everglades to the west. With a population of 453,579 (as of 2016 census), Miami is the largest city in the greater South Florida area and one of the youngest cities in the entire United States. More than 65 percent of its population is Hispanic, and Spanish is the most commonly heard language.

Miami has been labelled “the Magic City” for its seemingly overnight development into an international tourist center. Historically, Florida has been vulnerable to natural disasters primarily from hurricanes. In 1992, Hurricane Andrew devastated the Miami area, causing $26.5 billion in damages. The unprecedented hurricane activity in the 2004 and 2005 seasons caused further impact to South Florida. Global warming will present a new and greater natural hazard to South Florida through rising sea levels and its impact on the land and drinking water supply.

In 2007, the Nobel Peace Prize was awarded jointly to Al Gore and the United Nation’s Intergovernmental Panel on Climate Change (IPCC) for their work on climate change. The IPCC’s work reviews scientific knowledge on greenhouse gases, their connection with human activity, and the potential impacts of increasing concentrations of these gases on the earth. Scientific consensus now recognizes that most of these changes are due to human activities. As stewards for current and future generations, dramatic steps must be taken to radically reduce global emissions of greenhouse gases if future climate change is to be limited and its widespread impact on the City and State reduced. The benefits, in addition to reducing emissions of greenhouse gases, include: reducing energy costs in the wake of skyrocketing costs of fossil fuels, decreasing dependence on other nations for energy supply,
creating new jobs and industries in a green economy, and allowing for future sustainable development by providing a model that can be replicated nationwide.

1.1. Energy Consumption in Miami
Buildings consume energy to provide basic functions such as cooling, lighting, heating water, and powering appliances and other electronics. Most buildings also waste energy. Miami buildings are unique in the United States in that they use most of the energy consumed from electricity on cooling. According to the “City of Miami Climate Action Plan” published in 2008, Miami can reduce their annual greenhouse gas emissions by approximately 975,000 metric tons by 2020 through improvements in energy efficiency in both new and existing buildings. More efficient generation and cleaner fuel sources of electricity can result in an immense reduction in Miami’s greenhouse gas emissions. Miami could also reduce its greenhouse gas emissions by more than 420,000 metric tons by increasing the use of renewable energy and the use of more efficient, local sources of power. Doing so can emphasize efforts to improve energy efficiency in existing buildings and their cooling and lighting systems, which altogether compromises more than half of electricity used in a typical South Florida building.

The purpose of this article is to acquaint readers with modern AC technologies design. Secondly, our goal is to calculate and compare energy consumption of two office buildings in a given climatic zone (Miami, Florida) with widely spread cooling systems (DX Coils and Chilled Water Coils), based on the simulation performed in the eQUEST. Positive results of the simulations can prove that further operation of the building, with an effective solution, can significantly reduce energy consumption, which is a vital factor for sustainable environmental development in the modern world.

![Map of climate types of Florida, USA.](image)

2. Background
A range of different air-conditioning systems are currently employed in buildings, their choice and suitability being dependent on the location of the building and its function. Some of the systems, for example, hybrid chilled ceilings, are relatively new developments. Others, such as thermoactive floors, have been in use for some time already. Over a century ago, British engineer A.M. Barker, devised a system of space heating which involved passing hot water through steel pipes integrated into the underside of a reinforced concrete floor; this ceiling-mounted heating system, patented in 1907, later became known in England as the “Crittall ceiling”. Air-conditioning systems also have a long history, beginning with their development by Carrier in the early 20th century. Induction systems came along later, followed in the late 1980s by chilled ceilings. A relatively new development, and so far mostly
restricted to Switzerland, is the hybrid chilled ceiling, which combines the different benefits of a thermoactive floor and a chilled ceiling.

2.1. Architectural integration
Air-conditioning systems should ensure the indoor environment is as comfortable and pleasant as possible; a high proportion of the energy they use should come from renewable sources; and their life-cycle costs should be as low as possible. In all systems, however, the idea is to lower the exergy and primary energy demand as far as possible, which means that in each individual building project, the availability of natural heat sinks at the location, e.g. cold night air, the ground or river water have to be examined to see if they are suitable for use in cooling. Regardless of the cooling performance of a system, there are always humidity loads (latent loads) to consider in a building, not just thermal (sensible) loads. From a technological point of view, air-conditioning systems can be classified according to whether they can only remove thermal loads, or also humidity loads from the indoor air. Because of the humidity loads, but also in order to ensure adequate input of fresh air, it is generally necessary to retrofit ventilation systems to air-conditioning systems that are only suitable for removing sensible loads. In terms of design, a distinction can be made between “visible” heat-transfer or air-conditioning systems and “invisible” ones that are integrated into the building components.

2.2. Invisible systems
Thermoactive concrete floors have water-bearing plastic pipes embedded into their core, the underside of the slab is then left exposed. Thermal loads from the rooms are taken up by the concrete and carried away by the cold water circulating in the pipes in the floors. Latent loads cannot be removed in this way. The significant thermal-storage capacity of the concrete mass is exploited in this system: part of the heat load can be stored for a time in the concrete floors and removed at a later point. Optimum use can be made of natural heat sinks such as night-time temperatures. Thermoactive floors are not suitable for use in combination with extensive suspended ceilings, so in offices special measures are needed to improve acoustic insulation. The system can therefore only be used in new buildings or in old buildings that are undergoing complete refurbishment.

Capillary matting, where water flows through a network of narrow tubes, is generally fitted to the underside of an exposed floor and plastered in, which makes it a system suitable for easy retrofitting in renovation programmes. It is also possible to integrate such mats into the concrete floor. The extent and position of the matting is adapted to the individual office grid, which means any later changes to

Figure 2. Thermoactive floor with water pipes.
internal layout can generally be accommodated relatively easily. Provided the thermal loads to be removed from the interior of the building are not very high, they can be dissipated for the most part via a cooling tower in combination with natural heat sinks such as cold night air.

Air-carrying pipes integrated into the concrete floor mean the concrete can be left exposed, but the inlet and outlet points have to be carefully integrated into the architectural detailing. Unlike other space-cooling systems, this type can remove both thermal and latent loads. It is, however, only suitable for new buildings. As with water-based thermoactive floors, a portion of the thermal load can be stored for a time in the concrete floor and released later.

Generally, the system is a special design which can be advantageous when the air quality in the rooms needs to be high, thus requiring a correspondingly high volume of air exchange (e.g. IDA 1:72 m3/h per person). Mostly, however, an air exchange of only 30 m3/h per person is designed, which is equivalent to an air quality level of IDA 3. An air-based thermoactive system in such a building would still be capable of removing the cooling load, but would usually be associated with an unnecessarily high volume of air exchange, and therefore high energy consumption on fans.

2.3. Visible systems

The most commonly used air-conditioning system is the fan coil unit. This method of circulating air should, however, only be used in places where there are high convection loads, e.g. in the form of waste heat from computers, as otherwise radiation asymmetries can occur. Fan coil units need special integration into parapets, ceilings or wall areas. Where a cooling tower is used for cooling, the time in which “free cooling” is possible, i.e. particularly efficient heat transfer to the environment when outside temperatures are low, is greatly reduced when compared to water-based thermoactive floors or capillary mat systems.

![Figure 3. Ceiling panels with cooling and acoustic functions.](image)

Water-based systems for heating and cooling floors have a big impact on the appearance of the interior space and need careful consideration at the design stage. Yet, as in this case such systems are generally not directly attached to the building mass, they have the advantage of being easily regulated and reacting fast. However, latent loads cannot be transported with standard systems of this type. Nor is it possible to store thermal loads, which restricts the option of exploiting “free cooling”. Some systems are however available on the market that make partial use of the mass of the floor slab and are also fitted to a ventilation system.

A hybrid chilled ceiling is a combination of a concrete floor, a water-based radiant chilled ceiling, and a duct system of ventilation onto which are fixed water-carrying pipes (Figure 5, bottom drawing). This system has so far been fitted mostly in Switzerland and is a relatively new form of air-
conditioning system for Germany. Depending on the loads to be removed, around 20 to 50\% of the ceiling surface (i.e. far more than with conventional ventilation systems) is fitted with suspended ventilation ducts. Arranged on the upper side of the ventilation ducts are nozzles through which air is blown onto the solid concrete floor when cooling is required. Because of the strong mixing of air in the void between the suspended chilled ceiling and the concrete floor, heat is transferred from the chilled ceiling to the concrete floor. In other words, the air circulation which is created draws heat out of the suspended chilled ceiling and transfers it to the concrete floor above, so that the storage mass of the floor slab can still be utilized despite the fact that the floor and the chilled ceiling are thermally separated.

![Figure 4. Hybrid chilled ceiling.](image1.png)

At night the thermal load in the floor slab is removed (via radiation) to the water-carrying pipes on the chilled ceiling. As hybrid chilled ceilings combine both a ventilation system and cooling via radiation, it can remove both sensible and latent loads. The waste air is vented conventionally via an exhaust air outlet, incoming air is brought into the room at low speed via the suspended chilled ceiling. The system can only be used in combination with a suspended ceiling, visible ventilation grilles are not necessary and acoustic insulation can be integrated into the suspended chilled ceiling.

### 2.4. Cooling loads

In order to keep the loads that have to be removed as small as possible, attention should be paid in the design of the building to the proportion of window area (moderate only) and to solar shading (preferably external). Furthermore, in the initial planning phase it is important to identify any heat sinks at the location, and ascertain at what times of the day or year these can be utilized. Generally, the amount of heat generated by users in office buildings varies between about 5 W/m2 and 9 W/m2, depending on the structure of the room and occupancy levels. Thermal loads generated by the operation of electrical equipment depend directly on how much equipment is in the room; the load can thus vary between around 7 W/m2 and roughly 40 W/m2 (Figure 6). As well as internal loads, consideration must be given to any additional external heat loads that need to be removed; the figure here is dependent on facade design, orientation and the climate at the location.

The cooling loads resulting from this are a key selection criterion when deciding on the type of air-conditioning system. With thermoactive systems, it is possible to remove thermal loads of around 40 W/m2, whereas with an air-based thermoactive floor and a high air-exchange volume this reaches around 60 W/m2; with a chilled ceiling combined with a capillary mat system or a fan, the figure is approximately 80 W/m2.
2.5. Thermal comfort
As well as removing loads, the chosen air-conditioning system must ensure thermal comfort in the interior space. The temperature required in the rooms depends on room usage, the clothing worn by the occupants and the outside temperature. As the operative (i.e. perceived to be neutral) temperature indoors is not static, but stands in relation to the outside temperature, an air-conditioning system has to be able to achieve different room temperatures. An optimally adjusted system therefore has to be in a position to keep the indoor temperature below the contractually agreed maximum and also to react flexibly to different weather conditions and, in particular, to changing internal loads. Regarding this point in particular the various systems differ considerably from one another.

With thermoactive components, flexibility is restricted as the high storage mass does not permit fast changes to indoor temperature. Individual adjustment of the temperature is generally not possible, as the pipes run across the divisions between the rooms. In theory separate pipe grids could be laid for each room, but this would be far more complicated and for this reason is barely used in Germany.

Capillary mats fitted to the underside of the floors have faster reaction times than thermoactive floors. If the temperature in different areas needs to be individually adjustable, then the system has to be zoned appropriately. This needs to be taken into account in the design stage. One advantage of capillary mats is that they have a particularly homogeneous surface temperature, which results from the close proximity of the pipes through which water flows. Unlike thermoactive floors, capillary mats can be fitted in the modernization of existing buildings.

As chilled ceilings and hybrid chilled ceilings have no directly connected storage mass, these systems operate very flexibly and can react quickly to varying loads. Because a large proportion of the cooling performance is delivered via radiation, a high degree of thermal comfort can be achieved. It can also be individually regulated.

2.6. Energy requirements
Fan coil units consume a lot of energy on the operation of fans or pumps. When used for chilling, too, their energy consumption is also significantly higher than for a water-based thermoactive floor or a hybrid chilled ceiling. In the case of a water-based thermoactive floor, a large part of the cooling is “free”, i.e. prepared without a refrigeration unit. This benefit is reduced, however, because of the higher energy consumption on pump operation, due to the slow response time of the system. The energy consumption of a water-based thermoactive floor is around 30-40% lower than for a fan coil unit. And around 15-25% lower than for a chilled ceiling. When hybrid chilled ceilings are regulated
optimally, a further small reduction in energy consumption can be achieved as compared to water-based thermoactive floors.

2.7. Cost analysis
Not only specific energy consumption, but also investment and maintenance costs should form part of an overall calculation of life cycle costs. Taking initial investment costs alone, then thermoactive concrete floors are the most cost-effective air-conditioning system, followed by fan coil units. If, however, with thermoactive floors additional acoustic insulation measures are required, which unlike in the case of fan coil units cannot be achieved using conventional systems, then this order is reversed.

In contrast, the maintenance costs of fan coil units are many times higher than with other systems. The lowest of all, in terms of maintenance costs, is a thermoactive floor. The maintenance costs for hybrid chilled ceilings are similar to that of chilled ceilings. They are marginally above those for thermoactive floors and considerably lower than for fan coil units.

2.8. Selection criteria
When choosing an air-conditioning system, several aspects generally need to be considered (Figure 13). With fan coil units the critical factor is whether they will be noisy; also their energy consumption is high. Investment costs for this option are comparatively low, but the follow-on costs are relatively high. Ceilings chilled with water carrying pipes are expensive to construct and have consequences for the design of the room.

Thermoactive concrete floors are attractive because of their low life-cycle costs and because for the user the system is hidden from view. The disadvantage lies, in particular, in the fact that there is virtually no way of controlling it, and that it reacts slowly to change. In areas where good acoustic insulation is important, special measures need to be taken which do not lead to a thermal separation between the concrete floor and the room. For example, heat-conducting metal ceiling panels are available which also have good sound-absorbing properties. Active regulation of the room temperature is only possible when additional, controllable systems are available. Because of the slow response times of this system, thermoactive concrete floors should only be used as the sole form of air-conditioning in places where relatively low and constant thermal loads are expected.

| Criteria                  | Fan convectors | Thermoactive floors | Capillary tube mats | Water-based chilled ceilings | Hybrid chilled ceilings |
|---------------------------|----------------|---------------------|---------------------|-----------------------------|------------------------|
| Visual impact             | [ ]            | [ ]                 | [ ]                 | [ ]                         | [ ]                    |
| Adjustment by user        | [ ]            | [ ]                 | [ ]                 | [ ]                         | [ ]                    |
| Operative temperature     | [ ]            | [ ]                 | [ ]                 | [ ]                         | [ ]                    |
| Energy use                | [ ]            | [ ]                 | [ ]                 | [ ]                         | [ ]                    |
| Investment cost           | [ ]            | [ ]                 | [ ]                 | [ ]                         | [ ]                    |
| Follow-on costs           | [ ]            | [ ]                 | [ ]                 | [ ]                         | [ ]                    |
| Flexibility for change of use | [ ]         | [ ]                 | [ ]                 | [ ]                         | [ ]                    |

Figure 6. Qualitative comparison of different air-conditioning systems.

One way of optimizing the system without fitting additional visible components is, for example, to combine a thermoactive floor with a capillary mat system. In this case the thermoactive component can be used as a passive system, and the capillary mat as an active system to cope with peak loads.
If capillary mats are used only, the position of the mats is critical. When positioned below the floor reinforcement (i.e. near the surface), the system can react far more dynamically to changing loads, but it loses a part of its thermal store effect. If the capillary mats are fitted deeper into the floor slab, the response times are slower and the storage capacity rises.

Hybrid chilled ceilings are attractive in that they are easy for the user to control, and their energy consumption is also low. These systems are very good, for example, in meeting rooms where loads vary considerably. One disadvantage is that there is no longer the option of an exposed concrete floor. Visually hybrid ceilings are like suspended ceilings.

3. Methodology
Research method of this paper is based on simulation of building energy efficiency and its energy consumption with help of eQUEST software. Preparation to simulation process starts with building models of chosen office building and specifying list of parameters that can be critical in the energy consumption field. After completion of simulation process eQUEST provides comprehensive reports that show detailed energy consumption prediction for the chosen interval.

3.1. Simulation software introduction
eQUEST is a sophisticated, easy to use and freeware building energy use analysis tool that provides professional-level results with an affordable level of effort. eQUEST was designed to allow to perform detailed comparative analysis of building designs and technologies by applying sophisticated building energy use simulation techniques but without requiring extensive experience in the "art" of building performance modeling. This is accomplished by combining schematic and design development building creation wizards, an energy efficiency measure (EEM) wizard and a graphical results display module with a complete up-to-date DOE-2 (version 2.2) building energy use simulation program. To get a more complete summary of the features and capabilities of this excellent program users can read the eQUEST Overview.

3.2. Sequence of work in eQUEST
eQUEST allows its users to construct either a schematic building envelop or full comprehensive complex model within the program. There are three input wizards in eQUEST that all have different levels of complexity: Schematic Design Wizard (simple inputs), Design Development Wizard (detailed input) and Energy Efficiency Wizard. Each wizard has extensive default inputs that are based on California Title 24 building energy code. One more option is detailed DOE-2 interface, that can be used in special cases if highest level of detailing is needed. Long-term average weather data (TMY, TMY2, TMY3, etc.) for more than one thousand North American locations are available via automatic download within eQUEST.

The eQUEST Schematic Design Wizard firstly requires general information about building design and then progressively delves deeply into details. Building description process consists of 53 data entering steps - each represented by a wizard screen that provides easy-to-understand choices of components and system options. It also offers advice in the form of "intelligent defaults" for each choice. These defaults are marked with green color and based on information gathered earlier during description process. Although the building description process can get quite detailed there is no need to complete every single step in the wizard. There is possibility to skip unnecessary steps if user is already satisfied with detailing level of model. At that point the wizard fills in missing information using eQUEST intelligent default process. In addition, eQUEST automatically skips steps that do not apply to chosen design.

After compiling description, eQUEST produces detailed simulation of created building model, as well as estimation of energy consumption. Although these results are generated quickly, they are quite accurate because eQUEST utilizes the full capabilities of DOE-2 (the latest version of a well-respected and popular building energy simulation program developed by the US DOE).
3.3. Office building
As an object for the calculations a typical office building in Miami was chosen with a total area of 5760 m². The structure is a five-story concrete building, quite simple from compositional and planning points of view in contrast with glass, high-rise, A-class office buildings. Because the office market in Miami is so congested at the moment, businesses are looking for a flexible, cost-effective solution in executive suites. The size of offices depends on a company’s needs and the industry they are in. Instant Offices are able to accommodate most inquiries, from one person through to 100 or more depending on the specifics.

![Typical office building in Miami and its model in eQUEST](image)

**Figure 7.** Typical office building in Miami and its model in eQUEST.

3.4. Simulation process in eQUEST

3.4.1. Starting point. Process starts from choosing wizard in main window of eQUEST. In our case we have chosen Schematic Design Wizard.

![Schematic Design Wizard in eQUEST](image)

**Figure 8.** Wizards in eQUEST.

3.4.2. Parameter input. Sequence of following floating windows are used to input all parameters related to the building design: location in climatic zone, geometrical size and orientation of the house, structure of envelope and its material with different options for insulation, openings percentage, HVAC systems and etc.
Figure 9. General information about two buildings with different cooling systems.

City of Miami (Florida, USA) was chosen as the location for the subsequent simulation in eQUEST, because the free database of this software includes only North American cities, and the climatic conditions of Miami are as close to the conditions of Nassau as possible. The climate conditions of Florida, USA and Bahamas are largely similar, as determined by the same geographical latitudes.

Miami has a tropical monsoon climate, with hot and humid summers and short, warm winters. Its sea-level elevation, coastal location, position just above the Tropic of Cancer, and proximity to the Gulf Stream shape its climate. With January averaging 20.7 °C (69.2 °F), winter features warm temperatures; cool air usually settles after the passage of a cold front, which produces much of the little amount of rainfall. Lows sometimes fall to or below 10 °C (50 °F), highs generally reach 21 °C (70 °F) or higher, and fail to do so on only an average of 12 days annually. Extreme temperatures range from −2.8 °C to 38 °C with the most recent freezing temperature seen at Miami International Airport being on December 25, 1989. The highest daily minimum temperature was 29 °C on August 4, 1993 (although the corresponding record for Miami Beach is 32 °C on July 17, 2001), and conversely, the lowest daily maximum temperature was 7 °C.

Figure 10. Climatic conditions of Miami.

The wet season usually begins during the month of May and continues through mid-October. During this period, temperatures are between 29 °C and 35 °C, accompanied by high humidity, though the heat is often relieved by afternoon thunderstorms or a sea breeze that develops off the Atlantic Ocean, which then allow lower temperatures, but conditions still remain very muggy. Much of the year's 1,570 mm of rainfall occurs during this period.
The purpose of this simulation is to compare amount of consumed energy by two buildings with different cooling systems but with exactly same area of 5760 m² each. An initial variant was chosen as the standard office building with DX Coils and as an alternative – same office building, but with Chilled Water Coils. The main parameter of comparing is different cooling equipment of buildings, but all other parameters must be unchanged and strictly fixed for the purity of the experiment. Despite the absence of shades and blinds on the photo, we decided to add them to the office building model, as this simple solution allows to reduce significantly the energy consumption on cooling of inner space, especially in the regions of southern latitudes with year-round active sun. Therefore, implementation of this simple passive technology is a must in modern office construction.

The model detailing process consists of fifty-three steps detailing each aspect of the building being prepared for the simulation. However, thanks to the intelligent algorithm of eQUEST there is no need to fill in each parameter manually. User only needs to choose the most critical parameters and all the rest will be completed with “intelligent default” process by wizard.

3.4.3. Specification of model. After completing the building description process in the dialog boxes, eQUEST generates a simplified model. Despite the fact that the visual appearance of generated model is quite primitive (for example in comparison with REVIT models), it has an extra broad range of physical parameters as well as a full set of engineering systems that are required for further simulation.
As we are satisfied with all characteristics of generated model we can get calculation of energy consumption by simulating building performance in eQUEST. Simulation can be started using the command Simulating Building Performance to achieve this. After a short-term calculation process, we can get a comprehensive report with all the sophisticated parameters.

4. Results and discussion

This section is devoted to the analysis of calculations obtained as a result of the simulation. Completed eQUEST simulation allow to consider quantitative information and compare the values for the two types of buildings.

4.1. Monthly Energy Consumption

Electricity consumption peak of an office building with DX Coils in August: 79240 kWh.

Electricity consumption peak of building with Chilled Water Coils house in August: 82290 kWh. Main uses of an office building: space cooling, miscellaneous equipment, area lighting.
Figure 15. Monthly energy consumption of an office building with Chilled Water Coils.

4.2. Annual Energy Consumption

Annual consumption of electricity of an office building with DX Coils: 734160 kWh. Annual consumption on space cooling: 325040 kWh. Annual consumption of electricity of an office building with Chilled Water Coils: 751830 kWh. Annual consumption on space cooling: 330440 kWh.

Figure 16. Annual energy consumption of an office building with DX Coils.

4.3. Comparison of Monthly Energy Consumption.

Comparison of the consumed amount of electricity demonstrates slight advantage of the DX Coils equipment. Usage of a cooling system with DX Coils can reduce electricity consumption by 17670 kWh on 5760 m² per year, which is anyway a benefit in monetary terms. But of course this difference is not decision making factor – such aspects as flexibility of system, its installation cost and etc. should also be considered.

5. Conclusion

This report aims to demonstrate how an eco-friendly approach to design can affect the choice of design, which in turn can lead to significant energy savings and also financial savings. The result of the simulation shows that usage of DX Coils in Miami’s conditions can reduce energy consumption by
3%. With usage of energy-efficient roof and foundation structures these percentages can increase significantly. Improved modern insulation will also give a significant increase to the overall efficiency of the building envelope. A positive effect on energy saving can be achieved by the selection of energy-efficient equipment for proper cooling of the building. With application of any combination of the abovementioned additional investments the expenses would not be ineffective. Any investment in solutions of green character (whether active or passive) will be paid back with only the payback period slightly increasing.

Dehumidification performance varies with the type of HVAC system. A basic, single-zone, constant-volume system may suffice for some applications in certain climates. But more demanding applications—particularly densely occupied spaces and humid climates—may require enhanced designs (or a different system type) to adequately manage or limit indoor humidity. If properly designed, controlled, and operated, the HVAC system can effectively dehumidify over a wide range of conditions. The key to success is careful analysis of full-load and part-load performance.

In conclusion, it is important to remember the relevance of using energy-efficient and environmentally friendly structures. They are not only beneficial personally and financially, but also by the responsibility towards society and future generations of our planet. Reducing the consumption of any resources is a highest priority in all developed countries. Therefore, proven financial feasibility of seemingly more expensive solutions and the awareness of the wider society is vital for future prosperity of humankind.

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