

## **Building Services Systems: Heating And Air Conditioning Design Approaches**

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### **ABSTRACT**

In the UK, it has been shown that 46 % of all energy demand arises from buildings and their design systems. The idea of designing a building for temperatures varying from -15°C to 35°C even if these range of temperatures might happen only once per year has become a problem for the industry. Overdesign leads to inefficiency and a waste of energy.

The design of a building depends on many aspects, such as climatic conditions, environment, and many others. Therefore, to overestimate demands and not include the most appropriate applications throughout the design process of building service system has become an issue to the sustainability of buildings.

This paper will look at an overview of the technical literature in the context of heating and air conditioning systems design. Moreover, it would provide a step by step approach of the design processes that should be taken into consideration. Finally, it would analyse two different building types, educational and office buildings, to distinguish between the different parameters and characteristics needed for the appropriate heating and air conditioning applications.

Hence, this paper aims to provide a summary, with a more realistic and accurate prediction of building service system, of how to maximise energy efficiency of such systems.

**Keywords:** Heating and air conditioning, building system, energy

### **1. INTRODUCTION**

Heating and air conditioning systems are designed in order to maintain a desired ambient condition in a space. In order to define these conditions, it is necessary to possess all the needs and functionality of the building and ensure that the correct applications are considered.

To select the most suitable system a range of criteria, such as temperature, humidity, operation cost, air movement, and life cycle assessment need to be considered to investigate how they shall affect each other through the design process. Heating and air conditioning loads normally contribute in the data process of quantitative evaluation since it narrows the

possible system choices to a minimum range of availabilities (Faber & Kell's, 2008). This is due to the specification of different building types and the impacts that these building services will have on them.

Heating and air conditioning capacity requirements will influence the building design and the approach that would be suitable for implementation. Each building design may require a different control zone to maintain their energy demand. It will also determine the services systems that can be optimised in this determinant zoning (ASHRAE 1995).

It is also important to mention that even though a specific heating and air conditioning system might be more efficient than other type, it can only be utilised if it matches a few requirements, such as the maintenance of the desired building environment and the system responds to the building without causing discomfort to people.

This paper will show the stages necessary to select and design an appropriate heating and air conditioning systems. Moreover, it will provide a technical literature survey of the most important design calculations and other requirements necessary throughout the process of building services selection. Furthermore, it will also differentiate between the design concepts of two building types and the characteristics that are needed to approach the correct system and also distinguish between its main characteristics.

## **2. SUSTAINABLE BUILDINGS**

In order to design the appropriate building systems in its most efficient way, one needs to consider sustainability issues. There is a range of strategies and elements that can be put into practise to maximise the benefits of designing heating and air conditioning systems.

### **2.1 Sustainable strategies for heating and air conditioning**

There is a range of applications in the design process of heating and air conditioning systems that can include aspects of sustainability. Among some of these (Faber & Kell's, 2008):

- Reduction of CO<sub>2</sub> emissions and energy demand: application of renewable technologies and low carbon policies as well as the utilisation of efficient equipment
- Adaption to climate change: reduction in avoidable heat gains and the possibility to adapt design systems to the future changes that might be faced due to the impact of climate needs
- Sustainable materials: provide a better life cycle assessment of the materials for the building systems
- Reduction of pollution: avoid discomfort in the indoor air

## **3. DESIGN PROCESS**

The process of building systems design requires a series of phases, which needs to take into account many design stages and requirements. In order to design the most appropriate heating

and air conditioning systems, this process has to be taken prior to the design itself. It would define the characteristics of the systems that are needed in the process of design and their functionality.

The efficiency of building services systems starts its design process by adopting some basic efficiency rules, which consists of: the avoidance of oversized systems, selection of correct pumps and fans, reduction of pressure drops that will lead to pump and fan power, and the recovery and use of waste sources of heating and cooling among others (CIBSE, 2006).

The design process is considered under the following stages:

### 3.1 Phased Design Stages

Before designing heating and air conditioning systems, a building program has to be created to define the most appropriate inputs in the design.

The program would include a range of data, such as the functionality of the building, its geometric data, materials, fabric, and site location among many others. Besides, in this design stage a range of data with regards to heating and cooling degree hours, monthly sunlight radiation, monthly wind speed and direction, and peak and average temperature would need to be considered. This will provide a better overview of the natural conditions faced in the location where the building is about to be built.

Furthermore, the phased design stages have to consider the needs in the design process for every space within a building. This means that an evaluation of indoor and outdoor air quality, ventilation, occupancy time, humidity, and the life cycle of the building would be required. It is essential to know the function of the building rooms in order to select the most suitable heating and air conditioning system. This is necessary because some areas of the building might need heating or ventilation for example. The systems need to perform its demand without affecting other areas of the building (ASHRAE, 1993).

### 3.2 Schematic Design

This is the design stage where comparisons of the range of pre-selected building systems are made. The comparison of requirements, such as the use of electrical or fuel systems, the size of piping and ducts for the application of ventilation requirements, the cost of operation, its suitability with the building function, lighting, and air quality among several others will be able to be distinguished and analysed.

### 3.3 Preliminary Design

The need to consider the local or national energy codes with regards to the building envelope and other systems, such as heating, ventilation and air conditioning (HVAC) or lightning is taken in the preliminary design process. It would ensure that all the heating and air conditioning systems requirements are in accordance to building codes. The analysis of the heat loss and heat gain, and ventilation control are defined in order to design the appropriate supply systems and the equipments needed. It would also decide on systems sizes that match with loading requirements.

### 3.4 Post Design Phase

This is the stage where testing for the selected systems would be made and analysed. It should feature requisites of equipment efficiency; systems control approaches, air quality and airflow volume and temperature (ASHRAE, 1993).

### 3.5 Design Calculations

Amongst all the design processes, calculations to select and evaluate building services heating and air condition systems are important to minimise errors in the performance of the building. Some of the most important ones concern the calculation of heat loss and heat gain calculation and also the building's fabric (CIBSE B1, 2006).

Heat loss calculation is analysed from the different temperature between the outside and inside of a building. It consists of two main heat loss elements; air movement (infiltration/ventilation) losses and the fabric losses. To minimise its effect the need of an airtight building that will benefit from internal and also from solar gains can be used in conjunction with thermal modelling to optimise the size of the heating systems' size (CIBSE B1, 2006).

Heat gain calculations need to consider the solar gains, which also depends on the orientation of buildings. Its calculation is based on the peak heat gains from ventilation, conduction and solar radiation gains.

Calculation for fabric losses considers the thermal resistance of each layer of the building construction and its internal and external surface resistance, which contribute to the U-values of the materials.

### 3.6 Building Envelope and the Design process

Heating and air conditioning systems need to be designed in conjunction with others building systems. Other systems will have an enormous effect on the performance, function, size, operating efficiency, and maintenance of heating and air conditioning systems. The building envelope can affect the HVAC system in many different ways, such as:

- Roof, floor, walls: the selection of these items can have an impact on the buildings heat loss and gain since it might affect the buildings' infiltration, solar radiation or even its thermal transmission.
- Envelope construction: it might cause humidification and dehumidification effects due to the transfer of moisture within the building spaces and the outdoors.
- Heat gain and heat loss: it might effect in the capacity of energy conversion of equipment, such as chillers and boilers and also on the size and the requirements of distribution systems such as ducts and pipes.
- Thermal mass: the choice of a strong envelope can affect the operating cycle of the heating and cooling systems since its causes thermal mass effect.

## 4. BUILDING TYPES DESIGN CONCEPTS

Buildings of many different types may be designed to be heated and air conditioned using a wide range of service systems and equipment. The choice in the implementation of a determinant system might be due to the functions needed or the purpose designed for that specific building type.

Below, two different building types are distinguished according to their main characteristics and air conditioning needs. It focuses on the design requirements necessary in order to select the appropriate building service system.

#### 4.1 Office buildings

Office buildings are normally occupied from 8am to 6pm. Its operational characteristics together with its requirements need to be considered in order to select the most functional systems for the plant. Occupancy rates play a major role in the selection of air distribution system. Offices with computing centres that might have to be operating on a 24h basis for example, will need to consider backup systems for these areas in case of failure in the central HVAC systems.

Office Buildings can be characterised for having both peripheral and interior zone spaces. Peripheral zones are the ones, which consist of variable loads due to the changing of sun position and weather conditions. During winter time, these zones require heating. Meanwhile, over intermediate seasons, it might require heating in one side of the room and cooling on the other one. On the other hand, Interior zoning demands a regular rate of cooling during all seasons since their thermal loading is generated mainly from lights, people and office equipment (ASHRAE, 1995). It will require that the interior air conditioning system allows flexibility to match all load situations. Therefore, the choice of variable air volumes (VAV) is the most required for this operation. The system should estimate if the amount of air movement and outdoor air can be matched at the required temperature without causing any overcooling (Keith Shepherd, 1999).

Lighting load in office building is of a high output to the heat load of the building. Computer centres and other electric equipment can provide loading as high as 50 to 110 W/m<sup>2</sup> (ASHRAE, 1995). From that, it is extremely important to familiarise with the electrical equipment that will be operated within the building in order to size the appropriate air handling unit for the implementation of the air conditioning system. At the zoning where electric load is higher than 65 W/m<sup>2</sup>, heat ought to be removed from the room by the use of air exhausts or water tubing (ASHRAE, 1995).

Normally, office buildings use the traditional dual duct, induction, or fan coil systems. When the induction or fan coil design is settled at the perimeter, it also uses an all air systems for the interior areas. For buildings that do not possess an economiser zone, the installation of a bypass multizone on each floor with a heating coil in each exterior zone duct is used (ASHRAE, 2000). This allows building floors with different levels of occupancy to be operated with high levels of energy saving due to its low fan power. Moreover, energy cost can also be reduced if the number of equipment room is reduced meaning it could be turned off in unoccupied areas and high pressure ductwork would not be required.

Total office building space needs are normally occupied by 8 – 10% of its gross area by the building electromechanics. The height that fan rooms require range from 3 to 5.5m since it depends on the distribution system selected. On office floors, induction or fan coil units need 3 to 5% of the floor area. Thus, pipes, ducts and other equipments will need 3 to 5% of each floor's gross area. All these elements need to be taken into consideration during the heating and air conditioning design system (CIBSE B2, 2006).

For smaller office buildings however, it might be a better choice to select a perimeter radiation system with conventional, single duct, low velocity air conditioning systems

supplying air from multizone units. For a medium sized building, air source heat pumps may be selected. Meanwhile, in larger ones, internal source heat pumps systems are possible with almost all range of air conditioning systems.

#### 4.2 Educational Buildings

To decide on the appropriate heating and air conditioning systems for educational buildings, a range of inputs needs to be considered. First of all, the need of understanding the functions of the school has to be analysed. Some organisations might differ in their educational methods and have night classes for example. Educational buildings have consistent dense occupancy when it is occupied. However, auditoriums, sporting facilities and other areas might vary its occupancy and therefore vary its amounts of ventilation and temperature required. Due to that, educational service systems need to be as flexible as possible within these rooms.

Larger external areas such as auditoriums or gymnasiums should have their own HVAC control as well as the administrative office since it normally stays open till longer periods of the day. Libraries should also consider the implementation of air conditioning as a method to prevent books from damages. Computer rooms will need additional cooling tools due to its high heat load that comes from the equipment (ASHRAE, 1995).

The choice for heating and air conditioning systems for educational buildings will depend on many things, such as if the educational building is new or existing. Besides, the type of HVAC to be considered also needs to account for seasonal periods of the year. During hot and dry climates, evaporative cooling might be the chosen type of cooling since the usage of air conditioning might not be priority for some educational buildings. However, the use of air conditioning or dehumidification tools in hot and humid environments is advised since it would prevent the formation of mould.

Since, educational building are normally not occupied during the night or over weekends and most of the time during the holiday periods, systems which incorporate night setback, hot water temperature reset and boiler optimisation are usually considered in the systems design. Setbacks tools can regulate systems to heat specific areas. After, it cools these areas down, once the spaces heat up due to the occupancy thermal loading (CIBSE B2, 2006). It saves energy by rearranging the heating and cooling environment temperature for the duration of the unoccupied period of the building.

Furthermore, the use of appropriate ventilation is a major importance when considering that it would control the air quality of the rooms and avoid odours or diseases to be spread around. Ambient air temperature should range at about 24°C [ASHRAE, 1995].

## 5. CONCLUSION

It has been shown that the design process throughout all the stages of a building is of great importance in the achievement of the most appropriate systems design. Its complexity and wide variety of systems options can make it hard to select the most appropriated one for a specific building. By following a general design concept and allow building service engineers to have an earlier input in the design process, the advantages seen will be of high magnitude.

The design process showed in this report is a general concept of how heating and air conditioning systems should be evaluated. There are others stages or methodologies that are possible to be used. The one in this report though is believed to be the most appropriate since it considers every step of the designing process.

Building types are relative challenging to define as only having one specific building service systems as a standard. Since, many building types differs from each other according to its own characteristics a general concept of what have been used in the past and that is believed to be correct and more appropriate have been shown in this report.

In conclusion, there is a huge gap in what is certain and uncertain in the design of building heating and air conditioning systems. The importance of developing modelling softwares with similar measures and output results would benefit the industry in a creating a standard approach for building types and help building service engineers in their design process.

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