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## HVAC and Facilities Management

– from know-why to know-how

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## **HVAC and Facilities Management – from know-why to know-how**

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### **Abstract**

*The purpose of this key-note paper is to set the scene for the sessions under the theme “HVAC and Facility Management” at Cold Climate HVAC 2009. The paper attempts to show the importance of implementing perspectives, considerations and methodologies related to Facilities Management (FM) when dealing with HVAC in all stages of the life cycles of buildings.*

*Compared to the traditional view on operation and maintenance (O&M) of buildings, FM must be seen as a change to a new paradigm. Where the traditional understanding of O&M takes the building as a starting point with a dominantly technical view on the physical condition, FM takes the activities in an organisation as a starting point with a dominantly management view on how the activities can be supported in an optimal way in both the short and long term.*

*The paper gives an introduction to what FM is, how it is defined in a new European standard and why it has become increasingly important. The relationships between FM and the building process are analyzed with particular focus on how considerations for FM can be integrated in the phases before occupation of buildings. Finally, the paper presents an overview of methods for procurement of FM tasks, including new forms of contracts based on partnerships and output specifications.*

*The paper is based on the authors many years of practical experience in Denmark, and since 2005 from being responsible for the development of FM as a new field of research and teaching at the Technical University of Denmark.*

**Key words:** Facilities Management, HVAC, Learning buildings, Commissioning, Procurement, Partnerships

### **INTRODUCTION**

The purpose of this key-note paper is to try to set the scene for the sessions under the theme “HVAC and Facility Management” at Cold Climate HVAC 2009. The paper attempts to show the importance of implementing perspectives, considerations and methodologies related to Facilities Management (FM) when dealing with heating, ventilation and air-conditioning in all stages of the life cycles of buildings, including briefing, design, construction, commissioning, operation, maintenance and development.

Conditions of cold climate has immense impact on the need for HVAC to create and maintain appropriate comfort levels in buildings and to control the related energy consumption compared to hot and moderate climatic conditions. However, the principles in relation to FM are not as dependent on the climatic conditions as for instance factors like location, size and type of organisation, existence of a provider market and access to supplies of energy, materials, spare parts and skills.

The paper is based on the authors many years of practical experience in Denmark, including 14 years working for DR (Danish Broadcasting Corporation), and since 2005 from being responsible for the development of FM as a new field of research and teaching at the Technical University of Denmark. This has from the beginning of 2008 included the management of a new externally funded research centre called CFM (Centre for Facilities Management – Realdania Research) and appointment as professor in December 2008. The research has mainly concerned FM in Denmark and the other Nordic Countries – Norway, Sweden, Finland and Iceland – but has also included collaboration with researchers from other European countries and around the world.

The paper is structured in three main sections. The first section gives an introduction to what FM is, how it is defined in a new European standard and why it has become increasingly important. The second section concerns the relationships between FM and the building process with particular focus on how considerations for FM can be integrated in the phases before occupation of buildings. The third section provides an overview of methods for procurement of FM tasks, including new forms of contracts based on partnerships and output specifications. Finally some conclusions are drawn.

## **FACILITIES MANAGEMENT – WHAT IS IT AND WHY?**

There are various definitions of FM. The European standard (CEN, 2006a) has the following definition of FM:

*“The integration of processes within an organisation to maintain and develop the agreed services, which support and improve the effectiveness of the primary processes”*

The standard also specifies that *Facilities Management* and *Facility Management* mean the same.

FM is often seen just as a new term for operation and maintenance (O&M) of buildings. On the contrary, FM must be seen as a change to a new paradigm. Where the traditional understanding of O&M takes the building as a starting point with a dominantly technical view on the physical condition, FM takes the activities in an organisation as a starting point with a dominantly management view on how the activities can be supported in an optimal way in both the short and long term. Buildings are means and not the ends for FM.

The distinction between primary processes and support processes is central to FM. A conceptual management model is included in the European standard as an annex, which explains that FM is the supply of facility services to support the demand of the primary activities in an organisation. The services can be provided internally and/or externally. The interaction between FM and the organisation responsible for the primary processes takes place on strategic, tactical and operational levels. The representative of the organisation on the strategic level is called the client, while the representative on the tactical level is called the customer, and the end users receives the services on the operational level.

The tasks of FM on strategic, tactical and operational levels can be described as follows (Jensen, 2008a):

- *Strategic tasks* have a long-term nature and relate to policies and strategies for development of the property portfolio and support functions in relation to the overall strategies and objectives of a corporation and structural changes in the surroundings.
- *Tactical tasks* include planning of specific changes in the property portfolio and support functions, partly to meet the long-term policies and strategies, partly with a view to adaptation to other changes within the corporation, for instance related to the current state of the market.
- *Operational tasks* include the daily operation of properties and support functions with a view to fulfil the needs of the corporation in the best way according to agreed service levels.

According to the European standard the scope of FM can be grouped around clients demands summarized under two main headings: *Space & Infrastructure* and *People and Organisation*. The demands related to *Space & Infrastructure* include accommodation, workplace, technical infrastructure, cleaning and other space & infrastructure related services, while the demands related to *People & Organisation* include health, safety and security, hospitality, ICT (Information and Communication Technology), logistics, and other support services. The distinction between the two main headings resembles the often used distinction between hard FM and soft FM.

There are a number of reasons why FM has emerged as a specific field of work and has become increasingly important with the emergence of FM as a professional discipline.

One of the important factors is the change from industrial society to information society. In the industrial society the factory building was the settings of the main activities. The operation of the factory buildings were closely connected to the demands which the production activities made, and it was often managed by the same persons who handled the production management. Concurrently with the increasing automation of the industrial production the number of employees in the physical production process was gradually reduced. Instead a gradual increase in the number of employees in for instance development, sales and economy departments took place, with office workplaces in administration buildings et cetera. At the same time a large number of new service companies

emerged, for instance within finance, marketing, counselling, media et cetera, where the work mainly was office based.

With the transition to the information society, office work changed from including a few trusted employees to include mass workplaces. With the increase of the office work the need for internal support functions also increased, such as reception, telephone exchange, mail distribution, printing, cleaning and supply of equipment and office supply. The property operation became more independent in relation to the activities in the building than at the industrial production.

Concurrently with the above mentioned development, which in most industrialised countries mainly occurred in the 1960'ies and the 1970'ies, an increase in the public administration took place together with the development of the welfare society, just as the areas of education, the social sector and the health sector also expanded heavily. In all areas the development entailed a heavy growth of the number of buildings to accommodate all new functions and workplaces. With the many new public buildings followed increased costs for property operation and support functions. After the 1970'ies the growth has changed into stagnation and pressure on the budgets to keep the tax burden down. Hence there is an increased focus on the possibilities to cut down on property operation and support functions to continuously be able to meet the demands to the core functions. Outsourcing of support functions has been one of the most frequently used means, and this development has been increased by EU legislation.

Throughout the 1960'ies the building industry became partly industrialised in many countries with the implementation of new ways of construction and a great variety of new materials. This development focused on quantity more than quality, and the long-term operational considerations were mostly ignored. The high growth of the number of buildings in itself implied that more people were involved in property operation. The increased problems with many buildings due to construction errors and bad quality implied increased demands to the qualifications of the persons who were involved in the property management.

With the energy crisis in the 1970'ies a rude awakening took place in connection with the galloping growth of production and consumption. The demands to the construction industry as to the heat insulation were strongly increased, and the awareness of the use of resources in connection with production, new building and building operation were slowly increased. At first this involved the energy area, but for instance the Brundtland report's emphasis on the need of a sustainable development has pushed the "green wave" with a more wide environmental perspective and recently the world climate has become a major global issue. With implementation of an environmentally friendly building design in connection within new buildings and environmental management, energy management and green accounts within existing buildings, environmental considerations have been part of everyday life in many companies, and today it represents a significant element of FM.

The increasing globalisation, which for instance is driven by new world trade agreements, rapid international capital movements supported by new communication technologies and

growth in the number and size of multinational companies, has implied that many companies witness a higher level of competition. In Europe the disintegration of the borders between East and West Europe, and also implementation of EU's internal market has supported this development. The answer to this challenge has from many management gurus and corporate managers been to concentrate on the core business of the companies, and to reduce or outsource the secondary functions.

The most important aspects in connection with the changes in office work and the development of FM is undoubtedly the effects of implementation of various forms of IT. Even if the IT development has a long story – the first punched card machines was for instance introduced in the 1950'ies – it is during the last 15-20 years that IT really has led to fundamental and wide spread changes of office work. Today the computer is taken as granted as a tool for everybody, but only 20 years back it was in most offices primarily secretaries and a few other employees who worked at computer terminals.

Initially the computer was mostly a replacement for the typewriter for text processing and was also used to search for data on a few central databases, but after the introduction of the internet the computer has become a highly efficient work and communication tool in practically all office based workplaces, and offices in private homes has become a common alternative, or perhaps rather a supplement for many people. And with the constant improvements of the mobile systems the fixation of the information work to the office as a physical workplace has been significantly reduced.

The consequences of the IT development are many-sided and of crucial importance to most companies. Under the headline Business Process Re-engineering (BRP) many companies have reorganised their work processes, and this has to a great extent occurred on the basis of the new possibilities which the IT development implies. A central part of BRP is definition of the company core business; hence also definition of the support functions.

In relation to the office work, introduction of new ways of working has accordingly been based on the possibilities which the IT development offers. Economically the IT development implies that the investments in establishment of office workplaces are higher than before, but IT also gives great possibilities to streamline and rationalise the office work. In both cases it gives FM an important role as to the development of the company. Furthermore the IT development offers a series of useful tools to FM.

Most of the conditions which are described above have helped to give the FM functions an increased importance as to work and economy. Next to staff salary, the FM costs are the highest expenditure in many companies. The FM costs are normally 15-30% of a company's total costs.

As the office has become a mass workplace and the increased attention in general on health and safety, the office environment has become an object of increased demands. This especially concerns indoor climate and ergonomics, where the increased introduction of IT has caused increased heat strain, screen radiation and changed work postures.

But also not specific work related conditions such as sport facilities and child care centre connected to the workplace has become of increased importance. In the companies' fight in attracting and maintaining highly qualified manpower such aspects of the FM function are important to the development of the company.

## **FACILITIES MANAGEMENT AND THE BUILDING PROCESS**

FM has focus on creating optimal physical surroundings for the activities in organisations and thereby the use aspects of buildings. This also means that FM is not only concerned with existing buildings and their operation, maintenance and adaptation during use. Development on new buildings gives the greatest possibilities to create optimal physical surroundings and for facilities managers it is essential to influence decisions and requirements in relation to new building projects. One of the problems in the building industry is a lack of learning from existing buildings in the planning of new buildings and FM can be regarded as the missing link in establishing this learning circle. Development of professional FM can bridge the gap between building operation and building design.

The most important FM-specific tasks in building planning can be identified as transfer of experiences from existing buildings, integration of considerations for operation and sustainability, requirements for documentation about the new building, considerations for user needs, planning and organisation of the coming building operation, and interior and move planning. This can be further specified in relation to the different phases of a building project as shown in Table 1.

<b>Building project phase</b>	<b>FM-specific tasks</b>
Decision	Incorporating real estate strategies Information on space needs etc. Estimation of impacts on cost of FM
Briefing	Organisation of user involvement Formulation of considerations for operation and sustainability Overall requirements for documentation
Design	Incorporation of considerations for operation, sustainability and user needs Formulation of operational concept Formulation of requirements for building automation system
Construction	Interior planning Prepare commissioning Contracting-out operational tasks
Occupation	Move Handling former building(s) Implementation of operational procedures

Table 1: FM-specific tasks in building project phases (Jensen, 2008c)

The most important task in table 1 in relation to design is the incorporation of consideration for operation, sustainability and user needs. The consideration for user needs involves user involvement and follow-up on the building brief during design (Jensen, 2006). A particular form of user needs is accessibility for the disabled and other users with special needs (Jensen, 2005). The considerations for operation and sustainability include a vast number of aspects related to the whole life cycle of the building after construction. Among the most important are:

- Flexibility and adaptability in relation to changing needs over time
- Logistics in relation to internal communication, transport and distribution
- Ease of maintaining and cleaning the building and the surrounding areas
- Possibilities to replace and reuse building parts
- Safety and security of the building, persons and assets
- Energy and resource consumption (electricity, heating, cooling, water etc.)
- Environmental impact on the surroundings (pollution, noise, dirt)
- Indoor climate and working conditions
- Building management systems and installations

One of the interesting concepts in this context is *learning buildings*. This concept was introduced by the American author Stewart Brand in his book: *How Buildings Learn – What Happens after they are Built?* (Brand, 1994). The concept has been further developed in the British Learning Building Group. This group defined a learning building as one that adds value and is timeless, through taking a holistic view on its design, production, and procurement processes as well as the needs of its lifetime occupants. Learning buildings possess the following key characteristics (McGregor and Then, 1999):

1. Adaptability - Ensuring the environment, both internal and external, can be configured and re-configured to suit different building users, their changing needs, work processes and layouts
2. Capability - Providing the potential to introduce, replace and change building elements, services and systems throughout any user's occupancy of the building and the building's life time
3. Compatability - Ensuring that all aspects of the building are wholly coordinated and integrated, and none are selected or installed without their impact upon, and the influences from, all other elements being considered
4. Controllability - Providing users with the means to maximize their use and operation of the building, its services and facilities, while minimizing the conflicts between corporate and individual values
5. Sustainability - To ensure that the building and its facilities as 'assets' are operated and maintained to enhance individual and corporate productivity, their health and well being at all times, and environmental responsibility throughout the entire life of the building

BIFM (British Institute of Facilities Management) is by far the largest national FM-association in Europe and around year 2000 they commissioned a project to the Building



Research Establishment (BRE) about bringing facilities expertise into the design process. This resulted in a report which analyzed why and when the facilities manager should be involved and contribute to the design process and why the facilities manager often is excluded from the design process (Jaunzens, 2001). The barriers for the involvement of the facilities managers were identified as a combination of the perception of the facilities managers within their own organisation and within the design team as well as the facilities manager's self-perception. The main problem seemed to be that facilities managers in general are not sufficiently qualified to be capable of and accepted as an equal dialogue partner in the design process. The report finishes with the description of a development plan for the facilities manager including recommendation for how to become empowered and a presentation of a self-assessment tool. In general the report expressed the viewpoint that the problem of facilities manager's limited contribution to the design process is related to a lack of the necessary competences and prestige.

This shows that it is important to increase the competence level of facilities managers, but it is at the same time necessary to increase the competences of designers in relation to take FM considerations into account. Involvement of consultants specialized in FM as adviser to the building client can be an appropriate solution if the FM organisation does not have the necessary competences or capacity to be involved in planning of building projects.

One of the areas of particular importance in relation to HVAC is commissioning. This is a relatively new area in relation to building projects, but it has been common practice in connection to the delivery of technically complex process industry plants, for instance in the chemical industry and off-shore industry. There has recently been a comprehensive international research undertaken by a working group (Annex 40) on Commissioning of Building HVAC Systems for Improved Energy Performance under the International Energy Agency.

Commissioning is usually seen as the activities that take place to optimize and document the operation of technical system in relation to the handover from the contractor to the building client prior to occupation of a building. The Annex 40 working group gives a wider definition (Visier, 2004):

*“Commissioning is a documented way to diagnose and verify building systems performance, and to propose ways to improve the performance in compliance with owner's or occupant's requests. Commissioning is performed in order to keep the system in optimal condition through the life of the building from viewpoints of environment, energy and facility usage.*

*The commissioning begins with pre-design phase and can be applied through life of building including all phases, which are pre-design, design, elaboration, construction and operation and occupancy phases.”*

Furthermore, commissioning is differentiated in the following types: Initial commissioning, retro-commissioning, re-commissioning and on-going commissioning. Initial com-

commissioning can concern new buildings or installing new equipment in an existing building. It begins with program phase and ends with post-acceptance phase. Retro-commissioning means the first time commissioning is being implemented in a building in which a documented commissioning was not implemented before. Re-commissioning occurs when building owners hope to verify, improve and document performance of a building system that has already had initial commissioning or retro-commissioning implemented in the past. Periodic re-commissioning can take place and the difference to on-going commissioning is, that re-commissioning refers to the original building system performance, while on-going commissioning lay emphasis on the performance optimization.

Besides definitions, methods and recommendations on commissioning the final report from the Annex 40 work group includes 27 case studies from 12 countries around the world, including countries with cold climate like Canada, Norway, Sweden and Finland, see [www.commissioning-hvac.org](http://www.commissioning-hvac.org).

ASHRAE (American Society of Heating, Refrigeration and Air-Conditioning Engineers), has published a guideline to the commissioning process in English (ASHRAE, 2005), and the Finnish research institute VTT has published a guidebook for life-cycle commissioning of buildings' energy efficiency and indoor climate – but in Finnish (Pietiläinen, 2007).

## **PROCUREMENT METHODS IN FACILITIES MANAGEMENT**

One of the big issues in FM is sourcing and for some outsourcing is a defining aspect of FM. Outsourcing is without doubt the most discussed and contentious topic with relation to FM. This is not at least related to the public field, where the debate can be highly politicised. At the same time outsourcing is obviously the tool which has led to the highest and fastest direct economical savings. To the creation of a market for FM services and establishment and development of provider companies, outsourcing has had a crucial importance.

Outsourcing is a general term to various concepts, which all concern external provision of services. Outsourcing is a term of the process through which services are changed from being carried out in-house into being provided by an external provider. Outsourcing is furthermore considered being an organisational tool in relation to management of FM functions. Most FM organisation is characterized by a mixture of internal and external provision of services and in general it is mostly operational tasks that are outsourced.

The degree of outsourcing of FM varies a lot from country to country and between the different FM services. In the Nordic countries the degree of outsourcing was estimated as 25% of the potential market in 2004 (Capgemini, 2005). In countries like the UK and the Netherlands the degree of outsourcing is much higher. In the Netherlands it was estimated as 58% in 2006 (Twynstra Gudde, 2007).

There are number of legal regulations of importance in relation to outsourcing. One of the most important of these concerns the protection of employment in the transfer of employees from one company to another. This is in legal terms labelled *Transfer of undertakings*. In the EU it is based on an EU directive, so there are similar legislations in all EU countries. In accordance with the transfer of undertakings regulation, a provider who takes ownership of a company – or a part of a company - must enter the rights and duties which were present at the time of the takeover. This also implies, that employees who are employed within a work field in a company which is subject to outsourcing must be offered employment in the company which in the future will manage the work field in question. The employees are for a period ensured the same terms of employment and salary as before the outsourcing. The conditions for pensions are often a very important issue in relation to outsourcing and transfer of employment.

In the public sector there are particular rules which are of importance in relation to outsourcing. In the EU, the regulation is based on an EU directive from 2006 (The Community Directive 2004/18/EC on procurement of public works, supplies and services). The regulation is based on principles of equal treatment, non-discrimination, transparency, proportionality and mutual recognition. The directive is implemented into national legislation in all the member countries. Besides there can be other national legislation that regulates aspects of outsourcing in each countries.

A difference between FM contracts for public and private clients is that public clients in general always have to be limited for a number of years – in the EU maximum 5 years in most cases – while private clients do not need to have time limited contracts. There are a number of different methods for contracting used in FM and there is rapid development of new types of contracts. There is a European standard with guidance on how to prepare FM agreements, which includes a number of recommendations for what needs to be considered in making contracts (CEN, 2006b).

The traditional way is to make contracts for each service, which is also called outtasking or classic procurement. This usually has a clear focus on price competition and the client has to make a detailed specification of the task to make sure that bids are comparable.

Another traditional method is to make a frame contract with a provider. With this type of contract the single tasks are not described in details beforehand but the hourly rates and procedures to order the individual task are specified.

This method can be developed in very rational and systematic ways. An example of this is from maintenance in the Danish pharmaceutical company Lundbeck. They have made frame contracts with a number of contractors and consultants, and the hourly rates are renegotiated every year with each provider. The contracts are managed by an IT system in Lundbeck which all provider have access to. Each task is ordered by a job order in the IT system including estimated time. The provider is obliged to report the number of hours used by each employee working for Lundbeck on a daily basis. The providers' staff has access to state-of-the-art offices, workshops and staff facilities like canteen, showers and cloak rooms at Lundbeck's premises on equal terms as directly employed staff. Further-

more, the providers have to use Lundbeck's internal store for spare parts unless a specific other agreement is made. Via the IT system Lundbeck always has an up to date overview of the spending and each month Lundbeck send each provider an overview of their own reporting to be used as the basis for invoicing (Madsen, 2008).

The trend in FM procurement is going towards more bundled contracts and collaboration based on partnerships between clients and providers. Particularly in municipalities we have in recent years had several examples of operational partnerships in Denmark, where a private provider takes on the responsibility for all O&M of a number of public buildings for a period of 3-5 years. The contract is based on a frame agreement with fixed hourly rates and fixed overhead on material cost or similar, together with a partnership agreement with common goals, objectives, rules and incentives for the collaboration. The actual maintenance tasks are planned and decided together in close collaboration between the client, provider and the users of the buildings. One of the benefits is that the tasks are planned together, so that the providers' production capacity can be utilized optimally. Among the pioneers in this development is Copenhagen Property, who have arranged several such operational partnership with positive results, including 20% more maintenance work for the same cost (Jensen et al, 2008b, pp. 187-194).

Another type of contracting of bundled FM services is function based procurement, where a provider takes on the responsibility of all O&M of a number of buildings for a fixed price. The precondition for this is that the client has specified the service levels as output requirement instead of input requirement. Input requirements mean specification of the resources and activities to be provided, while output requirements mean specifying the expected normal condition and time to react and complete repairs in case the normal condition is disturbed. This involves transfer of risk from the client to the provider, but it also gives the provider real incentives to optimize his service. The pioneer in Denmark in function based procurement of FM is the pharmaceutical corporation Novo Nordic, who has made great savings by this method. The method is best suited to uncomplicated buildings like offices (Jensen et al, 2008b pp.195-199).

If the bundling of services is increasing to include all or most FM services it is often called Integrated FM (I-FM) or Total FM (TFM). There are a number of examples of these kinds of contracts, particular among multinational companies as clients, who increasingly make cross-border contracts with multinational operating FM providers. However, the market for I-FM is very much consolidated with a small number of potential providers and therefore the competition is limited. In the Nordic Countries the market for I-FM is dominated by ISS, Core Service Management and Johnson Controls.

Public-Private Partnerships (PPP) is another type of collaboration which combines the delivery of a building project and the FM services over a long period of time. There are many variations of PPP. The private part is usually responsible for design, construction, financing and operation of the building. The number of FM services can be restricted to hard FM, but it can also include various soft FM services. The private part is typically organized as a consortium (Special Purpose Vehicle) including a contractor, a FM provider and an investor. The contract period is often 25-35 years, if the private part is re-

sponsible for financing and owning the building. After the contract period, the ownership can be transferred to the public part, or the ownership can stay with the private part. If the public part is responsible for financing and ownership, the contract period is often shorter, for instance 15 years (Jensen et al 2008b, pp. 135-151).

The benefit of PPP from a FM perspective is that it, to a higher degree than traditionally organized building projects, gives incentives to take FM considerations into account during design and construction and the involvement of a FM provider in the consortium from the start gives a stronger position for FM in the decision process. One of the challenges for the public part is that the requirements both for the building and the FM services have to be described as output specifications. However, the experiences with PPP are still fairly limited - at least in Denmark.

## CONCLUSIONS

The purpose of this key-note paper has been to set the scene for the sessions under the theme "HVAC and Facility Management" at Cold Climate HVAC 2009. The paper shows the importance of implementing perspectives, considerations and methodologies related to Facilities Management (FM) when dealing with heating, ventilation and air-conditioning in all stages of the life cycles of buildings.

FM is often seen just as a new term for operation and maintenance (O&M) of buildings. On the contrary, FM must be seen as a change to a new paradigm. Where the traditional understanding of O&M takes the building as a starting point with a dominantly technical view on the physical condition, FM takes the activities in an organisation as a starting point with a dominantly management view on how the activities can be supported in an optimal way in both the short and long term.

The first section introduced FM based on the definition in the European standards from 2006 and explained that FM has become increasingly important because of the change from industrial society to information society and the development in office work, IT, cost of building operation, sustainability, staff requirements etc. The relationships between FM and the building process were analyzed with particular focus on how considerations for FM can be integrated in the phases before occupation of buildings. The concept of learning buildings was introduced and the importance of commissioning in relation to HVAC and FM was emphasized. Finally an overview of methods for procurement of FM tasks was presented including trends towards procurement bundled rather than single services and new forms of contracts based on partnerships and output specifications.

Conditions of cold climate has immense impact on the need for HVAC to create and maintain appropriate comfort levels in buildings and to control the related energy consumption compared to hot and moderate climatic conditions. However, the principles in relation to FM are not as dependent on the climatic conditions as for instance factors like

location, size and type of organisation, existence of a provider market and access to supplies of energy, materials, spare parts and skills.

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