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St Mary's Street Project

Introduction

"Urbanization trends Over 50 per cent of the world's population now lives in urban areas, and much of the future growth of the world's population will take place in cities". (Keirstead and Shah, 2013)

As the St Mary's Street construction project takes shape the focus now turns to the design and installation of services within the building. In order to achieve as many of the construction and environmental targets as possible, design and installation of services needs to be explored in depth. The procurement cost to purchase specific services may be a significant factor within overall budgets but can be much lower down the agenda in terms of meeting the wider range of requirements. Decarbonisation, ecologically friendly, zero carbon emissions, and almost non-existent embodied energy is what is foremost on most agendas, none moreso than new buildings. The UK is one of the world leaders in pushing the political agenda by recognising and acting on the impact and threat of climate change and passed the Climate Change Act in 2008. This piece of legislation has been used worldwide as a model to shape the future and reduce greenhouse gas emissions globally.

As the UK made its bold statement in 2008 about reducing the production of greenhouse gas emissions by a staggering 80% by 2050, such a figure many cynics would think unachievable in such a short timescale, however, in 2020 just 12 years later the figures appear to have surpassed resulting in a significant achievement. Legislating these targets in Central Government for the country as a whole to achieve, the work is then passed to each and every local authority, businesses and individuals to play their own part in ensuring the targets are met. (Clean Growth Strategy, 2018)

The UK is well known for its advanced thinking in terms of climate change and, as a result, has been chosen to host the next major United Nations (UN) climate change summit Conference of Parties – (COP -26). The UK were to co-host with Italy in Nov 2020 however, due to covid-19 restrictions, this has been postponed until Nov 2021. Heads of state will come together with experts on climate change to discuss and

coordinate the best course of action to ensure the reduction of greenhouse gases are continuously reduced. (Gov UK, 2020)

As updated information is disseminated, local government set targets they too must meet in order for the overall strategy of the country to achieve its targets. These are followed by strategic planning and developing local plans that all contribute to the bigger picture and greater cause.

Energy use and the ambitious shift to 'clean heating' targets announced by the Prime Minister in 2018 as part of the 'Green Growth Grand Challenge' to ensure energy use in all new buildings is halved by 2030', will require collaborative working as a necessity. (A Future Framework for Heat in Buildings: Gov Response, 2018).

The Renewable Heat Incentive, 2011 (RHI) financially supports low-carbon heat technologies in homes and businesses across the UK. £4.5 billion has been made available for systems such as heat pumps, biomass boilers and solar water heaters, moving towards the scaling down and eventual move away from all heating by fossil fuel. (A future framework for heating in buildings, Gov response, 2018)

As developers and consumers play the biggest role in use of power and subsequent heat it is important that both parties fully understand their roles. For the developers the cost of purchase and installation will always be a factor when choosing which heating system should be used. Government help in terms of providing a framework for developers to work within will allow some flexibility to the decarbonisation agenda. However, what can be fairly inexpensive to install does not always reflect in the maintenance or running costs for the consumer. Therefore, it is paramount that the two work together to ensure both sides of the equation are equal. It is clear from the literature available that no one solution fits all. Affordability is a sticking point therefore information needs to be made available on affordability and running costs to all parties.

As the country strives to move away from its use of fossil fuels and its commitment to end its unabated coal generation by 2025, the future does appear to be electric. A cleaner healthier environment can be achieved by cutting carbon and emissions, our air quality improves and with that diseases like asthma will also improve, increasing quality of life for many consumers. By increasing investments that help drive down

the cost of technologies, benefits of decarbonisation within the power sector become clearer. (A future framework for heating in buildings, Gov response, 2018)

In a response to Government Spending Review 2020, CIBSE stated that to support Infrastructure the government needs to

"Incentivise offsite manufacturing for new projects". (30 September 2020 CIBSE News)

Whereas in terms of their support for energy change they should be looking to "Invest, at the scale needed to trigger transformational change, in low carbon heat technologies. (30 September 2020 CIBSE News)

In order to achieve the CIBSE statement the whole country's best efforts would be required, to scale up the production of electricity use, develop technologies to enhance the uptake, increasing manufacturing for worldwide production would ensure that the UK is a market leader when it comes to all things electrical. It is important to consider fully the natural elements around our shores that can be harnessed to provide the cleaner power that will undoubtedly boost the country's economy. By Central Government financially supporting initiatives through legislation and frameworks this can be done in a controlled and sustainable way.

As local government rises to the challenge of also meeting these ambitious challenges, they too must develop a plan that is controlled to ensure its own levels of sustainability. Cardiff City Council have an existing 15-year plan that was developed in 2006 and runs until 2021, however, work on the next Local Development Plan will have been continuous throughout the term of the existing. In their response, Cardiff City Council confirmed their own commitment to helping the over-arching strategic aim of the UK as whole.

As part of the planning proposals, the council stated they would actively encourage developers of major and strategic sites to incorporate schemes which generate energy from renewable sources and low carbon technologies. As part of planning applications, opportunities to minimise carbon emissions particularly associated with heating, cooling and power systems for new developments will be looked upon

favourably. Within the local plan the council also encourages independent energy assessments, investigating the financial viability and technical feasibility of incorporating such schemes to support applications (Cardiff city Council LDP, 2006-2021)

> *"Development proposals are required to maximise the potential for renewable energy".* (Cardiff City Council LDP, 2006-2021)

Therefore, it is important to recognise the level of detail that must be included with the proposal of all heating systems considered for the new build at St Mary's Street to ensure that services, power systems, materials and fabric choices are done so following the criterion laid out:

- Sustainability
- Whole life cycle and recyclability
- Efficiencies – Greenhouse emissions, decarbonisation, zero carbon
- Installation, maintenance and replacement costs
- Longevity of components and ease of change
- Future proofing

As construction is a large contributor to the production of greenhouse gases, carbon emissions and pollution, it is crucial that wherever possible, Building Research Establishment Environmental Assessment Method (BREEAM) is introduced at the earliest stages, not only for new building but refurbishment and retrofit. The framework/criterion used throughout the BREEAM system and its processes are holistic in its all-encompassing assessments. To identify a BREEAM assessor at the very inception of an idea can provide the cohesive glue of collaborative working. The process is extremely detailed and calls for all parties to contribute to the overall aim of gaining the very best award possible given the constrains and limitations of the project. The system has 9 main categories it assesses against with a final category for innovation able to boost the overall score. A score of 85+ will give the excellence award, many buildings being able to attain this when the environment is at the very heart of the project.

Project – Proposal

Cardiff Local Development Plan states the co-location of high density and mixed-use development can present significant opportunities for utilising renewable and low carbon technologies, including energy supply systems. Major development sites and identified strategic sites will play a key part in shaping the future development within Cardiff and play a substantial role in the city meeting its renewable energy targets as identified in the Renewable Energy Assessment (REA). Particular attention will be given to developments of more than a 100 domestic dwellings or commercial properties/developments of more than 1,000m^2 (Cardiff LDP 2006-2021)

The project building is essentially in several parts and zones as it provides a multi-functional service to its users and occupiers, all requiring something slightly different. Ensuring the correct services are installed to meet all these needs will be a challenge, making the wrong choice could prove expensive. Not only do systems need to meet all the current requirements in terms of British Standards but need to be financially viable in terms of their longevity and user costs.

As part of a team on this project, I have been asked to complete 3 tasks relating to the installation of services including HVAC and lighting, building fabric and equipment choices, giving a clear explanation as to how they will operate within the building, the level of maintenance required, how they differ in their operations within different sections/zones, and if they can offer cost savings in terms of energy. Finally, to critically appraised the building fabric and equipment choices in terms of design and installation practice in the context of sustainable futures, low carbon and energy costs. There is often a wide and complex agenda to meet when a project of this size is considered with months of preparatory work taking place prior to planning permission being sought so, trying to balance priorities can be difficult.

Not all British Standards originate from the UK, quite often standards will be developed internationally then modified to meet the needs of the UK. Some standards, therefore, are identified by International Standardisation of Organisation (ISO) or European Standards (EN) which is an indication they originated either internationally or via the European agenda. If standards are not suitable for use in the UK, they will be modified by the British Standards Institution (BSI) established in 1901 as the Engineering Standards Committee and published with the ‘BS’ letters followed by the initials

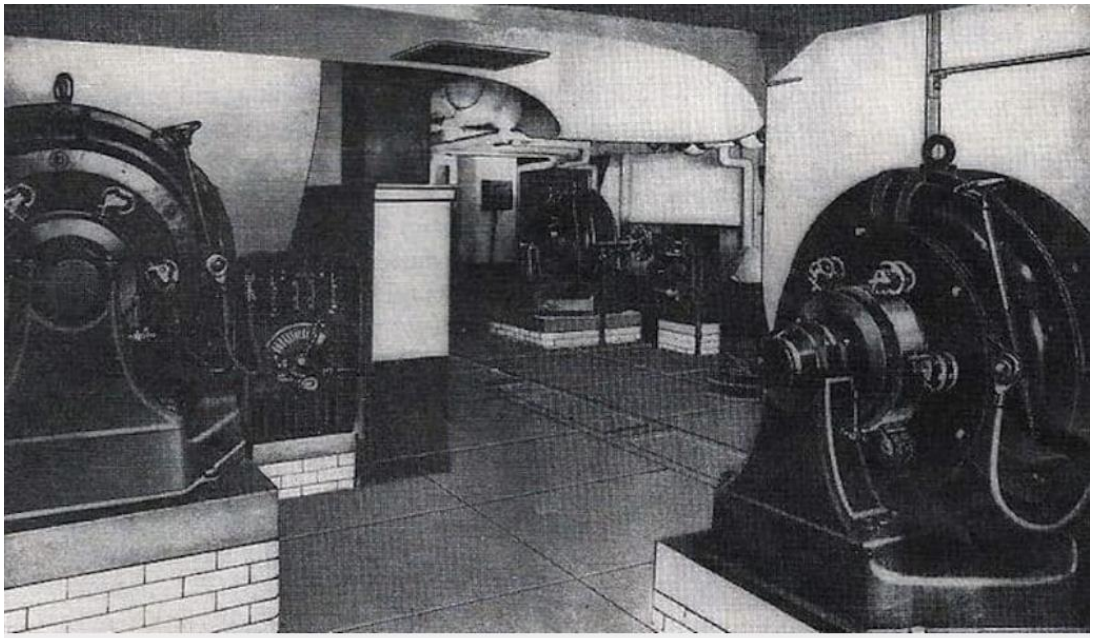
identifying region. Some of the following service selections have originally been developed in other parts of the world or Europe resulting in being modified to (BS) and there use in the UK.

The first service system to be examined is a heating, ventilation, and air conditioning system to service the building as a whole and its multiple uses.

HVAC Technologies and Installations

Traditional Air Conditioner

First invented by a 26yr old American Willis Carrier 1902, to solve the issue of humidity in a publishing company by allowing the ink to dry quicker and stop the paper expanding in the moist environment. The system was first used in an office-based environment at the New York stock exchange in 1903. The system designed by Alfred R. Wolff, used three ammonia-absorption machines, each of which had a cooling capability equivalent to a hundred and fifty tons of ice. Like most early prototypes the machines were huge and noisy and took up large areas. As systems are further developed, they become more compact requiring less space.



Stock Exchange Basement with Sturtevant fans driven by DC electric motors

Figure 1: The history of Air Conditioning (Kimpton.co.uk, 2018)

Air handling units are designed to move internal air around a building by pumping fresh air into a space via a ducting system and extracting stale air in the same way.

Mechanical systems are used when the area it serves is not able to or be adequately ventilated by natural methods.

Air handling units take fresh air from outside the building via a vent, normally situated on the building where the best prevailing wind is considered to be. The air enters the unit and goes through a series of filters that either heat or cool the air before passing through the fan and a plenum box that balances the air before passing to the diffusers and pumped to the necessary spaces through ducting. As the air circulates in the area the stale air will be extracted via a vent and back through ducting to the air handling unit to go through a similar process, either recycled with fresh air to circulate again or extracted out of the building. Recycling some of the stale air helps reduce the amount of air conditioning used.

> *"Guidance on recirculated air in air-conditioning and mechanical ventilation systems is given in HSE document L24 Workplace health, safety and welfare, Workplace (Health, Safety and Welfare) Regulations 1992, Approved Code of Practice and guidance (paragraph 32)".* (BR approved document F, 2010)

Room	Extract rate
Rooms containing printers and photocopiers in substantial use (greater than 30 minutes per hour).	Air extract rate of 20 l/s per machine during use. Note that, if the operators are in the room continuously, use the greater of the ***extract*** and ***whole building ventilation*** rates.
Office ***sanitary accommodation*** and washrooms	***Intermittent*** air extract rate of: 15 l/s per shower/bath 6 l/s per WC/urinal
Food and beverage preparation areas (not commercial kitchens)	***Intermittent*** air extract rate of: 15 l/s with microwave and beverages only 30 l/s adjacent to the hob with cooker(s) 60 l/s elsewhere with cooker(s) All to operate while food and beverage preparation is in progress
Specialist buildings/spaces (e.g. commercial kitchens, sports centres)	See Table 6.3

Figure 2: Building Regulations Approved Document F, 2010

Sports centres (inc. swimming pools) CIBSE Guide B:2005, Section 2.3.21

> *'Ventilation of car parks are covered within sections 6.18 to 6.21 of the approved document (F) Further guidance can be found in Code of practice for ground floor, multi-storey and underground car parks published by the Association for Petroleum and Explosives Administration (www.apea.org.uk); CIBSE Guide B:2005, Section 2.3.23.3; and Health and Safety Publication EH40'* (BR approved doc F, 2010)

Traditional HVAC systems use a refrigerant liquid as part of the chilling process and, as this liquid can be harmful, 'leak checks' should be carried out during routine maintenance. Some systems have replaced the refrigerant with saline water so guidance should be sought in terms of legionella contamination produced by the Health and Safety Executive (HSE), Legionnaires' Disease. The document gives guidance on the control of legionella bacteria in water systems in paragraphs 79-144. (BR Approved Doc F, 2010)

When calculating how much fresh air is required for each space a number of factors are taken into consideration, dependant on the area being assessed by the m^2, occupancy level and activity undertaken are all considered. The average adult inhales between 0.10 - 0.12 litres of air per second and exhales 3-4% carbon dioxide, a sedentary person produces approximately 59g of water vapour per hour. (BBC Bitesize, 2020) Total fresh air flowrate for a room is given by the flowrate per person multiplied by the number of occupants in the area based on 10l/s m^2 Minimum ventilation rate should be not less than 0.3 l/s per m^2 internal floor area, this calculation increases dependant on the activity and the space it is used for, for example washrooms and kitchens, the air exchange rates are more frequent due to the amount of contaminants present. (CIBSE, 2011)

All mechanical air handling or HVAC systems are required in their operations to provide heating or cooling consistent with the current guidelines and meet the Building Regulations stated above. Maintenance should also conform with the guidance and legal requirements for all aspects of cleaning and maintenance undertaken. Since their invention, the use of air handing units has become very popular, especially now both heating and cooling processes can be achieved. A system that can provide heat during cold months and cooled air during hot weather has increased in popularity and

used as a means of ventilating complex buildings. However, older style systems powered using fossil fuels have seen a decline in popularity as more is understood about the environmental impact of fossil fuels.

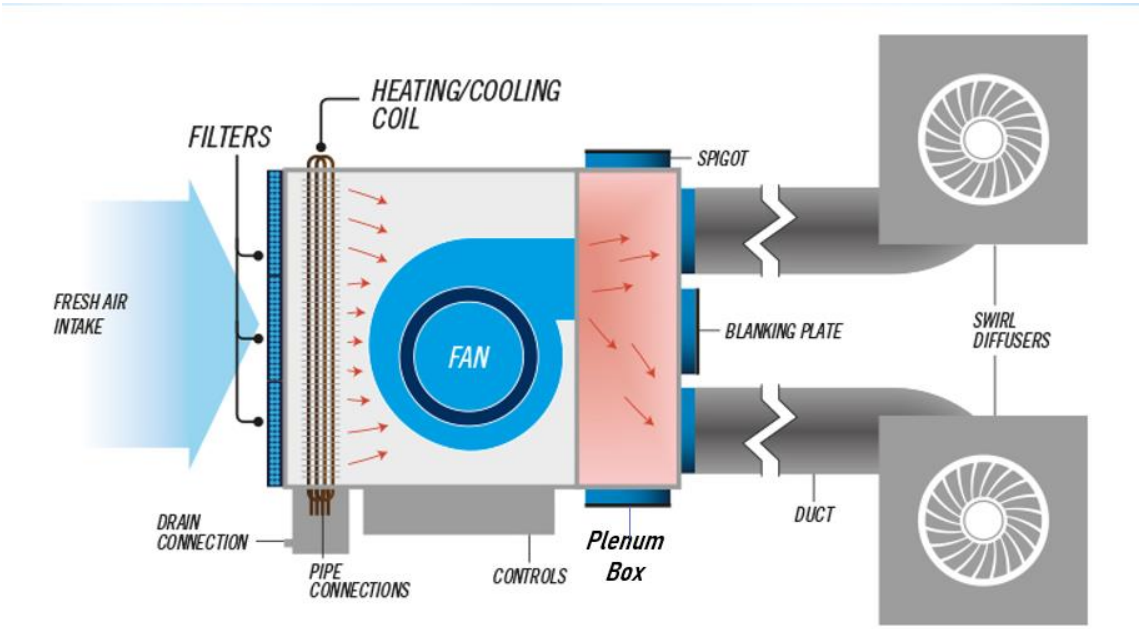


Figure 3: Traditional HVAC system: Indoor Air Quality, (Natel, 2020)

Figure 4: Roof mounted Air Handling Unit (AHU) Indoor Air Quality, (Natel, 2020)

Even with advances in technology and design, HVAC systems are still extremely bulky, requiring extensive service design within a building that requires additional ceiling heights or raised floor levels. Ducting can be noisy as the large cylindrical tubes tend to vibrate, so require extensive insulation, fire protection and dampers,

adding to overall material costs. Maintenance of the ducting including cleaning access for the purpose of replacing filters, fans, and coils, is essential therefore, additional consideration about access points must be a focus during design of the system. Guidance is given in Building Regulations part F as to the minimum dimensions of service points.

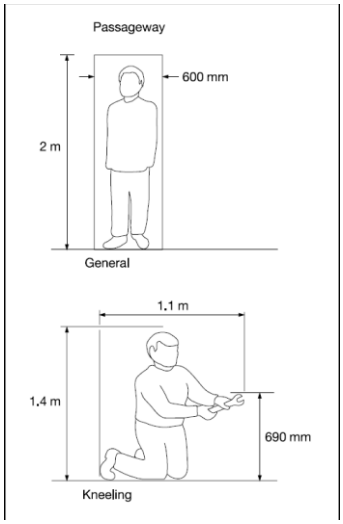


Figure 5: Ventilation maintenance spaces: BR Approved Document F

Figure 6: HVAC system, Siderise.com, 2020

New Hybrid VRF

The more modern air handling and heating systems have been available for over thirty years. Variable Refrigerant Flow (VRF) or also known as Variable Refrigerant Volume (VRV) systems are much ‘cleaner’ as they are powered in their entirety by electricity. Invented in 1982 by the Japanese company Daikin Industries Ltd, the systems can provide simultaneous heating and cooling, responding rapidly to changes in building load during periods of heavy demand. The system also works without the need for

ducts, therefore reduction in height of rooms and materials have a positive impact on the overall build cost. The (VRF) system can support multiple indoor units that are utilised by a single outdoor condensing unit, either with a heat pump or heat recovery system. (daikin.co.uk)

The hybrid (VRF) technology can deliver different occupant-selected temperatures to multiple zones, making it ideal for a complex building with diverse occupancy needs and patterns (trane.com). VRF systems are adaptable to almost any environment due to their versatility and smart technologies. Systems can maintain set temperatures using the minimum amount of energy and be programmed to shut down when no occupants are detected. Due to the smart technologies this system uses the higher installation cost is recovered over time as energy usage is much lower as are no carbon emissions.

> *'VRF systems are based on the flow of refrigerant between an external condensing unit and multiple internal evaporators (typically fan coil units). Each internal evaporator serves a different thermal zone within the building, and the flow of refrigerant to each evaporator is adjusted depending on the local requirement'* (Ferguson, 2020).

The use of a VRF system is ideal for a complex building structure with many functions and a hybrid system can be installed in several parts to maximise the efficiency of its use within each zone. All zoned areas operate independently through a central board therefore can be maintained from a single point of access. An individual system can support 64 individual air conditioning units serviced by one outdoor unit; the demand required in each diverse zone can be accommodated easily. The electrical cabling is easily concealed and much more discrete so can be run adjacent to other electrical cabling required for lighting and power direct from the plant room. VRF systems commonly fall into two categories: a two or three pipe system, with the three-pipe system providing the best flexibility for the heating and cooling to operate simultaneously. A heat recovery system works using a three-pipe system allowing heat from zones requiring cooling to be used to heat zones that require heating. This extremely cost-efficient system is more expensive but will provide payback over its economical use (daikin.co).

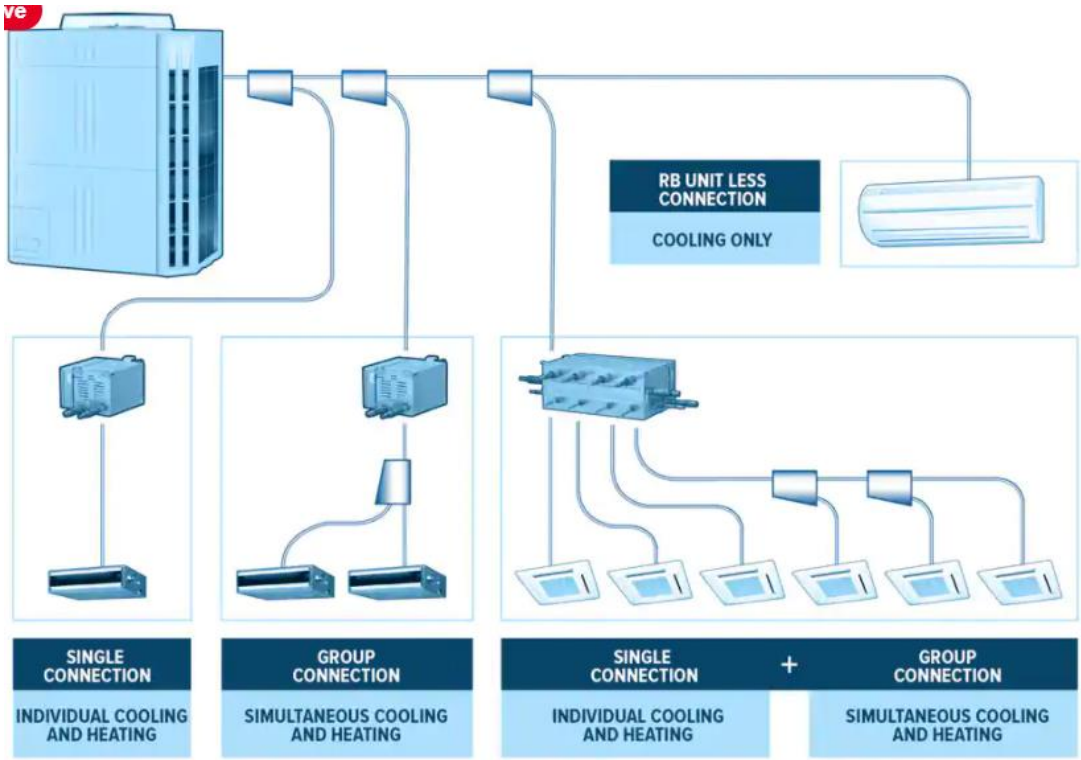


Figure 7: Ductless VRF system: Ferguson, 2020

Natural Ventilation

Natural ventilation should not be forgotten about when designing a building of multiple use. The use of natural air flow is of course free and should be considered at all stages of a project's development. By careful design and attention to detail, natural ventilation can be used in conjunction with a mechanical system allowing further cost savings and reducing energy use. Natural ventilation is generally considered as wind-driven or wind-induced which creates a cross ventilation when a difference in pressure is created from one side of a building to another. As the high pressure draws air in on one side and releases on the low-pressure side, the stack effect is created. As the cooler air enters the building at low level, its buoyancy circulates upwards and (as this process takes place) the air is heated by the building occupants and equipment and eventually released via a vent at the top of the building. Cross ventilation is suitable for buildings up to approximately 12 to 15m in depth (five times the floor to ceiling height, or 2.5 times the floor to ceiling height if openings can only be provided on one side). Beyond this, providing sufficient fresh air creates draughts close to openings, and additional design elements such as internal courtyards are necessary, or the inclusion of elements such as atriums that combine cross ventilation and natural stack

effects. For the cross ventilation of the stack effect to work efficiently a number of considerations need to be made:

- The depth of the building must not exceed a maximum of 15m
- For optimum effect of the stack system, the area should not exceed five times the floor to ceiling height, or 2.5 times the floor to ceiling height if openings can only be provided on one side
- Internal courtyards and atriums (providing open areas with additional height)

Whilst natural ventilation may be preferable, mechanical ventilation may be necessary where:

- The building is too deep to ventilate from the perimeter.
- Local air quality is poor, for example, if a building is next to a busy road.
- Local noise levels mean that windows cannot be opened.
- The local urban structure is very dense and shelters the building from the wind.
- Air cooling or air conditioning systems mean that windows cannot be opened.
- Privacy or security requirements prevent windows being opened.
- Internal partitions block air paths.

A disadvantage of cross ventilation is that it tends to be least effective on hot sticky days when needed most. (designingbuildings.co.uk)

CIBSE provides much information on the use of natural and mechanical ventilation within non-domestic buildings - AM10 – Natural ventilation in non-domestic buildings, 2005 and CIBSE Guide B2: Ventilation and air conditioning should be used in conjunction with Building Regulations approved document F1 ‘Means of ventilation and approved document - L2: Conservation of fuel and power in buildings other than dwellings, to achieve the best results. (IHS, 2020)

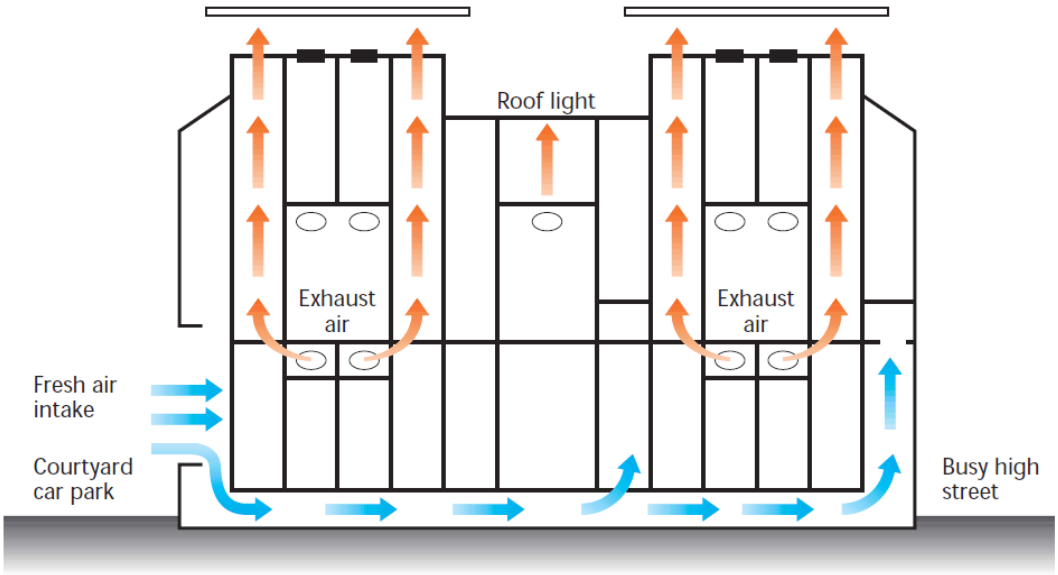


Figure 8: Natural Ventilation: Rising Stack, Google image 2020

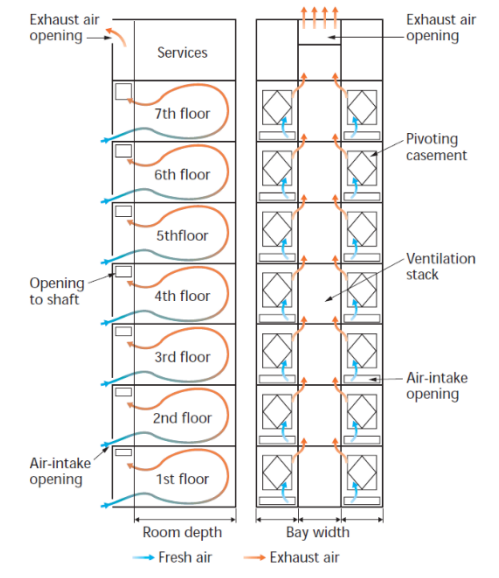


Figure 9: Natural Ventilation in high rise structure: CIBSE, 2020

Mixed-Mode Ventilation

This type of ventilation might be an option suitable for a complex building servicing different types of activity space. By using natural and mechanical ventilation both systems can be used to their full potential, the use of opening windows to allow air to enter the building at different floor levels, whilst providing a stack ventilation to operate

within the reception and retail outlet area with mechanically opening and shutting vents. Additional support can be added to these areas if and when required, although the mechanical systems would be used more readily in other area/zones for example the gymnasium, carpark and kitchen areas. When assessing all types of renewable energy sources for service system like heating, cooling and ventilation it is important to link them to how they will be initially powered and what of our natural resources can be utilized to generate the power in the most efficient way.

> *"It has been estimated that the energy consumption of buildings accounts for more than a third of the total energy consumption worldwide and that in Europe the building stock is responsible for around 40% of all energy used"* (Lechtenböhmer & Schüring, 2011; Schmidt, 2014).

Therefore, combining service power with thermal power on a smart grid or district heating system would provide far more flexibility and sustainability of renewable energy for such a complex building. (Advances in Building Energy Research, journal, volume 13, 2019)

Using the ground beneath us is one of the most sustainable energy sources we can utilise. As the temperature below ground is based on undisturbed conditions, a constant temperature can be maintained throughout the year. This constant temperature can be harnessed and used to power energy systems. As the conversion of energy is so good this renewable heat source is also sustainable, clean and environmentally friendly as it generates minimal, if any, greenhouse gases. (Lanterman & Lee, 2007).

Geothermal Piles

The use of geothermal piles should be a serious consideration for this building project as a significant contribution to the production of renewable energy and de carbonisation. By combining the pile foundation (necessary to support the structure) with a closed-loop ground source heat pump system, it can provide a source of heat and a heat sink that can be stored and used as necessary. Geothermal heat exchange technology is one of the most efficient methods of heating and cooling, by transferring heat to and from the earth. The heat in the earth is collected and transferred through the loops by a heat transfer fluid, such as water with anti-freeze or a saline solution, to a unit within the building. The harnessed heat passes through a compressor and

heat exchanger which increases its temperature before releasing into the building at a higher temperature. The closed loop systems are manufactured offsite and filled with the necessary solution before it is locked off by a valve mechanism. Absorber pipes are pressurised as an integrity test and as a way of preventing any collapse due to the fluid concrete. Pressure is maintained until the concrete cures; the tops of the pipes are left exposed as they will be connected to a heat exchanger in the building.

When concreting, the tops of the pipes are held back to avoid damage and a tremie pipe is placed to the base of the pile. Concrete is poured through the tremie and it is raised up as the concrete fills the pile. Once the pile is finished, the absorber pipes are connected to a heat exchanger which is then connected to a secondary circuit of pipes in the floors and walls of the building. (Tomlinson & Woodward, 2008)

The capital cost for the installation of a heat pump is higher than other forms of renewable energy however, payback period is normally between 3-6 years. The ground loop system contained within the geothermal pile has a projected life span of over 200 years. (Skanska, 2011)

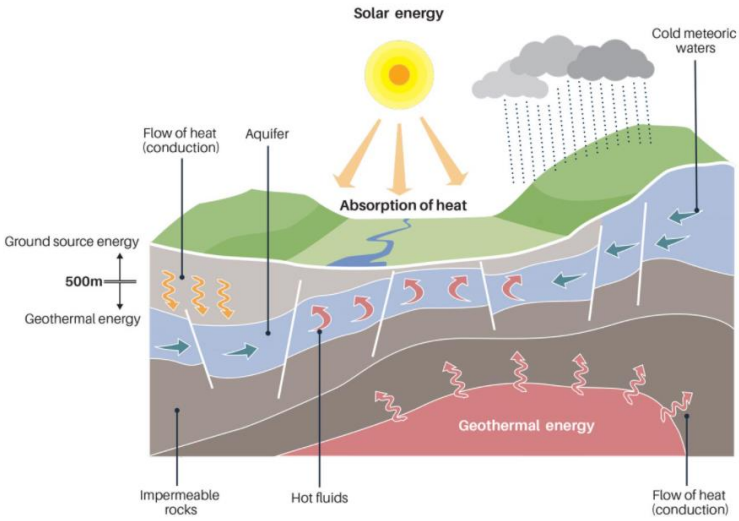


Figure 10: Geothermal Energy: British Geological Society

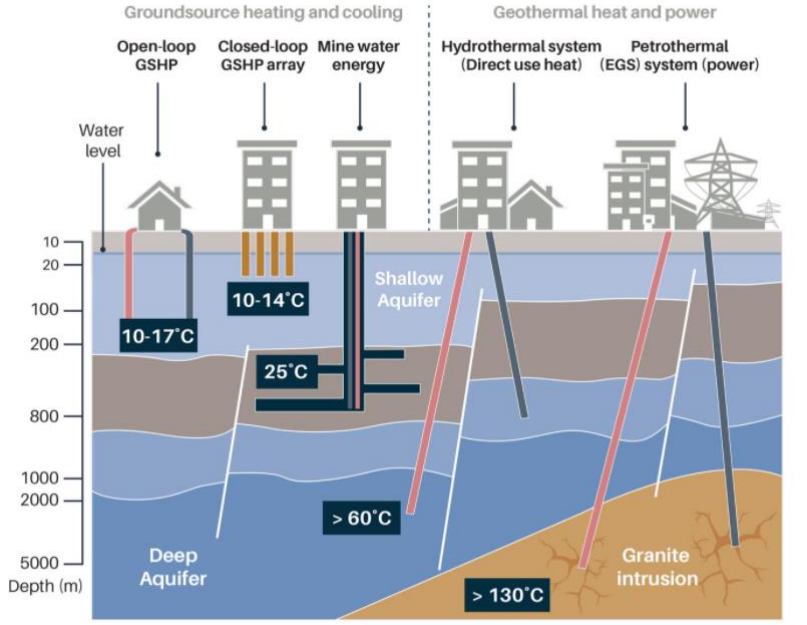
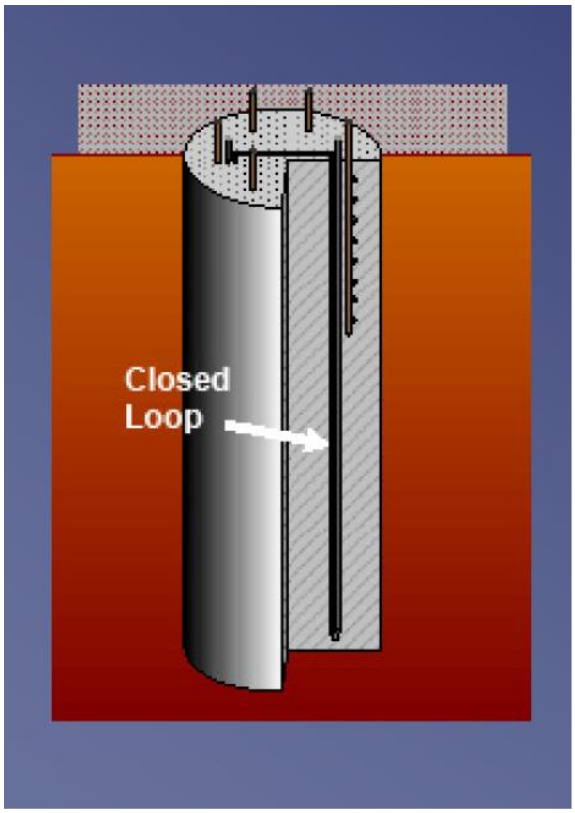


Figure 11: Ground source heating and cooling & Geothermal heat and Power BGS, 2020



Typical section through pile

Figure 12: Section through geothermal pile with closed loop system: SKANSKA,

Figure 13: Green solution energy piles SKANSKA

Lighting

Natural Light

Historically designers got carried away with how a building should look, and how it should be noticed for its aesthetics, little notice was taken of how the occupants were to work and function within. Over the years more importance has been placed on how both exterior and interior material choices, layout and lighting affect those operating within the building and more importantly how they perform.

Humans have evolved circadian rhythms and our building designs should reflect the importance of those rhythms. Our bodies produce hormones that respond to different times of the day and exposure to daylight. This means the type of light we are exposed to will influence how our bodies react. Melatonin is the body's natural hormone that regulates our sleep pattern and different light exposure can affect the way in which this hormone operates. Research suggests that exposure to cooler blue rich light can suppress the production of melatonin which results in a person's alertness. It is important that, for work environments, the right type of lighting is essential for good productivity levels. If a natural light cannot be maintained, it is important that any artificial lighting is as close to that of natural light as possible. By adopting a Human Centric Lighting approach (assessment of daylight performance in buildings), the benefits to health and wellbeing are at the centre of design (live science, 2020).

For a time in construction natural lighting fell out of favour with architects and those responsible for building design. However, due to new technologies, materials and the impact of climate change, whole life cycles and sustainability firmly on the agenda, natural lighting has become fashionable again. The greater understanding of how natural light impacts on the inhabitants and users of buildings, is now a primary focus of the architect and maximised to its full potential. Case studies show that by improving daylight design, this increases individual productivity by as much as 23%, reduces sick building syndrome (SBS) symptoms as well as absenteeism, and reduces annual energy loads by between 27% and 88% (Herschong et al, 2002).

European Standard EN 17037 has extended its scope to target multiple aims in respect of daylighting and occupant comfort levels. Introduced in 2018, the standard deals exclusively with the provision of natural lighting in both commercial and domestic buildings. The new standard is set to replace a number of standards used throughout Europe to provide a unified standard. This new European standard is unique as its focus is on the quantity and quality of daylight in a building. The following standards relate to lighting within buildings.

BS 8206-2-2008 is specific to the UK only, the standard deals with daylighting provision, design methods and lighting calculation for the provision of artificial lighting.

EN 17037- 2018 goes beyond the BS standard by dealing exclusively with daylight and including further methods of calculation for design parameters that did not feature in the British Standards.

EN 12464-1 and EN 15193 are existing standards that look at daylight and the provision for artificial lighting now superseded by the new all-encompassing EN 17037

- Scope of European Standards for Natural Lighting
- Daylight provision
- Assessment of view out of windows
- Access to sunlight
- Prevention of glare
- How the provision of daylighting design is measured

The new European standard covers the need for providing openings that deliver well dispersed natural lighting into a building which reduces the need for artificial light use and provides a balance between solar gain and heat loss. The standard is not confined to new build as there is scope to use on refurbishment projects where the methods can be used to assess existing opening and recommendations to meet the new standards.

The standards do not specify the level of luminance but instead base the standards on a minimum level of 300-lux the level, studies have found, to be the minimum required for prolonged office work where artificial lighting is not required. Lighting can also impact on mood and interpersonal relationships at work and therefore job satisfaction (Boyce, 2003).

A study conducted by Imperial College London in 2017 found that by improving daylight, thermal comfort, acoustic balancing, pleasant exterior views and good air quality, there was a productivity improvement of between 5% and 8% of business turnover. The college's report also suggested that the payback period for initial investment into the design or an upgrade of a building was as little as 24 months.

> *"A satisfactory visual environment can be achieved by electric lighting alone, but most people have a strong preference for some daylight. This is supported by the Workplace (Health, Safety and Welfare) Regulations 1992 (TSO, 1992), which require access to daylight for all workers where reasonably practicable"*. (CIBSE Guide A, 2019)

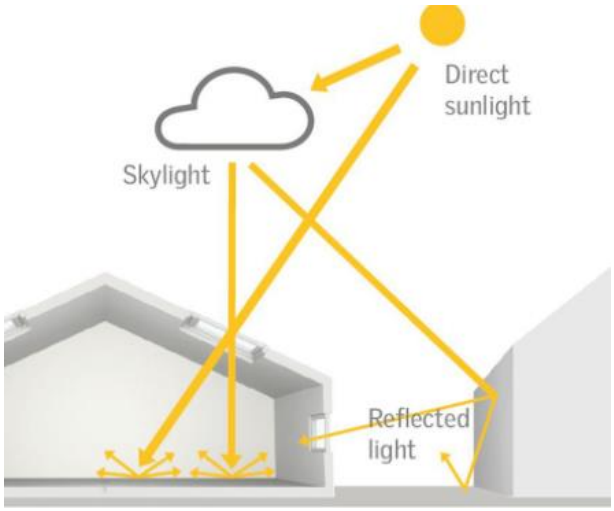


Figure 14: Natural lighting: Velux, 2020

Artificial lighting

Although natural light is generally a preferred option by most for working, the need for artificial light will be required in most environments at some time during the day. How that lighting is designed and delivered to ensure the comfort levels of the users is achieved can be a complicated task. There is much published documentation and guidance on the subject, not to mention the building regulations and British standards that must be met before a single light is illuminated. In order to design a lighting system for use in the workplace many factors will be considered. Not only the strength of light required but the colour, the spread of the light across the working plane, as well as the most energy saving bulbs.

As discussed above in natural lighting, the effects of artificial lighting also need to be considered to ensure wellbeing and comfort levels are maintained as a direct impact on productivity. As much as 90% of a business cost is spent on staffing with only 1% on energy efficiency therefore, it is crucial that productivity is maintained throughout the working day and a concerted effort is given to the way in which the workplace is lit. Therefore, ensuring comfort levels are maintained will have a cost saving as staff remain productive, alert and at work.

Building Services Research and Information Association (BSRIA) studies have confirmed the rapid growth in lighting controls. For example, a recent study of the French Lighting Market in Non-Residential Buildings (BSRIA) 2014, projected growth

of almost 15% per annum in 2013-2017. This is almost double the projected growth rate in the market for lamps and almost 10 times the growth rate for luminaires. These, as mature markets, tend to follow the cycles in construction (BSRIA, 2011).

BSRIA research in North America has shown a similar rate of growth for light controls. In commercial buildings, there is increasing emphasis on employee comfort, and its clear effects on performance. Studies have suggested that lighting, like temperature and air freshness, all have an impact on people's satisfaction and productivity. A study conducted by 360 Magazine earlier this year suggested that, in the UK, 32% of office workers are unhappy with the light intensity and only 21% have any control over it (designingbuildings.co.uk).

The choice of lighting within a workplace can be challenging, none more so than in today's environment where the workspace has a requirement to be much more fluid that it once was. With the demand to ensure workspace become more flexible in terms of its usability and ability to change use, the design of a lighting system needs to be ever more responsive to these changes, or at least be changed far more easily with the minimum of disruption.

> "*Commissioning Code L defines a process to minimise the risk of a completed lighting design performing very differently to the original design concept. It also emphasises the importance of providing the customer with accurate operating and maintenance information, which may now exist as a building information management software model, rather than as traditional paper-based documentation*." (Parry, 2018)

Lighting installations are becoming increasingly complex. This is largely due to the evolution in recent years of LED's as the most common light source, which in turn has increased the range of luminaire types and styles available to architects and lighting designers. The technologies used in lighting controls are also evolving and now often form an intrinsic part of the lighting installation (designingbuildings.co.uk).

The information available on lighting is vast with more than enough to fill several library shelves. From the previously mentioned considerations made when designing lighting systems to where the lights will be installed, what activity they support, who will use them and for how long, are all part of the initial thought process. Should they be direct

or indirect, issues of glare at the working plane, atmospheric, displays for retail outlets, and what tones are best used in each of these environments, the subject becomes a minefield. Whilst all these issues are taken into consideration, the human element is also a primary focus, after all is it not the end users that are being catered for in all aspects of light? There is vast amount of information available on the subject along with guidance and best practice notes that all contribute to satisfying Building Regulations, some of which are listed below:

Building Regulations 2010, Approved Documentation L2A – conservation of fuel and Power.

Building Regulations 2010, Approved Documentation L2B – conservation of fuel and Power: Updated 2011, 2013 & 2016

Lighting and Energy efficiency |LG9 lighting guide 9 - CIBSE

> *"BREEAM was conceived as a tool for helping developers and their teams to take a structured approach to delivering more sustainable buildings. The BREEAM UK New Construction 2014 and BREEAM UK Refurbishment and Fit-out 2014 schemes assess performance against 51 individual assessment issues spanning nine categories"*

• Management • Energy

• Health & wellbeing • Transport

• Water • Materials

• Waste • Land use and ecology

• Pollution• Management • Energy

• Health & wellbeing • Transport

• Water • Materials

• Waste • Land use and ecology

• Pollution

- Innovation being the 10 categories of BREEAM

Lighting, whether natural or artificial, could fall into several categories within the BREEAM assessment when striving to achieve excellence rating.

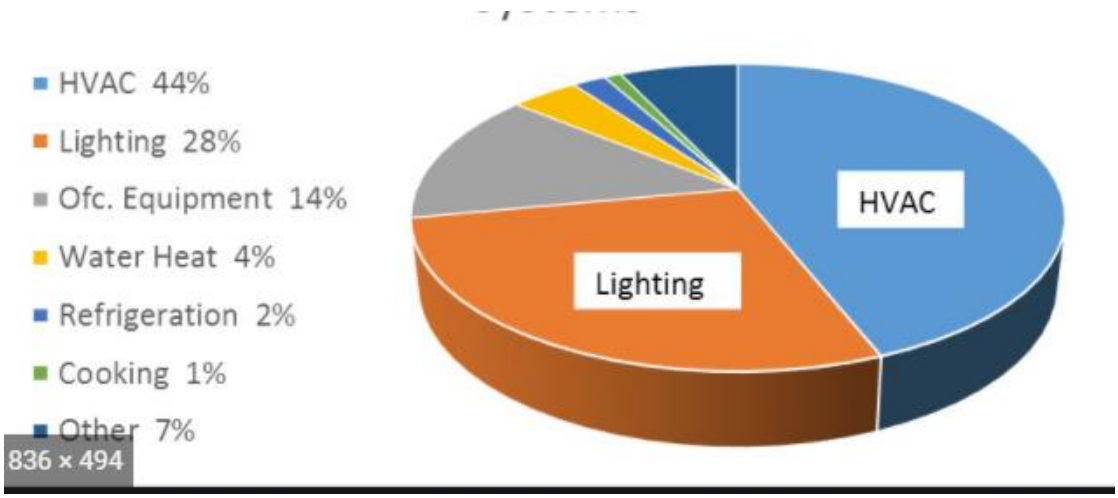


Figure 15: Typical commercial building energy use. (Bluehatmechancial.com 2020)

Emergency lighting – BSI British Standards

BS 5266-1:2016: Since 2005 the legal requirement for the installation of emergency lighting systems is the same as for fire-alarm systems. The main changes were to emergency safety lighting and standby lighting. This guidance covers all aspects of emergency lighting from its design, installation, maintenance and certificates, not to mention logbooks and record keeping for all non-domestic buildings. This document should be used in conjunction with EN 1839 - 2017 and BS EN 50272 - 2010. Further guidance is recommended that, BS EN 50172:2004, 4.1 specifies compliance with the wiring rules given in HD 384/HD 60364. The UK applicable parts of HD 384/HD 60364 are implemented in the IET Wiring Regulations (BS 7671) (BSI, 2016).

> "Particular attention is drawn to legal requirements in respect of emergency lighting. Further guidance is given in the Building Regulations 2010, Approved Document B [23] and its equivalents in Wales [24], Scotland [25] and Northern Ireland [26]". (BSI, 2016)

BS 5266 - 2016 recommends the provision of horizontal illumination at floor level along the centre line of a defined escape route (permanently unobstructed) not less than 1 lux, and 0.5 lux for anti-panic areas, to exclude a 0.5m border around the route. In addition, for escape routes of up to 2m wide, 50% of the route width should be lit to a minimum of 1 lux. Wider escape routes can be treated as a number of 2m wide bands (BSI, 2016).

Emergency lighting – European Standards

EN 50172:2004: Emergency escape lighting systems

EN 1838:1999: Lighting applications - Emergency lighting was withdrawn and replaced by BS EN 1838:2013

> *"European Standard specifies the provision of illumination of escape routes and safety signs in the event of failure of the normal supply and specifies the minimum provision of such emergency lighting based on the size, type and usage of the premises. This standard relates to the provision of electric emergency escape lighting in all workplaces and premises open to the public. This European Standard does not cover private domestic premises, but its provisions are applicable to common access routes within multi-storey dwellings. This European Standard is also applicable to standby lighting used as emergency escape lighting. There are emerging way guidance techniques that, when applied to escape routes in addition to conventional emergency lighting luminaires, can enhance its effectiveness in an emergency".*

Emergency lighting is critical within all buildings but non-moreso than in buildings that are used by the large numbers of the public. Often building are complicated in design with multiple floors and escape routes that all require electricity to power potential escape routes. So, attention to detail is needed when designing lighting systems, to deal with emergency situations when occupants of a building are frightened, which results in behavioural changes of the individual. Generally, when a building is to be evacuated in an emergency, it is due to fire or some other situation that requires the electricity supply to be interrupted, with this comes loss of services. The loss of services induces further panic and even the most rational individual can make irrational decisions. The layout of a building might be complicated with alternative means of escape not initially clear, for example shopping malls frequently use escalators and lifts, but where are the staircases to emergency exits (often a safer part of the building) due to its construction method and materials providing additional fire break time.

An emergency lighting system requires a significant amount of time and energy in order to get it right, and in some respects is far more important than the rest of the lighting system in everyday use. The emergency lighting is only used in emergency situations so needs to work and work well enough for evacuation of a building speedily.

Facilities

Luminaires are covered within the scope of emergency lighting and refers to how devices are tested and whether they have a self-test mode or done remotely by a centralised panel. Luminaire with inhibiting mode refer to the protection of the batteries discharging when the lighting is not required. High risk task luminaire is for risk task area lighting in areas of high risk.

Power Supply

BS 5266-1:2016 BSI - Gives a wider explanation and guidance on emergency lighting within buildings. The wider context covers how different lighting systems can be used, and how different systems can be applied to different categories of buildings with diverse requirements.

Central power supply systems: Battery backup used in this type of system that supply emergency power to safety equipment without any restriction in power output should only use batteries with a declared life expectancy of at least 10 years at a 20°ambient temperature. Central power supply systems and their associated batteries should be located in an area of low fire risk and should be separated from the normal mains power incoming control room. Central power supply systems with battery backup are often cheaper to install however, they are costly to maintain and labour intensive as each luminaire and battery backup must be checked individually, often taking several hours (safelincs.co.uk).

Slave emergency light fittings are powered by a centrally located energy source, a slave power box. Several luminaires are connected to a single power source. In the event of a mains power failure the slave power box switches over to emergency power supply. Slave luminary systems are often used in large complex buildings and are monitored via a control panel. Shortened battery life in self-contained emergency lighting luminaires can take place due to temperature fluctuations however, the slave system can withstand extreme temperature fluctuation making them ideal solutions for industrial purposes (safelincs.co.uk). The slave emergency lighting is often expensive

to install initially but offers savings in terms of low maintenance as the system the test of the backup power system only requires a visual inspection of the battery system in one location (safelincs.co.uk).

Duration

The duration of the emergency lighting will depend on the complexity of the building and whether it can be evacuated immediately. If it can, then a minimum 1hr can be applied to the emergency lighting duration. However, BS5266 - 2016 contains detailed information on the recommended duration of systems in various premises. A 3hr period is normally seen as a minimum requirement in a building that is not immediately evacuated.

Figure 16:Common emergency lighting signage: Safelincs, 2020

*Although a number of European Standards have been referred to within this document, it is not clear that after 31 December 2020, (When the UK leaves the European Union) what EN standards will continue to be enforced.

References

BlueHat Mechanical. 2020. *Bluehat Mechanical - The Commercial Refrigeration & HVAC Experts*. [online] Available at: <https://bluehatmechanical.com/> [Accessed 22 December 2020].

BREEAM. 2020. *BREEAM: The World'S Leading Sustainability Assessment Method For Masterplanning Projects, Infrastructure And Buildings - BREEAM*. [online] Available at: <https://www.breeam.com/> [Accessed 12 November 2020].

Building Regulations 2010. Approved Document F. 2016. *Cardiff Local Development Plan 2006-2021*. [ebook] Cardiff. Available at: <https://www.cardiff.gov.uk/ENG/resident/Planning/Local-Development-Plan/Page 51/default.asp> [Accessed 2 November 2020]..

Cibse.org. 2020. *CIBSE - Building Services News And Policy*. [online] Available at: <https://www.cibse.org/news-and-policy> [Accessed 7 November 2020].

Cibse.org. 2020. *CIBSE - Building Services News And Policy*. [online] Available at: <https://www.cibse.org/news-and-policy> [Accessed 13 November 2020].

Constructionmanagermagazine.com. 2020. *CPD: How Building Envelope Design Can Enhance Light Quality – Construction Manager*. [online] Available at: <https://www.constructionmanagermagazine.com/cpd-how-building-envelope-design-can-enhance-light-quality/> [Accessed 9 November 2020].

Currie & Brown Chris Ward BRE Global Ltd 2017, 2017. *Delivering Sustainable Buildings*. Value of BREEAM to Retail in the UK. [online] BRE Global Ltd. Available at: <https://www.bregroup.com/> [Accessed 12 December 2020].

Daikin.co.uk. 2020. *VRV And VRF Systems*. [online] Available at:

<https://www.daikin.co.uk/en_gb/about/daikin-innovations/variable-refrigerant-volume.html>

[Accessed 28 November 2020].

Designingbuildings.co.uk. 2020. *Natural Ventilation Of Buildings*. [online] Available at: <https://www.designingbuildings.co.uk/wiki/Natural_ventilation_of_buildings> [Accessed 11 November 2020].

Designingbuildings.co.uk. 2020. *Geothermal Pile Foundations*. [online] Available at: <https://www.designingbuildings.co.uk/wiki/Geothermal_pile_foundations> [Accessed 26 November 2020].

Designingbuildings.co.uk. 2020. *Smart Office Lighting*. [online] Available at: <https://www.designingbuildings.co.uk/wiki/Smart_office_lighting> [Accessed 26 November 2020].

Designingbuildings.co.uk. 2020. *Aspects Of Daylighting Design Covered By EN 17037*. [online] Available at: <https://www.designingbuildings.co.uk/wiki/Aspects_of_daylighting_design_covered_by_EN_17037> [Accessed 9 November 2020].

EDUCATION, O. and office, H., 2020. *Human Centric Office*. [online] OMS PROJECTS. Available at: <https://projects.omslighting.com/office-education/human-centric-office-2/> [Accessed 1 December 2020].

Ferguson.com. 2020. *Variable Refrigerant Flow (VRF) HVAC Systems & Solutions - Ferguson*. [online] Available at: <https://www.ferguson.com/content/jobsite-solutions/variable-refrigerant-flow-systems?icid=cont_solut_bsns_industry-solutions-hvac_vrf-solutions> [Accessed 11 November 2020].

Safelincs.co.uk. 2020. *Fire Safety & Fire Protection Equipment*. [online] Available at: <https://www.safelincs.co.uk/> [Accessed 22 December 2020].

Designingbuildings.co.uk. 2020. *Geothermal Pile Foundations*. [online] Available at: <https://www.designingbuildings.co.uk/wiki/Geothermal_pile_foundations> [Accessed 26 November 2020].

Building Regulations 2010. Approved Document F.

GOV.UK. 2020. *Clean Growth Strategy: Executive Summary*. [online] Available at: <https://www.gov.uk/government/publications/clean-growth-strategy/clean-growth-strategy-executive-summary> [Accessed 19 November 2020].

Gov.uk. 2020. *COP26 - GOV.UK*. [online] Available at: <https://www.gov.uk/government/topical-events/cop26> [Accessed 22 November 2020].

Hawkins, G., 2011. *Rules Of Thumb Guidelines For Building Services*. 5th ed. [ebook] BSRIA. Available at: <http://www.bsria.com/uk/> [Accessed 26 November 2020].

Herschong, 2003. Illuminating Engineering Society of North America. *Journal of the Illuminating Engineering Society*, 32(1), pp.100-113.

Bsria.com. 2021. *Illuminance (Light)*. [online] Available at: <https://www.bsria.com/uk/instrument/calibration/illuminance-light/> [Accessed 26 November 2020].

IHS Markit. 2020. *IHS Markit - Leading Source Of Critical Information*. [online] Available at: <https://ihsmarkit.com/index.html> [Accessed 1 December 2020].

Www-tandfonline-com.ezproxy.uwtsd.ac.uk. 2020. [online] Available at: <https://www-tandfonline-com.ezproxy.uwtsd.ac.uk> [Accessed 15 November 2020].

Keirstead, J. and Shah, N., 2013. *Urban Energy Systems*. Abingdon, Oxon: Routledge, p.3.

Ltd, K., 2018. *History Of Air Conditioning | Kimpton Air Conditioning Wirral | HVAC History*. [online] Kimpton Energy Solutions. Available at: <https://www.kimpton.co.uk/history-air-conditioning/> [Accessed 28 November 2020].

BBC Bitesize. 2021. *Lung Volumes And Vital Capacity - Cardio-Respiratory System - Eduqas - GCSE Physical Education Revision - Eduqas - BBC Bitesize*. [online] Available at: <https://www.bbc.co.uk/bitesize/guides/z3xq6fr/revision/2> [Accessed 30 November 2020].

ResearchGate. 2020. *Researchgate | Find And Share Research*. [online] Available at: <https://www.researchgate.net/> [Accessed 23 November 2020].

2010. *Non-Domestic Building Service Compliance Guide*. London: RIBA Bookshop Mail Order.

Safelincs.co.uk. 2020. *Fire Safety & Fire Protection Equipment*. [online] Available at: <https://www.safelincs.co.uk/> [Accessed 22 December 2020].

Santamouris, M., 2019. *Advances In Building Energy Research*. London: Earthscan.

Science, L., 2020. *How Blue Leds Affect Sleep*. [online] livescience.com. Available at: <https://www.livescience.com/53874-blue-light-sleep.html> [Accessed 10 November 2020].

Siderise. 2020. *Services | DWX – Acoustic Barrier For Ducting | HVAC | Products | SIDERISE*. [online] Available at: <https://www.siderise.com/products/hvac/dwx-acoustic-barrier-for-ducting/services> [Accessed 19 November 2020].

Tomlinson, M. and Woodward, J., 2008. *Pile Design And Construction Practice*. 5th ed. Oxon London & NY: Taylor & Francis group.

Tregenza, P. and Wilson, M., 2013. *Daylighting*. Hoboken: Taylor and Francis.

Bibliography

GOV.UK. 2020. *Approved Documents*. [online] Available at: <https://www.gov.uk/government/collections/approved-documents> [Accessed 7 November 2020].

BREEAM. 2020. *BREEAM: The World'S Leading Sustainability Assessment Method For Masterplanning Projects, Infrastructure And Buildings - BREEAM*. [online] Available at: <https://www.breeam.com/> [Accessed 12 November 2020].

Www-ihsti-com.ezproxy.uwtsd.ac.uk. 2020. [online] Available at: <https://www-ihsti-com.ezproxy.uwtsd.ac.uk/CIS/> [Accessed 1 November 2020].

Building Regulations 2010. Approved Document F.

Cibse.org. 2020. *CIBSE - Building Services News And Policy*. [online] Available at: <https://www.cibse.org/news-and-policy> [Accessed 7 November 2020].

Cibse.org. 2020. *CIBSE - Building Services News And Policy*. [online] Available at: <https://www.cibse.org/news-and-policy> [Accessed 13 November 2020].

(Advances in Building Energy Research, 2019)

Gov.uk. 2020. *COP26 - GOV.UK*. [online] Available at: <https://www.gov.uk/government/topical-events/cop26> [Accessed 22 November 2020].

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Www-tandfonline-com.ezproxy.uwtsd.ac.uk. 2020. [online] Available at: <https://www-tandfonline-com.ezproxy.uwtsd.ac.uk> [Accessed 15 November 2020]

.2020. [online] Available at: <https://www.sciencedirect.com/science> [Accessed 3 December 2020].