University of East Anglia

Design Guide Part 3: Design philosophies and criteria for heating, cooling, ventilation and light in buildings

RIBA Stages 1 – 2

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Contents

1 Introduction

1.0 Prior Reading

It is imperative for readers of this document to first refer to the introductory Part entitled:

‘*Design Guide Part 1 – Principles and overview’*.

Part 1 gives vital information and context that apply to all projects.

1.1 Purpose of the UEA Design Guide

The Design Guide (as a whole) is written for employees of the UEA, architects and external consultants and contractors. The purpose of the Guide is to act as a briefing document to give designers an overview of the design requirements, constraints and challenges presented by the UEA’s specialist needs. It applies to all new-build and refurbishment projects controlling quality in the production of designs, specifications and the subsequent performance of buildings.

The Design Guide aims to discuss strategic matters and does not provide an exhaustive treatment of statutory or best practice design and compliance requirements; its primary purpose is to establish a starting point for design *briefs*. It is the responsibility of readers/duty holders to ensure subsequent designs are complete, compliant and able to meet the final approved brief when measured in use.

1.2 Purpose of this Part of the Design Guide

This Part of the design guide is written for designers of heating, cooling, ventilation and lighting (HCVL) strategies from the Preparation and Brief stage (RIBA Stage 1[1]) to the Concept Design Stage (RIBA Stage 2), including employees of the UEA and external consultants and architects. The purpose of the guide is to act as a briefing document to give designers an overview of the design requirements, constraints and challenges presented by the UEA’s specialist needs; it applies to new-build and refurbishment projects.

Relevant information sources such as best practice guides are detailed throughout this document and, where relevant, included in the Appendix (providing a list for quick reference).

1.3 Interpretation

Any part of the Design Guide may be referenced in project contractual documentation in order for the UEA to control quality. The following interpretations apply:

Enforced requirements; the use of the word(s) ‘shall’, ‘are required’, ‘is required’ ‘must’ or ‘will be’ denotes a requirement that is non-negotiable and shall be used as the basis for designs, technical submissions and/or activities. If such a statement conflicts with a statutory obligation then a report to the Head of Sustainability, Utilities and Engineering (hereafter

[1] http://www.ribaplanofwork.com

‘Head of S.U.E’) and Infrastructure shall be produced highlighting the conflict, for his or her final decision regarding compliance.

Requirements needing confirmation; the use of the word ‘may’ denotes a negotiable requirement or indication of a solution, where innovation and further calculation, design and discussion may be required to arrive at an optimised solution.

Quality; the Design Guide aims to arrive at the UEA’s highest design aspirations and standards. It may be that, at the UEA’s sole discretion, solutions are value engineered during subsequent design iterations. Designers are encouraged to consider where value engineering may result in an improved financial performance should funding constraints occur.

Currency of third party documents; where superseded standards and regulatory documents are referred to in the text, the reader shall apply current versions and disregard superseded versions.

Proof; where the word ‘proof’ is used e.g. ‘proof is required’, a written report or installation certificate must be produced for approval depending on context.

Approval and proof; all designs shall be approved by the UEA. Approval shall be interpreted as meaning written approval from either the UEA’s appointed approving authority or by the Head of S.U.E where no other approving authority is appointed. Approvals shall be sought prior to design decision points or installation activities (depending on context) and shall be made in writing. Where approvals are sought, a written technical submission shall accompany the request setting out, with proof (e.g. calculations, drawings), the case for the approval. The purpose of the approval process is to ensure designs meet the strategic requirements of the UEA.

The obligations owed by external architects, consultants and contractors to UEA and their liabilities to UEA is not in any way diminished or otherwise reduced by the approval process. UEA is not taking over the roles and duties of the external architects; consultants and contractors who will remain fully and totally responsible for the design and/or works carried out by them or on their behalf by their staff; agents; sub-consultants or sub-contractors.

1.4 Version control and updates

Any new or amended content is highlighted in yellow so readers can easily identify changes from previous versions. Where no yellow highlights exist the document either remains unchanged or it is the first version to be published.

2 Key Principles for HVAC & Light in Buildings

The following principles shall be applied to all HCVL designs. The order of the principles doesn't represent a hierarchy of importance.

- New buildings shall achieve the Passivhaus Classic standard and an Energy Performance Certificate rating of A with refurbishments achieving the EuroPHit standard and no less than a rating of B.
- Designs must produce a workable strategy for maintaining comfort conditions currently and for 40 years from the date of commissioning in consideration of the UKCIP02 climate change scenarios. CIBSE's *Future TRY/DSY Hourly Weather Data Set - Norwich*[2] shall be used in dynamic simulation applications to determine future comfort related risks; the 2050's high scenario shall be used[3].
- Designs will be checked against criteria by measuring 'Performance in Use' (PIU) following a use period of 24 months with criteria flowing through to FM contracts for ongoing checks.
- New buildings must source 10% of energy demand from renewables. However, the renewable energy system may be located at another site on the UEA campus if connected to one of the site's energy networks. The output of renewable energy systems must produce a benefit to the operation to the district heating and cooling and power distribution systems.
- Building regulations, 2nd tier documents[4] and best practice guides shall be considered as minimum requirements, in 2nd tier documents 'recommended' shall be interpreted as 'required'.
- Passive cooling systems are preferred combined where necessary with mixed mode systems for meeting peak loads.
- High thermal mass/slower response is preferred for constantly occupied spaces where as low thermal mass/faster response is preferred for buildings with varying occupancy.
- In most cases heat and cold will be sourced, where required, via the district heating and cooling networks.
- Heating and cooling systems with a high radiant fraction are preferred.
- Residential buildings are not actively cooled.
- Unless a special process requirement arises, the UEA does not de-humidify air.
- Return temperatures on the district heating network must be maintained as low as possible and always below 50ºC.

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[2] Future CIBSE *TRY/DSY Hourly Weather Data Set Norwich* – Product Code WD16NOR
[3] As discussed in 'TM48 2009 *Use of climate change scenarios for building simulation'* published by the Chartered Institute of Building Services Engineers
[4] Such as the Non-Domestic Building Services Compliance Guide – for use in England

- Return temperatures on the district cooling network must be maintained as high as possible.
- Systems and components capable of the highest energy efficiency ratings on a seasonal basis shall be used.
- Designs must consider the need for future adaptation to facilitate growth of the campus and change of use of spaces.
- Overheating in high performance buildings must be avoided by ensuring gains from pipe & duct losses are insignificant.
- Fully modulating, weather compensated space heating & cooling circuits shall be employed.
- Heat and cold recovery must be employed where possible either passively or actively e.g. in air handling units or using building fabric.
- All systems will be monitored and controlled via the campus's Trend BMS System and so components that communicate directly with this protocol are preferred.
- Plant areas must allow sufficient room for future change and expansion of systems.
- It is likely that the increased pipe insulation thickness required for compliance with this Guide requires ceiling voids to be deeper than for conventional designs.

3 HVCL Philosophies

3.0 Introduction

The HVCL philosophies are premised on four principle drivers:

1. Meeting the needs of the building users throughout the life of the building
2. Reducing operational costs throughout the life of the building
3. Minimising negative impact on the environment throughout the life of the building
4. Reducing complexity in design and operation

The sections below discuss the philosophies in more detail.

3.1 Low Energy Design

3.1.1 Introduction

This section applies to heating, cooling and ventilation designs. Designs must follow the principles and processes set out in CIBSE[5] *Guide L Sustainability.* Grants and funding available for low carbon solutions should be maximised.

The UEA's current fabric strategies for delivering low energy design are:

For teaching and learning spaces, offices and IT facilities; the use of Termodeck slabs in a cross laminated timber (CRT) structure has proved very successful in terms of energy efficiency. Triple glazed windows with blinds in between the second and third pain of glass deliver good comfort. During the summer, the Termodeck slabs are cooled using low temperature night time air and where the design requires it, cooling can be augmented using the district cooling system (DCS) or chillers where a connection to the DCS is not feasible.

For residential spaces; the use of cross a CRT structure, including CRT floor slabs and triple glazing has delivered good efficiency and buildability.

3.1.2 Fabric first

Increasing levels of insulation shall be implemented to reduce heating and cooling loads and should be considered as the principle low energy design strategy. Designers shall concentrate mainly on fabric U-values, because this delivers optimum whole life costing; thermal bridging should also be reduced to a minimum. Carbon sequestration is delivered by timber structures which is a valuable climate change mitigation strategy.

All new building projects shall meet the requirements of the Passivhaus Classic Standard when measured in use. All refurbishment projects shall meet the EuroPHit standard when measured in use. Guidance on minimum U Values and air permeability can be obtained from the Head of Sustainability, Utilities and Engineering.

(Section on air permeability omitted).

3.1.3 Energy consumption targets

Building energy consumption (reductions/increases) is to be determined and agreed before a project commences to ensure the best reduction measures are chosen.

3.1.4 Simplicity

Simple, robust passive strategies and high ceilings to absorb stale air are preferred. Overly complex strategies and systems shall be avoided.

3.1.5 Low and zero carbon (LZC)

LZC technologies should be considered for all new and refurbishment building projects.

[5] Chartered Institute of Building Services Engineers

District heating; integration with the campus's district heating system (DHS) is a requirement for all new buildings refurbishments where technically and economically feasible. If a connection cannot feasibly be installed, a report outlining the reasons shall be given to the Head of S.U.E *and* the Head of Energy & Utilities for a final decision.

District cooling; integration with the campus's district cooling system (DHC) is a requirement for all new buildings refurbishments where technically and economically feasible and where mechanical cooling is required. The Head of S.U.E *and* the Head of Energy & Utilities shall be the final decision makers regarding feasibility.

Private power network; all new and existing buildings within the campus boundary shall be connected, where feasible, to the UEA private power network and will be supplied with low carbon power from the centralised CHP generators. The Head of S.U.E *and* the Head of Energy & Utilities shall be the final decision makers regarding feasibility.

Low carbon and renewable power generation technologies; photovoltaic (PV) systems should be considered for all new buildings and refurbishments and their fabric/landscape designed in such a way to support PV generation. Proposals for PV systems shall be discussed with the Head of S.U.E *and* the Head of Energy & Utilities to ensure the campus's power export arrangements with the Distribution Network Operator (UK Power Networks) are sufficient for the scheme.

Low carbon and renewable heating and cooling technologies and approaches; renewable heating and cooling technologies and natural gas must be considered where connection to the district systems is not feasible. It is the UEA's preference to explore the feasibility of renewable systems rather than opt for gas as a default position.

However, renewable technologies may also be considered for buildings that *are* connected to the district systems but such systems must produce an operation benefit to the district systems rather than displacing their use. For example, where the DHS cannot meet peak heating loads due to existing infrastructure being undersized, a gas absorption heat pump may be used in the coldest months to augment the heat supplied by the DHS.

The following technologies shall be considered:

- Solar hot water
- Air source heat (and cooling) pumps
- Ground source heat (and cooling) pumps
- Biomass heating
- SEDBUK A rated gas boilers
- Gas absorption heat pumps
- Gas CHP

More detailed design information regarding LZC technologies can be found in Part 4: *General requirements for HVAC systems*.

When night time or fresh air cooling strategies are being considered for buildings with older ventilation systems a study must be undertaken to determine if this approach uses less energy than mechanical cooling. In older systems the specific fan power might be so high that mechanical cooling is a more energy efficient approach – especially where temperature differences are low.

3.2 Comfort Criteria and Design Philosophy for UEA Spaces

3.2.1 Introduction

Comfort criteria for each type of space are taken from relevant guidance documents of which a comprehensive list can be found below in the Appendix. However, because of the importance of comfort criteria in terms of user experience and energy consumption, the principle criteria are detailed in the sections below for clarity.

A set of criteria is presented for each generic space type. For less conventional spaces such as those accommodating specialist research projects, specific criteria will be produced as part of the brief development process.

The main space types discussed below are:

- Teaching and learning spaces i.e. seminar rooms and lecture theatres
- Residential spaces
- Specialist spaces i.e. research & laboratory spaces
- Office spaces
- Server and telecoms rooms

It is understood that site specific constraints may make the criteria detailed below difficult or impossible to achieve. Examples of such constraints are: the imposed building geometry such as when refurbishing an existing space, listed building status of certain buildings or when space availability doesn't allow for a successful natural ventilation strategy. Where this is the case designers must strive to reach the highest level of compliance possible (to this Guide) and present their solutions and findings for discussion.

3.2.2 Teaching and learning spaces

The criteria below are required as a minimum where a BREEAM standard is not included in the brief. The criteria for teaching spaces is taken from the Education Funding Agencies (EFA) Baseline Designs – Environmental Services Strategy[6] (with some modification) and are as follows:

1. **Carbon performance**; An Energy Performance Certificate rating of A or better for shall be achieved for new buildings and no worse than B for refurbishments;
2. **Indoor air quality**; when using natural ventilation maximum carbon dioxide concentrations in occupied teaching rooms of less than 1500 parts per million shall be achieved. When using mechanical ventilation, average concentration during the occupied period of less than 1000ppm shall be achieved with a maximum of 1500ppm not being exceeded for 20 consecutive minutes. Measurements shall be taken at seated head height.
3. **Light**; the recommendation of CIBSE's *Lighting Guide 5: Lighting for education*[7] shall be adopted; the preference is to use a balanced ambient light approach. It is desirable for daylight to be delivered into spaces from two sides with a minimum of

[6]https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/388141/Baseline_designs_environmental_services_strategy_2014.pdf
[7] CIBSE Lighting Guide 5: Lighting for education produced by the Society for Light and Lighting

30% glass to wall ratio; an increase in ratio will be required where external obstructions exist. A building orientation of North/South is preferred with higher angle south light being controlled by shading. Window heads should extend up to the ceiling height of 3.3m to aid light distribution. Spaces are required to be assessed using climate based daylight modelling in place of daylight factors.

4. **Heating**; 19 - 21ºC shall be achieved internally and according to the response times and durations specified for individual projects. Comfort shall be measured on an Operative Temperature basis[8] (T_{op}), when winter design conditions of -5ºC external exist. Heat will be sourced from the district heating system where feasible. The supply of heat to individual spaces should be interlocked with actuated windows so that heat cannot be lost through windows left open. Heated room control thermostats to be within 2ºC of actual air temperatures. Heat recovery shall be included where possible;

5. **Maximum summertime temperatures**; the UEA employs an adaptive approach to measuring summertime overheating as set out in European Standard EN 15251[9] (and as adopted by CIBSE). This approach allows the internal summertime temperature (using T_{op}) to increase as external (dry bulb) temperatures increases. Comfort can be achieved because occupants adapt to higher internal temperatures when outside temperatures are also increasing. Designs shall allow adaption to take place e.g. the use of openable windows and desk/ceiling fans.

   Designs using thermal mass in ceilings, with secure night ventilation and external shading to reduce the possibility of overheating, shall be considered. Free-running buildings (i.e. those not requiring mechanical cooling) are the preference of the UEA but constraints may result in this approach not being feasible.

   The UEA's strategy is to allow adaptation to take place as the temperature increases up to 27 ºC (T_{op}). As the internal temperature approaches 27 ºC a combination of local air movement from desk or ceiling fans and adaptation shall be maintained. Active cooling shall be used to ensure temperatures do not exceed 27 ºC (T_{op}).

   Where cooling systems are required for peak periods, chilled water shall be sourced from the district cooling system where feasible and recovered when possible.

6. **Noise**; operational background noise levels in teaching and learning spaces to be considered: e.g., unoccupied operational noise level from window actuators to be not more than 5dB above unoccupied indoor ambient noise level.

Designers of teaching and learning spaces should refer to CIBSE's TM57:2015 *Integrated school design* for guidance regarding successful strategies and processes.

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[8] Operative Temperature (T_{op}); a temperature index that accounts for air temperature as well as mean radiant temperature

[9] EN 15251 - Indoor Environmental Input Parameters for Design and Assessment of Energy Performance of Buildings Addressing Indoor Air Quality, Thermal Environment, Lighting and Acoustics

3.2.3 Residential spaces

The criteria below are required as a minimum where a BREEAM standard is not included in the brief.

1. **Carbon performance**; An Energy Performance Certificate rating of A or better for shall be achieved for new buildings and no worse than B for refurbishments;
2. **Indoor air quality;** bedrooms and day rooms will be provided with trickle ventilators for whole dwelling ventilation with openable windows providing purge ventilation. A mechanical system extracts air from bedrooms and day rooms with heat recovery to intake air. Shower rooms, WCs and kitchens have a similar strategy activated by local air quality or by means of activation of the lighting system.
3. **Light**; the recommendations in CIBSE's *Lighting Guide 9: Lighting for communal residential buildings*[10] shall be adopted. Natural light shall be supplemented with internal lighting systems according to the guidance given in Part 6: *General requirements for electrical systems*
4. **Heating**; 19 - 21ºC shall be achieved internally and according to the response times and durations specified for individual projects. Comfort shall be measured on an Operative Temperature basis[11], winter design conditions of -5ºC external. Heat will be sourced from the district heating system where feasible. The supply of heat to individual spaces should be interlocked with actuated windows so that heat cannot be lost through windows left open. Heated room control thermostats to be within 2ºC of actual air temperatures. The currently preferred approach is to use a conventional wet radiator system.
5. **Maximum Summertime Temperatures;** residential spaces are not mechanically cooled. The adaptive approach described in Section 3.2.2 should be employed with overheating risk being reduced by considering methods described in such guides as CIBSE's *How to manage overheating in buildings*[12].
6. **Noise**; operational background noise levels in residential spaces to be considered: e.g. operational noise level from extract systems to be not more than 5dB above unoccupied indoor ambient noise level.

3.2.4 Specialist spaces

Due to the diverse and specialist nature of research and laboratory spaces, a bespoke brief shall be developed for each project. As a minimum however the requirements set out in Section 3.2.2 'Teaching and Learning Spaces' shall be adopted.

Toilets and bathrooms may have an ACR much higher than other spaces and may be as high as 10 to suit the level of use of the space.

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[10] CIBSE Lighting Guide 9: Lighting for communal residential buildings

[11] Operative Temperature (T_{op}); a temperature index that accounts for air temperature as well as mean radiant temperature

[12] CIBSE Knowledge Series KS16: How to manage overheating in buildings

3.2.5 Office spaces

The criteria below are required as a minimum where a BREEAM standard is not included in the brief.

1. **Carbon performance**; An Energy Performance Certificate rating of A or better for shall be achieved for new buildings and no worse than B for refurbishments;
2. **Indoor air quality;** office spaces shall meet the requirements set out in the Approved Document of the Building Regulations and/or CIBSE Guide A i.e. for spaces with no significant emitters of pollutants (e.g. photocopiers), fresh air supply of 10 litres per second per person shall be provided resulting in carbon dioxide levels of between 700 and 1200 ppm.
3. **Light**; the requirements set out in CIBSE's Lighting Guide 7: Office lighting[13] shall be followed. Natural light shall be supplemented with internal lighting systems according to the guidance given in Part 6: *General requirements for electrical systems*
4. **Heating**; 19 - 21ºC shall be achieved internally and according to the response times and durations specified for individual projects. Comfort shall be measured on an Operative Temperature basis[14], winter design conditions of -5ºC external. Heat will be sourced from the district heating system where feasible. The supply of heat to individual spaces should be interlocked with actuated windows so that heat cannot be lost through windows left open. Heated room control thermostats to be within 2ºC of actual air temperatures.
5. **Maximum summertime temperatures**; the UEA employs an adaptive approach to measuring summertime overheating as set out in European Standard EN 15251[15] (and as adopted by CIBSE). This approach allows the internal summertime temperature (using T_{op}) to increase as external (dry bulb) temperatures increases. Comfort can be achieved because occupants adapt to higher internal temperatures when outside temperatures are also increasing. Designs shall allow adaption to take place e.g. the use of openable windows.

   Designs using thermal mass in ceilings, with night ventilation and external shading to reduce the possibility of overheating, shall be considered. Free-running buildings (i.e. those not requiring mechanical cooling) are the preference of the UEA but constraints may result in this approach not being feasible.

   The UEA's strategy is to allow adaptation to take place as the temperature increases up to 27 ºC (T_{op}). As the internal temperature approaches 27 ºC a combination of local air movement from desk or ceiling fans and adaptation shall be maintained. Active cooling shall be used to ensure temperatures do not exceed 27 ºC (T_{op}).

   Where cooling systems are required for peak periods, chilled water shall be sourced from the district cooling system where feasible and recovered when possible.

[13] CIBSE: Lighting Guide 7: Office lighting produced by the Society of Light and Lighting
[14] Operative Temperature (T_{op}); a temperature index that accounts for air temperature as well as mean radiant temperature
[15] EN 15251 - Indoor Environmental Input Parameters for Design and Assessment of Energy Performance of Buildings Addressing Indoor Air Quality, Thermal Environment, Lighting and Acoustics

3.2.6 Server and telecoms rooms

The UEA's data network features a centralised server facility and so most new-build and refurbishment projects will exclude the need for significant data processing.

For server rooms a Power Utilisation Efficiency (power into the room /power used by ICT equipment) should be less than 1.5,

Room temperatures maintained between 15 and 27ºC using natural ventilation and passive cooling where feasible. Mechanical ventilation can be considered where higher power devises are used.

3.3 Discussion of Preferred HVAC Strategies

Designs shall consider the need for each individual space or groups of spaces, rather than applying an overarching approach to all spaces in a project. For example, a lecture theatre with highly variable occupation will require a different approach to an office space with a largely fixed population even though they might both be located in the same building.

In consideration of the fabric first approach, ventilation becomes the principle driver of potential thermal energy loss and so accurate control of supply air is paramount to meeting the varying levels occupancy (e.g. by means of CO_2 sensors). It follows that a variable air volume approach is best employed but where occupancy levels can be very variable (e.g. in a lecture theatre), it may not be efficient to meet heating and cooling loads via supply air. In these circumstances it might be more efficient to provide heat and cold by separate wet emitter systems so that excessive supply air recirculation can be avoided. This latter approach benefits from the principle that water is a more efficient medium for transporting energy than air, in terms of distribution energy for pumps vs fans.

As the requirements of individual buildings are very specific, it follows that a detailed cost and energy model is required to determine the optimum solution. The UEA will provide projections for occupancy levels on an hourly basis as well as future weather data sets to ensure HVAC designs are optimised for current and future use.

All systems will be fully monitored and controlled via the site's Trend BMS system and so getting control algorithms absolutely right, over a period of time, is the aim.

4 Appendix – Guidance and Best Practice Documents

In addition to the Approved Documents of the Building Regulations the following best practice and design guides are referenced in this text.

CIBSE *Future CIBSE TRY/DSY Hourly Weather Data Set Norwich* (Product Code WD16NOR)

CIBSE TM48 2009: *Use of climate change scenarios for building simulation*

HM Government *Non-Domestic Building Services Compliance Guide – for use in England*

CIBSE *Guide L Sustainability*

Education Funding Agency *EFA Baseline Designs – Environmental Services Strategy*

CIBSE Lighting Guide 5: *Lighting for education* (produced by the Society of Light and Lighting)

EN 15251 - *Indoor Environmental Input Parameters for Design and Assessment of Energy Performance of Buildings Addressing Indoor Air Quality, Thermal Environment, Lighting and Acoustics*

CIBSE TM57:2015 *Integrated school design*

CIBSE Lighting Guide 9: *Lighting for communal residential buildings* (produced by the Society of Light and Lighting)

CIBSE Knowledge Series KS16: *How to manage overheating in buildings*

CIBSE Guide A *Environmental design*

CIBSE: Lighting Guide 7: *Office lighting* (produced by the Society of Light and Lighting)