Proceedings of Conference: ***Air Conditioning and the Low Carbon Cooling Challenge***, Cumberland Lodge, Windsor, UK, 27-29 July 2008. London: Network for Comfort and Energy Use in Buildings, http://nceub.org.uk.

Air-conditioning: The impact of UK regulations, the risks of un-necessary air-conditioning and a capability index for non-air conditioned naturally ventilated buildings.

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Abstract

The UK building regulations have been rapidly evolving. New methodologies have been developed in part driven by the EU EPBD. In this paper the UK building regulations and energy performance calculations as they relate to naturally ventilated (NV), mechanically ventilated (MV) and air conditioned (AC) buildings are reviewed. Calculations are carried out for typical, best practice and advanced fabric and systems and observations made on how the results may influence future adoption of air conditioning. Calculations of overheating potential and risks of unnecessary air-conditioning are discussed. A design methodology is proposed that could help to address some of the risks and provide a capability parameter to quantify design quality and allow design comparison.

Keywords

Air-conditioning, Natural ventilation, Building design, Simulation, Overheating

Introduction

Naturally ventilated or hybrid ventilated buildings are common. The importance of good understanding and good practice in design and operation of these buildings is being heightened by the recent increase in outdoor temperatures and the increased focus on reductions in building energy use across a number of countries.

The building regulations in the UK have recently been updated in part to align with the requirements for Energy Performance Certificates (EPC's) as required by the EU Energy Performance of Buildings Directive (EPBD) [1]. For domestic buildings the carbon emissions calculation methodology for building regulation compliance and EPC's is SAP2005 [2] while for non domestic dwellings the newly released national calculation method (NCM) [3] is implemented in the Simplified Building Energy Model (SBEM) which is planned to be used for the majority of buildings while for more complex buildings accredited dynamic simulation tools may be used.

In part due to the poor performance of existing (including recently constructed) buildings during recent warm summers and also to avoid unnecessary energy use for air-conditioning, the regulations now include the requirement to demonstrate that naturally ventilated buildings will maintain comfortable temperatures during warm summer periods. The guidelines for how the building design is shown to comply with this requirement have also been recently updated.

In order to assess the likely impact of the new regulations, guidelines and methodologies on future air conditioning, the ease of compliance to the new carbon emissions regulations and also the associated EPC energy rating was analysed for naturally ventilated, mechanically ventilated and fully HVAC options using a common type of office building. Compliance to the summer overheating criteria was also analysed for the same building.

Current regulations applied to an example building
A recent exercise was carried out at the request of the Scottish Building Standards agency to investigate compliance with the latest building regulations and the possible impact of future improvements in these regulations [4]. An example office was used in this project which was based on a fully detailed and costed design. The same example building is used as an example here (figure 1).

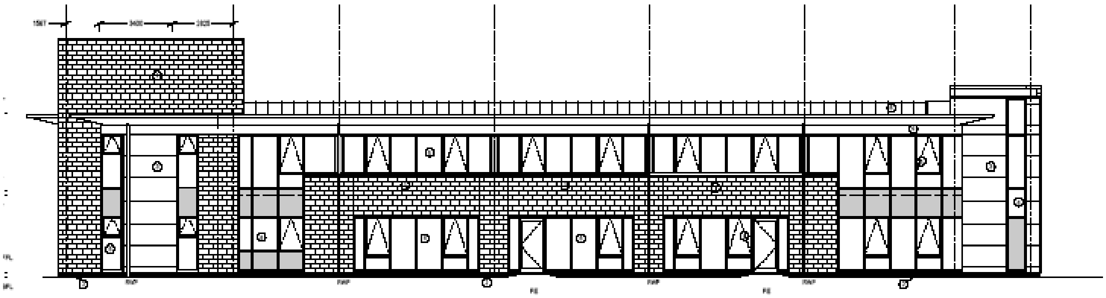

Fig.1. *The example building*

To illustrate the operation of the UK building regulation compliance calculations and energy performance calculations as implemented in SBEM a range of measures were applied to the building to represent; ‘2007 Typical fabric and systems’, ‘2007 Typical fabric and 2008 Best Practice systems’, ‘Advanced fabric and 2008 Best Practice systems’ and ‘Advanced fabric and Advanced systems’. These packages are detailed in Appendix 1. The levels set for the parameters come from a scoping review carried out as part of the Building Market Transformation project [5].

Figures 2, 3, and 4 give the results calculated using the SBEM tool for the Naturally Ventilated (NV), Mechanically Ventilated (MV) and Fully Air Conditioned (AC) versions of the building. (Note: the results shown are for the Scottish Regulations and EPC calculations).

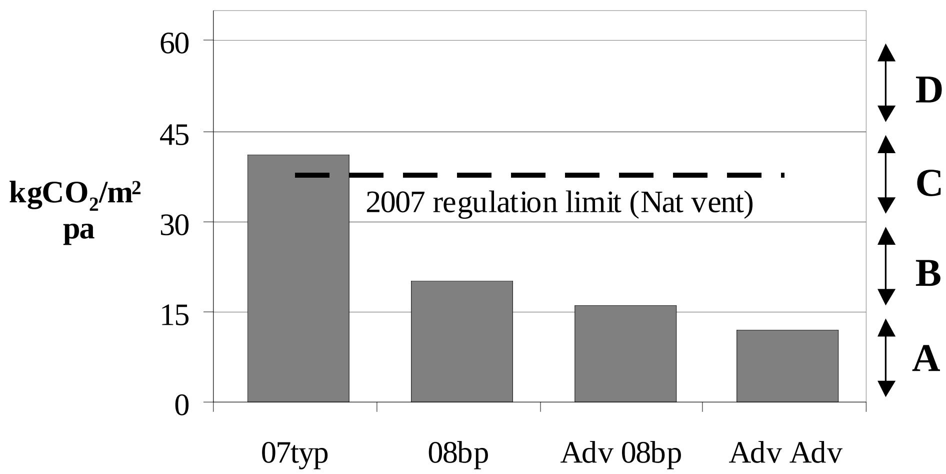

Fig.2. *Carbon performance and energy rating for the naturally ventilated (NV) design options. Detailed input parameter values are given in appendix 1.*

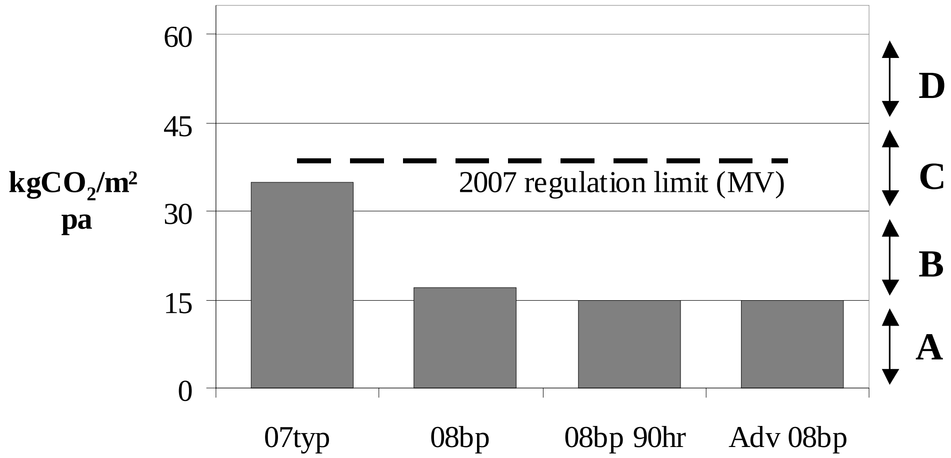

Fig.3. *Carbon performance and energy rating for the mechanically ventilated (MV) design options with heat recovery (no cooling). Detailed input parameter values are given in appendix 1.*

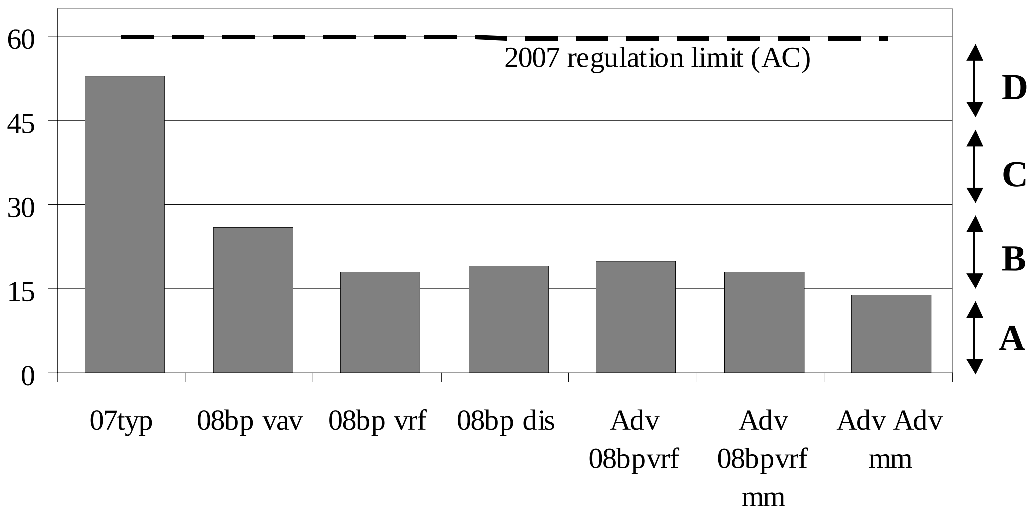

Fig.4. *Carbon performance and energy rating for the mechanically ventilated and cooled (AC) design options. Detailed input parameter values are given in appendix 1.*

The regulation compliance level is shown in the graphs and it can be seen that the '2007 typical fabric and systems' (07typ) package gives compliance to the regulations for the MV and AC cases but fails to pass the criteria in the NV case. The NV building has a carbon performance of 40 kgCO2/m^2 pa but fails the NV limit of 37.6 kgCO2/m^2, while the AC building with a higher carbon performance of 53 kgCO2/m^2 passes the AC limit of 59.7 kgCO2/m^2.

Mechanically ventilated and fully air conditioned buildings appear to comply with the regulations with 2007 typical systems and fabric if heat recovery ventilation is implemented. Additional scenarios were run without heat recovery and shown to fail.

The Energy Performance Certificate labelling is referenced absolutely rather than being dependent on building HVAC type and the labelling reflects the actual emissions. The AC '07typ' building is rated as a 'D' reflecting the higher emissions while the MV and NV buildings are given a 'C' rating.

Where the ‘2008 best practice systems’ are applied to the ‘2007 fabric’ buildings then all of the building types achieve a ‘B’ rating.

The improvement of the fabric to ‘Advanced’ standards with associated insulation and infiltration improvements has a positive impact on the calculated performance of the naturally ventilated and mechanically ventilated design options but has a negative impact in the case of the AC design option as the increase in cooling energy is greater than the reduction in heating energy.

The results of the calculations would appear to suggest that the historical tendency for air conditioned buildings to use more energy and have associated higher carbon emissions than naturally ventilated buildings [6] may not necessarily apply in the future? (Note: historically AC buildings have tended to be deeper plan, have higher IT density, longer operating hours and less opportunity for daylight than NV buildings which accounts at least in part for the difference in historical survey data).

The calculation results would also tend to suggest that for future regulations the same calculated CO_2 emissions rates could be applied across NV, MV and AC building types.

The calculations reflect the output of an idealised model which may not necessarily reflect actual operation. Studies of buildings in operation have found that there can be significant differences between calculated and actual energy performance [7] also surveys have found that many buildings have errors in implementation or operation which cause energy use to be higher than intended. The more novel, complex or highly serviced a building then in general the higher the risk that these problems will arise. The performance of future buildings will need to be monitored closely to avoid miss-steps.

The natural ventilation design option, in order to meet the building regulations, must also meet criteria for avoidance of excessive summer temperatures. The example building used here was shown to meet the criterion using the gains calculation method in CIBSE TM37 [8], this required the window area to be reduced from the originally submitted design (more details in next section) [4].

Overall the most recent building regulations could be viewed as providing a greater challenge to developers of naturally ventilated buildings than they have done in the past.

Criteria for avoiding overheating in current UK regulations

In the England and Wales regulations [9] criteria 3 (of the 5 criteria) is aimed at limiting the effect of solar gains with the aim of countering excessive temperature rise in summer. Compliance with criteria 3 can be demonstrated in a number of ways, these are summarised in the Compliance Checklist as; (i) Gains =< $35W/m^2$ per CIBSE TM37, (ii) T < 28^oC for =< X hrs/yr when tested against CIBSE DSY [10], 1% is suggested for offices or (iii) BB101 [11] for schools which refers to use of the ‘ClassVent’ and ‘ClassCool’ tools in which CIBSE AM10 [12] calculation methods are embedded. While the checklist summarises the most common methods, other more detailed methods are allowed, the CEN standards 13791 and 13792 provide the criteria all methods must meet to be considered valid [13,14].

In the Scottish regulations the TM37 gains method is suggested as well as the CIBSE requirement for offices that occupied hours above 28^oC should not exceed 1% [15]. The Scottish regulations allow for the calculated CO_2 emissions to be adjusted down by 5% where the design temperatures achieved are always below 28^oC although the calculation method for meeting this criterion is not explicitly set.

Both the Scottish and E+W regulations mention CIBSE TM36 [16] for further guidance for going beyond the requirements of the current regulations.

The example building described in the previous section was deemed to have complied with the regulations using the TM37 method. It is worth reviewing the process used in this case as several iterations were involved in achieving a design which passed.

The initial building design had around 50% glazing (as a ratio with external wall area). The TM37 gain limit of 35 W/m^2 is adjustable by location, in our case the building is in Central Scotland (between Glasgow and Edinburgh) so the limit is 45.15 W/m2 to account for the lower local outdoor temperatures.

TM37 gives two ways to estimate the internal gains: (a) using standard tables, or (b) based on designers detailed assessment of the potential use of the space. The standard tables for use with method (a) are given in the TM37 document as an appendix, an example of a detailed assessment using method (b) is also given in TM37 for an open plan office space similar to that of the example building (Section 6.1). Both of these methods initially failed. On discussion of a range of options including solar control, thermal mass, more complex calculation methods etc. it was decided that the developers preferred option would be to reduce the glazing area to 40% by replacing some glazed elements with insulated spandrels. With this reduced glazing area the detailed assessment method (b) based on the TM37 example open office calculation then gave a ‘Pass’ as shown in table 1 and the building was then deemed to be compliant.

As a cross check dynamic simulation was run with the building modelled in ESP-r software [18] including an air flow network and proportional window opening between 20 and 22^{o}C for the CIBSE Glasgow summer design year, both of the internal gains scenarios from TM37 were included in the simulations, the results were somewhat consistent in that the reduced gains scenario (b) appeared to show compliance with less than 1% of occupied hours > 28^{o}C while the higher gain scenario (a) again failed (table 2). The dynamic simulation was carried out for both ‘2007 typical’ fabric and ‘Advanced’ fabric options (appendix 1). The ‘Advanced’ fabric option was marginally more prone to overheating by this criterion.

Table 1. *Overheating calculations for the example building (40% glazing) using the TM37 method for a standard gains scenario (method (a)) and a reduced gains scenario (method (b)).*

Method: TM37	(a)	(b)	
Solar gains	34	34	W/m2
Occupant gains	6	2.4	W/m2
Lighting gains	0	0	W/m2
Equipment gains	15	6.2	W/m2
Total gains	55	43	W/m2
Target (35*1.29)	45.15	45.15	W/m2
Pass/Fail	**FAIL**	PASS	

Table 2. *Overheating calculations for the example building using the Dynamic Simulation method (ESP-r) with the same gains scenarios as in table 2. The percentage values represent the proportion of annual occupied hours when the 28°C threshold is exceeded.*

Method: Dynamic	(a)	(b)	
2007 reg fabric	8.5%	0.5%	occ hr
Advanced fabric	12.3%	0.7%	occ hr

In the more recent versions of the SBEM tool [17] an overheating risk assessment calculation is carried out and a value returned indicating a ‘high’, ‘significant’, ‘moderate’ or ‘low’ risk of overheating however the calculations behind this metric are not yet public domain and the use of the calculations has not yet been defined. For the example office the SBEM tool overheating output for the ground and first floor offices was ‘High’ and ‘High’, adding exposed thermal mass and shading to the construction did not change the results, only by reducing the equipment load from around 42kWh/m2 p.a. to 7kWh/m2 p.a. by selecting alternative activities within the space in addition to the exposed mass and shading did the results improve to ‘Moderate’ and ‘Significant’.

Risk of un-necessary air-conditioning

The current building regulation compliance practices in the UK do not generally comprehend the adaptive nature of comfort in free running naturally ventilated buildings that is well established and documented in the CEN Standard EN15251 [19] and also in CIBSE Guide A [20]. The adaptive criteria have been shown in occupant surveys to better represent occupant comfort (and discomfort) when compared to a fixed threshold. For warmer climates the adaptive criteria can allow significantly higher ‘comfortable’ temperatures than non-adaptive criteria, particularly where ceiling fans are provided.

The modelling of people, their behaviours and the equipment use in free running naturally ventilated buildings is somewhat subjective as illustrated by the differences between TM37 scenario (a) and scenario (b), the assumptions on occupancy, lighting and equipment gains vary greatly and have a large effect.

Occupant use of blinds and shading devices are coarsely and subjectively represented. Use of windows for ventilation and cooling is generally represented either as a fixed ventilation rate, a variable ventilation rate or, when an air-flow network is sometimes used in dynamic simulation, may be represented as some proportional window opening based on an indoor temperature. The use of ceiling fans is generally not considered in the UK but may be a future option. The modelling of lighting as always ‘off’ in the summer period per TM37 may not be appropriate particularly where blinds have been deployed to avoid glare or direct solar heat gains. By allowing the designer flexibility to assess the risk of overheating based on the ‘planned’ occupancy and use of the space then no account is taken for possible change in use in future e.g. from low occupancy low IT intended use to high occupancy, high IT use (e.g. call-centre).

Conversely if the designer was required to have all the input variables set at a worst case value then the combination of the worst cases may be totally unrealistic and could lead to the incorrect conclusion that natural ventilation is not an option.

Figure 5 illustrates the different risks related to specification of overheating criterion, if there is no regulation for overheating then there is a high risk that after some time in operation the building will be retro-fitted with air-conditioning, if the criteria are unrealistically over-robust then there is a high risk that at the design stage the designer will un-necessarily opt for an AC building. There is a third risk represented on the graph as ‘NV not chosen’ which is the risk that AC will be preferred to passive measures such as shading, mass and night ventilation due to cost, logistics, perceived risk, sales or rental value, time delays or other reasons.

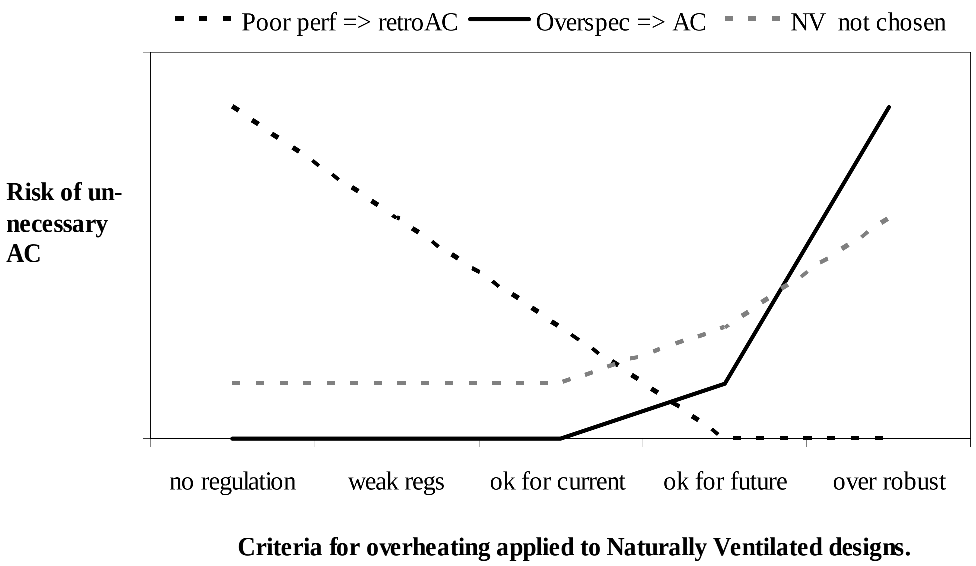

Fig.5. *Risk of un-necessary air-conditioning including risk of retrofit to poorly designed buildings, risk of AC due to over robust criteria for NV and risk that AC will be selected in preference to NV due to economic or other reasons.*

A proposed approach using a building comfort capability index (C)

The current approach could be summarised as being to calculate the building performance for a single set of pseudo worst-case input parameters and measure performance against a pass-fail criterion. A similar approach was taken in the electronics industry in the 1980’s where significant efforts were made to synthesise ‘realistic worst-case’ simulation parameter sets for creating competitive designs through avoiding the risk of an expensive design failure or the opposing risk of un-necessarily complicated, costly and un-competitive designs [21]. More recently in electronics the approach has changed from this pass/fail test to an assessment of the robustness of the design to realistic variation in input parameters and the calculation of a capability parameter [22]. This second approach is employed in many industries and commercial organisations and would appear to have some value in the area of building design.

Here a detailed methodology is described for deriving a design capability parameter (C) for the summer comfort performance of a naturally ventilated building. This depends on robust algorithms representing occupant behaviour and representation of uncertainty in building operation and climates within dynamic simulation. The development of this methodology and the underlying behavioural models and uncertainties is still the subject of research and development. The design comfort capability parameter approach need not necessarily depend on conclusion of this research, it would be possible to apply based on currently available or simplified underlying models and still provide benefits.

It is proposed that the comfort criteria the performance of a building in free running, naturally ventilated mode should be measured against is the adaptive comfort criteria. It is relatively simple to apply the adaptive criteria in dynamic simulation. Figure 6 and table 3 both show the summer performance relative to the adaptive criteria in the CEN standard for; (a) a south facing thermally lightweight office, (b) the same office with an external shade applied, and (c) the same office with the external shade and an exposed concrete ceiling to add thermal mass.

This simulation includes ventilation through an airflow network and window opening modelled using the Humphreys model representing occupant adaptive behaviour. More detail is given in a previous publication [23].

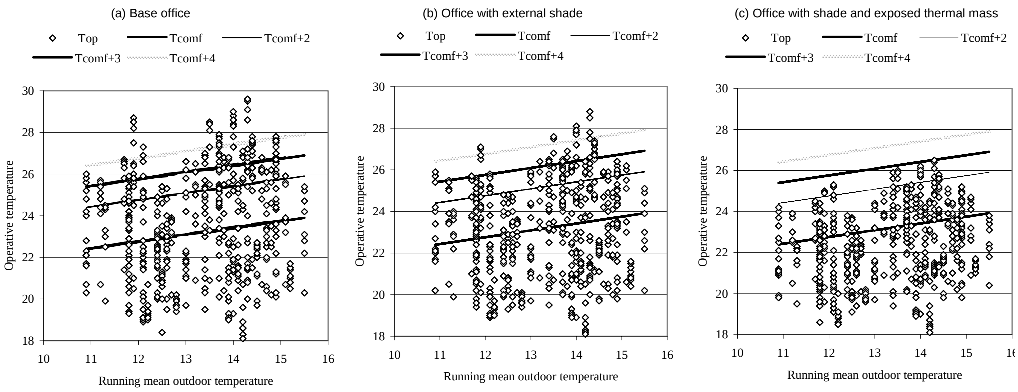

Figure 6 *The summer performance of the three office design variants is compared against the adaptive comfort criteria, the left graph (a) shows the baseline office, the center graph (b) shows the baseline office with an external shade added, the right graph (c) shows the baseline office with an external shade and an exposed concrete ceiling. All units are ^{o}C.*

Table 3. *Design variant results for adaptive comfort criteria*

Building design variant	**Occupied hours > Tcomf+2 (category I)**	**Occupied hours > Tcomf+3 (category II)**	**Occupied hours > Tcomf+4 (category III)**
Base case - typical south facing office.	32 %	17 %	5.5 %
Base case with external shading.	22 %	7.2%	2.3 %
Base with shading and exposed mass.	5.3 %	0	0

Modelling of the ventilation in terms of an airflow network rather than making more generalised assumptions better reflects the short time-base variation in airflow resulting from variations in wind speed and wind direction and also allows occupant window opening behaviour to be directly incorporated.

The modelling of a wide range of occupant behaviours such as window opening, light and blind use and occupancy patterns is being actively developed and implemented in dynamic simulation and the available algorithms have been shown to give reasonable agreement with field survey data [24]. These occupant behavioural algorithms are generally stochastic in nature and represent the spread in occupant behaviour between more active users of adaptive opportunities and more passive users.

The variability in occupant behaviour is one uncertainty that impacts on building performance, other uncertainties are variations in internal gains, variations in climate, variability in construction parameters etc.

Uncertainty analysis is already well established in building simulation [25]. Monte-Carlo analysis can be used to generate the distribution in output parameters resulting from variation in input parameters.

The proposal here is that a building is dynamically simulated in a Monte-Carlo method for appropriate distributions representing possible variation in internal equipment and lighting gains, climate, occupancy, window opening behaviour, light and blind use etc and the resulting output distribution be compared against the adaptive comfort criteria to generate a building summer comfort capability index C.

The methodology and the capability parameter is illustrated here for the simple example shown in figures 7 and 8 where performance of the thermally lightweight office for one summer day was simulated in Monte-Carlo mode with the input variation being only due to variation in window opening behaviour as described by the Humphreys algorithm [23]. The maximum, minimum and mean operative temperature (Top) for that day is shown in figure 7, this illustrates possible range in temperatures due to the variation between more ‘active’ and ‘passive’ use of the windows. The operative temperatures are shown in figure 8 normalised to the comfort temperature (Tcomf) for that day.

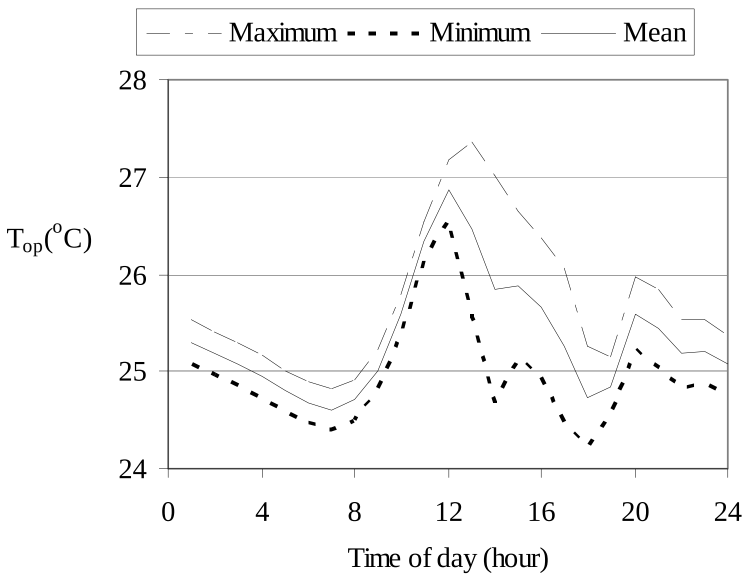

Figure 7 *The predicted range in operative temperature for a single day in summer day due to the variation in window opening behaviour represented by the stochastic nature of the Humphreys algorithm run in a Monte-Carlo mode.*

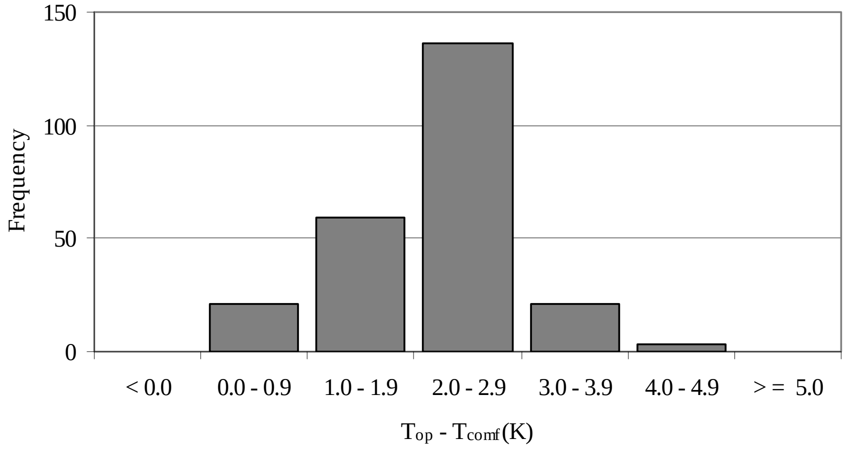

Figure 8 *The predicted distribution of the deviation from optimal thermal comfort temperature (T_{op} – T_{comf}) for the same summer day as in Figure 10 due to the variation in occupant behaviour as embedded in the Humphreys algorithm.*

The comfort capability (C) of the building (considering only this one day and this single source of variation) can then be calculated [20] using the equation:

C = (specification limit – mean) / (3 x sigma)

Where for a class II building per the CEN standard [19] the specification limit is Tcomf+3 and the mean and sigma are for the Top-Tcomf distribution.

In the same way, the Monte-Carlo simulation method can be applied to capture all the input parameter variations and generate an overall output distribution (Figure 9).

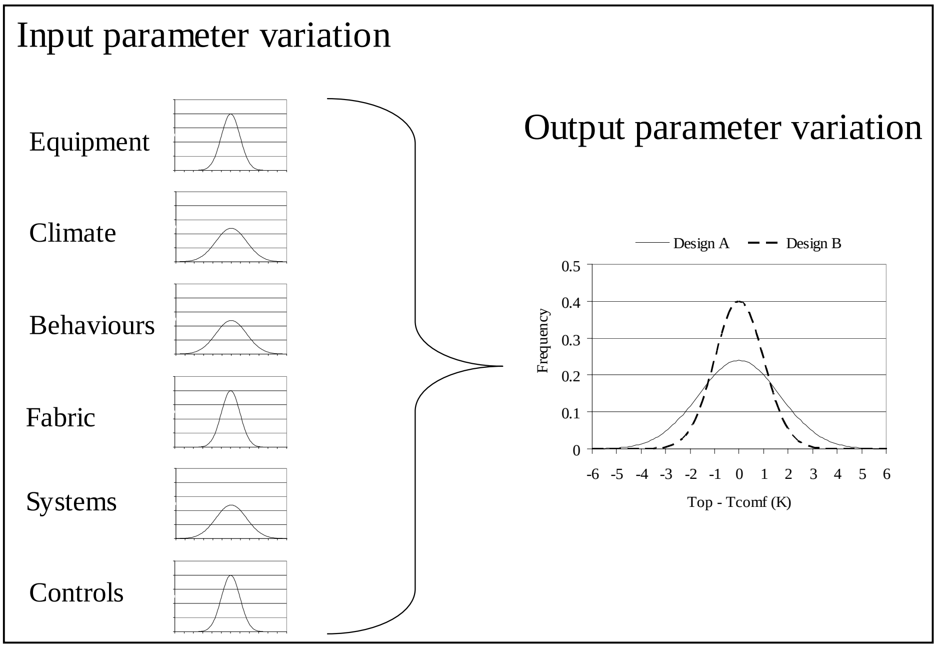

Figure 9 *The variation in input parameters combined in dynamic simulation using Monte-Carlo method to give a resulting variation in output parameters for Design A and Design B (see also Figure 10).*

Figure 10 illustrates how the performance could be analysed in this way for two different design options. This illustration shows the two design variants to have similar average performance. However option A has poor performance for some combinations of possible input parameters that may result in significant overheating while option B is clearly more robust for the modelled changes in patterns of use, climate, fabric etc. This type of analysis can be carried out for any of the comfort or energy use outputs from the simulation.

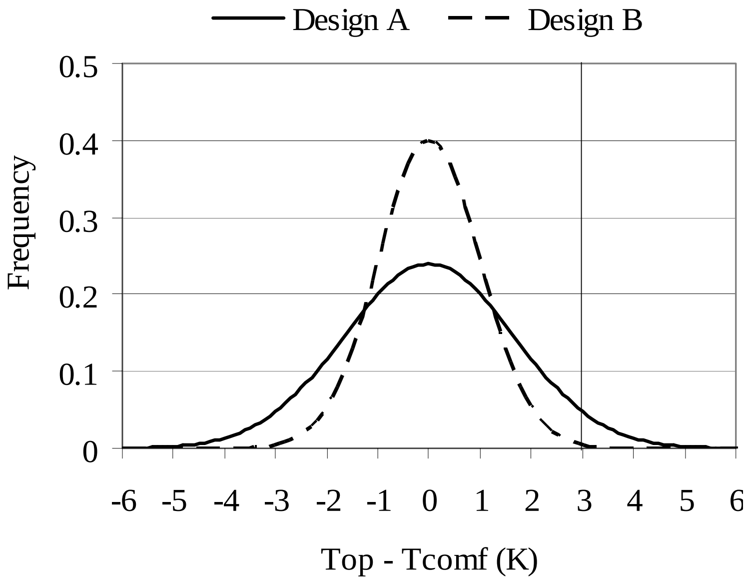

Figure 10 *Distributions representing the comfort performance of Design A and Design B for a range of input parameters representing variation in climate, internal gains, occupant behaviour, construction etc. Design A has a comfort capability of C = 1 when compared to the* T_{comf} *+ 3K limit for a category II building, Design B has a comfort capability of C = 0.6.*

Implementation of this methodology would require the specification of standard distributions in input variables (internal gains, behaviours etc) to be modelled. These could be derived from existing survey data, climate projections etc.

The example office here which only passed the overheating criteria for a very low set of internal gains assumptions would have a lower comfort capability (C = 0.5 say) while a heavyweight, well shaded building with night ventilation in a rural location could have a higher comfort capability (C = 1.2 say).

One of the advantages of this method would be that it would allow building designs to be benchmarked and compared using a simple index in a language that has already permeated other industries. It would give building designers, specifiers or building owners a value which would relate to the capabilities of the building and the limits beyond which comfortable conditions would not be guaranteed without taking action in mitigation (e.g. addition of shading or night ventilation, selection of low power IT equipment, provision of AC etc.).

Conclusions

The UK building regulations allow a fully serviced office building design to have a higher level of calculated emissions than the equivalent naturally ventilated design option however the energy rating for EPC certificate which is based on the absolute emissions and will give a better rating to the building design which achieves the lowest carbon emissions.

With current typical levels of fabric and system performance then the naturally ventilated design in this study was a marginal fail to the current building regulations emissions criteria while the air-conditioned design was a pass. These typical designs achieved a ‘C’ rating with natural and mechanical ventilation and a ‘D’ with air conditioning including cooling.

Applying current best practice systems to the typical fabric led to the naturally ventilated, mechanically ventilated and the air-conditioned designs achieving a calculated ‘B’ rating and similar calculated emissions levels. This equivalent calculated performance for the highly serviced design is discussed in the context of historical data and some questions are raised over whether this calculated performance will be achieved in practice.

The UK building regulations now have increased focus on summer overheating criteria but there are several methods of demonstrating compliance. An analysis of these methods was carried out and issues identified which could lead to a risk of un-necessary air conditioning either through implementation of air-conditioning in a building which does not require it or through the creation of a building which performs poorly and has to be subsequently air-conditioned.

The factors behind these risks are reviewed including the use of fixed rather than adaptive comfort criteria and the variation in occupant behaviour, building use, internal gains, fabric, climate etc.

A methodology is then proposed for assessing the building performance which includes a capability parameter (C) which can be used to compare the capability of different designs and provide an indication of design quality. This methodology is widely used in other industries where the quality metric has provided significant benefits over the use of pass/fail criteria.

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Appendix 1: *Detail of parameters used for the SBEM calculations.*

		Fabric		HVAC System					Lighting
		Insulation (wall, roof, floor, glazing U (W/m^2K)).	Infiltration (fabric air permeability (m3/m2/h @ 50Pa)).	HVAC system type	Heating system (fuel, type, efficiency % or COP)	Ventilation system type and heat recovery efficiency (%)	specific fan power (w/l/s) and duct leakage (%)	Cooling system type	Lighting system (Installed W/m2, control type, display lighting type)
Natural Ventilation	label								
'2007 typical fabric and systems'	07typ	0.25 / 0.16 / 0.25 / 1.8	10	heating only	gas lthw boiler 87%	natural ventilation	na / na	No cooling	12.7W/m2, manual on/off control, standard display lighting
'2007 typical fabric and 2008 best practice systems'	08bp	0.25 / 0.16 / 0.25 / 1.8	7.5	heating only	ground source heat pump cop 4	natural ventilation	na / na	No cooling	7W/m2, photosensing control, high efficiency display lighting
'Advanced fabric and 2008 best practice systems'	Adv 08bp	0.13 / 0.13 / 0.13 / 0.8	2.5	heating only	ground source heat pump cop 4	natural ventilation	na / na	No cooling	7W/m2, photosensing control, high efficiency display lighting
'Advanced fabric and Advanced systems'	Adv Adv	0.13 / 0.13 / 0.13 / 0.8	2.5	heating only	ground source heat pump cop 5.5	natural ventilation	na / na	No cooling	3.4W/m2, photosensing control, high efficiency display lighting
Mechanical Ventilation	label								
'2007 typical fabric and systems'	07typ	0.25 / 0.16 / 0.25 / 1.8	10	heating and ventilation	gas lthw boiler 87%	Mechanical ventilation 65% HR	1.5 / na	No cooling	12.7W/m2, manual on/off control, standard display lighting
'2007 typical fabric and 2008 best practice systems'	08bp	0.25 / 0.16 / 0.25 / 1.8	7.5	heating and ventilation	ground source heat pump cop 4	Mechanical ventilation 75% HR	1 / na	No cooling	7W/m2, photosensing control, high efficiency display lighting
'2007 typical fabric and 2008 best practice systems (90% HR)'	08bp 90hr	0.25 / 0.16 / 0.25 / 1.8	7.5	heating and ventilation	ground source heat pump cop 4	Mechanical ventilation 90% HR	1 / na	No cooling	7W/m2, photosensing control, high efficiency display lighting
'Advanced fabric and 2008 best practice systems'	Adv 08bp	0.13 / 0.13 / 0.13 / 0.8	2.5	heating and ventilation	ground source heat pump cop 4	Mechanical ventilation 75% HR	1 / na	No cooling	7W/m2, photosensing control, high efficiency display lighting
HVAC with Cooling	label								
'2007 typical fabric and systems'	07typ	0.25 / 0.16 / 0.25 / 1.8	10	HVAC single duct VAV	gas lthw boiler 87%	Mechanical ventilation 65% HR	2.3 / 6%	air cooled heat pump seer 2.5	12.7W/m2, manual on/off control, standard display lighting
'2007 typical fabric and 2008 best practice systems (VAV)'	08bp vav	0.25 / 0.16 / 0.25 / 1.8	7.5	HVAC single duct VAV	air source heat pump cop 4.5	Mechanical ventilation 75% HR	1 / 2%	air cooled heat pump seer 4.5	7W/m2, photosensing control, high efficiency display lighting
'2007 typical fabric and 2008 best practice systems (VRF)'	08bp vrf	0.25 / 0.16 / 0.25 / 1.8	7.5	HVAC VRF	air source heat pump cop 4.5	Mechanical ventilation 75% HR	1 / 2%	air cooled heat pump seer 4.5	7W/m2, photosensing control, high efficiency display lighting
'2007 typical fabric and 2008 b. p. systems (Disp. Vent, chill. beam)'	08bp dis	0.25 / 0.16 / 0.25 / 1.8	7.5	HVAC disp vent / chill beam	air source heat pump cop 4.5	Mechanical ventilation 75% HR	1 / 2%	air cooled heat pump seer 4.5	7W/m2, photosensing control, high efficiency display lighting
'Advanced fabric and 2008 best practice systems (VRF)'	Adv 08bpvrf	0.13 / 0.13 / 0.13 / 0.8	2.5	HVAC VRF	air source heat pump cop 4.5	Mechanical ventilation 75% HR	1 / 2%	air cooled heat pump seer 4.5	7W/m2, photosensing control, high efficiency display lighting
'Advanced fabric and 2008 best practice systems (VRF - mixed mode)'	Adv 08bpvrf mm	0.13 / 0.13 / 0.13 / 0.8	2.5	HVAC VRF mix mode	air source heat pump cop 4.5	Mechanical ventilation 75% HR	1 / 2%	air cooled heat pump seer 4.5	7W/m2, photosensing control, high efficiency display lighting
'Advanced fabric and Advanced systems (VRF - mixed mode)'	Adv Adv mm	0.13 / 0.13 / 0.13 / 0.8	2.5	HVAC VRF mix mode	air source heat pump cop 5	Mechanical ventilation 75% HR	1 / 2%	air cooled heat pump seer 6	3.4W/m2, photosensing control, high efficiency display lighting