Improvements to Energy Standards for New Buildings within Scottish Building Regulations 2021: Overheating in New Homes

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0. Executive Summary

1 The main aim of this report is to assess the likelihood of overheating risk in new homes in Scotland, under the improved standards of building fabric and in the context of projected temperature increases due to climate change.

2 Dynamic thermal modelling was undertaken according to CIBSE TM59 methodology for five dwelling typologies including a semi-detached house and single- and dual-aspect flats. The Glasgow DSY1 2020 high emissions scenario weather file was used to assess the overheating risk. Only the dual-aspect flat typologies failed the CIBSE TM59 overheating criteria.

3 Given that the dual-aspect flats only exceeded the overheating criteria to a limited extent, all of the passive risk mitigation packages evaluated in England and Wales should be sufficient for controlling the overheating risk. This paper provides commentary on the suitability of those packages with the lowest capital cost.

4. A high-level comparison of historical weather data suggests that in Scotland southern inland locations (around Glasgow) have higher peak summer temperature compared to the rest of the locations reviewed. This suggests that the passive risk mitigation packages proposed in this paper should be suitable for controlling the risk of overheating for at least most locations in Scotland.

1. Introduction

1.1 The main aim of this report is to produce data to establish the likelihood of overheating risk in new homes in Scotland in the context of projected temperature increases due to climate change

1.2 It is coupled with an assessment of the need for passive mitigation measures to address any overheating risk identified, based on a review of research previously undertaken in England and in Wales

1.3 At this stage, this research excludes any evaluation of the costs and benefits of applying mitigation measures.

2. Dynamic Thermal Modelling

Building Typologies

2.1 The building typologies were selected from those used in the overheating modelling work carried out previously in England and Wales. They include a range of typologies and they were shown from the previous work to demonstrate a range of overheating risk. These typologies are detailed in Table 1:

Type	Dwelling Form	Size	Aspects	Ventilation Strategy	Heating System	Construction Type
1.	Apartment / Flat	2b4p	Single	Nat. vent	Individual	Mid-rise
1b.	Apartment / Flat	2b4p	Single	MEV (plus nat. vent)	Individual	Mid-rise
2.	Apartment / Flat	2b4p	Dual	Nat. vent	Individual	Mid-rise
2b.	Apartment / Flat	2b4p	Dual	MEV (plus nat. vent)	Individual	Mid-rise
3.	Semi-detached house	3b5p	Triple	Nat. vent	Individual	Timber frame

Table 1: Dwelling typologies used to assess overheating risk for Scotland

Modelling Approach and Overheating Assessment Criteria

2.2 The overheating risk for each of the building typologies was determined through dynamic thermal modelling. The modelling followed the CIBSE TM59 methodology and the results were assessed against the CIBSE TM59 overheating criteria. This is the same approach as used for both the England and Wales assessments.

2.3 Core modelling assumptions (e.g. internal gains, occupancy schedules and window openings) have been adopted from the England and Wales assessments. Details can be found in Annex A.

Building Specification

2.4 As agreed with the Scottish Government team, all buildings have been modelled using a timber-frame build up on the basis that this is the dominant construction type in Scotland. The use of this construction type results in a ‘low’ thermal mass for the constructions.

2.5 The fabric specification applied to the buildings is based on the ‘2021 advanced case’ in Section 4.5 of the AECOM report “Improvements to Energy Standards for New Buildings within Scottish Building Regulations 2021: Modelling Report – Domestic” (May 2020). These have been summarised in Table 2:

Building Element	U-value and details (W/m²K)
External Walls	0.13
Corridor Wall	0.13
Party Wall	0.00
Floor	0.10
Roof	0.09
Window / Rooflight	0.80 (with g-value of 0.57)
Door	1.00

Table 2: 2021 Advanced Case Fabric Specifications

Weather Data

2.6 The TM59 standard requires the simulation to use the DSY1 2020s high emissions scenario, 50th percentile weather data published by CIBSE. CIBSE has published DSY1 weather data for 14 UK locations of which two are in Scotland; Glasgow and Edinburgh.

- DSY1 (Design Summer Year 1) is intended to represent a moderately warm summer.
- The 2020s weather data is intended to represent 2011 to 2040.
- A high greenhouse gas emissions scenario was adopted.
- The percentile represents that likelihood that the mean air temperature will be less than predicted (50th percentile used here).

2.7 The TM59 standard suggests that further analysis may be undertaken to account for heat waves and/or future climate change. CIBSE publishes additional weather files to facilitate this including: different future time periods to the end of the century, different Design Summer Years to represent alternative heat wave scenarios, different emission scenarios (low, medium and high) and different percentiles (10th, 50th, 90th percentiles).

2.8 A sample dwelling simulation was run using both the Edinburgh DSY1 2020s high emissions scenario 50th percentile weather file (Edinburgh_DSY1_2020High50) and the equivalent Glasgow weather file (Glasgow_DSY1_2020High50) to determine which resulted in higher overheating risk based on the CIBSE TM59 criteria.

2.9 The results of the sample test showed that the Glasgow weather file resulted in higher overheating results for the sample dwelling. Therefore, the Glasgow weather file was used for the full assessment as it is more challenging to comply with.

3. Results

CIBSE TM59 Criteria and Building Category

3.1 CIBSE TM59 sets out two compliance criteria for dwellings; both need to be met to demonstrate an acceptable risk of overheating:

- Criterion A applies to living rooms, kitchens and bedrooms. It requires that the internal temperature does not exceed a defined comfort temperature by 1°C or more for more than 3% of the occupied hours over the summer period (1^{st} May to 30^{th} September).
- Criterion B applies to bedrooms only and requires that the internal temperature between 10pm and 7am shall not exceed 26°C for more than 1% of annual hours. Therefore 33 hours or more is recorded as a fail.

3.2 The assessment has been run assuming Category II buildings, which is the same as the previous England assessment. Category II assumes that the buildings have a normal level of expectation of being occupied by vulnerable and fragile persons.

Results

3.3 Figure 1 and Figure 2 show how well each of the dwelling typologies met Criterion A and Criterion B respectively based on the outputs from the dynamic thermal simulation modelling.

3.4 The semi-detached house and the two single-aspect flats all passed both Criteria A and B of CIBSE TM59. Both dual-aspect flat typologies passed Criteria B of CIBSE TM59 (bedrooms), but both living rooms failed Criteria A albeit to a limited extent.

3.5 For the sample dwellings used in this analysis, the greater glazed area of the dual-aspect flat increased the solar gains to the extent that the net effect was to increase the risk of overheating compared to single-aspect flats. It is noted from experience that, depending on the design and location, dual-aspect flats can be at lower risk of overheating than single-aspect flats because the dual-aspect provides the potential to benefit from cross-ventilation (where wind drives greater ventilation rates through the dwelling).

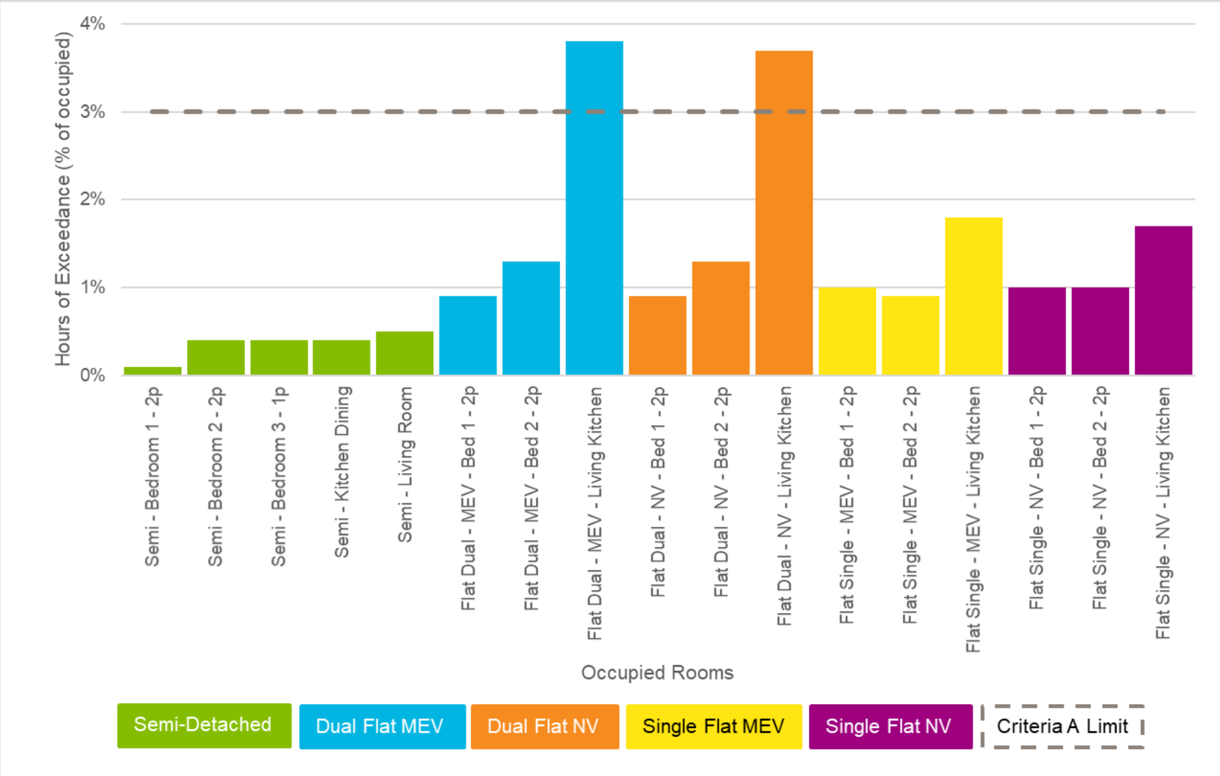

Figure 1: Percentage overheating hours – CIBSE TM59 Criteria A

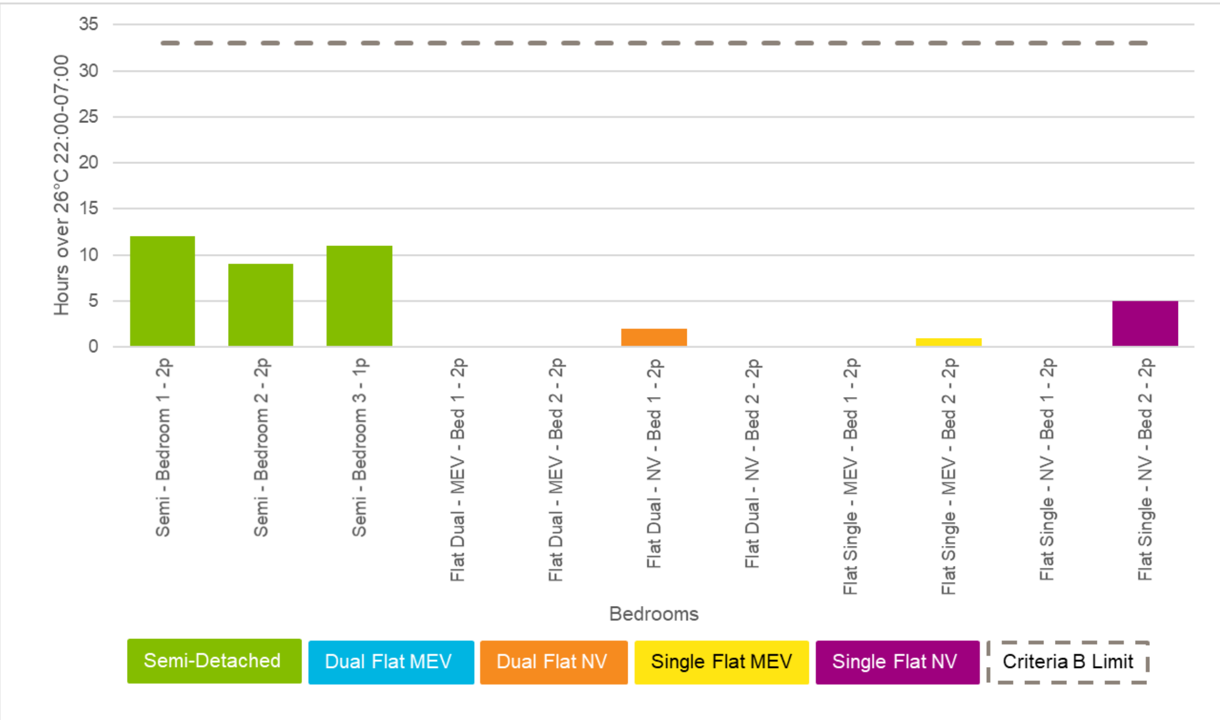

Figure 2: Hours of overheating – CIBSE TM59 Criteria B (bedrooms)

Mitigation Measures

3.6 Based on these results, the Scottish Government will need to consider whether to require mitigation measures to all new dwellings or only specific dwelling typologies. For both England and Wales, the consultation-stage Approved Documents propose mitigation measures based on characteristics of the dwelling (e.g. single or multiple aspect facades).

3.7 As the results of this analysis showed that dual-aspect building typologies only exceeded Criterion B to a limited extent, it may be possible to sufficiently reduce the overheating risk through improved occupant behaviour alone. For example, guidance could be provided by the Scottish Government on ways in which occupant behaviour could reduce internal temperatures during the summer period.

3.8 Both England and Wales have evaluated similar packages of passive measures to control the overheating risk. Each package included measures to reduce solar gains entering the building and some had additional ventilation provisions to remove heat from the building. A further package was evaluated which, in addition to these measures, also included thermal mass to moderate the peak temperature in the building[1]. The passive packages evaluated by England and Wales are summarised in Table 3.

3.9 Both the English and Welsh analysis showed higher exceedances of the CIBSE TM59 criteria than this analysis for Scotland. It is noted that for Wales they assessed the overheating risk based on 'Category I buildings', i.e. it assumes that the dwellings have a high probability of being occupied by vulnerable and fragile persons and results in Criterion A being more stringent. England assessed the overheating risk based on 'Category II buildings' as is the case for the Scottish analysis presented in this paper.

3.10 Given that the dual-aspect flats only exceeded Criterion A to a limited extent, the results suggest that all of the passive packages presented in Table 3 could be used to comply with Criterion A and that there is no need for active cooling to comply. It is understood that English and Welsh Building Regulations cannot control the fitting of internal blinds and, if that is similarly the case in Scotland, then Package 1 would not be suitable for including in Scottish Building Standards. Package 5 would be expected to be the lowest capital cost option but this most restricts the glazing area in flats which will reduce natural daylighting and may make reduce demand (and the price that the developer can charge) for such housing. Package 2 is expected to have higher capital costs than Package 5 but does allow for greater glazing areas in flats.

[1] Note that the addition of thermal mass can both reduce and increase the risk of overheating in different circumstances. Thermal mass moderates temperature fluctuations so that peak temperatures are generally reduced during the day. However, it results in temperature remaining warmer overnight which may, in particular, make bedrooms less comfortable for sleeping.

Package	Details
Package 1	• Internal blinds on all windows except on north façade; vertical slats on east and west facades and horizontal slats on south for effective shading.
Package 2	• Lower g-value glazing (0.4) with high light transmittance (0.7). • Reduced glazing ratios in flats to 25% of floor area (without a reduction in openable glazing area).
Package 3	• Fixed external shading to allow for ventilation plus secure ventilation at night. • Reduced glazing ratios in flats to 25% of floor area (without a reduction in openable glazing area). • Additional openable windows on third aspect for semi-detached house to encourage cross-ventilation and bring total glazing to floor area ratio of 20%.
Package 4	• As for Package 3 plus high thermal mass[2].
Package 5	• An additional lower cost risk mitigation package was evaluated to support the English consultation only. It consists of modifications to window openings: reduced glazing ratios in flats (to 20% of floor area) and increase in openable window area in houses (to 20% of floor area).

Table 3: Passive mitigation packages

[2] Classification as per SAP 2012 conventions (August 2017, v7.01), Appendix 5

4. Weather Data Comparison

4.1 To assess the potential impact of location on the overheating risk of new homes in Scotland a high-level comparison of weather data for different parts of the country has been carried out. This analysis compares peak temperature data for a number of locations (inland, coastal and islands) in Scotland to identify the potential impact location will have on overheating risk.

4.2 The Met Office operate several weather stations in Scotland and publish historic data from the locations listed below:

- Lerwick
- Stornoway Airport
- Wick Airport
- Nairn
- Braemar
- Leuchars
- Paisley
- Dunstaffnage
- Tiree

4.3 For the purposes of this analysis, six locations have been selected to compare a range of climates covering different areas of Scotland including inland, coastal and island locations. Figure 3 shows which locations have been selected for this comparison[3]:

[3] https://www.metoffice.gov.uk/research/climate/maps-and-data/historic-station-data

Figure 3: Locations in Scotland, selected locations labelled

4.4 The data analysed covers a 10-year sample period from 2010 to 2019 (2020 data is currently provisional and therefore has been excluded). Figure 4 and Table 4 show the 10-year average of the peak temperatures recorded for each month at each selected location.

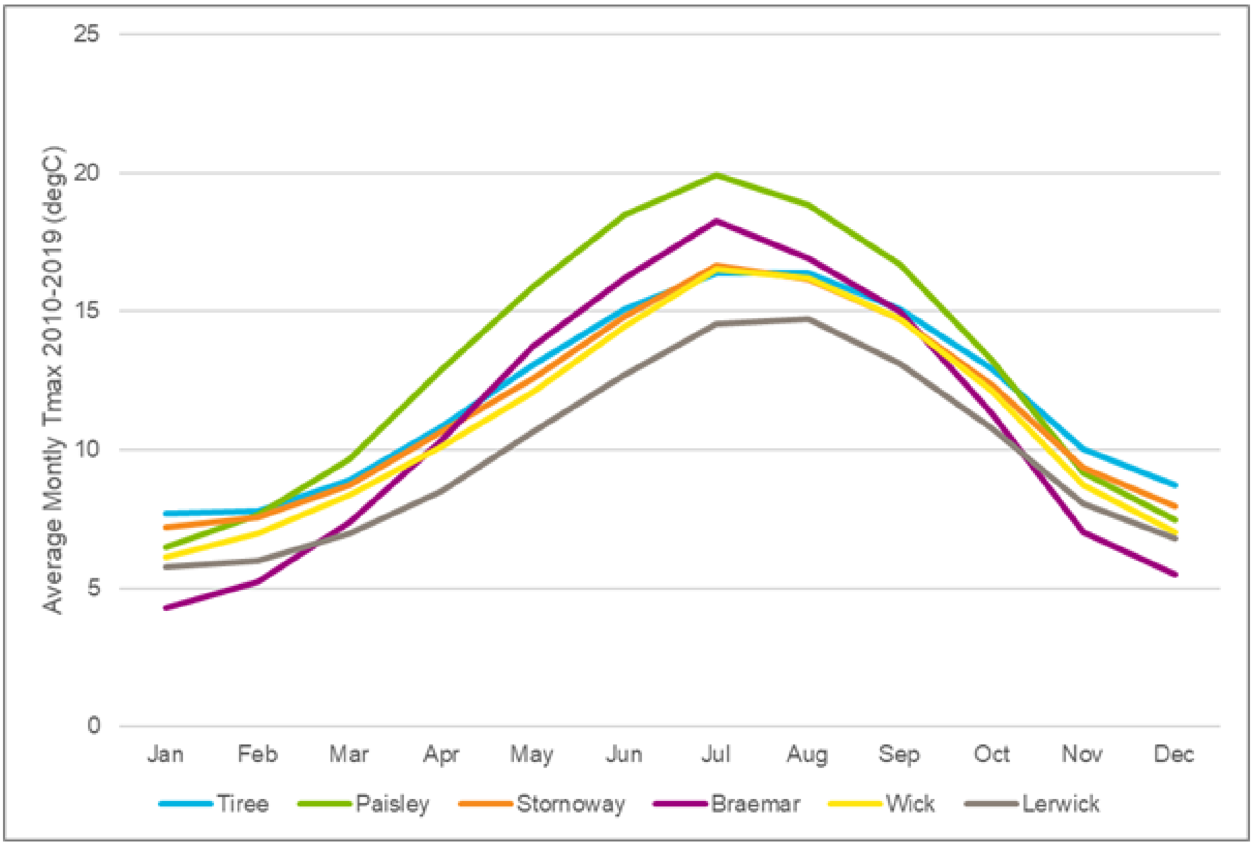

Figure 4: Average monthly maximum temperature (Tmax) data for sample 10-year period (2010-2019)

Month	Tiree	Paisley	Stornoway	Braemar	Wick	Lerwick
Jan	7.7	6.5	7.2	4.3	6.1	5.8
Feb	7.8	7.6	7.6	5.2	7.0	6.0
Mar	8.9	9.7	8.7	7.4	8.4	7.0
Apr	10.8	12.9	10.7	10.3	10.1	8.5
May	13.1	15.9	12.6	13.7	12.1	10.7
Jun	15.1	18.5	14.8	16.2	14.5	12.7
Jul	16.4	19.9	16.7	18.3	16.5	14.6
Aug	16.8	18.8	16.2	16.9	16.2	14.7
Sep	15.1	16.7	14.7	15.0	14.7	13.1
Oct	12.9	13.2	12.3	11.3	12.1	10.8
Nov	10.0	9.2	9.3	7.0	8.7	8.0
Dec	8.7	7.5	8.0	5.5	7.0	6.8

Table 4: Average monthly maximum temperature (Tmax) data for the sample 10-year period (2010-2019)

4.5 Figure 4 and Table 4 show that the average peak temperatures recorded in Paisley are the warmest of those selected from March to October; for six months of the year this is at least 1.5°C hotter than the next warmest location.

4.6 The most northerly location, Lerwick, has the lowest average peak temperature, which is approximately 2°C lower during the summer months than the next most northerly location, Wick; and is cooler than Paisley by approximately 5°C during the summer.

4.7 The coastal and island locations of Tiree, Stornoway and Wick all have similar average peak temperatures during the summer months, with less than 1°C difference between them. These locations are at least 2°C cooler than Paisley during the summer.

4.8 The overheating analysis presented in Section 3 is based on Glasgow weather data. Given that the average peak temperatures are greatest for Paisley/Glasgow in Table 4, it would reasonable to expect that risk of overheating in new homes is similar or lower in at least most of the rest of Scotland assuming that Paisley/Glasgow continues to have the highest peak temperature in the future. This further suggests that the mitigation measures proposed for Glasgow should be suitable for controlling the risk of overheating for at least most other locations as well.

5. Conclusions

5.1 Dynamic thermal simulation has shown that the sample building typologies all pass Criteria B (bedrooms) for CIBSE TM59, with only dual aspect flats failing Criterion A for their living room spaces when using the Glasgow DSY1 2020 high emissions scenario weather file.

5.2 Given that the dual aspect flats only exceeded Criterion A to a limited extent, all of the passive risk mitigation packages evaluated in England and Wales should be sufficient for controlling the overheating risk. This paper provides commentary on the suitability of those packages with lowest capital cost.

5.3 A high-level comparison of historical weather data suggests that in Scotland southern inland locations (around Glasgow) have higher peak summer temperature compared to the rest of the locations reviewed. This suggests that the mitigation packages proposed in this paper should be suitable for controlling the risk of overheating for at least most locations in Scotland assuming that southern inland locations continue to have the highest peak summer temperatures.

6. References

6.1 Research into overheating in new homes, Phase 1 report. Published by MHCLG, September 2019.

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/835240/Research_into_overheating_in_new_homes_-_phase_1.pdf

6.2 Research into overheating in new homes, Phase 2 report. Published by MHCLG, September 2019

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/845483/Research_into_overheating_in_new_homes_-_phase_2.pdf

6.3 Research into overheating in new homes, research for the Welsh Assembly, unpublished Technical Working Group papers.

7. Addendum

7.1 Two additional CIBSE TM59 assessments were carried out using dynamic thermal simulation modelling, focusing on the naturally ventilated dual aspect flat.

i) The CIBSE TM52 building type was changed from Category II to Category I. Category I assumes the building has a high probability of being occupied by vulnerable and fragile persons[4]. It results in Criterion A being more stringent.
ii) The glazing specification was changed from a U-value of 0.8W/m²K and a g-value of 0.57 to a more common double-glazing standard, with a U-value of 1.4W/m²K and a g-value of 0.7.

7.2 The following figures show how the naturally ventilated dual aspect flat performs against the CIBSE TM59 Criterion A and Criterion B based on the outputs from the modelling. The original results for the flat are included for comparison.

7.3 Both modifications increased the extent that the living space failed CIBSE TM59 Criterion A. The modification of the glazing specification had a limited increase on the hours of exceedance. However, the change in building category had a more significant impact and may be expected to require greater mitigation measures to address. Whilst the bedrooms increased their hours of exceedance, in both instances this was not enough to result in any bedrooms failing CIBSE TM59 Criterion A.

7.4 The change in CIBSE TM52 building category does not impact the CIBSE TM59 Criterion B results. The change in glazing specification has a minor increase in the number of hours of exceedance, while still passing Criterion B.

[4] The initial analysis described in the main body of this document used Category II which assumes that the buildings have a normal level of expectation of being occupied by vulnerable and fragile persons.

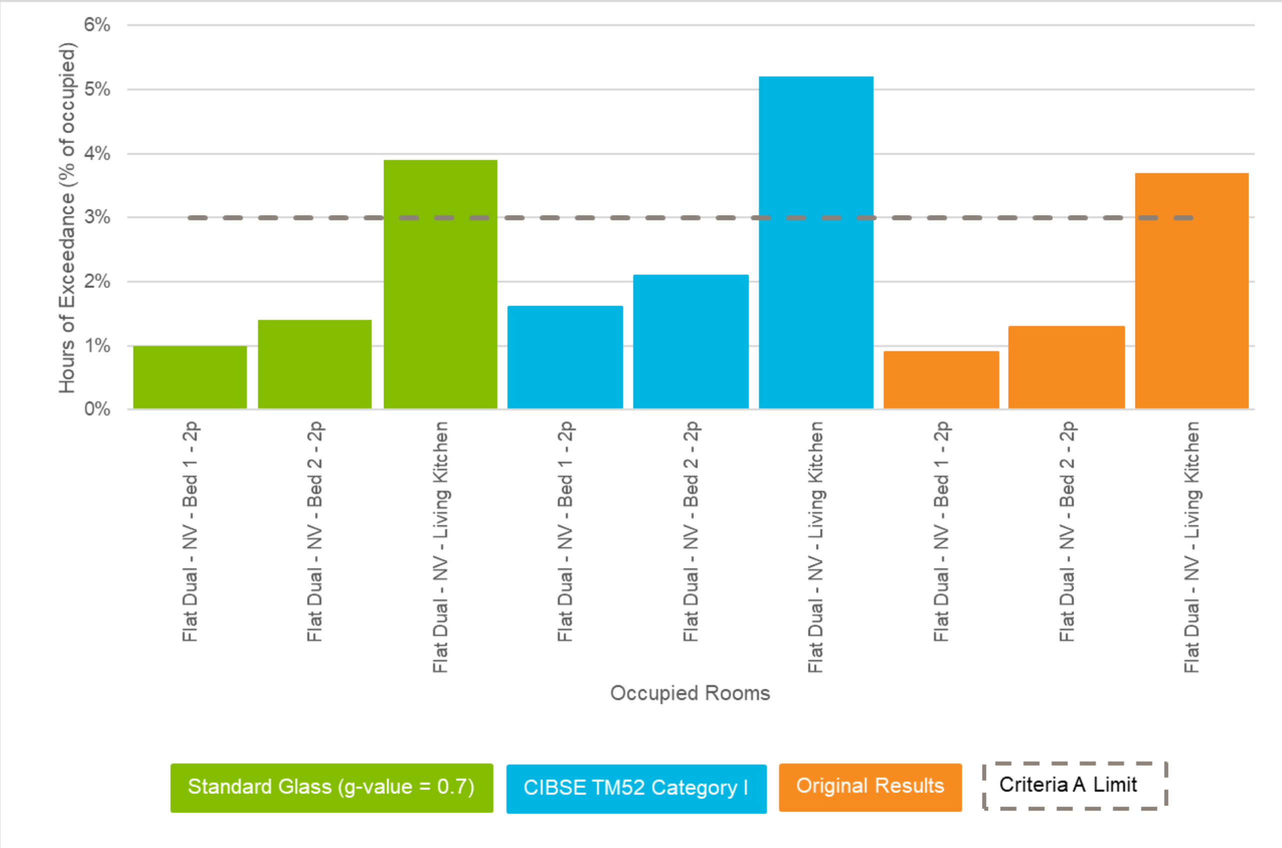

Figure 5: Percentage overheating hours – CIBSE TM59 Criteria A

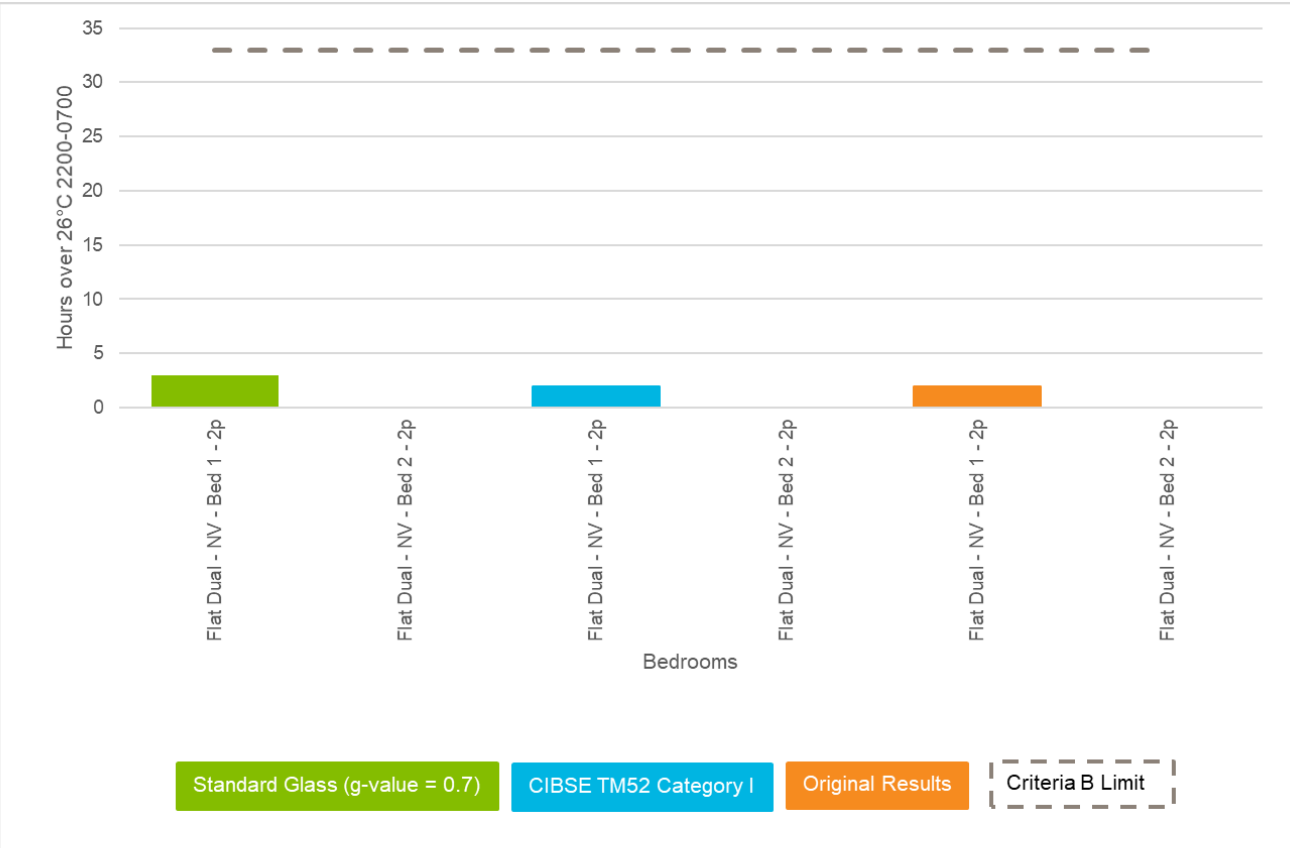

Figure 6: Hours of overheating – CIBSE TM59 Criteria B (bedrooms)

Annex A Modelling Assumptions

The following tables detail the internal gains applied to the dynamic thermal models used in this assessment.

Room types	Max. no. of people	Occupancy (Sensible) - W	Lighting – W/m²	Equipment – W	Occupancy/Lighting and Equipment Schedule
Bedrooms – Double	2	150	2	80	In line with CIBSE TM59
Bedrooms – Single	1	75	2	80	In line with CIBSE TM59
Living room/Kitchen – 1bed	1	75	2	450	In line with CIBSE TM59
Living room/Kitchen – 2bed	2	150	2	450	In line with CIBSE TM59
Corridors	-	-	2	-	In line with CIBSE TM59
Bathroom	-	-	-	-	N/A
Toilet	-	-	-	-	N/A
Store	-	-	-	-	N/A

Table 4: Occupancy, lighting and equipment loads in the apartments / flats

Room types	Max. no. of people	Occupancy (Sensible) - W	Lighting – W/m²	Equipment – W	Occupancy/Lighting and Equipment Schedule
Bedrooms – Double	2	150	2	80	In line with CIBSE TM59
Bedrooms – Single	1	75	2	80	In line with CIBSE TM59
Living/Dining – 2bed	2	150	2	150	In line with CIBSE TM59
Living room – 3bed	2	150	2	150	In line with CIBSE TM59
Kitchen – 2bed	2	150	2	300	In line with CIBSE TM59
Kitchen/Dining – 3bed	2	150	2	300	In line with CIBSE TM59
Study – 3bed	0	-	2	80	Lighting & Equipment schedule as in bedrooms
Dressing	0	-	2	-	Lighting schedule as in bedrooms
Bathroom	0	-	-	-	N/A
Toilet	0	-	-	-	N/A

Room types	Max. no. of people	Occupancy (Sensible) - W	Lighting – W/m²	Equipment – W	Occupancy/Lighting and Equipment Schedule
Store	0	-	-	-	N/A

Table 5: Occupancy, lighting and equipment loads in the houses

Room types	Storage required (litre)	Standing loss (W)	Schedule
House – 3 bed	210	59	Continuous
Communal Corridors with District heating*	n/a	420	Continuous
* Losses from a communal heating system are based on average 10W/m loss over a 21m long corridor and multiplied by two for both flow and return pipes. For pipe sizing an apartment block with more than 5 apartments per floor has been assumed.			

Table 6: Heat gains from hot water storage losses in houses and communal heating in corridors

The following section details the ventilation rates applied in the dynamic thermal models.

Infiltration Rates

The air infiltration rates have been calculated from CIBSE Guide A based on the following air-permeability rates:

- Naturally ventilated mid and high-rise apartments: 0.43 ach (based on air tightness of 6 $m^3/m^2/hr$ at 50Pa)
- Mechanically ventilated mid and high-rise apartments: 0.25 ach (based on air tightness of 3 $m^3/m^2/hr$ at 50Pa)
- Houses: 0.30 ach (based on air tightness of 6 $m^3/m^2/hr$ at 50Pa)

All unheated loft spaces in the houses have an assumed infiltration rate of 1.0 ach.

Mechanical Extract Ventilation in Apartments

Half the apartment typologies are assumed to have MEV (Mechanical extract ventilation), with supply in bedrooms and living rooms and extract from bathrooms and kitchens. The ventilation rates are taken from the Approved Document F, Table 5.1b. The following rates are assumed to be on continuously;

- Apartments – MEV – 1 bed (46m^2): 13.8 l/s
- Apartments – MEV – 2 bed (72m^2) corner: 21.6 l/s

Apartments modelled with MEV are assumed to also have the facility to open windows for additional natural ventilation in the same way as the purely naturally ventilated dwellings.

In line with the TM59 standard, boosted mechanical ventilation rates are not included in the assessments.

Note, in Approved Document F a 2-bed dwelling is assumed to have 17 l/s if the second bedroom is occupied by 1 person. As the 2 bed typologies both have double bedrooms an additional 4 l/s per occupant has been added. Also, a minimum rate of 0.3 l/s is required per m2 area and therefore the ventilation rate for the 1-bed and the 2-bed corner apartments have been adjusted to meet this criterion.

		Supply (litres/ sec)			Extract (litres/ sec)		
Room types	**Total MEV**	**Living rooms**	**Bedroom 1**	**Bedroom 2**	**Kitchens**	**Bathroom**	**En-suite**
1bed apartment	13.8	6.9	6.9	-	8.5	5.3	-
2bed apartment corner	21.6	7.2	7.2	7.2	9.6	6.0	6.0

Table 7: Airflow rates for MEV system in apartments

Natural Ventilation

The following table shows the areas of external glazing in each dwelling type as a percentage of external wall area and the percentage of openable glazing relative to floor and wall areas.

Dwelling Type	External Window Area (m²)	Percentage Glazed Area Relative to External Wall Area	Percentage Openable Glazed Area Relative to External Wall Area	Percentage Glazed Area Relative to Floor Area	Percentage Openable Glazed Area Relative to Floor Area
Semi-detached	16.5	13%	5%	14.3%	6%
Dual flat	34.1	59%	18%	47.3%	13%
Single flat	17.0	68%	38%	23.6%	16%

Table 8: Window and natural ventilation opening areas in dwellings

Windows and patio and balcony doors are modelled to start to open in occupied rooms when the indoor operative temperature exceeds 22°C and are fully open when temperature exceeds 26°C. Similarly, window and door openings are modelled to start closing as the internal temperature drops below 26°C and are fully closed when internal temperature drops below 22°C. The air changes achieved through openable windows are based on the openable area that windows can achieve as per architectural drawings and assuming no further restrictions apply.

Internal doors are assumed to be open all the time, except for bedroom doors which are assumed to be closed during the period 22:00 – 09:00. Bedrooms doors are modelled with an undercut in line with English Approved Document F requirements, equivalent to 1% of the door area during the night hours when shut. The external entrance door is assumed to be shut all of the time.

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