13416

NHSScotland New Build Health Buildings DSM Modelling – MAIN REPORT
Design Exemplars: Health Centre/ OPD & Ward

For: **Health Facilities Scotland (HFS)** **part of NHS National Services Scotland**

Final Report v1

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Contents

1 Executive Summary

The overall objectives of this study were to investigate the implication of various approaches to dynamic simulation modelling scenarios, plus complimentary solar and daylighting assessments, for use in the design of new build Health Centres and Hospitals in Scotland.

An ‘exemplar’ approach was used, illustrated with appropriate examples of building analysis models for both Health Centre and Hospital buildings. The approach was to use two recent and typical NHS Scotland developments, constructed in IES’s market leading VE software as exemplar study models. The approach taken and comparison of results could be expected from any similar simulation software.

Health Centres and Hospitals have very different operational needs and one of the objectives was to use practical examples to help provide briefing information that would assist designers in understanding underlying issues that enable them to maximise the benefits derived from their analysis and improve performance in these two types of new healthcare facilities.

The following design aspects were considered and included where agreed in the approach to these works in close cooperation between IES and Mabbett & Associates Ltd (M&A) who researched and provided realistic input data for IES to model.

The analysis work was mostly focussed towards representative areas so to concentrate where the effort could have maximum impact.

- Analysis framework for a typical health care building in Scotland – based on exemplar Health Centre & Hospital models.
- Thermal comfort.
- Energy usage.
- Compliance vs ‘Real’ building models based on standardised ‘NCM’(1) data and realistic input data. This demonstrates the importance of accurate room data templates and the need for realistic analysis to allow testing of design and ensure ‘fit-for-purpose’.
- Mitigation of Mechanical solutions – by considering passive design solutions such as natural ventilation with no mechanical cooling.
- Effect of different occupancy patterns and operational hours – the Health Centres and Hospital have very different utilisation profiles.
- Construction types – effect of increasing insulation thermal insulation and air-tightness of building envelopes. Note that the baseline simulations assumed the current 2015 version of Section 6 regulations which already has much improved insulation levels and reduced permeability compared to previous versions of Section 6. For example wall U-value has reduced by about a third.
- Alternative ventilation of spaces – to demonstrate the importance of correct window design.
- Interconnection between the occupied spaces and adjacent ceiling voids and service voids.
- The study concentrates on areas which have proven and recorded risks, are in frequently repeated spaces and are heavily occupied by patients and staff, i.e. single bedroom and consulting exam room in either hospitals or health centres. This includes an awareness of patient needs and human nature, e.g. isolation and vulnerability to temperatures of bed-bound patients.

(1) *The National Calculation Method for the EPBD (Energy Performance of Buildings Directive) is defined by the Department for Communities and Local Government (DCLG) in consultation with the Devolved Administrations (DAs).*
www.uk-ncm.org.uk

- Future weather files (future weather for Glasgow using CIBSE data to indicate how energy and overheating demands will alter).
- Consideration of ‘nearly zero energy’ design options.
- Artificial lighting / daylighting / shading issues.
- Orientation of wings / wards and in particular bedroom & consulting exam rooms.

2 Health Centre

2.1 Introduction

This simulation report details the modelling investigation of a recent and typical health centre development, that we used as an exemplar study model. The study focused on a typical GP or out-patient wing, containing typical and representative consulting exam rooms and support spaces. Modelling is used to predict building performance, it helps design teams reduce risk and produce the best possible building for its occupants and the environment. Models are critically dependent on the quality of the data selected to go into their calculation, with poor data will come a poor representation and therefore misdirection for the design path. Past cases exist where model outputs have been criticised but instead this is the result of poorly selected inputs. Successful models are built by competent modellers working with their design teams who together have selected the most appropriate inputs.

This report details the use of a Dynamic Simulation Model (DSM) which is a sub-hourly time based simulation utilising hourly weather data and test building attributes including building form, fabric, internal gains, ventilation air exchanges, operation profiles and building HVAC systems. The simulation then produces hourly data for energy and environmental metrics from which modellers can produce statistical reports to detail exactly how the building is predicted to perform.

The use of a model at the design stage is only the first step in its life as a companion to the building. The model can continue to be used during the operational stage by calibrating the model using metered data. This calibrated evolution can then be used to check building performance and identify if the building is moving outside of its intended parameters and exactly which of these are vulnerable. This is an ongoing process as buildings are currently under the strain of the environment and their operational use which requires specific maintenance. A high performance building is one that continues this for its life and not simply on the first opening of its doors.

The analysis has been undertaken based on the backdrop of the latest Section 6 Scottish Building Regulations from 2015. These regulations have guided aspects such as fabric within the tested models. It is worth noting the latest NHS Scotland buildings constructed would have been built to the inferior 2010 standards and that performance detailed by this analysis to 2015 will only be more pressured when the regulations evolve again in the near future. There are definite diminishing returns in aspects of building design previously identified as being key factors. Indeed these may soon be dead ends and therefore the remaining factors not previously under the spotlight now become crucial in continued performance improvement. Only a full sub-hourly analysis under a structured assessment will provide this opportunity.

2.2 Modelling Scenarios

2.2.1 NCM Base Case

The NCM Base Case is a representation of health centre models presented to NHS Scotland for newly designed developments. It is based around the deployment of a Section 6 Building Regulations model where the primary modelling objective is compliance. The National Calculation Methodology was created by the UK government for the purposes of a like for like operational comparison so to assess the performance of fabric, HVAC system efficiencies, lighting and other such building performance factors. The NCM approach would maintain no change in operation hours, room set-points, ventilation flowrates or illuminance levels. However with this comes clear its intention to serve compliance as a limited number of building type and activities are available to select and assign to the model's spaces. This is not a problem for compliance as the space will use the same operation in both compliance Actual and Notional models but it if modellers are actively trying to use this minimal list to represent their *real* building design then straightaway a limit has been introduced to correctly represent the true building activities and operation. Examples include room set-points being lower than are intended for the design and using lower ventilation airflow rates to meet comfort conditions. Both of these examples would result in significant differences to the calculated and operational energy use.

As the modelling objective is primarily compliance then it results in a poor representation for a detailed investigation into *real* building energy use and occupant comfort needs. This leads to mismanaged findings, which negatively influence the final design and handicap the building throughout its operational life.

2.2.2 Corrected Base Case

The Corrected Base Case model is specified to better represent the true operation of a health centre based on experience with similar developments and learning outcomes involved. Room Data Sheets (RDS) were produced (see Appendix B) which specify the health centre activity and define the following:

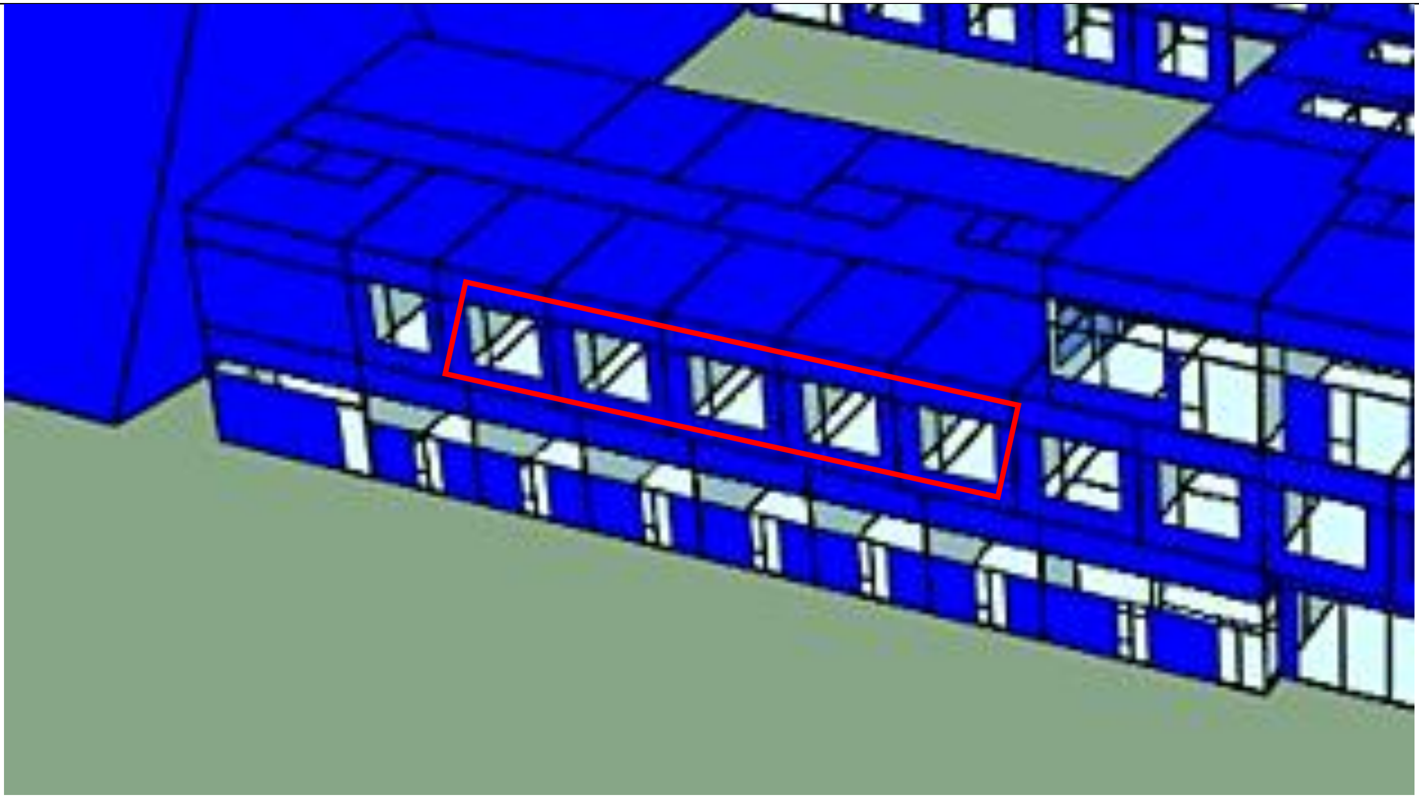
- Room heating set-point
- Infiltration rate
- Fixed air exchange rate (supply or extract)
- Internal gains - occupancy, lighting and equipment
- Time based operating schedules

2.2.3 Sensitivity Analysis

A modelling sensitivity analysis was undertaken by performing iterations of the Corrected Base Case. The following settings were identified as options for investigation either due to concerns raised from previous developments or having been identified as clear opportunities to improve design in future developments.

Description	**Settings - Corrected Base Case**
Consulting Exam Room window configuration	10% openable area large single pane
Consulting Exam Room window opening control	Window opens when internal temperature is above 23°C and outside air temperature above 10°C
Trickle ventilation	No
Ceiling void configuration	Internal gains on & no ventilation air exchange
Ceiling void insulation	No
Weather file	Glasgow Test Reference Year 2005
Air infiltration	0.125 Air Changes per Hour
External wall	U-value = 0.15 W/m^2 K
Roof	U-value = 0.15 W/m^2 K
External window	U-value = 1.6 W/m^2 K, g-value = 0.6
Window shading	No
Lighting	See Room Data Sheets in Appendix B

2.3 Health Centre Geometry

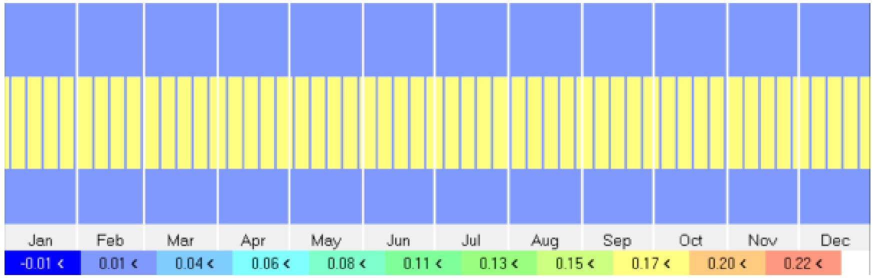
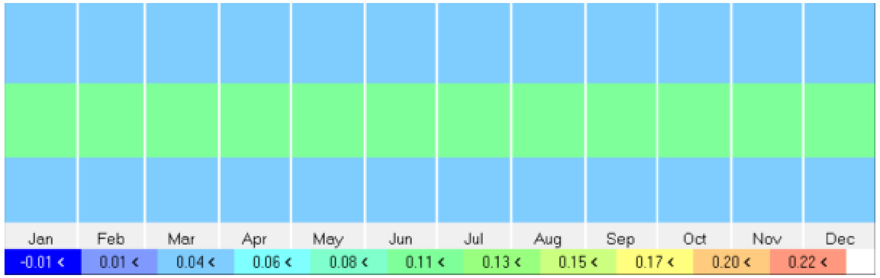


Health Centre consulting exam rooms under analysis

2.4 Sensitivity Analysis

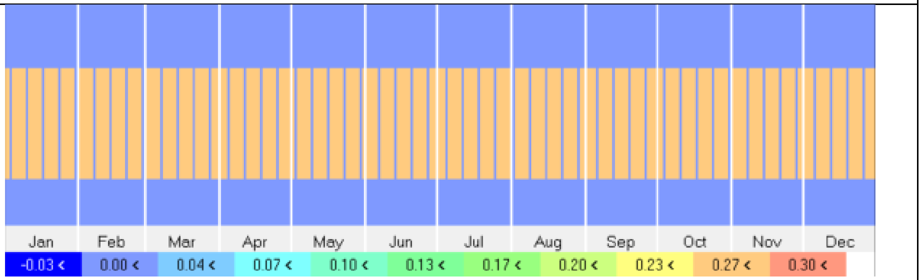
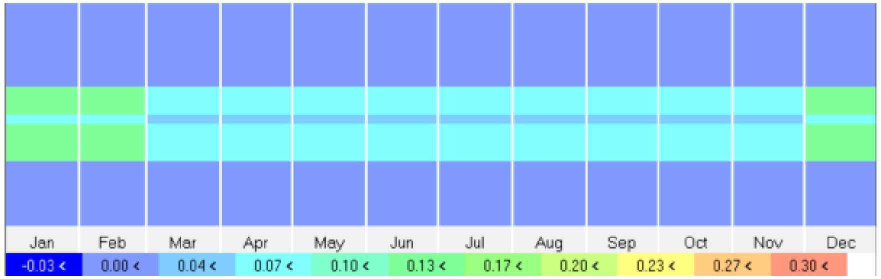
2.4.1 Corrected Base Case Comparison

2.4.1.1 Consulting Exam Room: Equipment Gain

Time Period	NCM Base Case (kW)
0 ↓ 24	
Time Period	Corrected Base Case (kW)
0 ↓ 24	

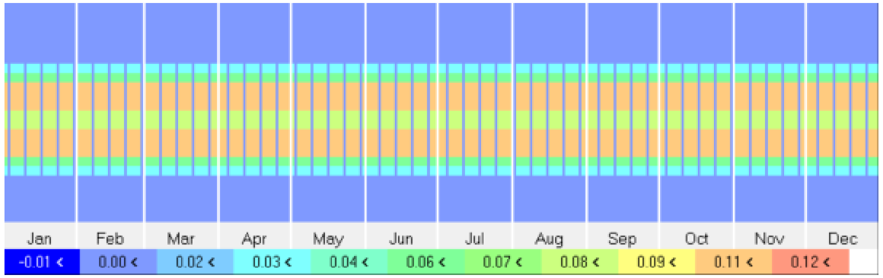
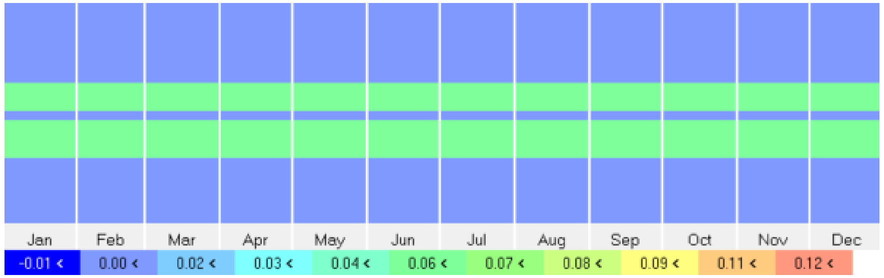
- Significant difference in the total annual equipment energy use.
- The NBC equipment gain peaks at approximately 0.17kW but without any background load outside of the daytime period.
- The CBC employs a profile which represents the true operations of the Consulting Exam Room's equipment in which the gain peaks at 0.10kW for daytime period and then a residual load is in place across evening and night.

2.4.1.2 Consulting Exam Room: Lighting Gain

Time Period	NCM Base Case (kW)
0 ↓ 24	
Time Period	Corrected Base Case (kW)
0 ↓ 24	

- The NBC again peaks at ~0.27kW for the daytime period.
- This process is repeated throughout the year even during the winter months in which the daylight hours are at a low.
- -The CBC portrays a more accurate representation of the actual use of artificial lighting and its corresponding lighting gain in the health centre due to the implementation of the information derived from the Room Data Sheets.
- CBC lighting gains differ depending on the season.
- CBC lighting gain peaks at ~0.11kW during the winter period.

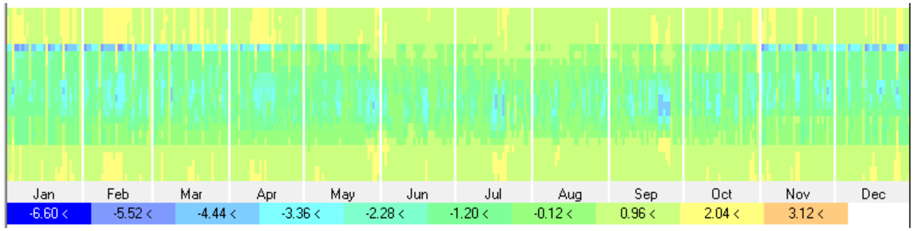
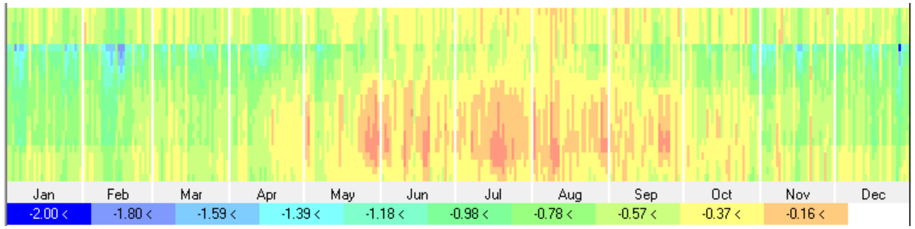
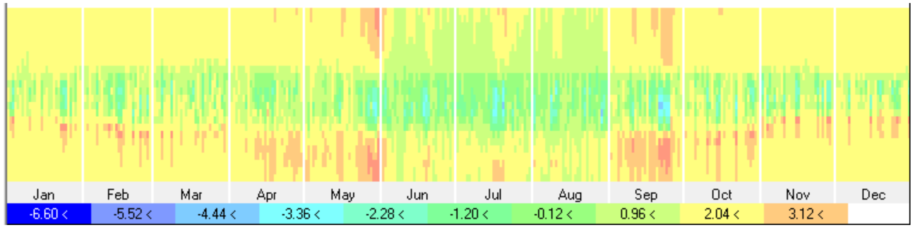
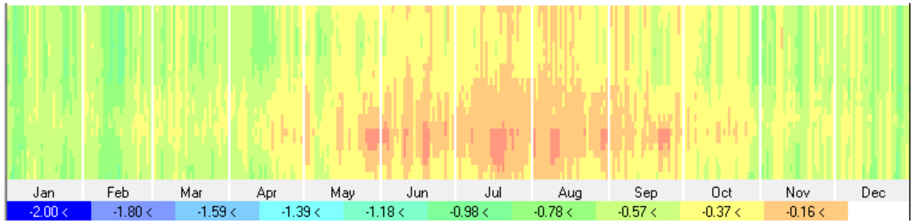
2.4.1.3 *Consulting Exam Room: People Gain*

Time Period	NCM Base Case (kW)
0 ↓ 24	
Time Period	Corrected Base Case (kW)
0 ↓ 24	

- NBC profile specifies a peak in people gain day at ~0.11kW.
- CBC utilised RDS to represent the occupancy levels in the Consulting Exam Room throughout the day and peaks at ~0.045kW.

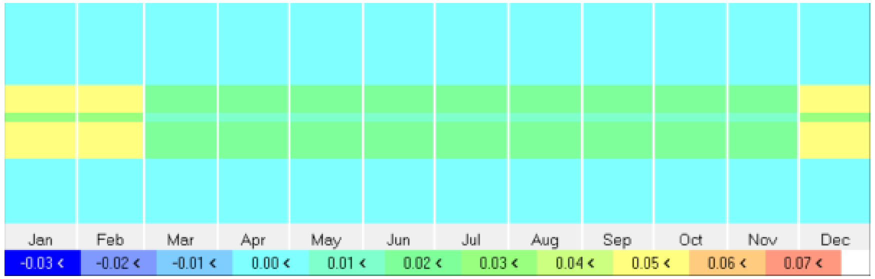
2.4.1.4 *Consulting Exam Room: Heating Energy*

- The heating energy of the cumulated 6 Consulting Exam Rooms is substantially lower in the CBC, 0.0164 MWh, that there is almost no point is displaying compared to the NBC, 7.4667 MWh.
- The primary reason is the substantial difference due to internal conduction in the CBC which is in the region of an 8.6 MWh gain compared to a loss of 4.4 MWh in the NBC. The following heat map charts show the annual variance in heat gain to the Consulting Exam Room from internal conduction. The large contingent of yellow area in the CBC identifies the space is being warmed by the well-sealed ceiling void space which remember is not present in the NBC.
- Note external conduction is similar in both still but is an order of magnitude less than the internal conduction the CBC receives.

Time Period	NCM Base Case (kW) – Internal Conduction	NCM Base Case (kW) – External Conduction
0 24		
Time Period	Corrected Base Case (kW) - Internal Conduction	Corrected Base Case (kW) - External Conduction
0 24		

Note the different magnitude of scale for the Internal and External views.

2.4.1.5 Consulting Exam Room - Ceiling Void: Lighting Gain

Time Period	Corrected Base Case (kW)
0 ↓ 24	

- The CBC specifies lighting gains in the ceiling voids which peaks slightly above ~0.045kW during the winter months.
- Drop in lighting gain through spring, summer and autumn periods.
- Remember the NBC has no ceiling void present.

2.4.1.6 Consulting Exam Room NBC v CBC Summary View

NBC does not model a ceiling void so no accumulation of gains is present.

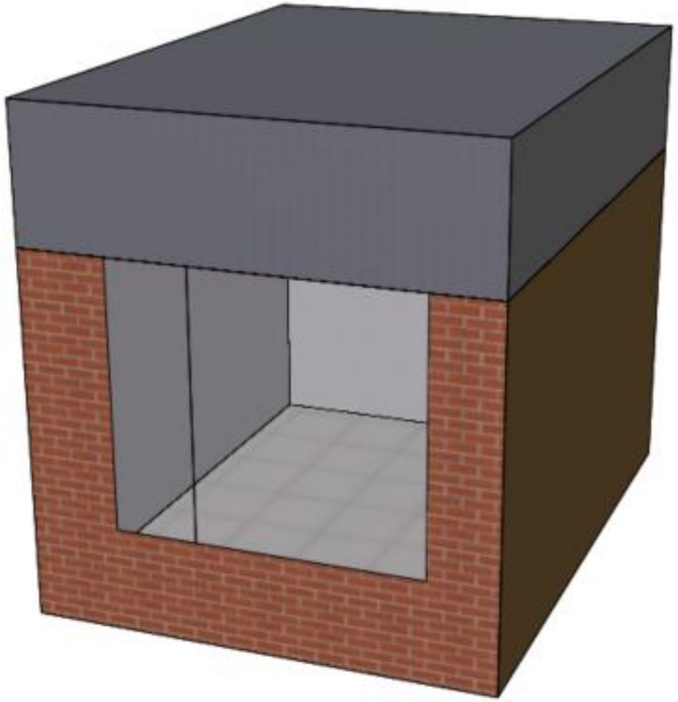
CBC accounts for heat gains in the sealed ceiling void therefore representing a build-up of heat.

NBC defines the health centre's internal gains and profiles from NCM activities.

CBC specifies the health centre's operations using data from past experiences to define the space activities and internal gains.

NBC (Heating set point varies with time) = 12°C and 22°C

CBC = 21°C and represents actual design specifications.



NBC maintains no change in operation hours of the health centre.

CBC represents the true operation of the health centre by specifying the time based operating schedule per activity

NBC models minimum supply airflow from assigned space activity plus an idealised approach of introducing outside air to prevent heat build-up.

CBC models a variable airflow rate based on a bulk airflow exchange through a window strategy for opening area and opening control.

2.4.2 Potential Optimisation Scenarios

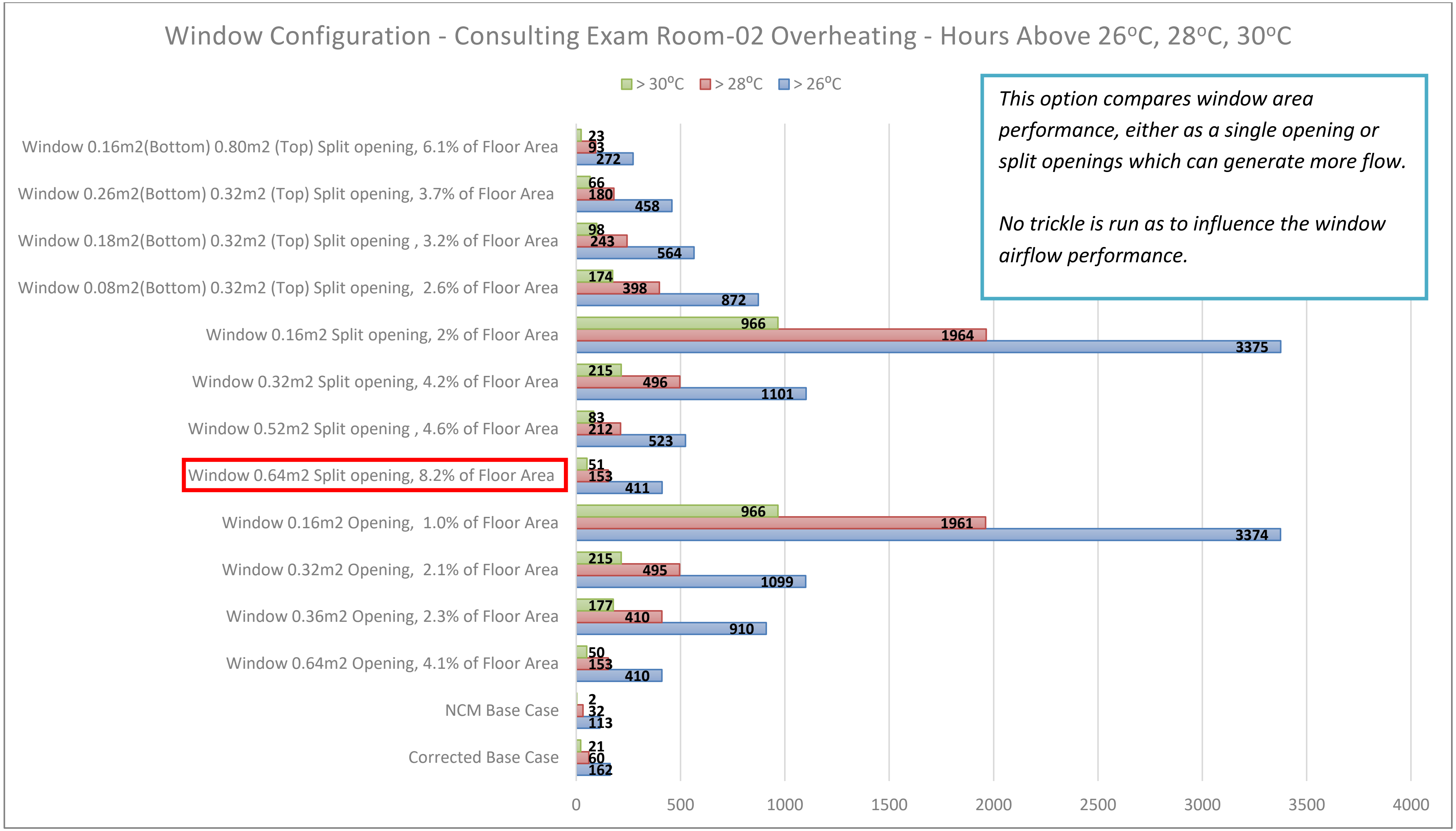
Optimisation scenarios were run across the following attributes identified as being key aspects of current performance where there is a need to investigate toward enhancing thermal comfort and reviewing the subsequent impact on energy use.

- Window configuration
- Window opening control
- Ceiling void gain and ventilation
- Future weather files
- Infiltration
- Fabric
- Façade glass transmittance and shading
- Lighting
- Trickle ventilation
- Ceiling void configuration

The charts detail the permutations assessed for number of hours through the year operative temperature statistics exceed 26°C, 28°C and 30°C.

The red box highlights the assessed measure carried forth to a combined optimisation scenario.

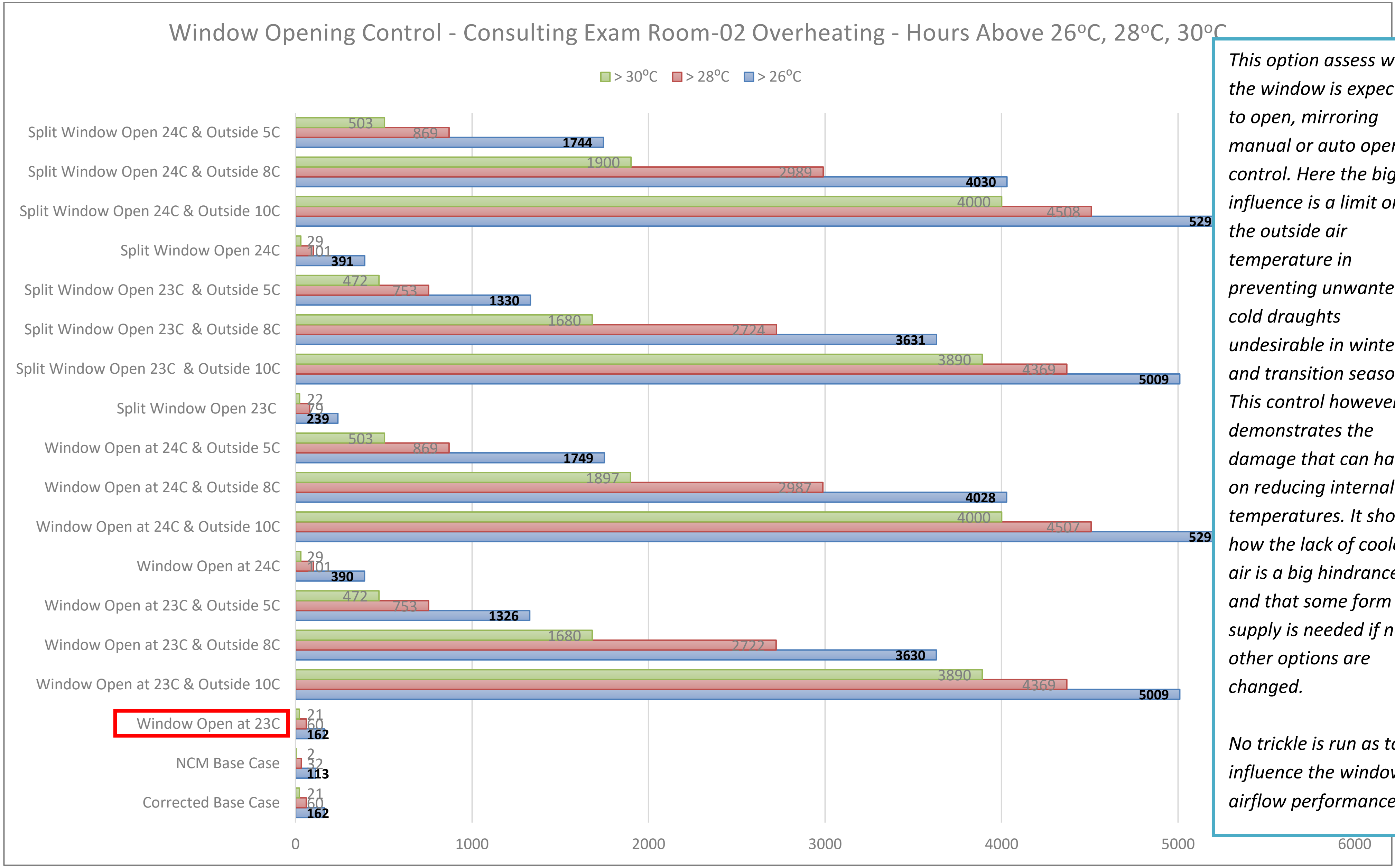
2.4.2.1 *Overheating*



Window Configuration - Consulting Exam Room-02 Overheating - Hours Above 26°C, 28°C, 30°C

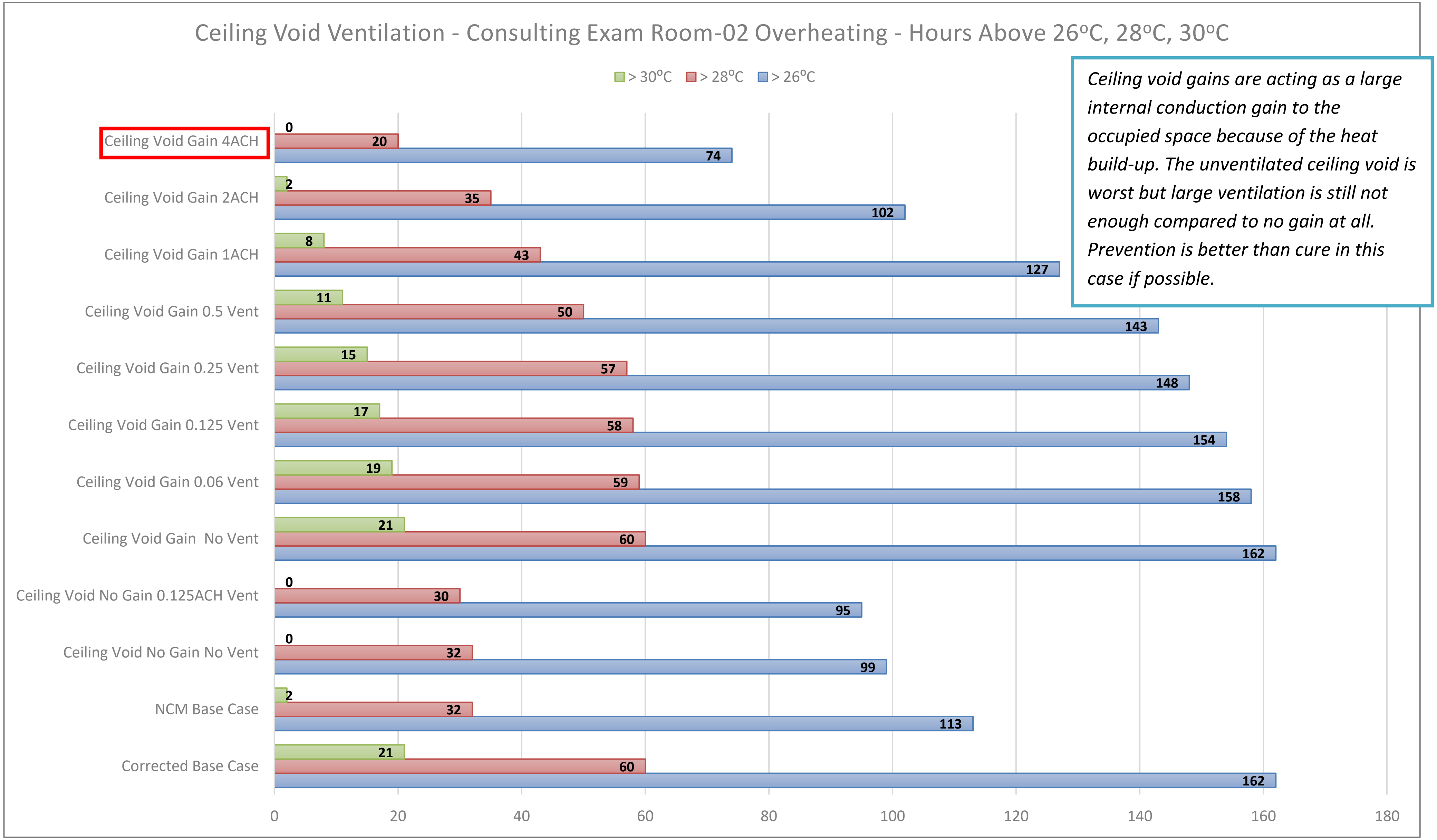
This option compares window area performance, either as a single opening or split openings which can generate more flow.

No trickle is run as to influence the window airflow performance.

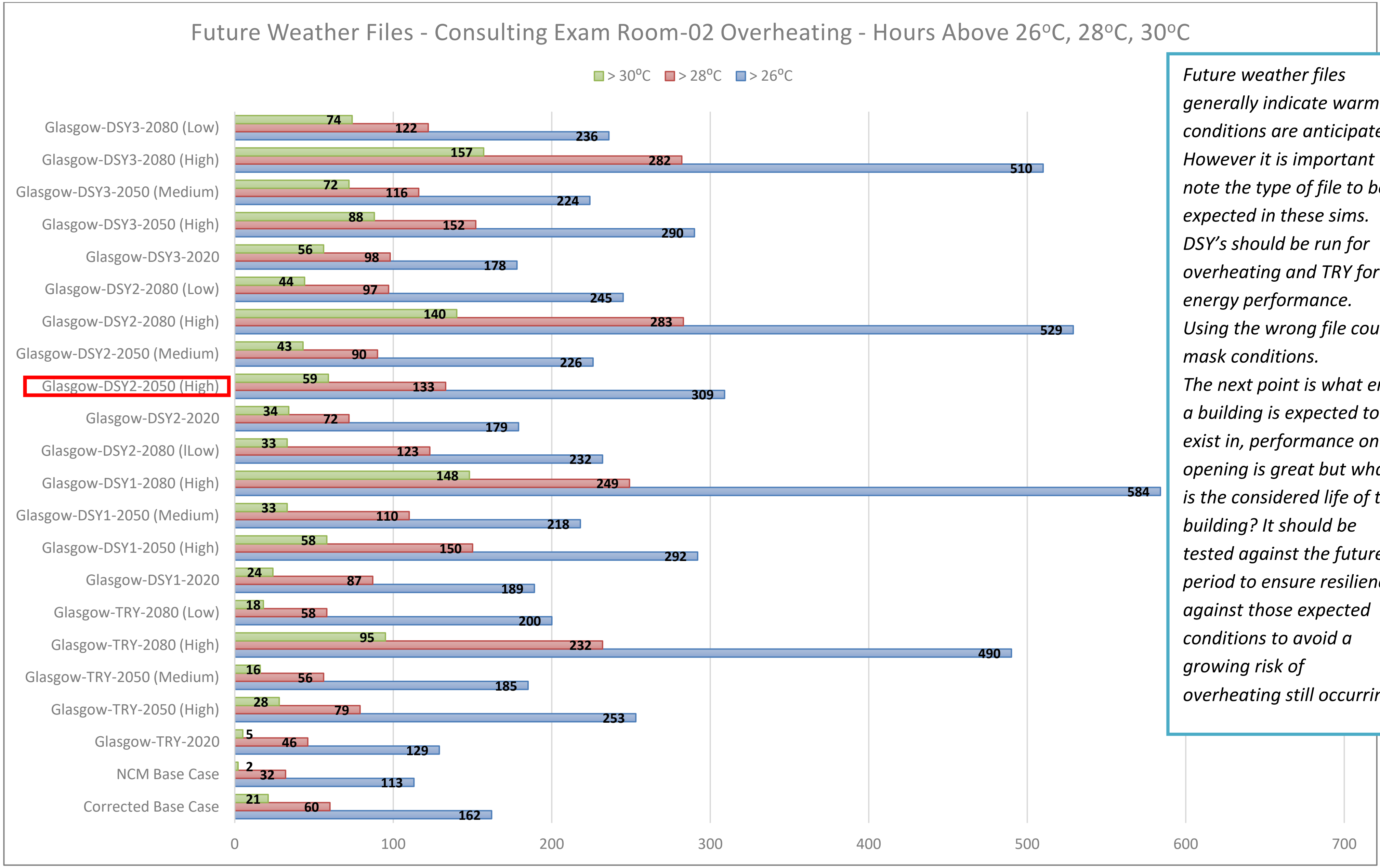


This option assess when the window is expected to open, mirroring manual or auto opening control. Here the big influence is a limit on the outside air temperature in preventing unwanted cold draughts undesirable in winter and transition seasons. This control however demonstrates the damage that can have on reducing internal air temperatures. It shows how the lack of cooler air is a big hindrance and that some form of supply is needed if no other options are changed.

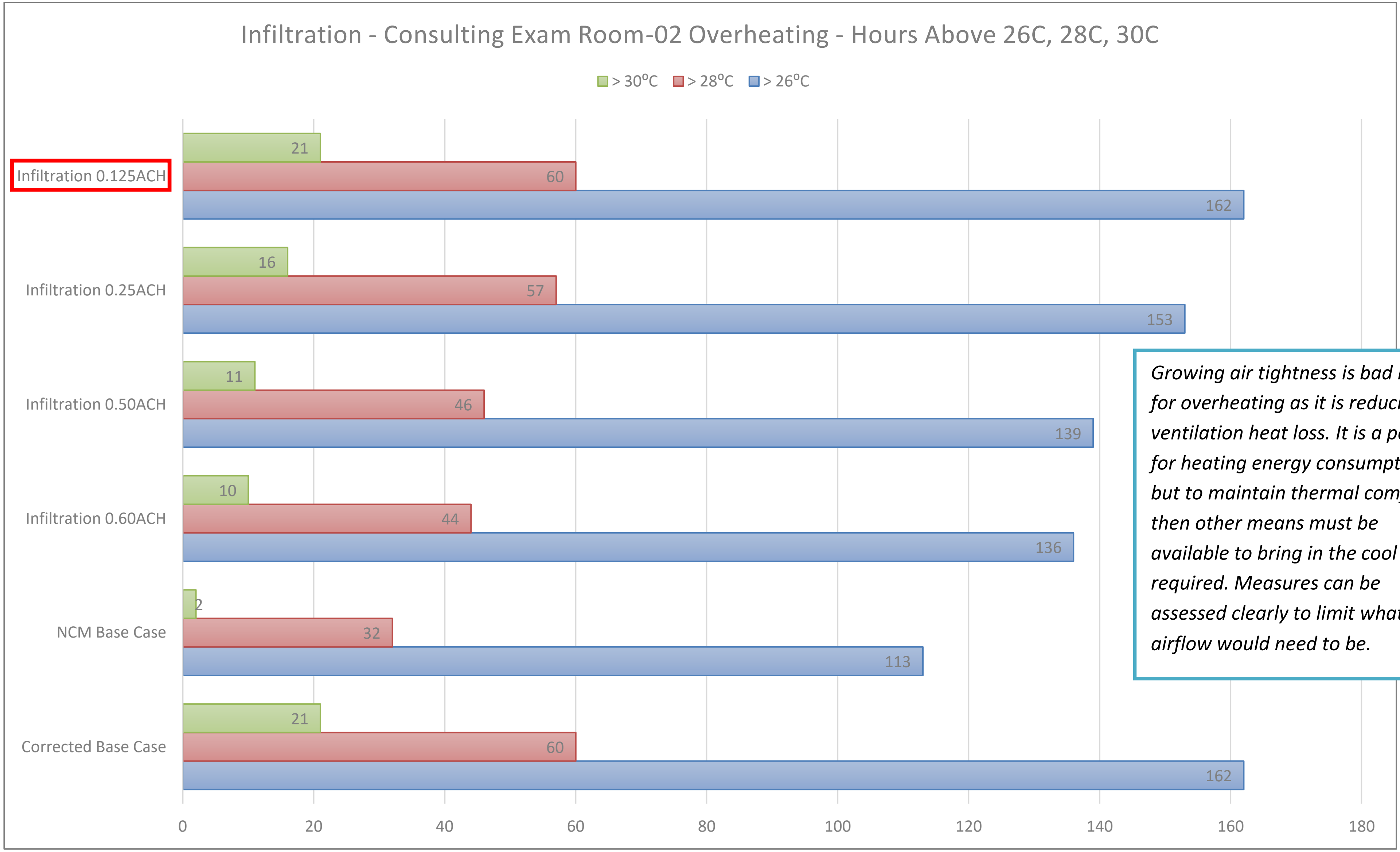
No trickle is run as to influence the window airflow performance.



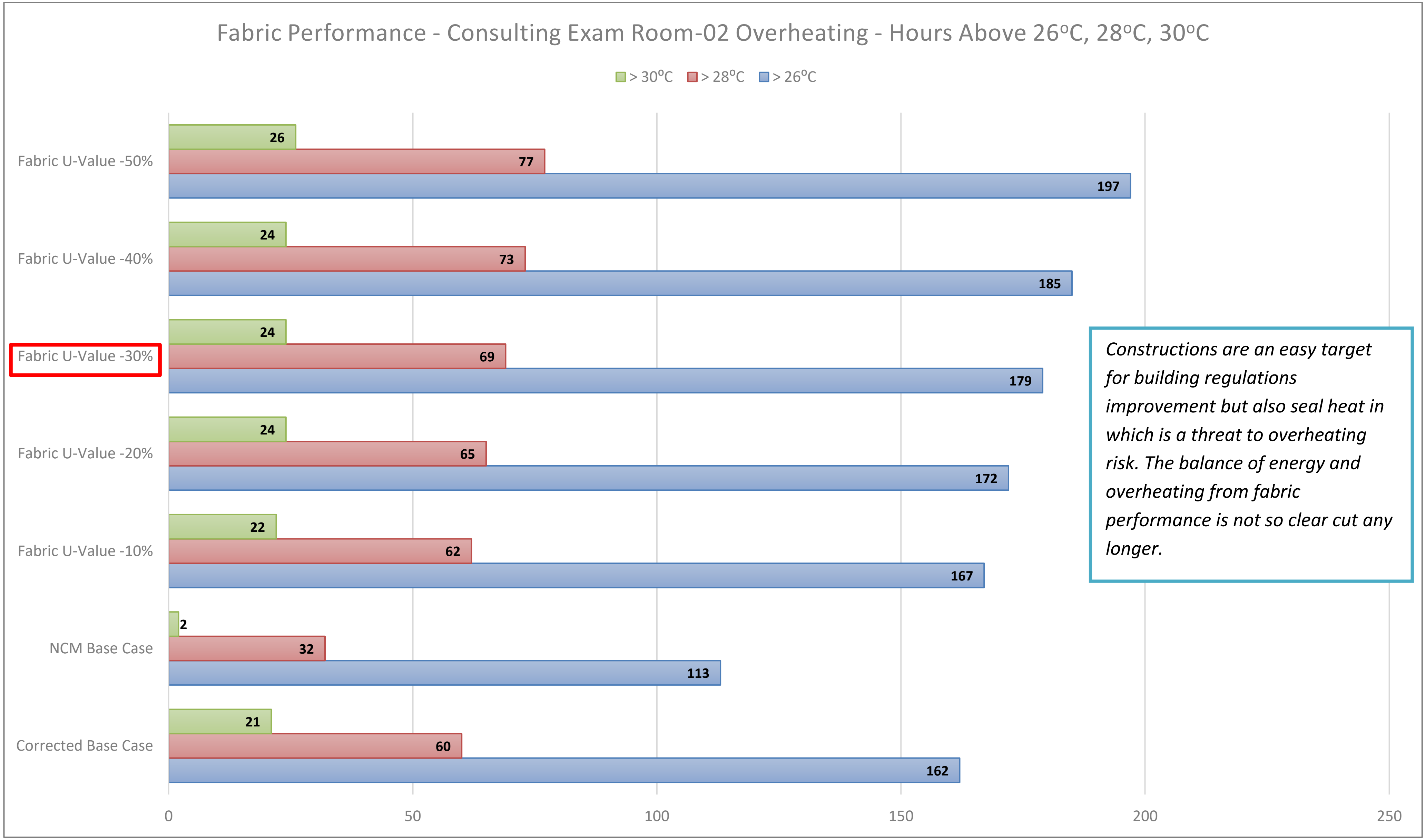
Ceiling void gains are acting as a large internal conduction gain to the occupied space because of the heat build-up. The unventilated ceiling void is worst but large ventilation is still not enough compared to no gain at all. Prevention is better than cure in this case if possible.



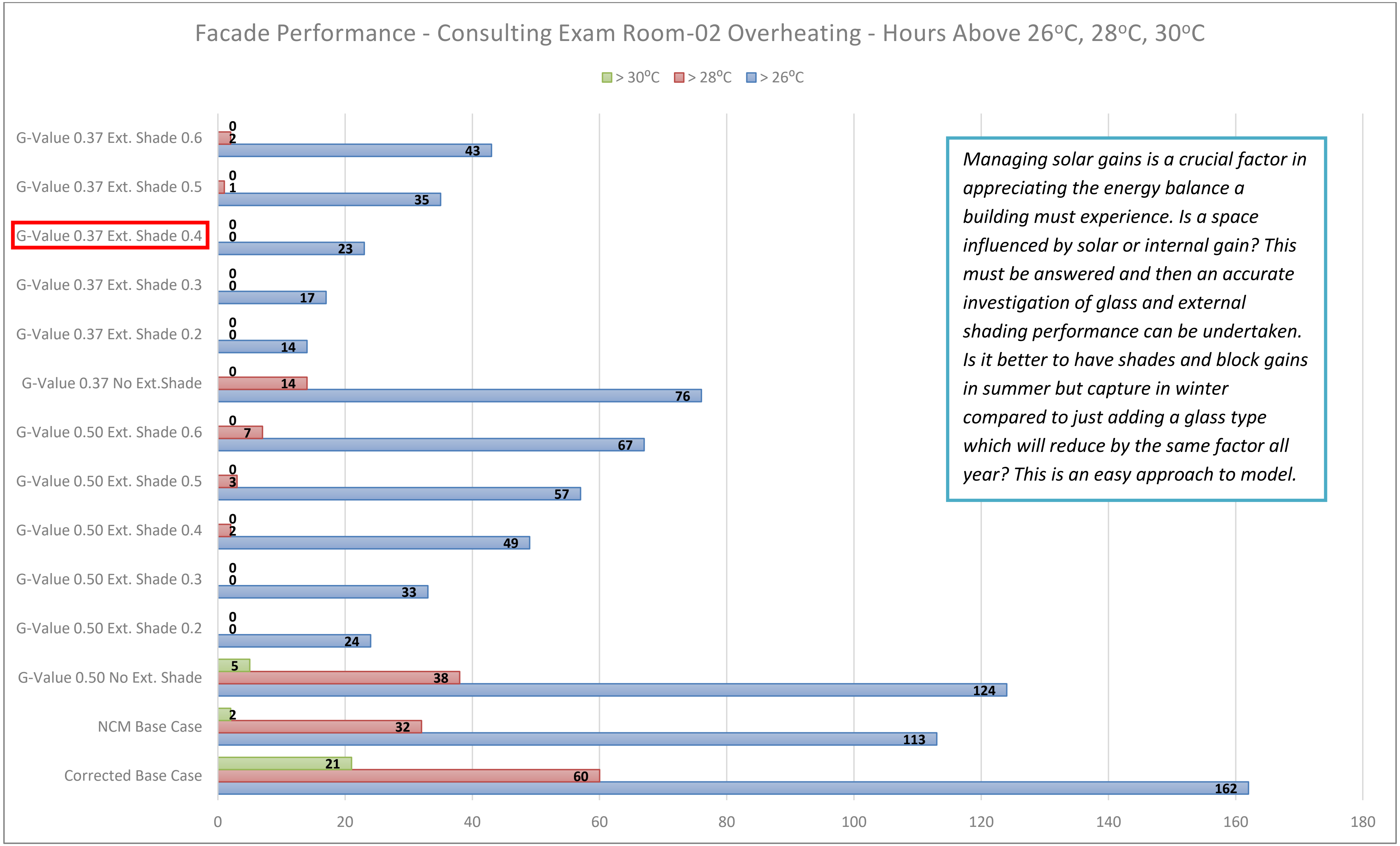
Future weather files generally indicate warmer conditions are anticipated. However it is important to note the type of file to be expected in these sims. DSY's should be run for overheating and TRY for energy performance. Using the wrong file could mask conditions. The next point is what era a building is expected to exist in, performance on opening is great but what is the considered life of the building? It should be tested against the future period to ensure resilience against those expected conditions to avoid a growing risk of overheating still occurring.



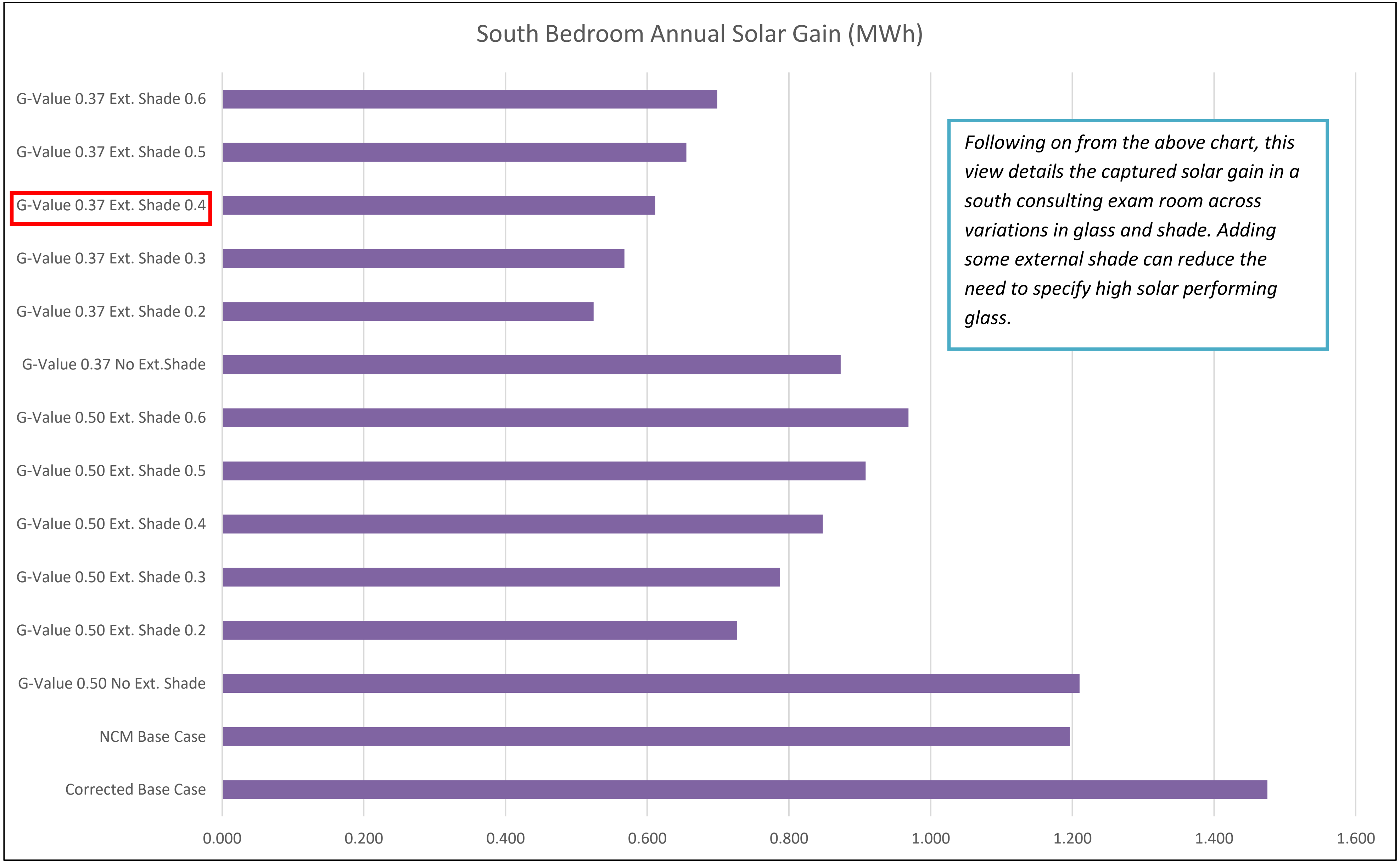
Growing air tightness is bad news for overheating as it is reducing ventilation heat loss. It is a positive for heating energy consumption but to maintain thermal comfort then other means must be available to bring in the cool air required. Measures can be assessed clearly to limit what this airflow would need to be.



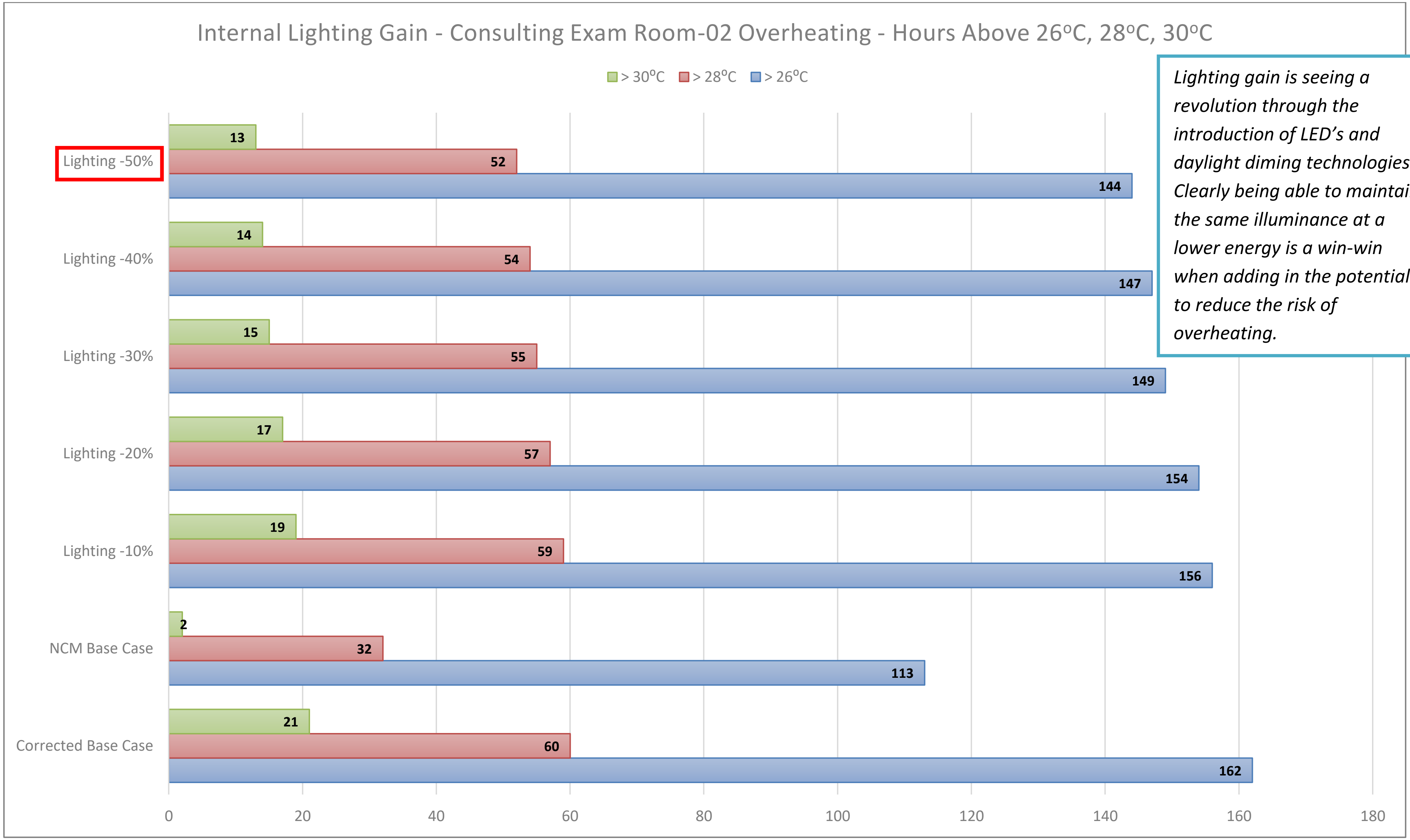
Constructions are an easy target for building regulations improvement but also seal heat in which is a threat to overheating risk. The balance of energy and overheating from fabric performance is not so clear cut any longer.



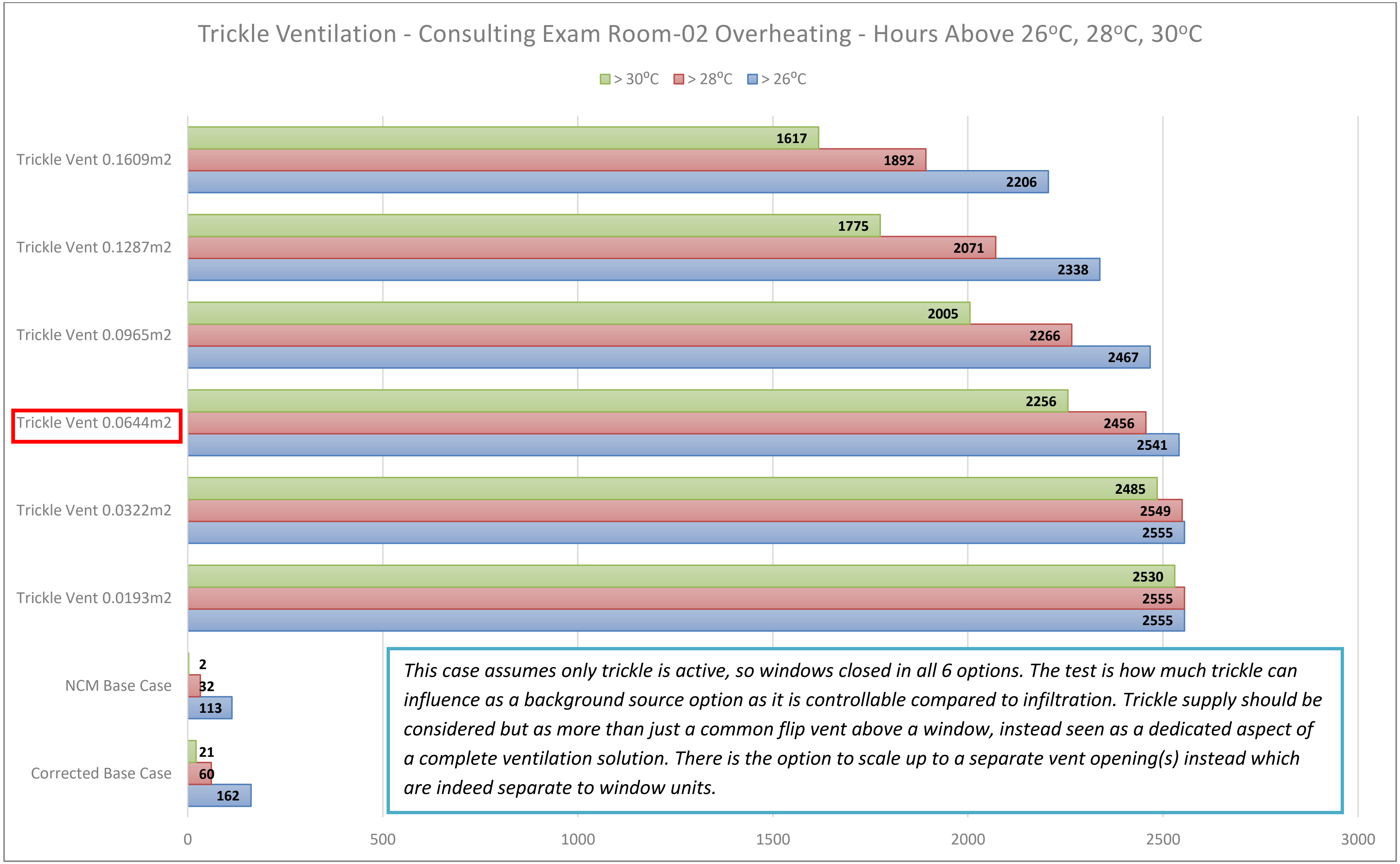
Managing solar gains is a crucial factor in appreciating the energy balance a building must experience. Is a space influenced by solar or internal gain? This must be answered and then an accurate investigation of glass and external shading performance can be undertaken. Is it better to have shades and block gains in summer but capture in winter compared to just adding a glass type which will reduce by the same factor all year? This is an easy approach to model.



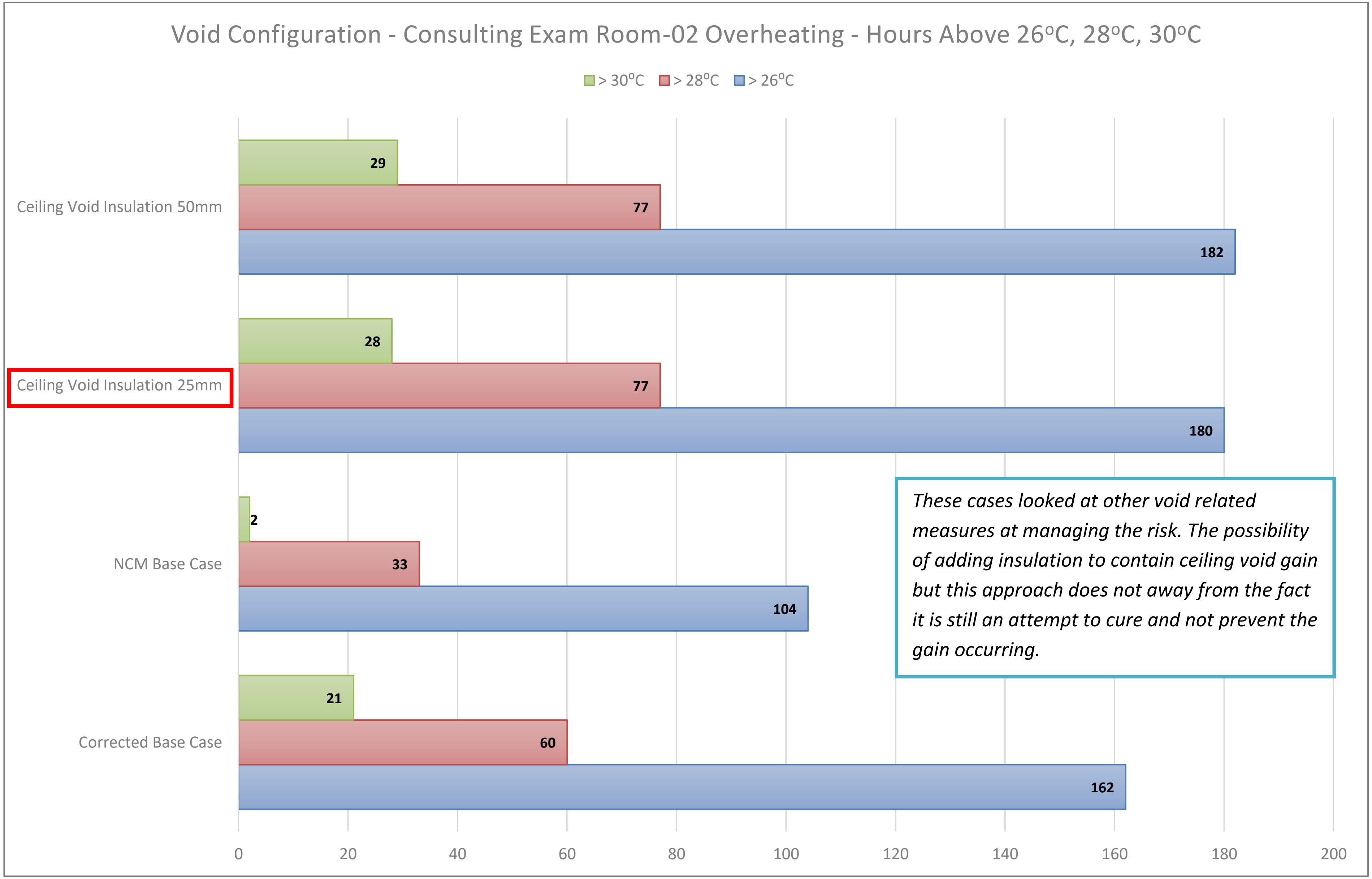
Following on from the above chart, this view details the captured solar gain in a south consulting exam room across variations in glass and shade. Adding some external shade can reduce the need to specify high solar performing glass.



Lighting gain is seeing a revolution through the introduction of LED's and daylight diming technologies. Clearly being able to maintain the same illuminance at a lower energy is a win-win when adding in the potential to reduce the risk of overheating.

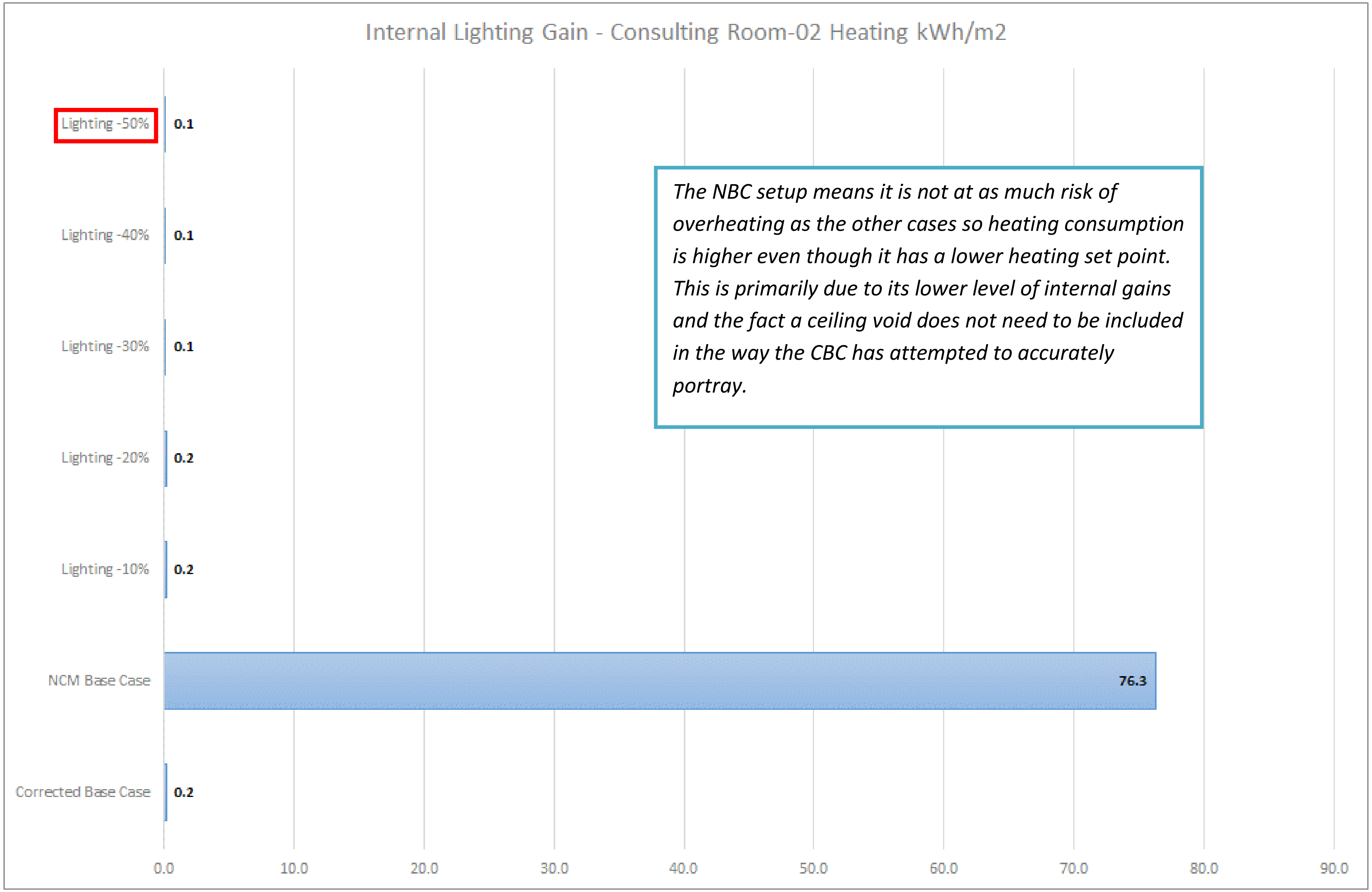


This case assumes only trickle is active, so windows closed in all 6 options. The test is how much trickle can influence as a background source option as it is controllable compared to infiltration. Trickle supply should be considered but as more than just a common flip vent above a window, instead seen as a dedicated aspect of a complete ventilation solution. There is the option to scale up to a separate vent opening(s) instead which are indeed separate to window units.

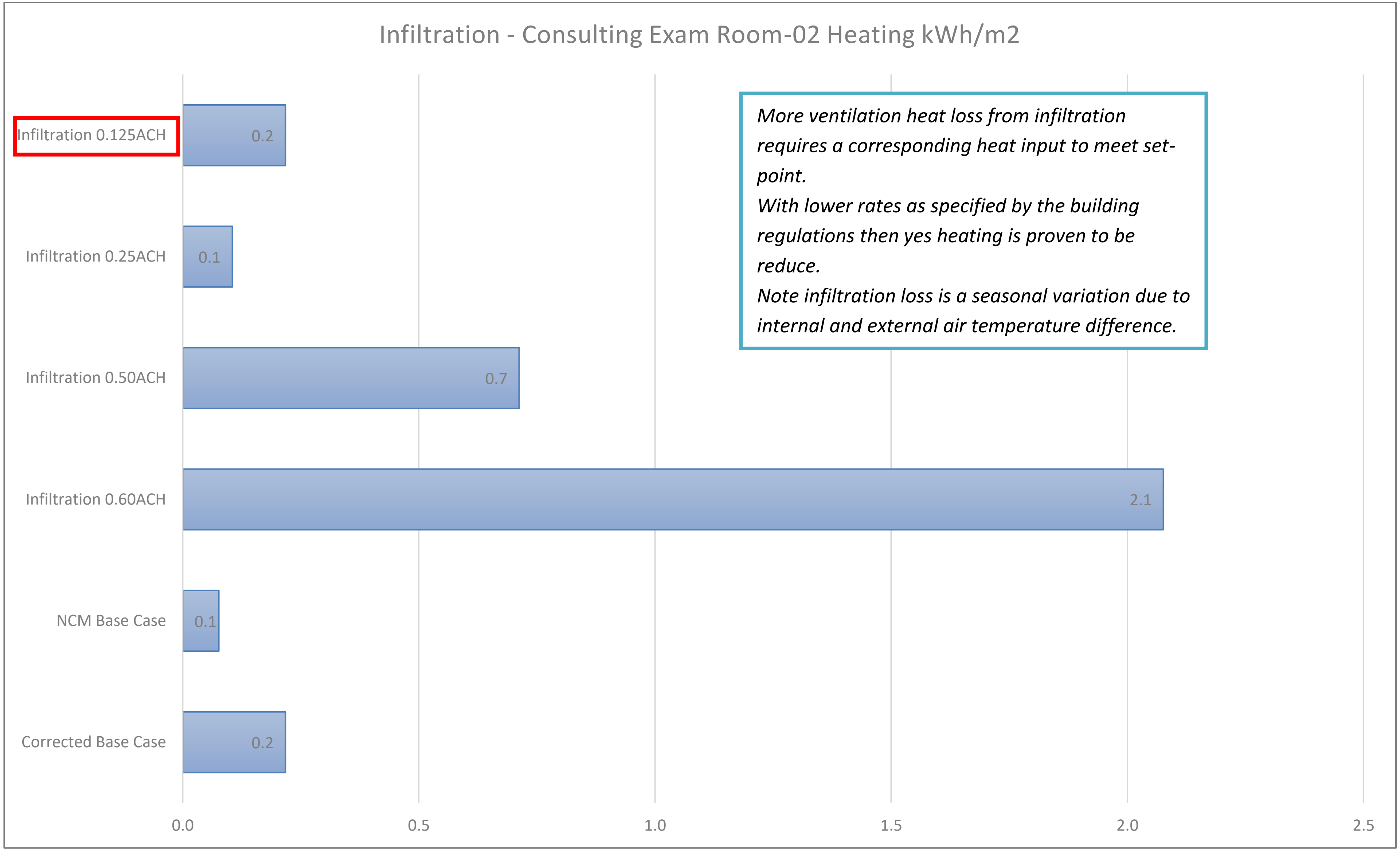


These cases looked at other void related measures at managing the risk. The possibility of adding insulation to contain ceiling void gain but this approach does not away from the fact it is still an attempt to cure and not prevent the gain occurring.

2.4.2.2 Heating Energy



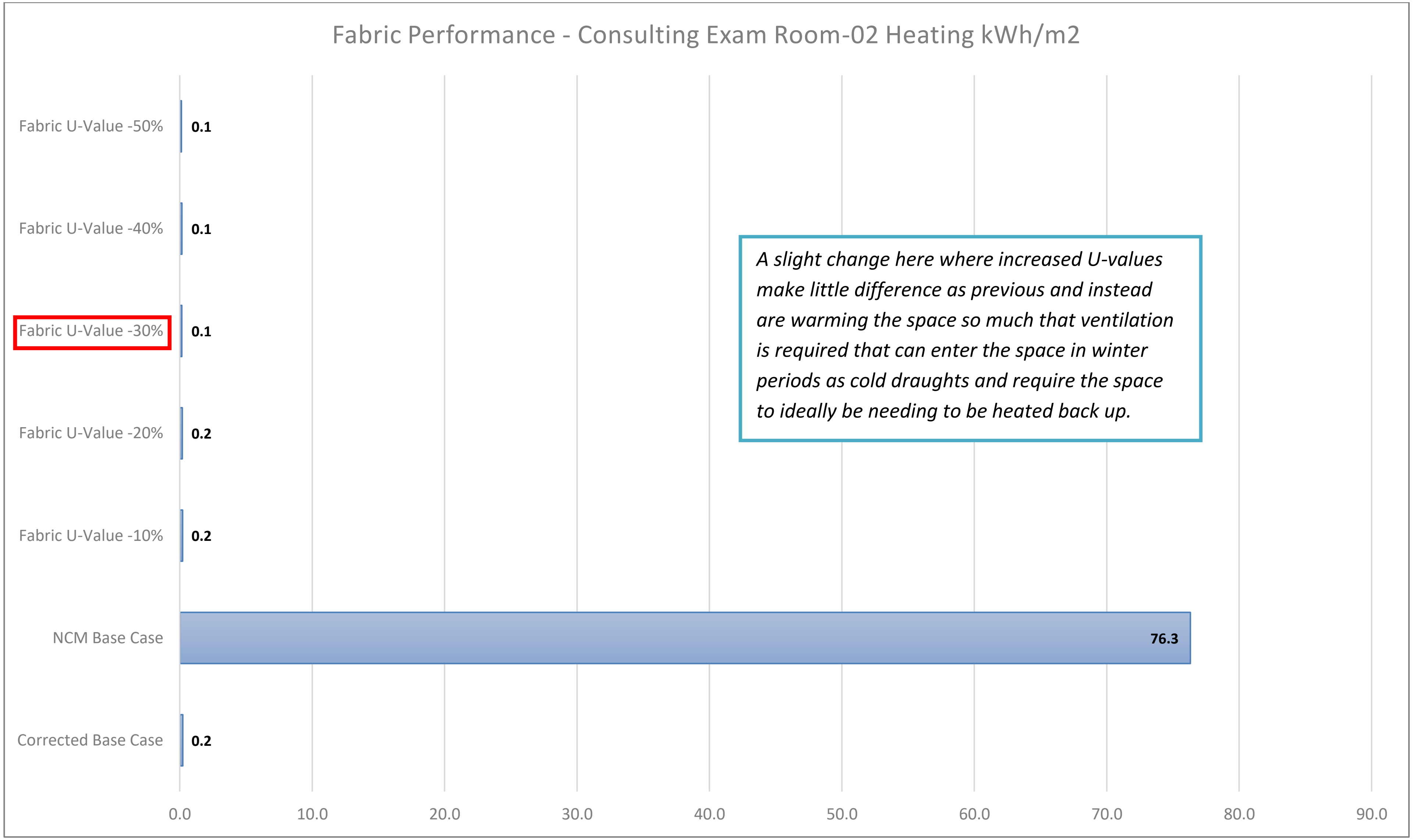
The NBC setup means it is not at as much risk of overheating as the other cases so heating consumption is higher even though it has a lower heating set point. This is primarily due to its lower level of internal gains and the fact a ceiling void does not need to be included in the way the CBC has attempted to accurately portray.



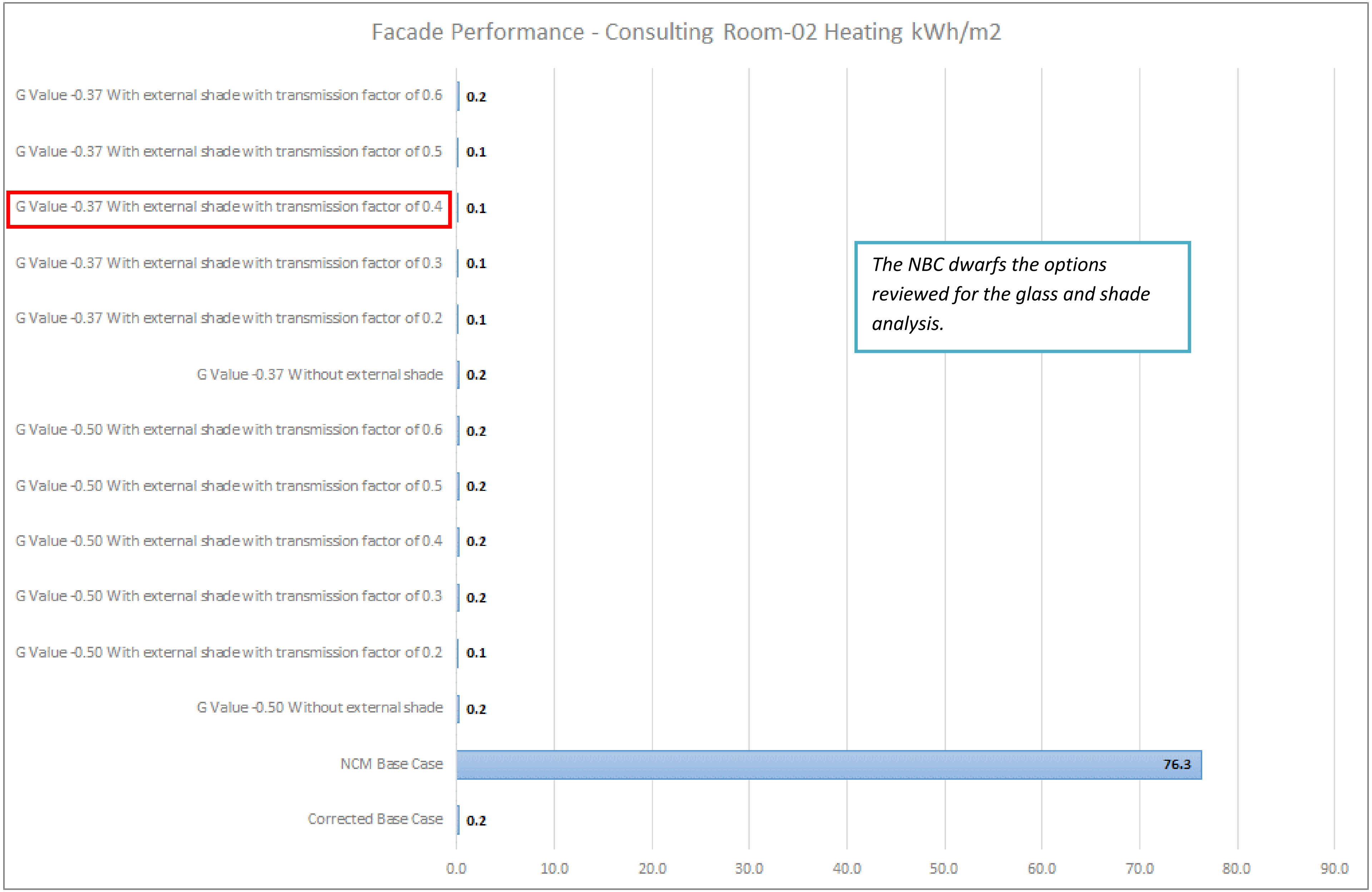
More ventilation heat loss from infiltration requires a corresponding heat input to meet set-point.

With lower rates as specified by the building regulations then yes heating is proven to be reduce.

Note infiltration loss is a seasonal variation due to internal and external air temperature difference.



A slight change here where increased U-values make little difference as previous and instead are warming the space so much that ventilation is required that can enter the space in winter periods as cold draughts and require the space to ideally be needing to be heated back up.



The NBC dwarfs the options reviewed for the glass and shade analysis.

2.4.3 Optimised Approach

Utilising the modelling sensitivity scenarios tested against the Corrected Base Case, a total of five optimised scenarios were modelled.

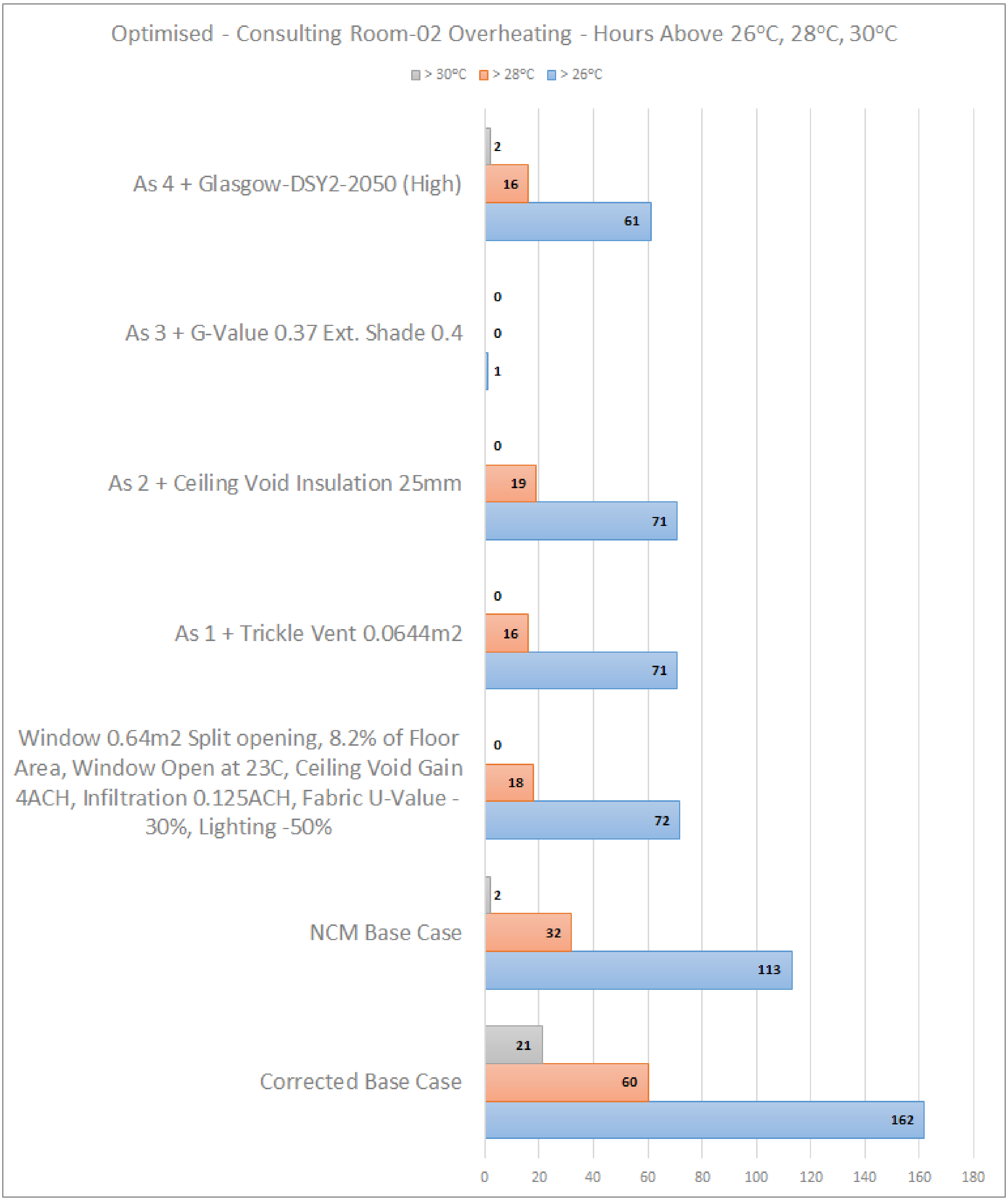
Case-01 combines a series of optimisation solutions with Cases-02 to 04 introducing further enhancement on each step.

Case-05 then tests the complete optimised model against a future weather scenario to assess the potential for regression back toward overheating.

Optimised Combined Scenario	Window 0.64m2 Split Opening, Opening 8.2% of Floor Area, Window Open at 23°C, Ceiling Void Air Exchange 4ACH, Infiltration 0.125ACH, Fabric -30%, Lighting -50%	Trickle vent opening Area of 0.0644m^2	Ceiling Void insulation 25mm	External window g-value of 0.37, external shade 0.40	Use of the future weather file Glasgow-DSY2-2050 (High)
Case-01	✓				
Case-02	✓	✓			
Case-03	✓	✓	✓		
Case-04	✓	✓	✓	✓	
Case-05	✓	✓	✓	✓	✓

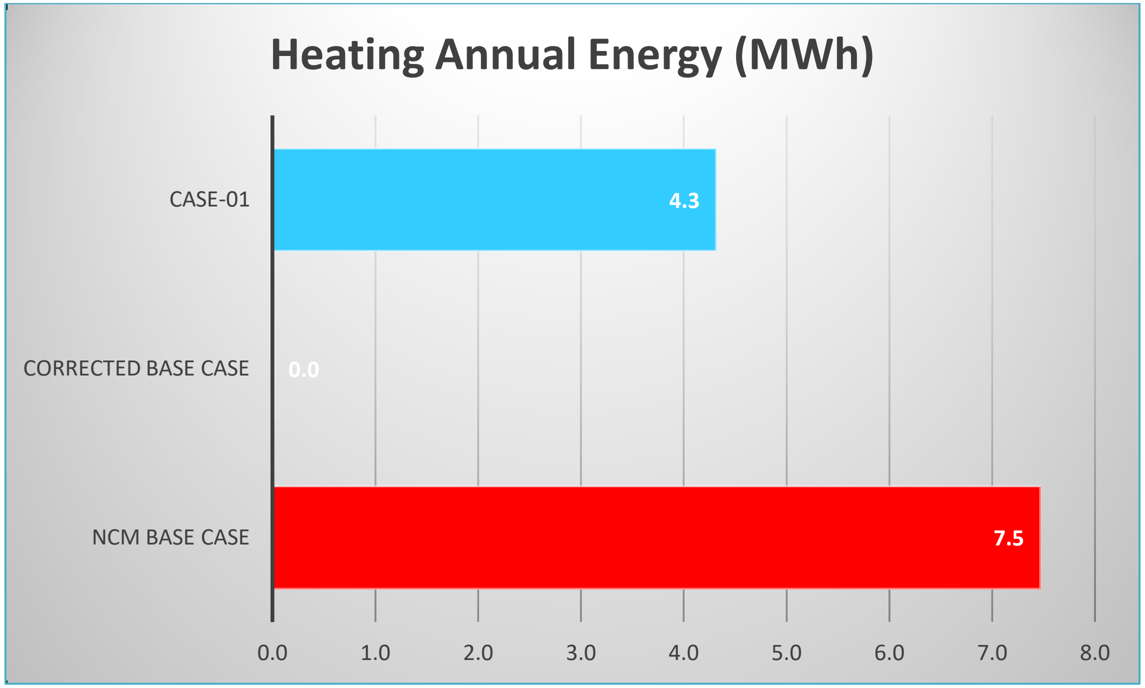
2.4.3.1 Consulting Exam Room Overheating

All of the optimised cases demonstrate lower risk of overheating compared to the NCM Base Case and Corrected Base Case models.



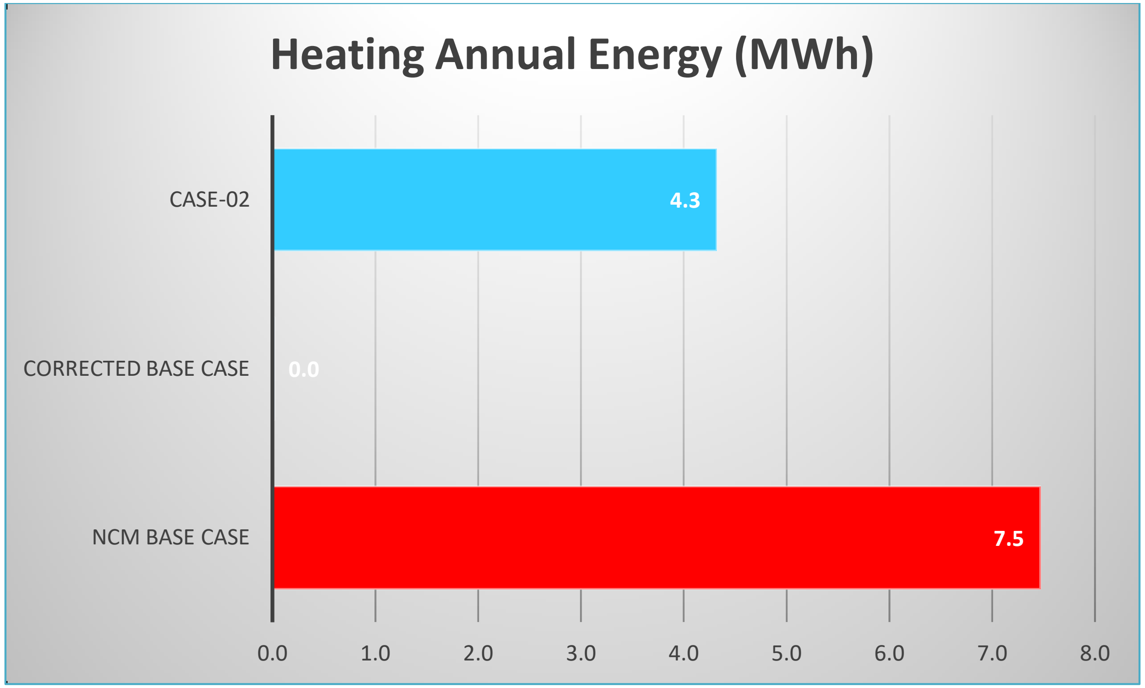
2.4.3.2 Consulting Exam Room Heating Energy

Case-01:



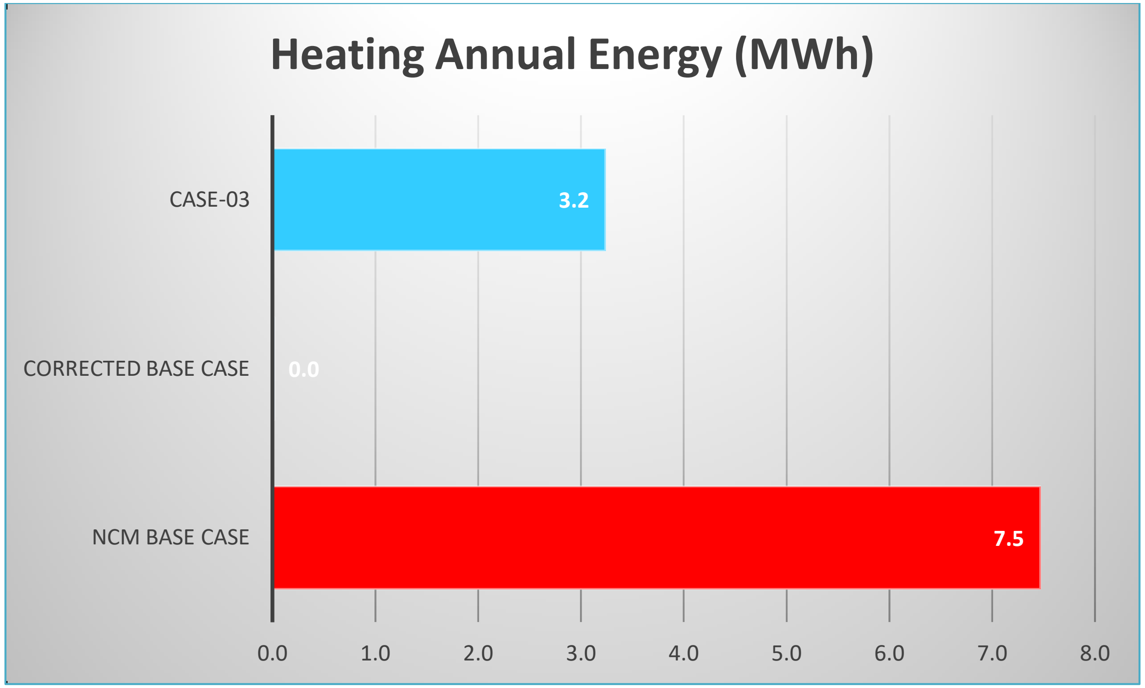
- Case 01 proposes the installation of windows with split openings of an area of 0.64m2, 8.2% of the floor area and to open at 23^{o}C. The Ceiling void is ventilated to 4ACH, the infiltration rate is 0.125ACH whilst also improving the building fabric u-value by 30% and reducing lighting by 50%.
- The Case-01 heating consumption is clearly larger than the Corrected Base Case due to a reduction in impact from the ceiling void gain to the occupied space. The heating for the CBC is negligible in comparison to the other models.

Case-02:



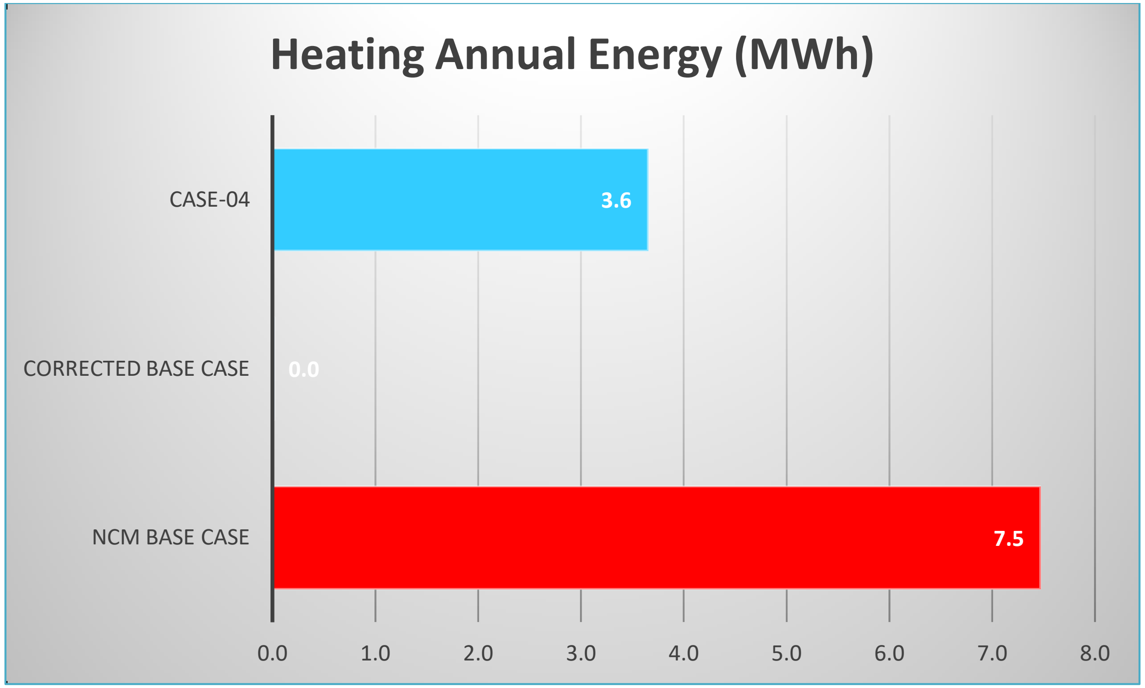
- In addition to the installations proposed in Case 01, Case 02 proposed the application of trickle vents of an area of $0.0644m^2$.
- Trickle vents introduce cool air in the form of natural ventilation and minimise the risk of spaces overheating.
- No noticeable change in heating alongside the minimal assistance to overheating.

Case-03:



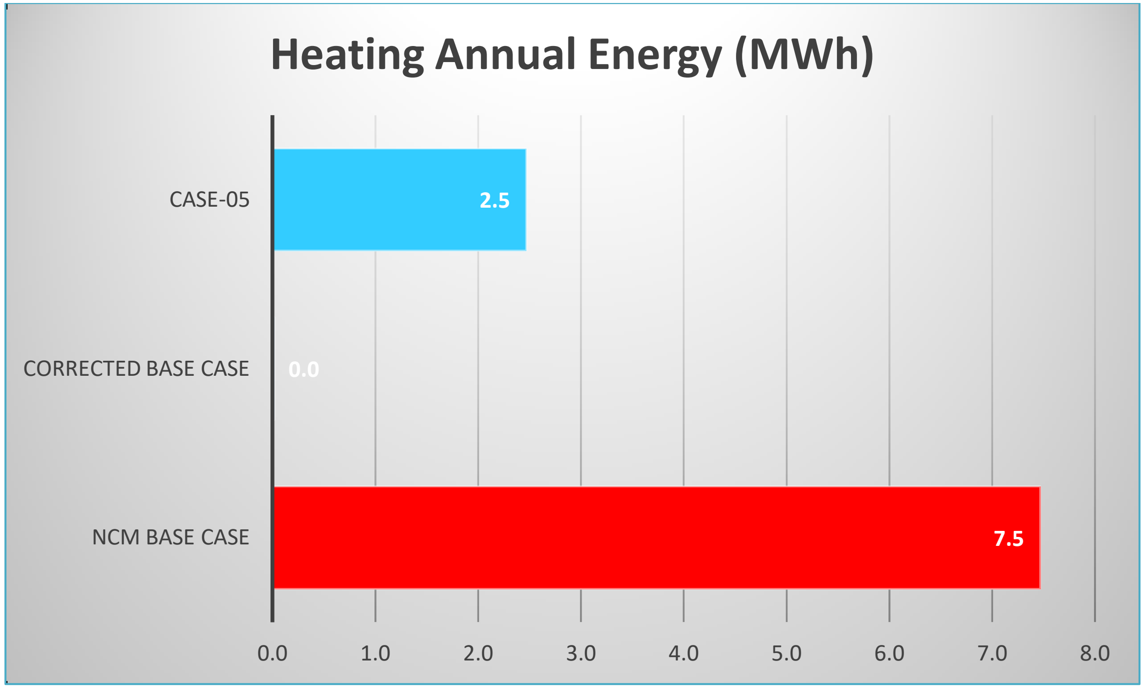
- In addition to installations proposed in Case 02, Case 03 proposes a 25mm insulation around the ceiling void.
- This actually reduces the heating load because the heat loss to the void is reduced which is now acceptable to consider as ceiling void gain is less and is being controlled through the void's purge ventilation.

Case-04:



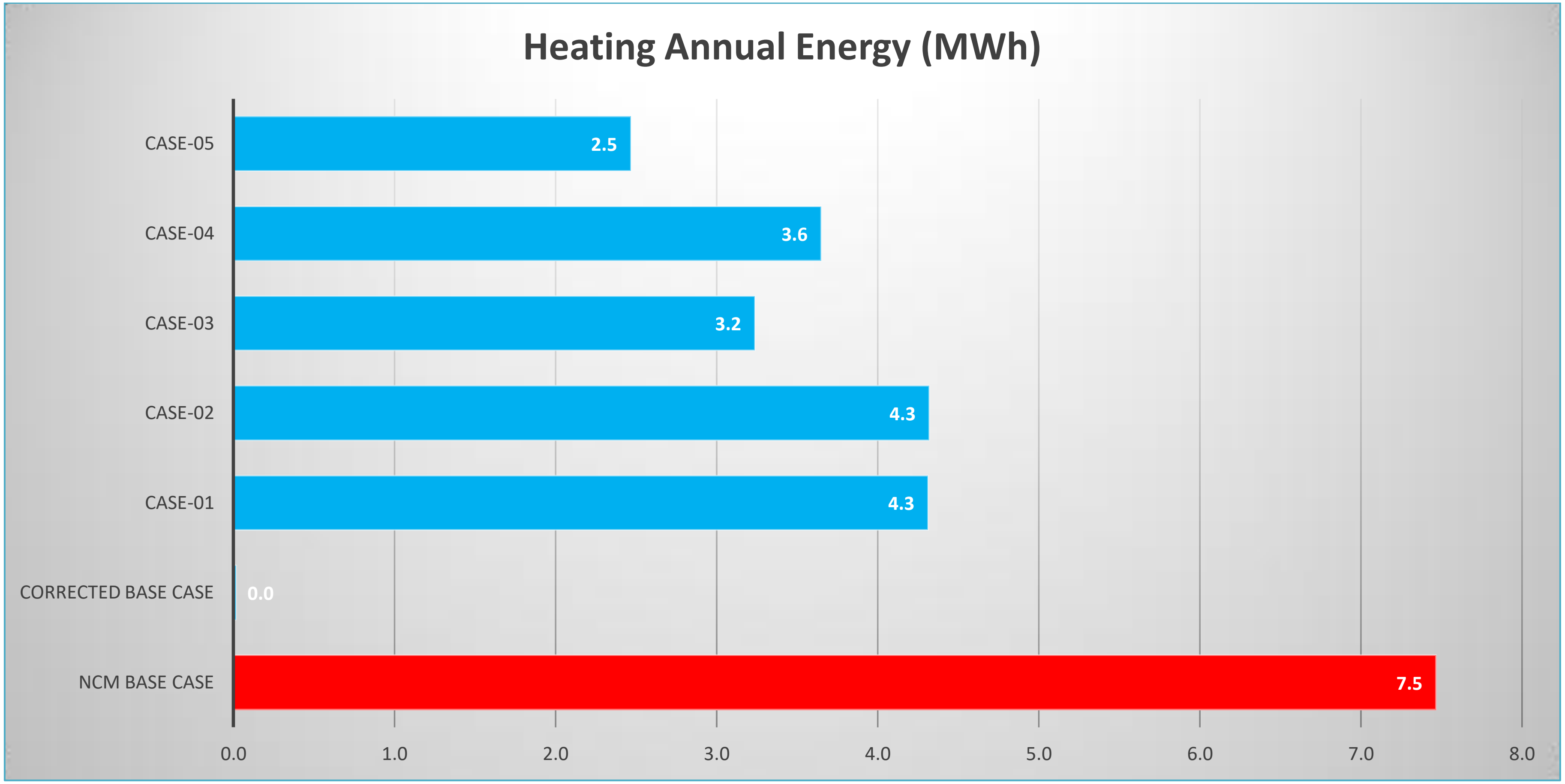
- In addition to installations proposed in Case 03, Case 04 proposes the installation of external windows with a g-value of 0.37 and external shading factor of 0.4.
- The reduction in solar gain to assist with internal comfort has reduced the beneficial offset to heating energy consumption through the year.

Case-05:



- Case 05 examines the installations proposed by Cases 01-04 in a future climate by utilising the Glasgow-DSY2-2050 (High) future weather file.
- Future climates are predicted to be warmer and the heating energy is reduced as a result in comparison to optimised Case-04.
- The predicted risk of overheating in the future is greater, therefore the health centre must be able to adapt to the future climate even though there is a benefit to consumed heating energy.

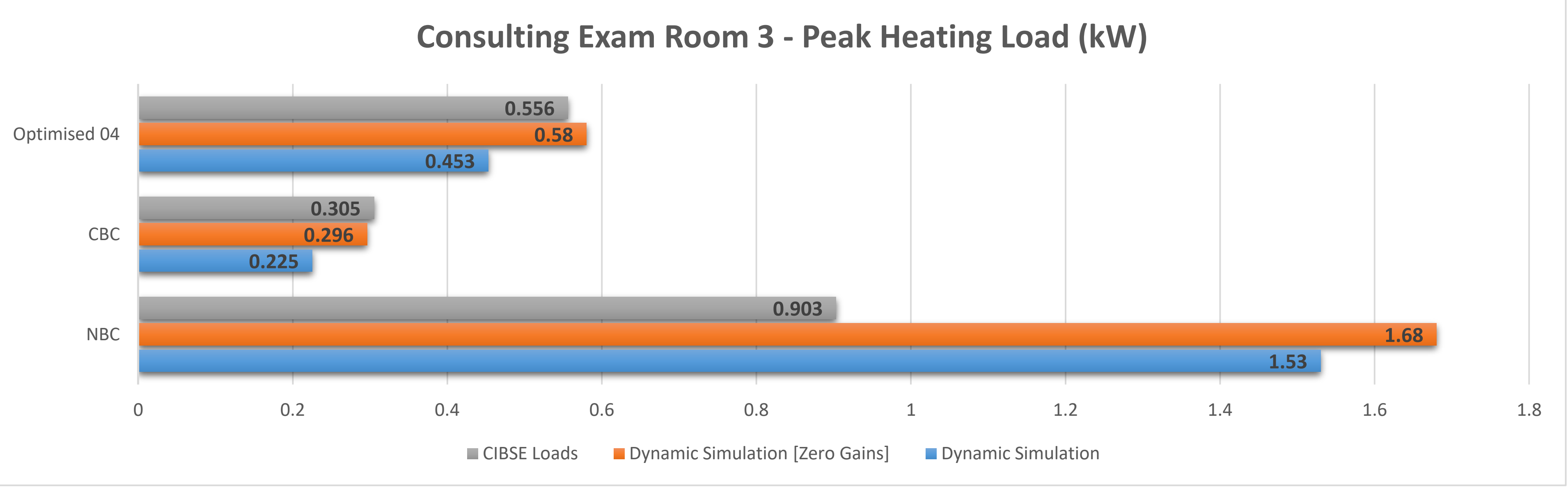
Energy consumption increases from the optimised measures when compared to the Corrected Base Case but is still in the region of 50% less compared to the NBC.



2.4.3.3 Consulting Exam Room Heating Loads

The peak heating load has been compared for the base building models and Case-04. Within this is a comparison of a static heating load calculated through the CIBSE Loads approach against the dynamic simulation route. With the static approach a number of factors are not included which may improperly influence the selection of plant equipment. For example internal gain heat loads are not included, profile variation is inherently not a factor due to the static nature of CIBSE Loads and this also means variation in natural ventilation heat loss cannot be accounted for.

Heating Load (kW)			
	Dynamic Simulation	**Dynamic Simulation [Zero Gains]**	**CIBSE Loads**
NBC	1.53	1.68	0.903
CBC	0.225	0.296	0.305
Optimised 04	0.453	0.58	0.556

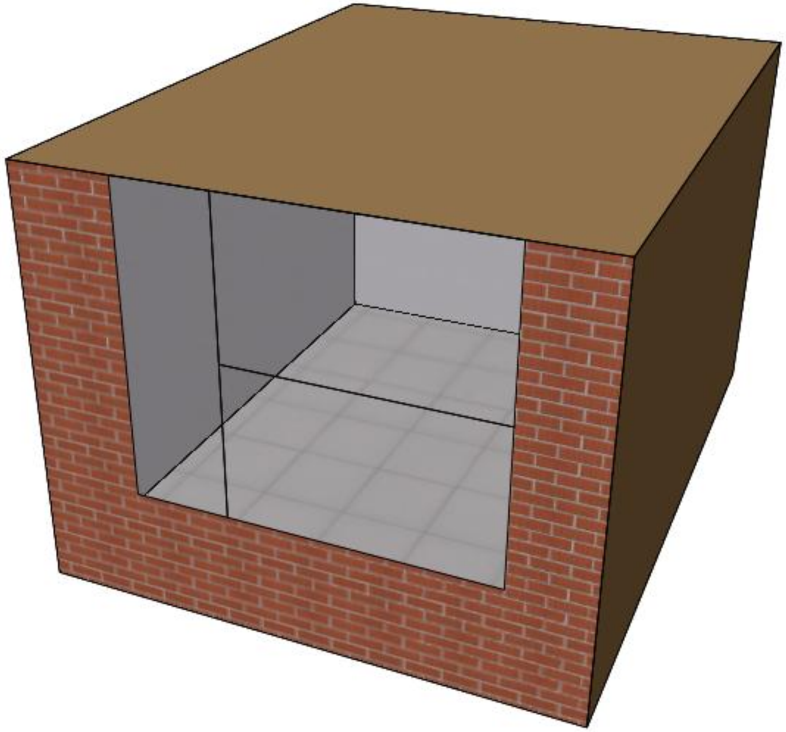


In the NBC model the static load assessment is noted to significantly underestimate the heating load compared to both DSM representations. Closer approximation is noted in the smaller load cases of the CBC and Case-04. Note the static load external design temperature is normally a set characteristic of the site but the dynamic weather file can show a larger difference and in many occasions a cooler temperature which may require a greater load. Fabric load effects are modelled very differently between static and dynamic models. Case-04 has a compensatory need for greater heat input during the coolest season compared to CBC due to its overheating risk significantly lessened.

2.4.3.4 Consulting Exam Room Case-04 v CBC Summary View

Optimised Case -04 Ceiling voids are infused with 4ACH of air and 25mm of insulation are installed on the void surfaces whereas the CBC ceiling voids lack ventilation and are uninsulated.

Optimised Case-04 hospital's external building fabric is due to a 30% improvement in performance in comparison with the CBC model



Increase in trickle ventilation opening area in Case-04 from $0.0196m^2$ as included within the CBC to $0.0.0644m^2$.

In Case 04, Lighting System is further improved by 50% in comparison with the CBC model

In the CBC, windows are configured to open when internal air temperature reaches 23°C and when outside air temperature is above 10°C

In Optimised Case-04 the window opens when the internal air temperature reaches 23°C

CBC does not include any form of window shading although the façade performance is improved in Optimised Case-04 by the incorporation of window and external shading of g-values of 0.37 and 0.40 respectively.

2.5 Solar Energy Impact

Using the SunCast solar visualisation simulation we have assessed the accumulated annual solar energy on the façade where the **Consulting Exam Rooms** are located and which faces predominantly South. We have then modelled East, North and West to compare the cumulative difference.

There is a clear variation in solar energy with this approach which provides invaluable details for early stage design on the façade surfaces most at risk to direct solar gain through glazing and transient external conduction gain. This data can be used for space activity planning to position occupied spaces where thermal and visual comfort can be suitably managed, identifying external shading needs and positioning photovoltaics for maximum energy generation.

It is important to note that analysis of façade solar gain capture and activity planning needs to consider profiles of operation. For example the South and West orientations do not have a significant difference but certainly west facing solar gain will be at lower angle and later in the day so what issue would this have for spaces with long day usage patterns.

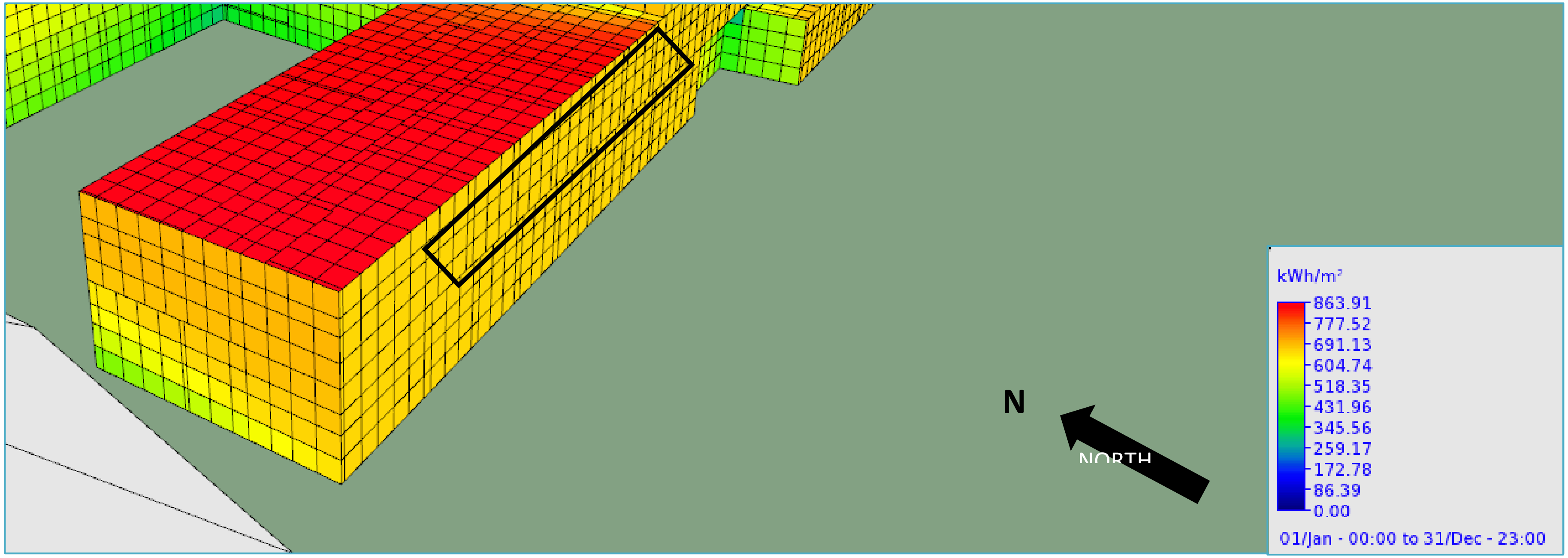
All figures are in kWh/m2:

South	East	North	West
750	**450**	**375**	**700**

The following visualisations show the captured solar energy variation across the façade.

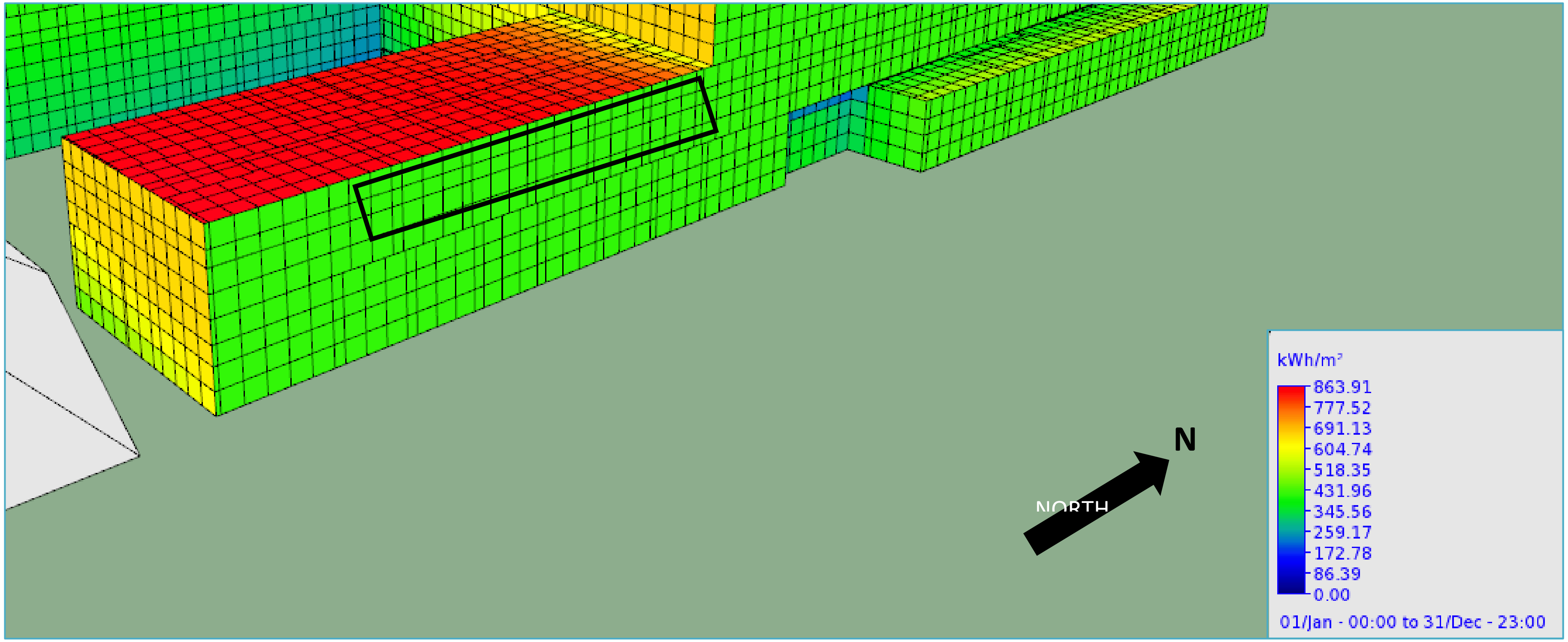
2.5.1 South

When set as a west facing façade the solar energy impact is in the region of ~750 kWh/m2.



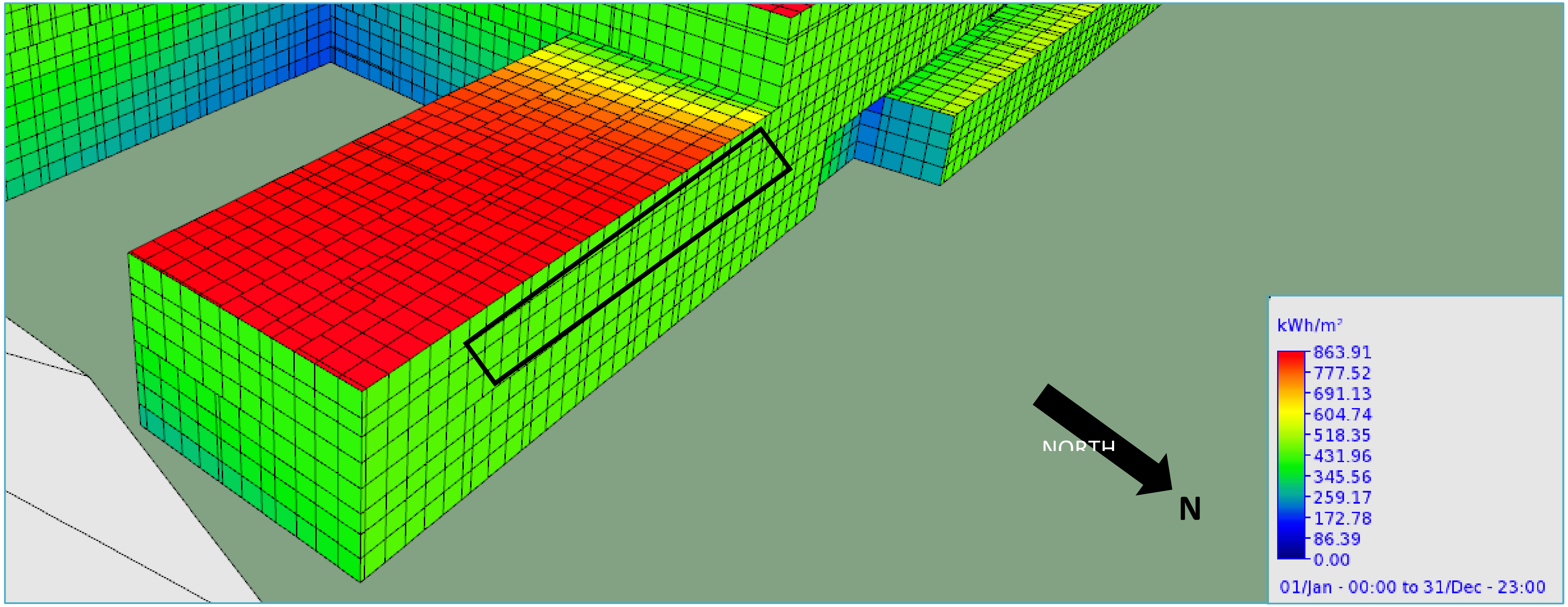
2.5.2 East

When set as a west facing façade the solar energy impact is in the region of ~450 kWh/m2.



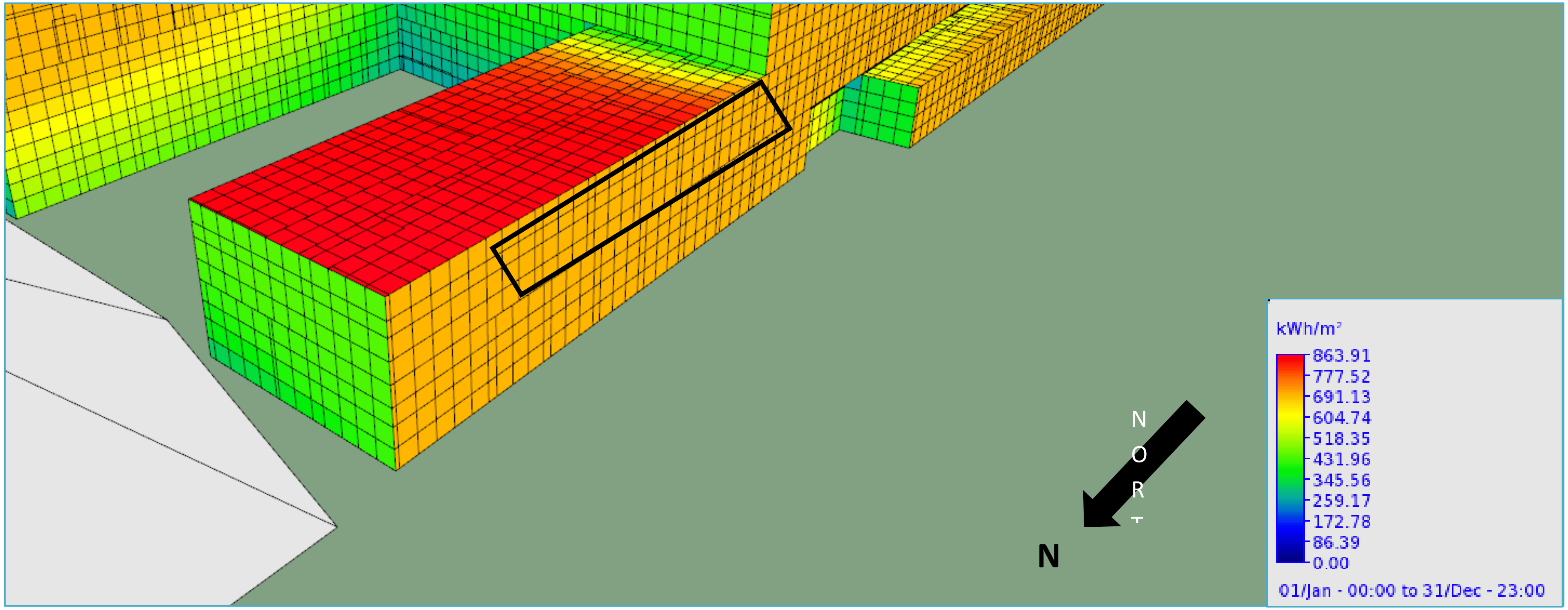
2.5.3 North

When set as a west facing façade the solar energy impact is in the region of ~375 kWh/m2.



2.5.4 West

When set as a west facing façade the solar energy impact is in the region of ~700 kWh/m2.



3 Hospital

3.1 Introduction

This report details the modelling investigation of a recent and typical hospital development that we used as an exemplar study model. The study focused on the predicted performance of a typical hospital wing containing a typical, representative ward with 100% single bedroom suites and support spaces. Modelling is used to predict building performance, and when successful helps design teams make better, more assured decisions based on evidence, reduce risk and result in the best possible building for its occupants and the environment. Models are critically dependent on the quality of the data selected to go into their calculation, with poor data will come a poor representation and therefore risks misdirection for the design path. Past cases exist where model outputs have been criticised but instead this is the result of poorly selected inputs. Successful models are built by competent modellers working with their design teams who together have selected the most appropriate inputs to meet the needs at each stage in the project.

This report details the use of a Dynamic Simulation Model (DSM) which is a sub-hourly time based simulation utilising hourly weather data and test building attributes including building form, fabric, internal gains, ventilation air exchanges, operation profiles and building HVAC systems. The simulation then produces hourly data for energy and environmental metrics from which modellers can produce statistical reports to detail exactly how the building is predicted to perform.

The use of a model at the design stage is only the first step in its life as a companion to the building. The model can continue to be used during the operational stage by calibrating the model using metered data. This calibrated evolution can then both be used to predict the effects of retrofit works and also to check building performance and identify if the building is moving outside of its intended parameters and exactly which of these are vulnerable.

The analysis has been undertaken based on the backdrop of the latest Section 6 Scottish Building Regulations from 2015. These regulations have guided aspects such as fabric within the tested models. It is worth noting the latest NHS Scotland buildings constructed would have been built to the pre-existing 2010 standards and that performance detailed by this analysis to 2015 requires higher standards of thermal insulation and air tightness. There are definite diminishing returns in aspects of building design, such as thermal insulation, which were previously identified as being key factors as overheating of buildings becomes more prevalent. Other factors not previously under the spotlight, such as shading, are now become crucial in striving for continued performance improvement. As the regulations and building standards become higher it is clear that only a full sub-hourly analysis provides the opportunity to quantify the improvements being made.

3.2 Modelling Scenarios

3.2.1 NCM Base Case

The NCM Base Case is a representation of the hospital models most frequently presented to NHS Scotland for newly designed developments. These involve the deployment of a Section 6 Building Regulations model where the primary modelling objective is compliance. The 'National Calculation Methodology' (NCM), was created by the UK government for the purposes of a 'like for like' operational comparison so to assess the performance of fabric, HVAC system efficiencies, lighting and other such building performance factors across all buildings with a similar use, e.g. hospitals. The NCM provides set input data including operation hours, room set-points, ventilation flowrates and illuminance levels. However with this comes clear its intention to serve as a benchmark compliance as there is a very limited number of building type and activities available to select and assign to the model's spaces. This is not a problem for compliance as all similar spaces will use the same operational data in their models. However, if modellers are actively trying to use this minimal list to represent their '*real'* building design then straightaway a limit has been introduced to correctly represent the true building activities and operation. Examples include NCM room set-points being lower than are intended for the design and using lower ventilation airflow rates to meet comfort conditions. Both of these examples would result in significant differences to the calculated and operational energy use. This gap is frequently referred to as the 'performance gap' and this can be reduced or eliminated by using more site specific and accurate input data in the real building model simulations.

It is known that designers frequently use NCM data in their design calculations and as the modelling objective is primarily compliance then it results in a poor representation for a detailed investigation into *real* building energy use and occupant comfort needs. This leads to mismanaged findings, which negatively influence the final design and handicap the building throughout its operational life.

3.2.2 Corrected Base Case

The Corrected Base Case model is specified to better represent the true operation of a hospital based on experience with similar developments and learning outcomes involved. Room Data Sheets (RDS) were produced for this project (see Appendix C) which specify the hospital activity and define the following:

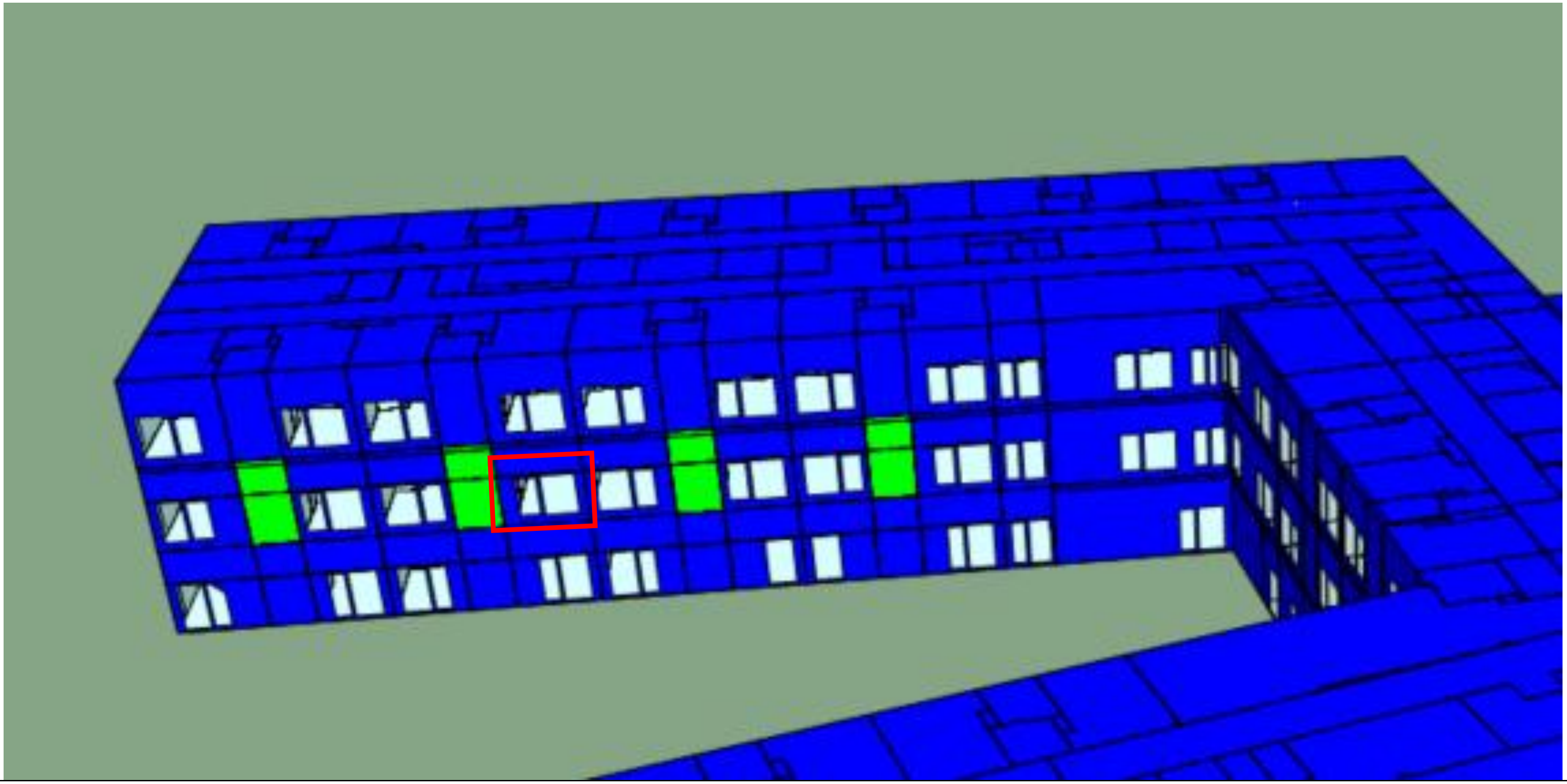
- Room heating set-point
- Infiltration rate
- Fixed air exchange rate (supply or extract)
- Internal gains - occupancy, lighting and equipment
- Time based operating schedules

3.2.3 Sensitivity Analysis

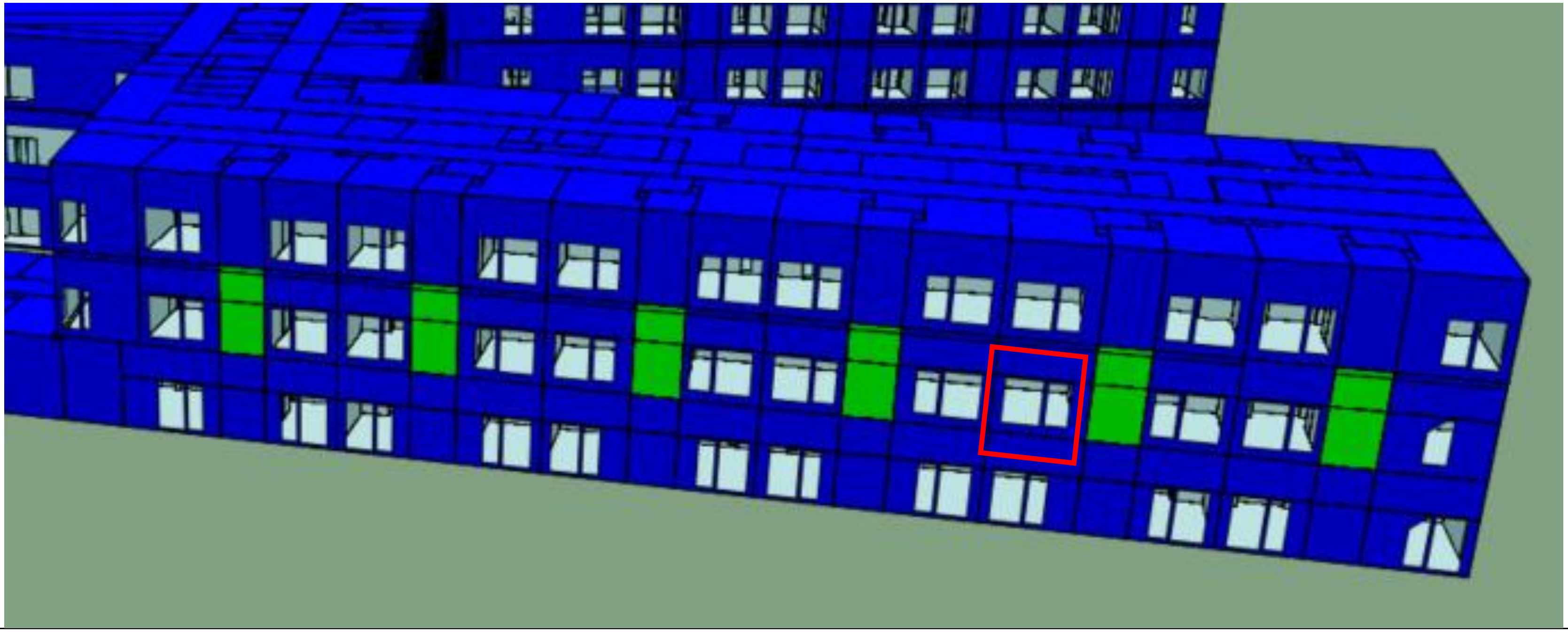
A modelling sensitivity analysis was undertaken by performing iterations of the Corrected Base Case. The following settings were identified as options for investigation either due to concerns raised from previous developments or having been identified as clear opportunities to improve design in future developments.

Description	Settings - Corrected Base Case
Bedroom window configuration	10% openable area large single pane
Bedroom window opening control	Windows open when internal air temperature is above 24°C and outside air temperature above 10°C
Trickle ventilation	Yes
Ceiling void configuration	Internal gains on & no ventilation air exchange
Ceiling void insulation	No
Weather file	Glasgow Test Reference Year 2005
Air infiltration	0.125 Air Changes per Hour
External wall	U-value = 0.2 W/m^2 K
External window	U-value = 1.6 W/m^2 K, g-value = 0.5
Window shading	No
Lighting	See Room Data Sheets in Appendix C

3.3 Hospital Geometry



South facing bedroom under analysis



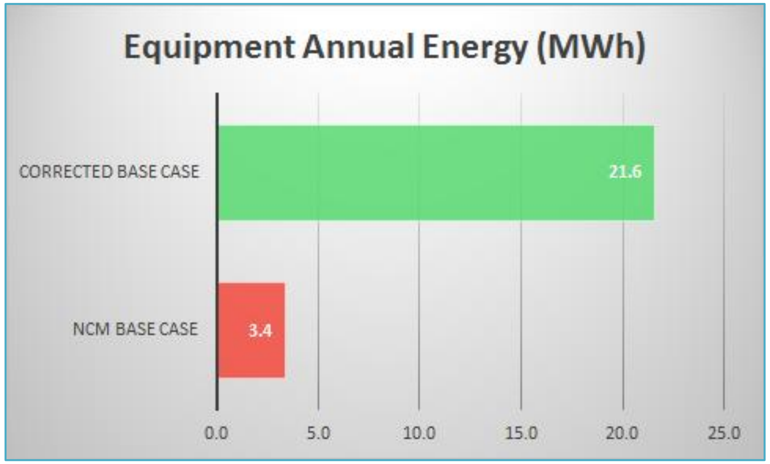
North facing bedroom under analysis

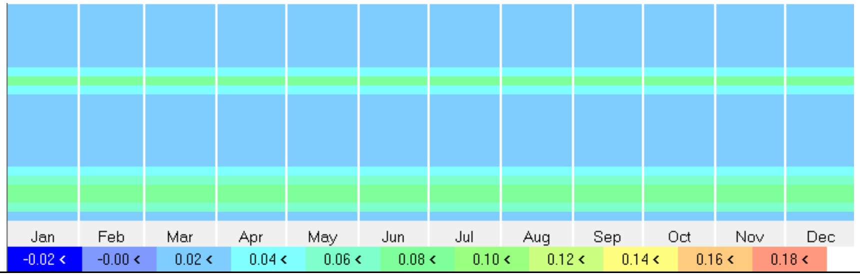
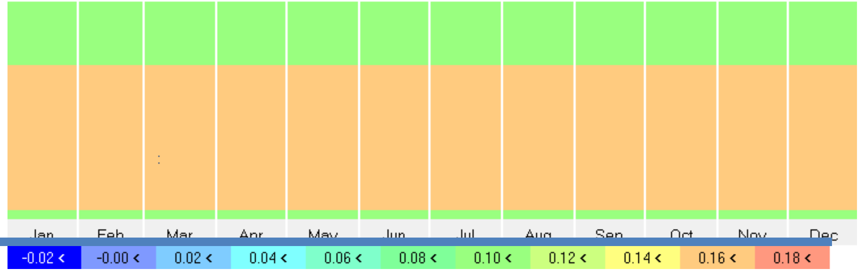
3.4 Sensitivity Analysis

3.4.1 Corrected Base Case Comparison

The following charts assess the cumulative annual energy for the 20 bedrooms within the ward alongside a yearly time period profile indicating when the load in a bedroom occurs.

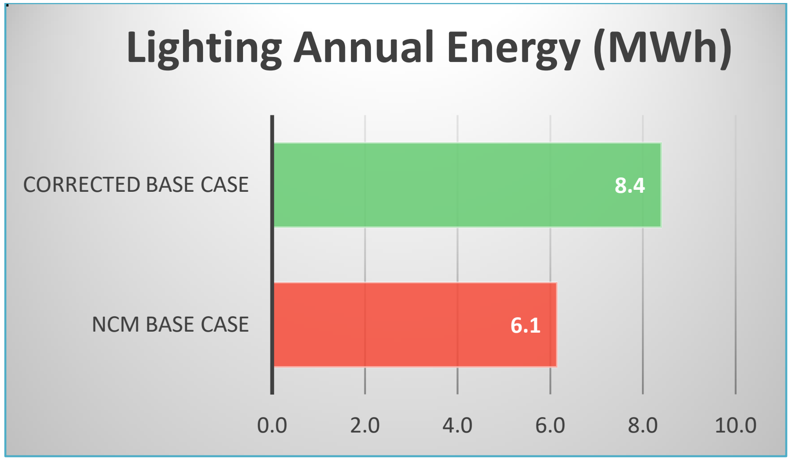
3.4.1.1 Bedroom: Equipment Gain



Time Period	NCM Base Case (kW)
0 24	
Time Period	Corrected Base Case (kW)
0 24	

- Substantial difference in the accumulated equipment annual energy for the 20 ward bedrooms and the peak value for exemplar bedroom.
- NBC utilises operating profiles based on the deployment of a Section 6 Building regulation model, the equipment gain peaks at ~0.08kW for two instances per day which are more representative of a residential activity.
- The CBC employs profiles which represents a more continuous use of bedroom equipment in which the gain peaks at ~0.14kW for the bulk of the day.
- As a result, the CBC has a significantly greater equipment annual energy.

3.4.1.2 *Bedroom: Lighting Gain*



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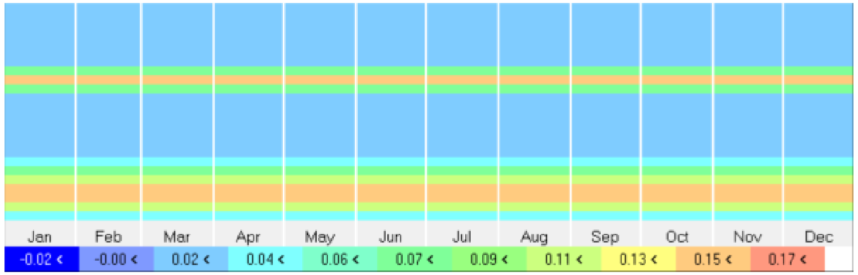
24</td><td> </td></tr>
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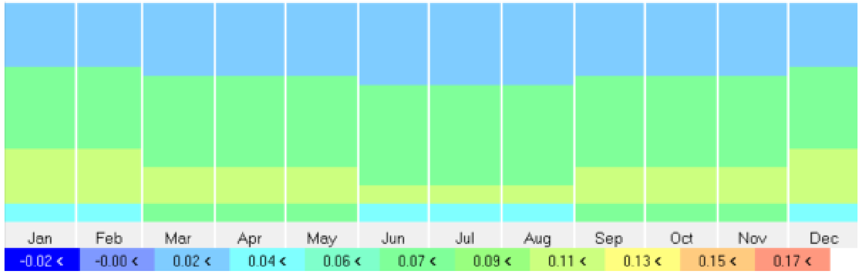
24</td><td> </td></tr>
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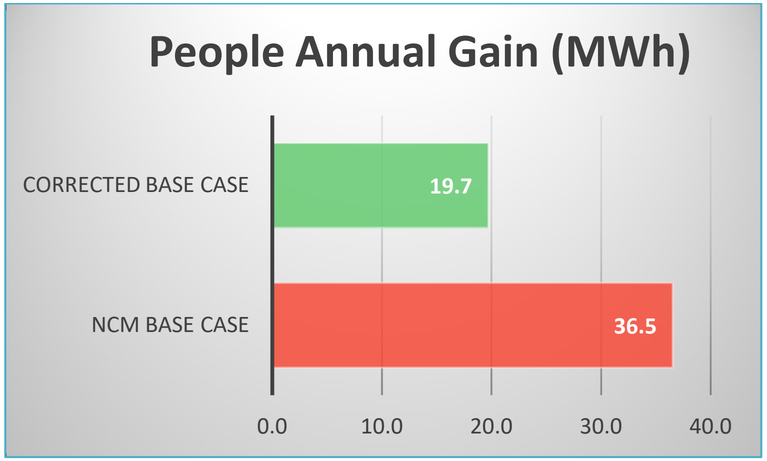
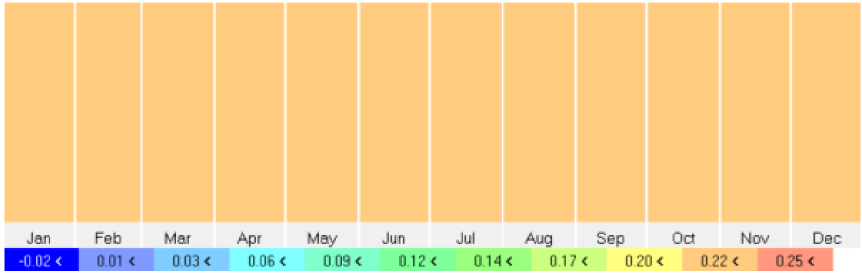
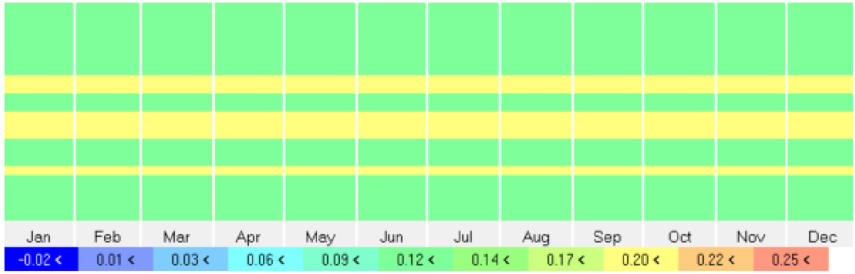
- The NBC peaks at two instances per day at ~0.15kW and appears to be more representative of a residential activity.
- This NBC profile is the same throughout the year regardless of the number of daylight hours.
- The CBC accounts for the use of artificial lighting dropping during spring and summer and then rising back into autumn and winter periods.
- Even though the CBC lighting gain peaks at a lower value, ~0.10kW, the lighting annual energy is greater than the NBC due to longer hours of operation.

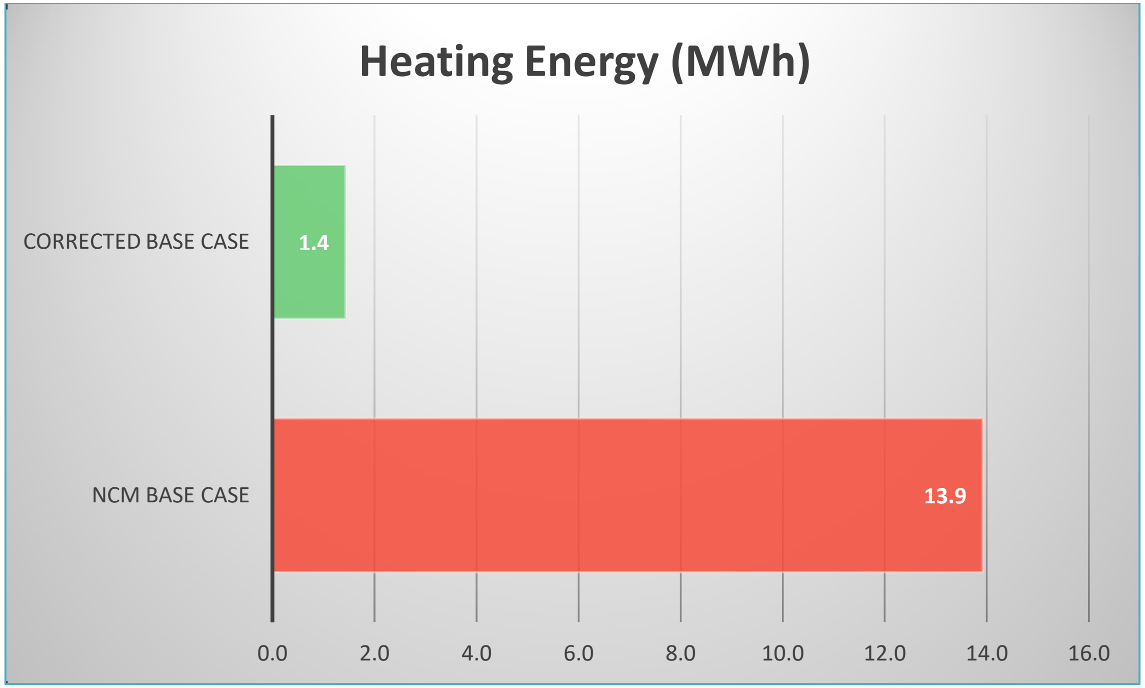
3.4.1.3 Bedroom: People Gain



Time Period	NCM Base Case (kW)
0 24	
Time Period	Corrected Base Case (kW)
0 24	

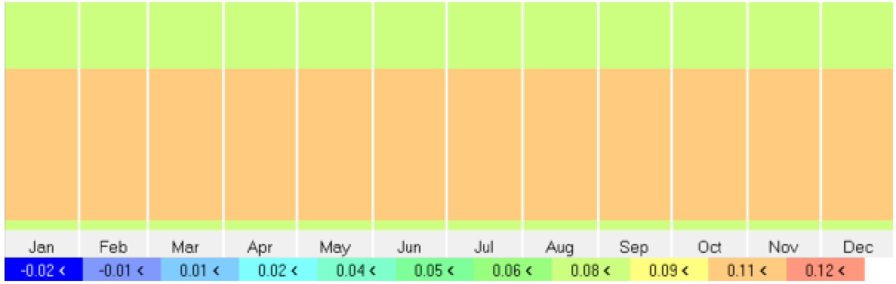
- NBC profile specifies a continuous occupancy gain throughout the day at ~0.23kW, note how different this is to the lighting and equipment profiles employed by the same model.
- CBC has three occupancy spikes in the bedroom throughout the day peaking at ~0.19kW and these represent medical experts and visiting hours.
- NBC people annual gain is far greater than the CBC annual people gain due to the continuous occupancy level.

3.4.1.4 Bedroom: Heating Energy



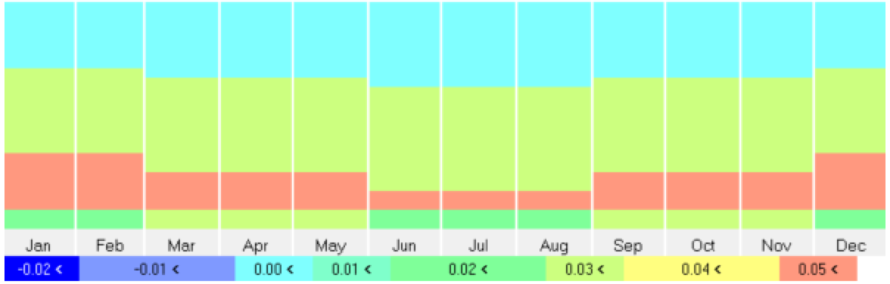
- NBC annual heating energy is approximately 10x the magnitude of the CBC.
- The effect of the heating energy usage is influenced by the internal gain loads attributed to the models. With the CBC there are ceiling void loads described below also influencing the energy use.
- Note even though the NBC has a heating set-point of 18^{o}C compared to the CBC of 23^{o}C, the energy use in the NBC is still higher overall.
- This heating energy is the load for the occupied bedroom space and excludes the heat load from the adjacent voids.

3.4.1.5 Bedroom - Ceiling Void: Equipment Gain

Time Period	Corrected Base Case (kW)
0 24	

- The NBC model does not model ceiling voids so no gain is included.
- The CBC specifies equipment gains in the ceiling voids which peak at ~0.1 kW.
- There is a continuous background equipment load overnight and ramps up to a peak constant during daytime hours.

3.4.1.6 Bedroom - Ceiling Void: Lighting Gain

Time Period	Corrected Base Case (kW)
0 ↓ 24	

- The NBC model does not model ceiling voids so no gain is included.
- The CBC specifies lighting gains in the ceiling voids which detail a peak of ~0.04 kW.
- Lighting gains run as per the bedroom usage with a seasonal drop in summer.
- Lighting daily profile follows the same usage as the bedroom.

3.4.1.7 Bedroom NBC v CBC Summary View

NBC does not model a ceiling void so no accumulation of gains is present.

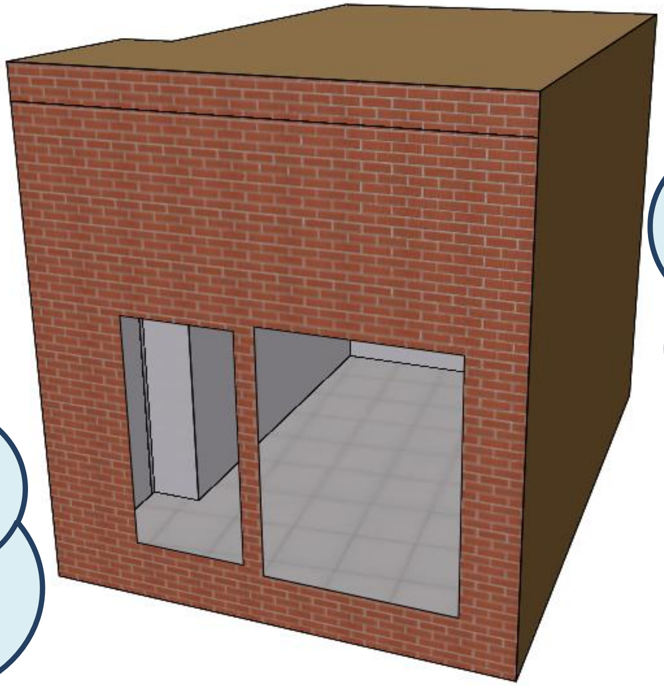
CBC accounts for heat gains in the sealed ceiling void therefore representing a build-up of heat.

NBC defines the health centre's internal gains and profiles from NCM activities.

CBC specifies the health centre's operations using data from past experiences to define the space activities and internal gains.

NBC = 18^{o}C

CBC = 23^{o}C and represents actual design specifications.



NBC maintains no change in operation hours of the health centre.

CBC represents the true operations of the health centre by specifying the time based operating schedule per activity.

NBC models minimum supply airflow from assigned space activity plus an idealised approach of introducing outside air to prevent heat build-up.

CBC models a variable airflow rate based on bulk airflow exchange through a window strategy for opening area and opening control.

3.4.1.8 *Ward Circulation: Equipment Gain*

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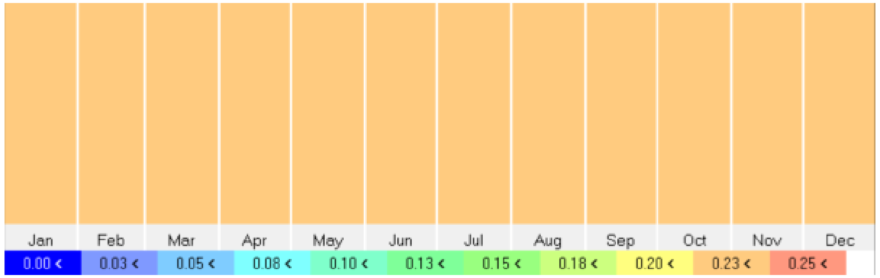
24</td><td>


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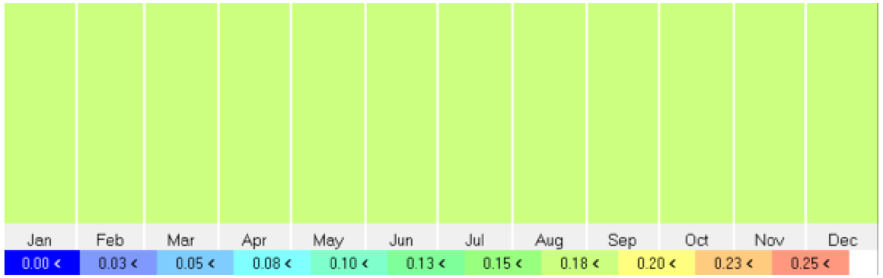
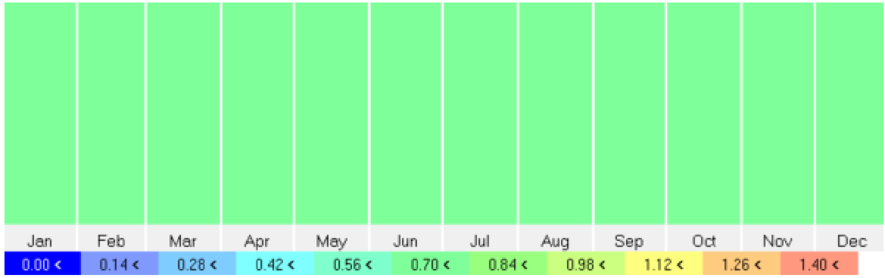
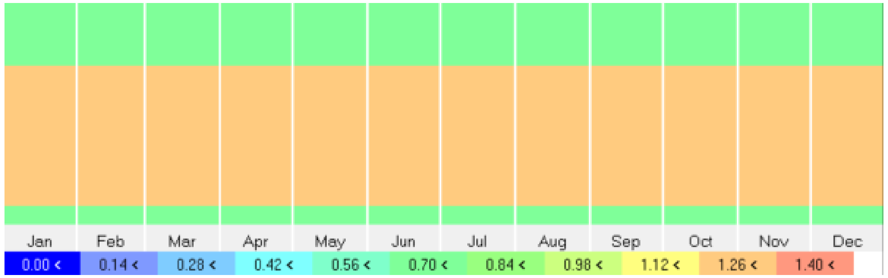
24</td><td>


</td></tr>
</table>

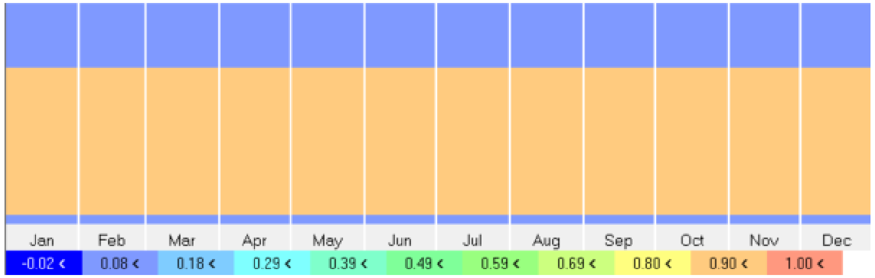
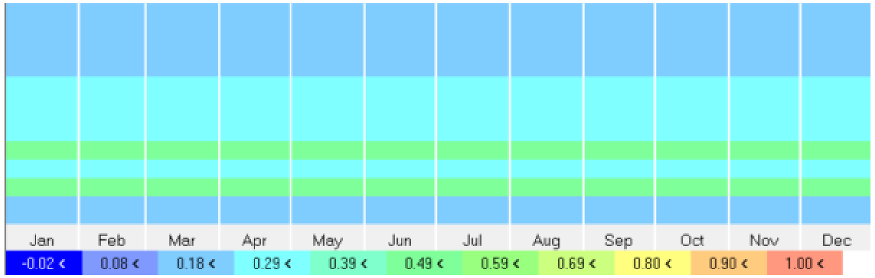
- The NBC runs with a constant equipment gain of ~0.22 kW.
- The CBC runs with a lower constant equipment gain of ~0.15 kW.

3.4.1.9 Ward Circulation: Lighting Gain

Time Period	NCM Base Case (kW)
0 ↓ 24	
Time Period	Corrected Base Case (kW)
0 ↓ 24	

- The NBC runs with a constant of ~0.56 kW.
- -The CBC lighting gain peaks at ~1.2 kW during daytime hours and operates at a minimum of ~0.6 kW overnight.

3.4.1.10 Ward Circulation: People Gain

Time Period	NCM Base Case (kW)
0 24	
Time Period	Corrected Base Case (kW)
0 24	

- NBC profile specifies a large daytime peak in people gain at ~0.86 kW.
- CBC peaks at ~0.45 kW for short periods with a lower backdrop throughout the day.
- The NBC has A minimum of 0 whereas the CBC has a minimum of ~0.09 kW.

3.4.2 Potential Optimisation Scenarios

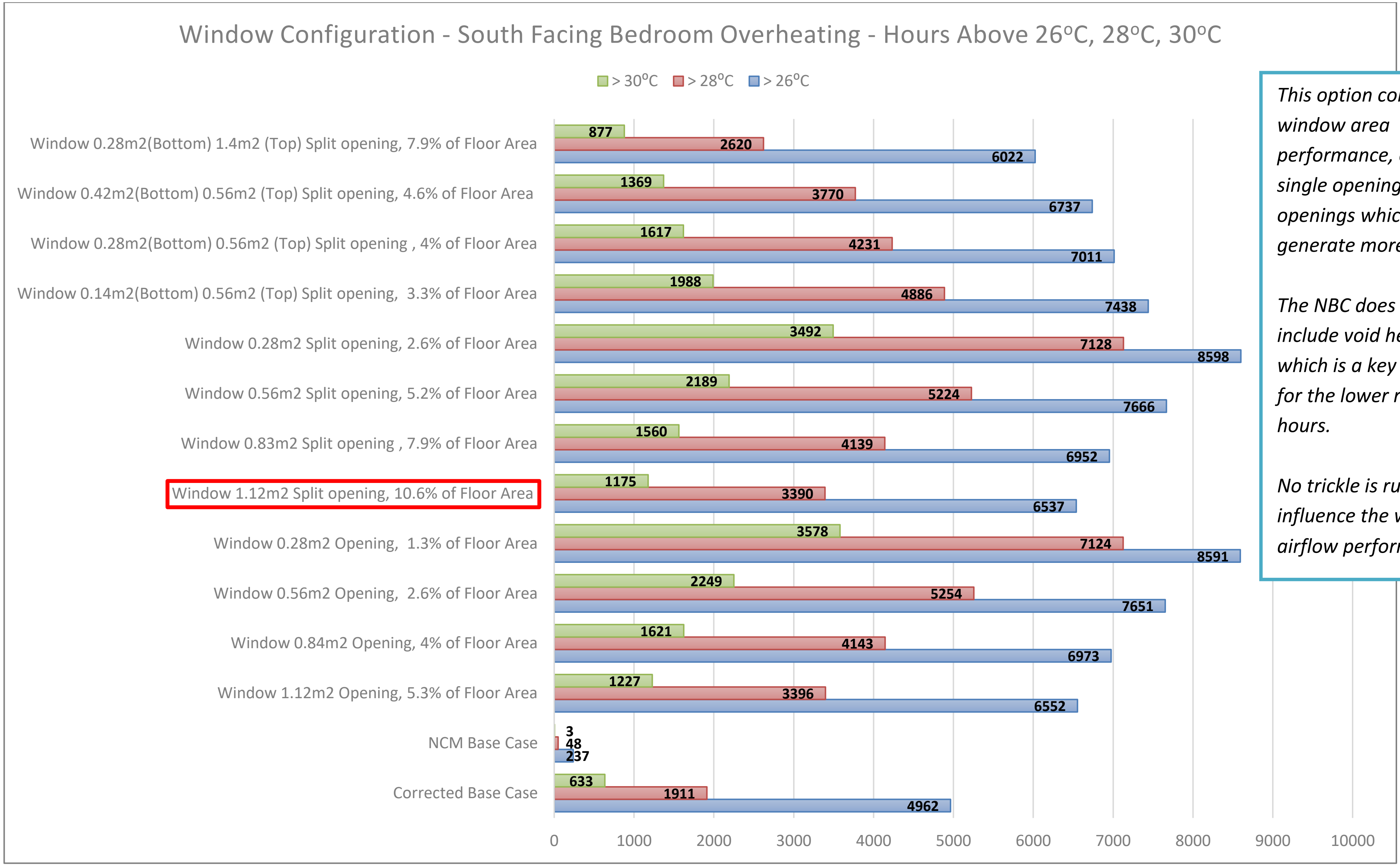
Optimisation scenarios were run across the following attributes identified as being key aspects of current performance where there is a need to investigate toward enhancing thermal comfort and reviewing the subsequent impact on energy use.

- Window configuration
- Window opening control
- Ceiling void gain and ventilation
- Future weather files
- Infiltration
- Fabric
- Façade glass transmittance and shading
- Lighting
- Trickle ventilation
- Ceiling void configuration

The charts detail for an exemplar bedroom space for the permutations assessed with operative temperature statistics exceeding 26^{o}C, 28^{o}C and 30^{o}C.

The red box highlights the assessed measure carried forth to a combined optimisation scenario.

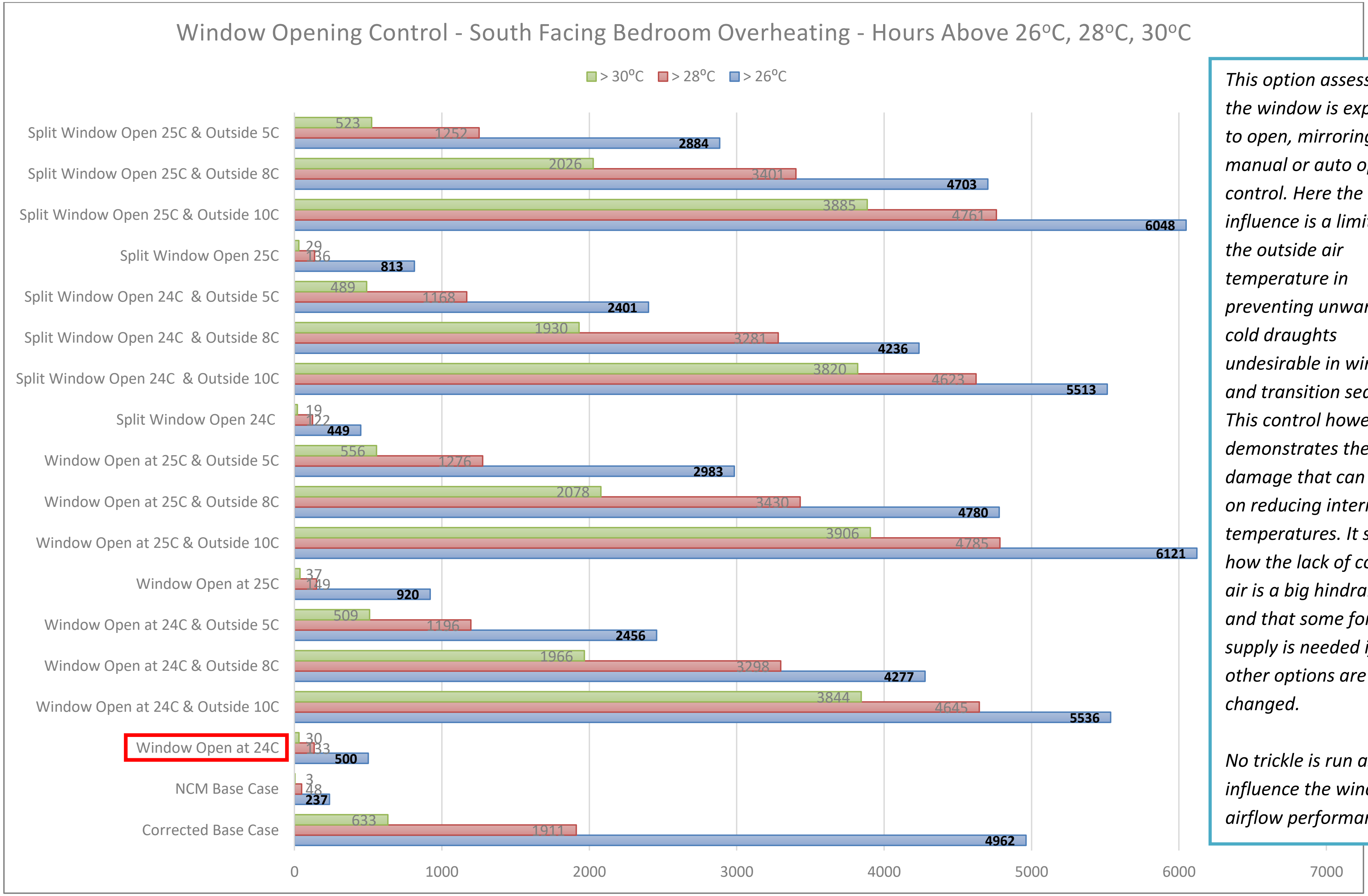
3.4.2.1 *Overheating*



This option compares window area performance, either as a single opening or split openings which can generate more flow.

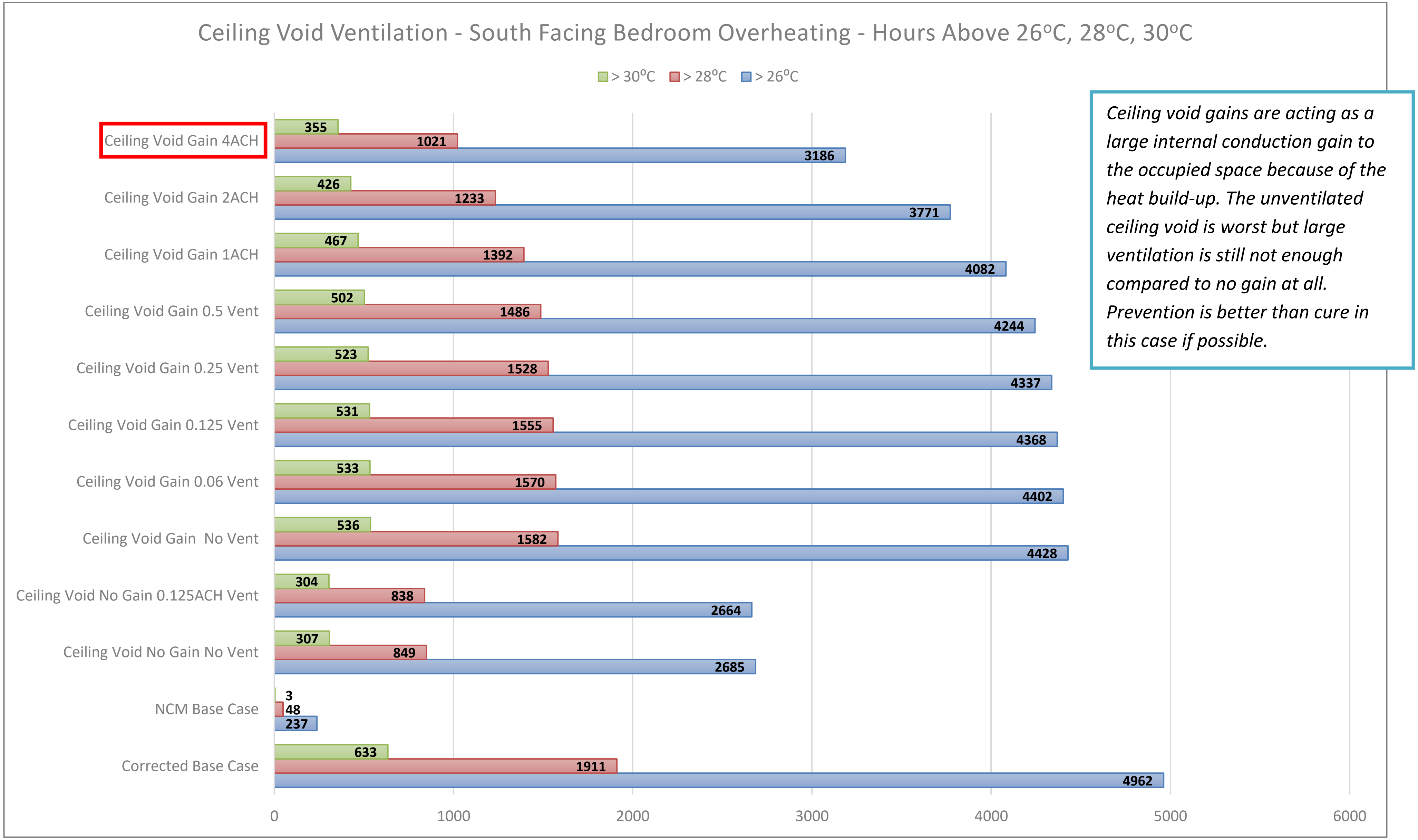
The NBC does not include void heat gains which is a key reason for the lower reported hours.

No trickle is run as to influence the window airflow performance.

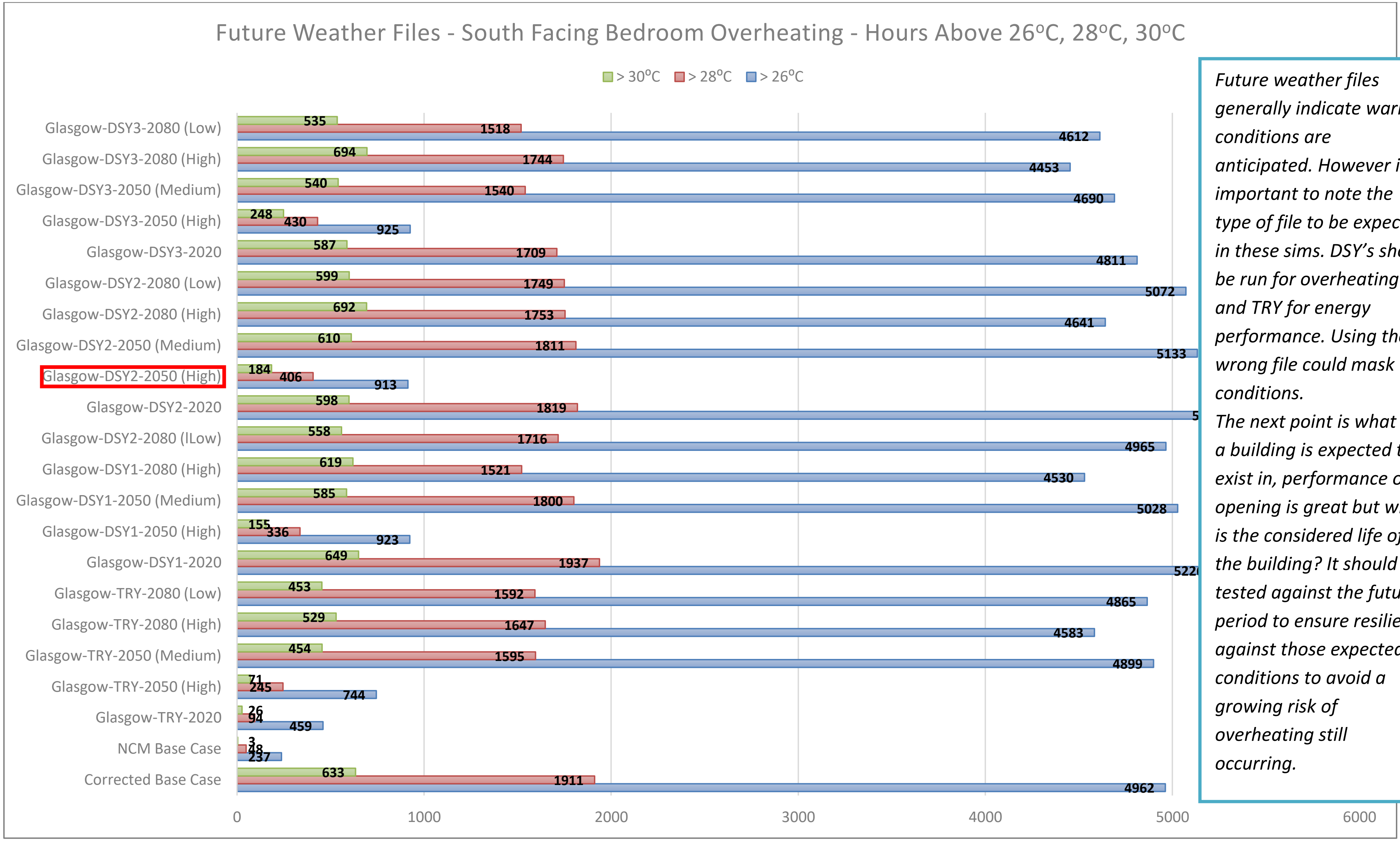


This option assess when the window is expected to open, mirroring manual or auto opening control. Here the big influence is a limit on the outside air temperature in preventing unwanted cold draughts undesirable in winter and transition seasons. This control however demonstrates the damage that can have on reducing internal air temperatures. It shows how the lack of cooler air is a big hindrance and that some form of supply is needed if no other options are changed.

No trickle is run as to influence the window airflow performance.

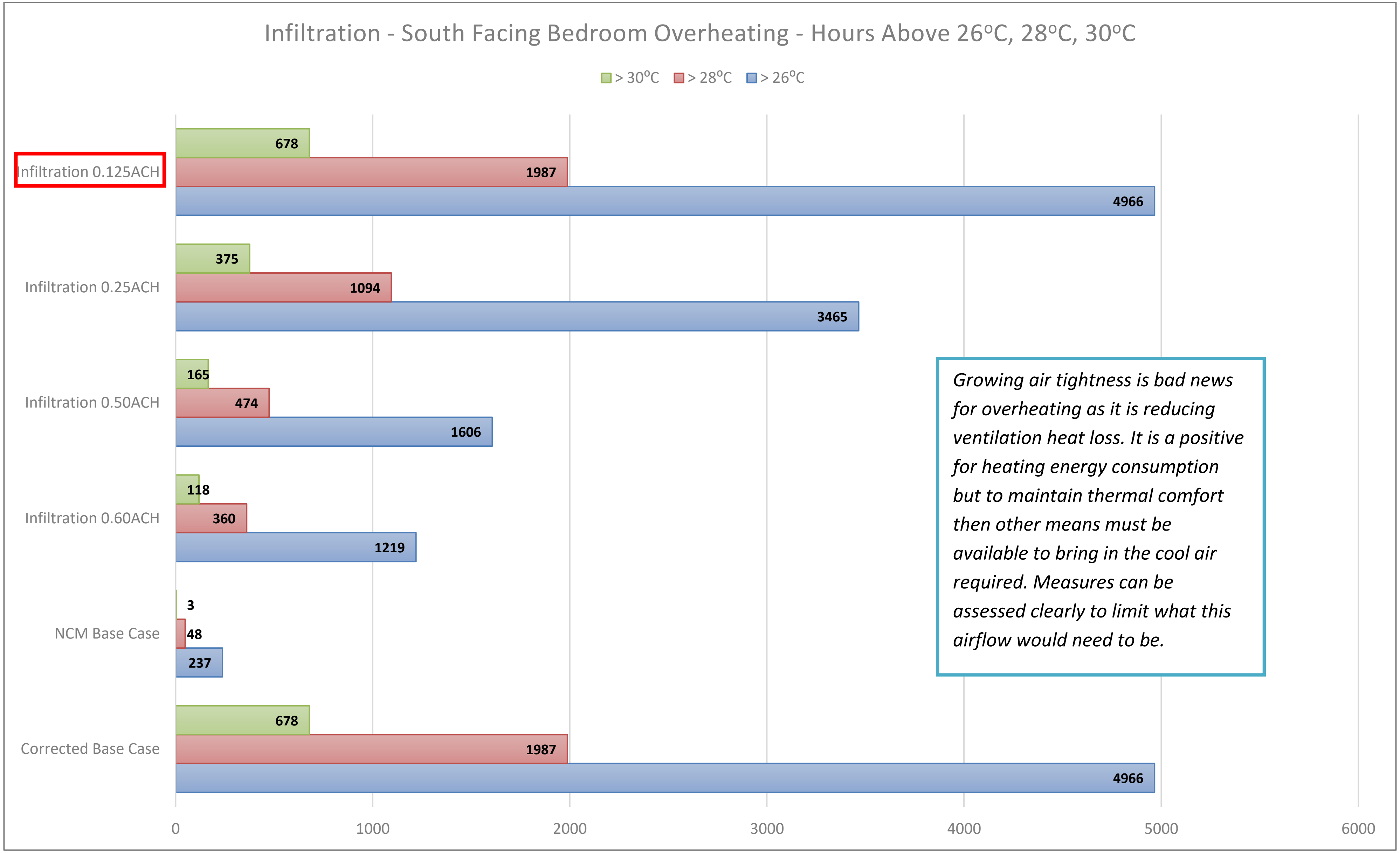


Ceiling void gains are acting as a large internal conduction gain to the occupied space because of the heat build-up. The unventilated ceiling void is worst but large ventilation is still not enough compared to no gain at all. Prevention is better than cure in this case if possible.

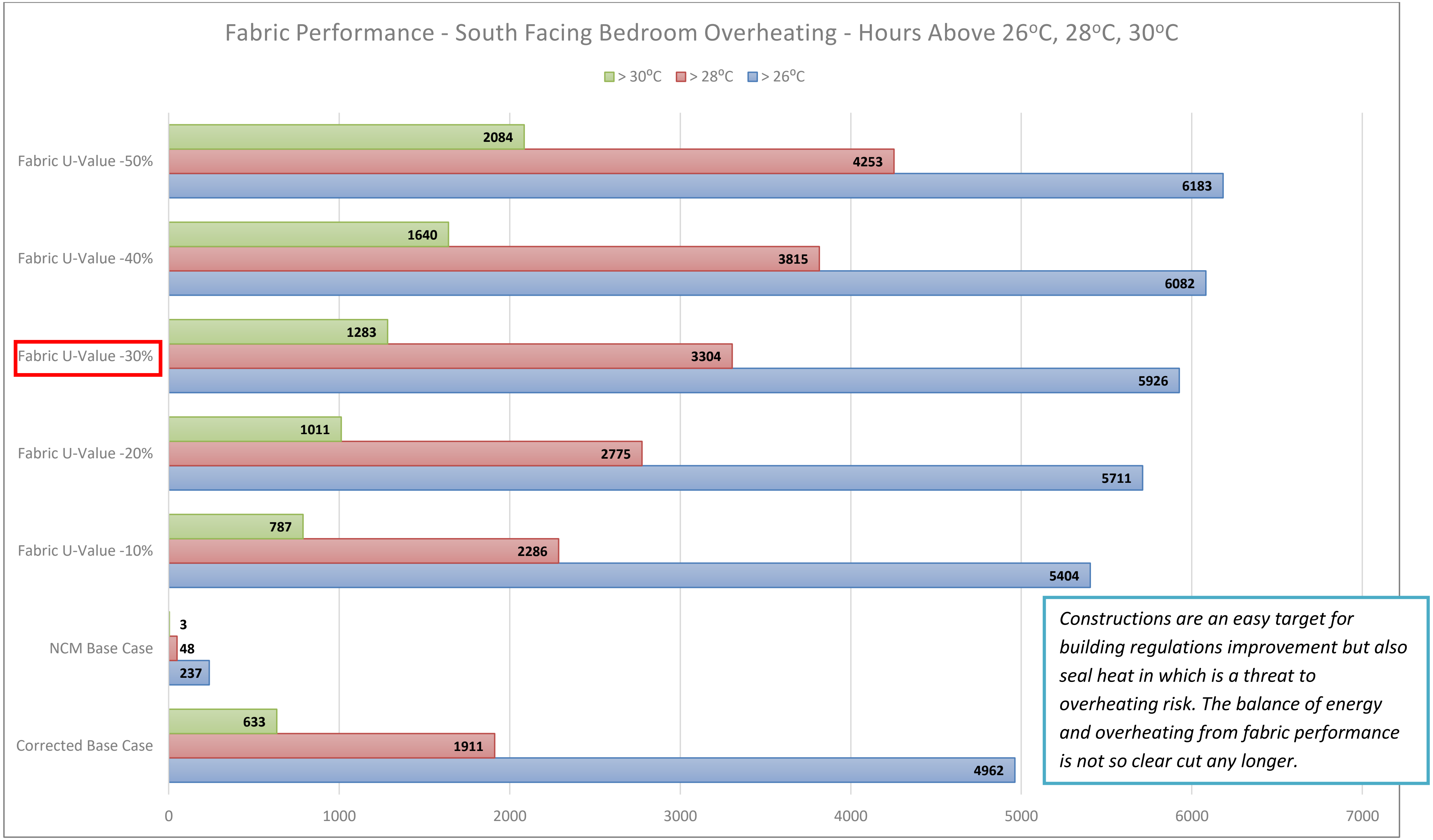


Future weather files generally indicate warmer conditions are anticipated. However it is important to note the type of file to be expected in these sims. DSY's should be run for overheating and TRY for energy performance. Using the wrong file could mask conditions.

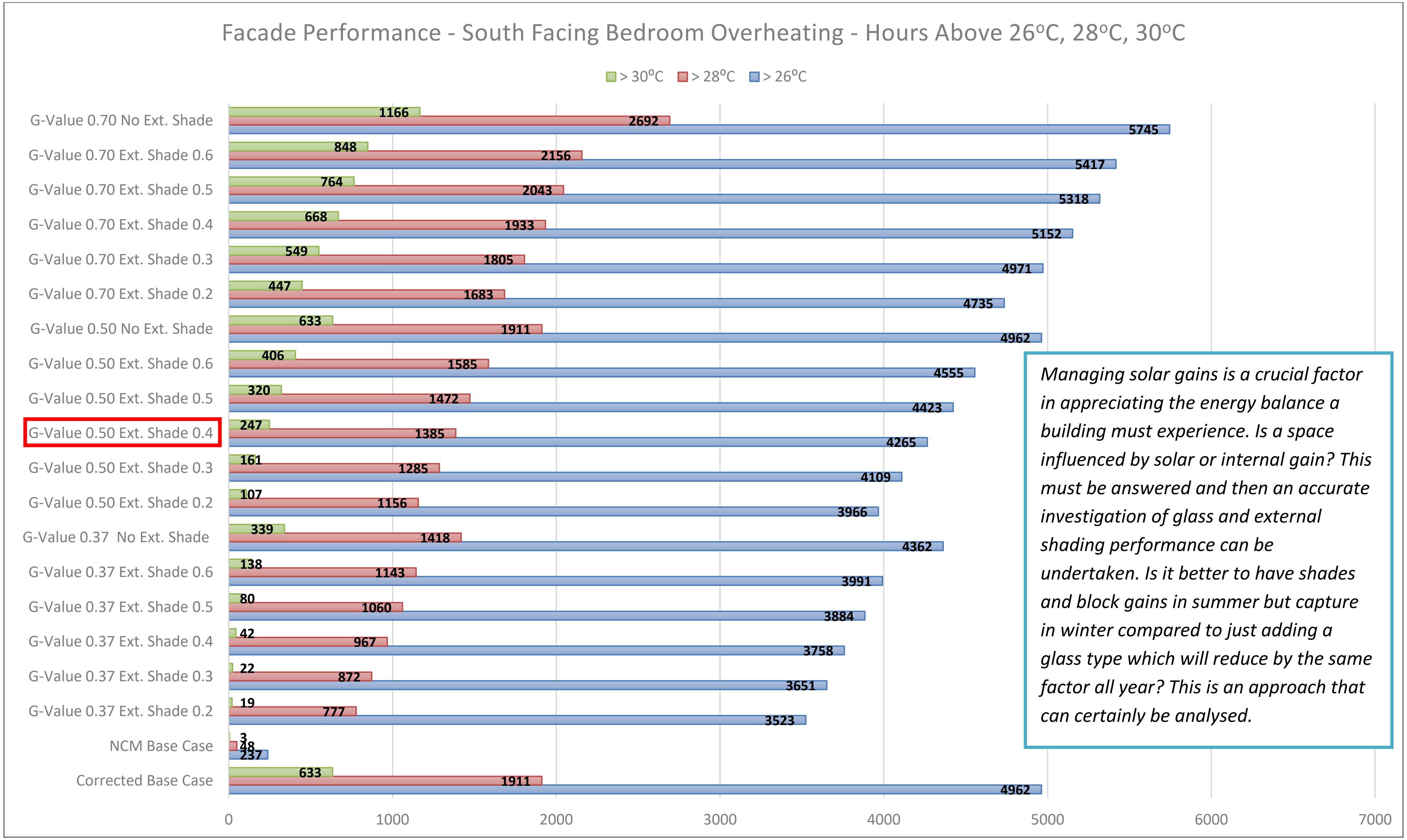
The next point is what era a building is expected to exist in, performance on opening is great but what is the considered life of the building? It should be tested against the future period to ensure resilience against those expected conditions to avoid a growing risk of overheating still occurring.



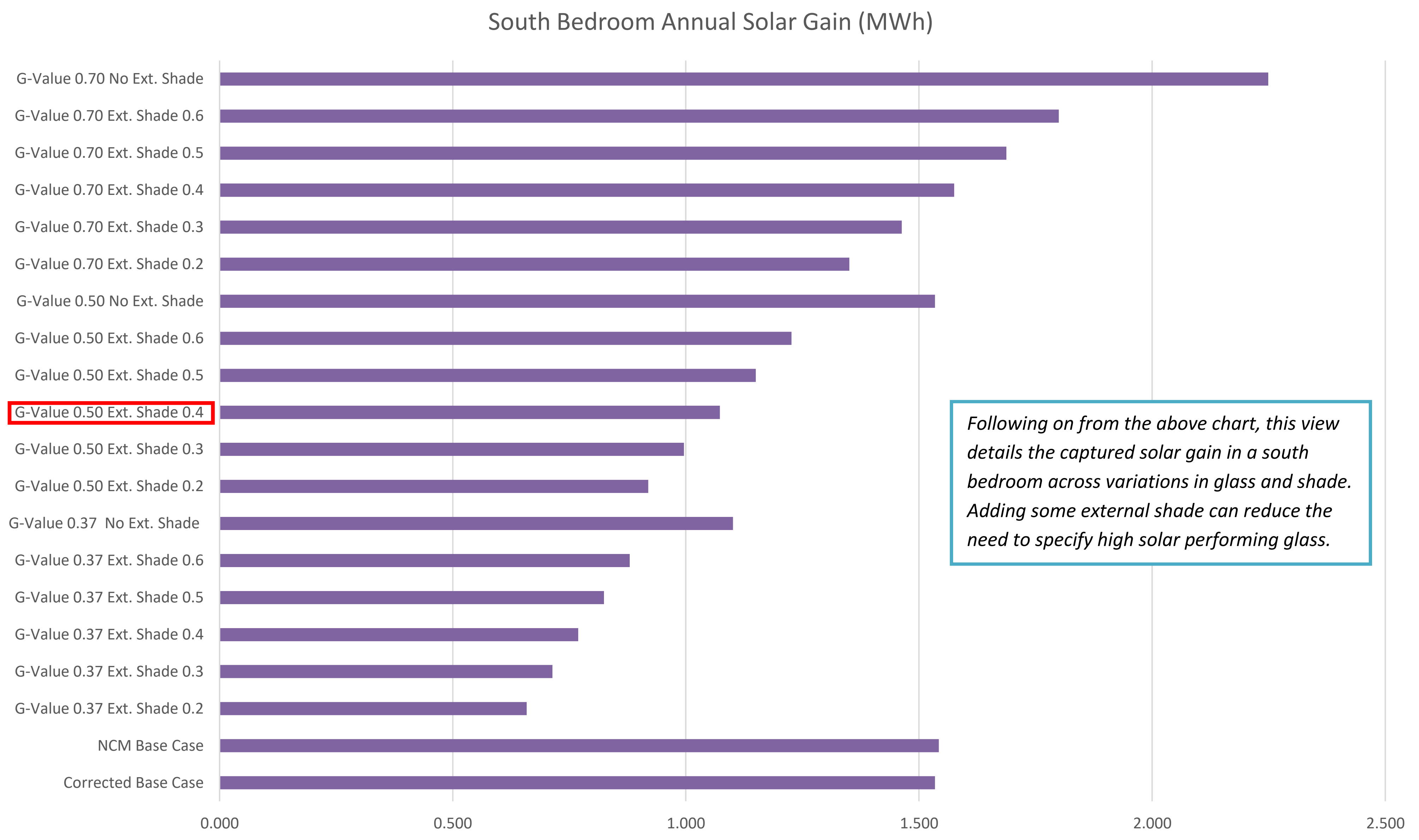
Growing air tightness is bad news for overheating as it is reducing ventilation heat loss. It is a positive for heating energy consumption but to maintain thermal comfort then other means must be available to bring in the cool air required. Measures can be assessed clearly to limit what this airflow would need to be.



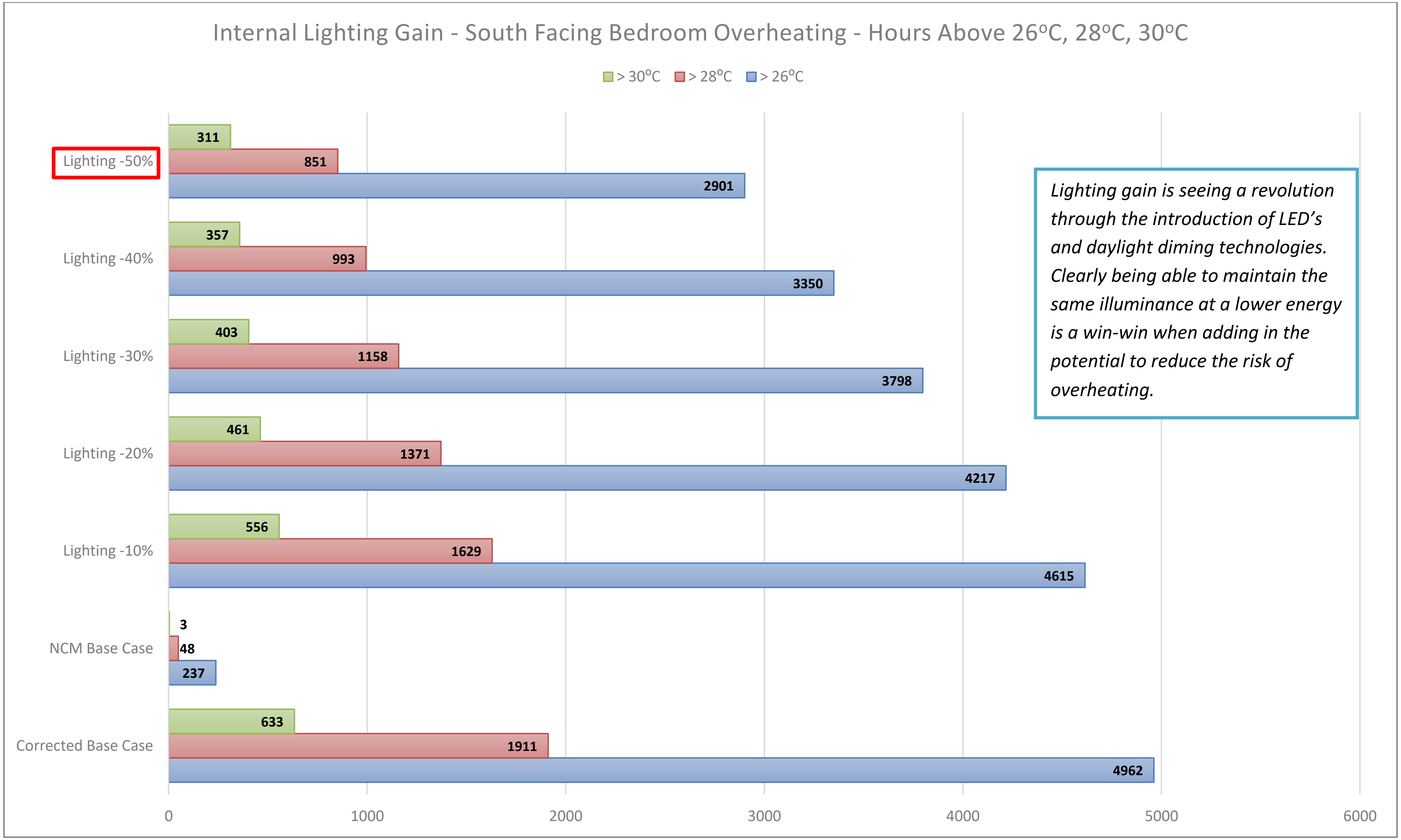
Constructions are an easy target for building regulations improvement but also seal heat in which is a threat to overheating risk. The balance of energy and overheating from fabric performance is not so clear cut any longer.



Managing solar gains is a crucial factor in appreciating the energy balance a building must experience. Is a space influenced by solar or internal gain? This must be answered and then an accurate investigation of glass and external shading performance can be undertaken. Is it better to have shades and block gains in summer but capture in winter compared to just adding a glass type which will reduce by the same factor all year? This is an approach that can certainly be analysed.

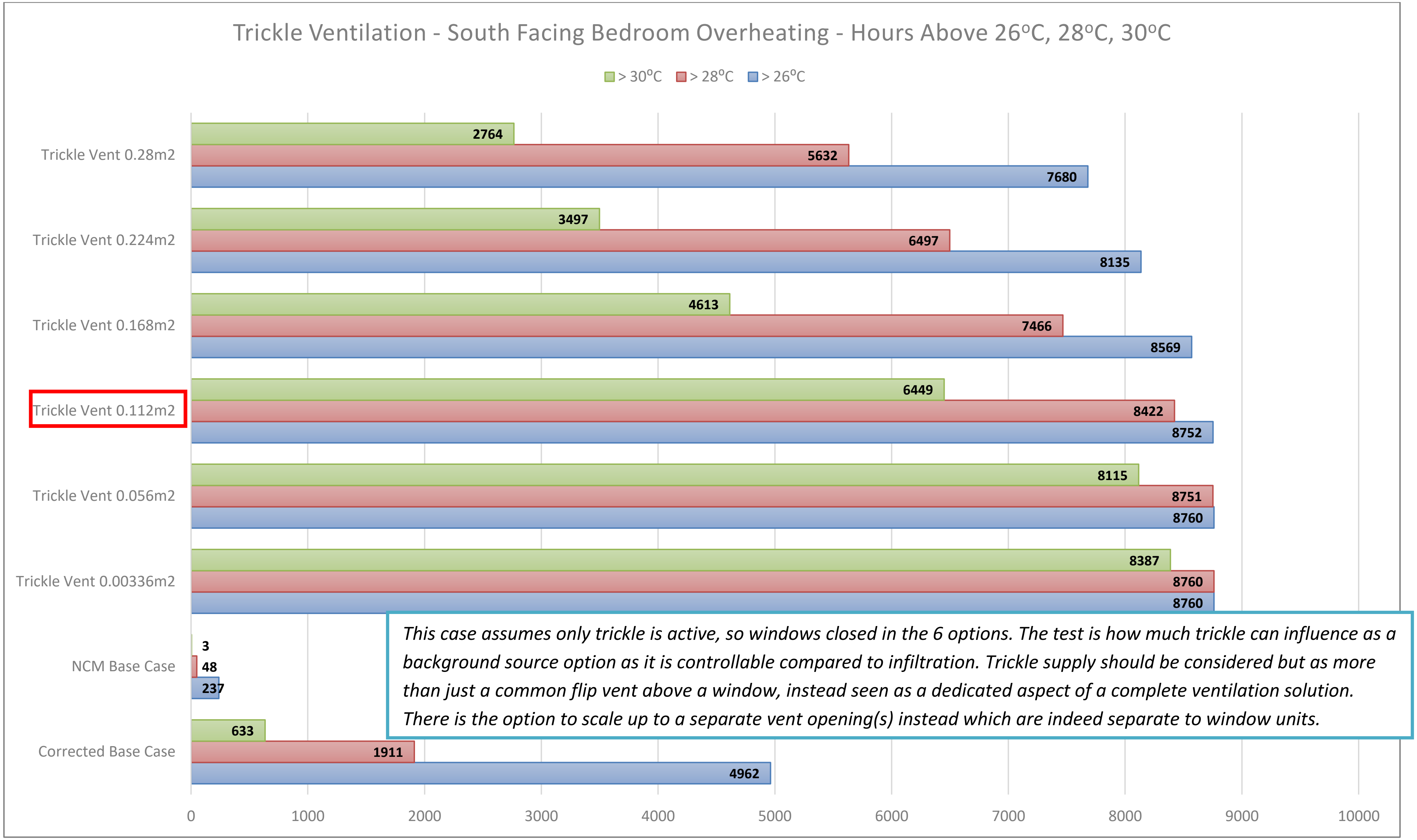


Following on from the above chart, this view details the captured solar gain in a south bedroom across variations in glass and shade. Adding some external shade can reduce the need to specify high solar performing glass.

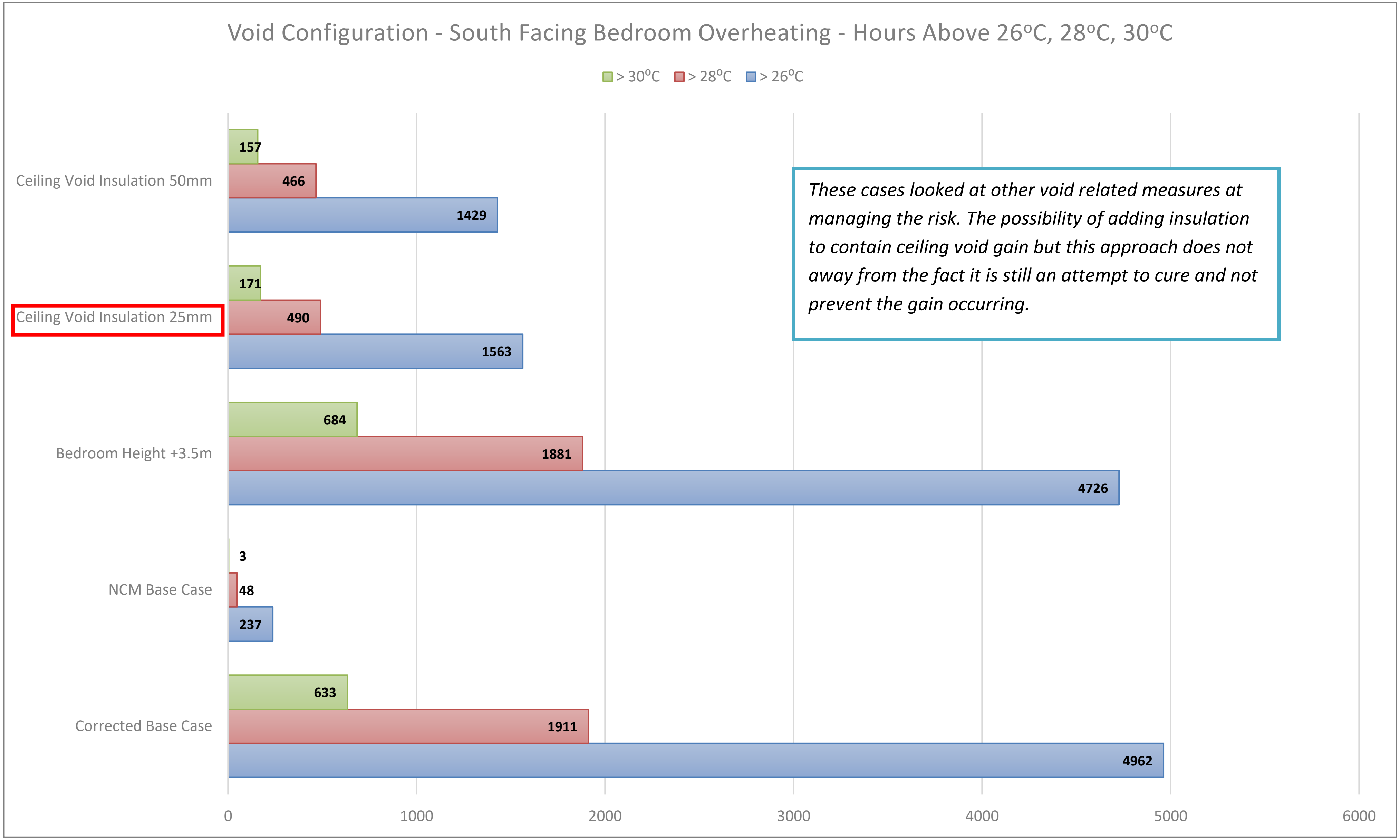


Internal Lighting Gain - South Facing Bedroom Overheating - Hours Above 26°C, 28°C, 30°C

Lighting gain is seeing a revolution through the introduction of LED's and daylight diming technologies. Clearly being able to maintain the same illuminance at a lower energy is a win-win when adding in the potential to reduce the risk of overheating.

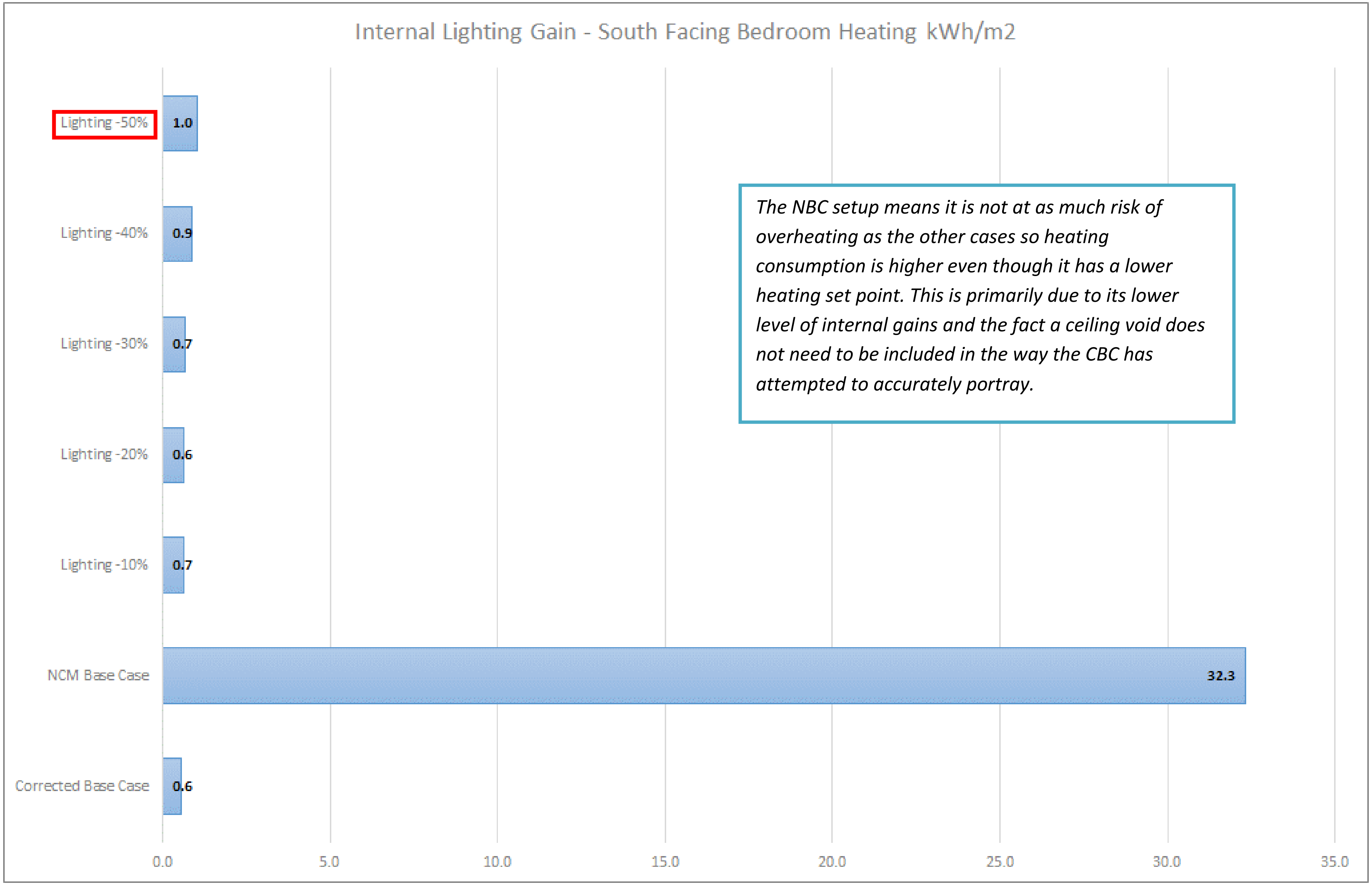


This case assumes only trickle is active, so windows closed in the 6 options. The test is how much trickle can influence as a background source option as it is controllable compared to infiltration. Trickle supply should be considered but as more than just a common flip vent above a window, instead seen as a dedicated aspect of a complete ventilation solution. There is the option to scale up to a separate vent opening(s) instead which are indeed separate to window units.

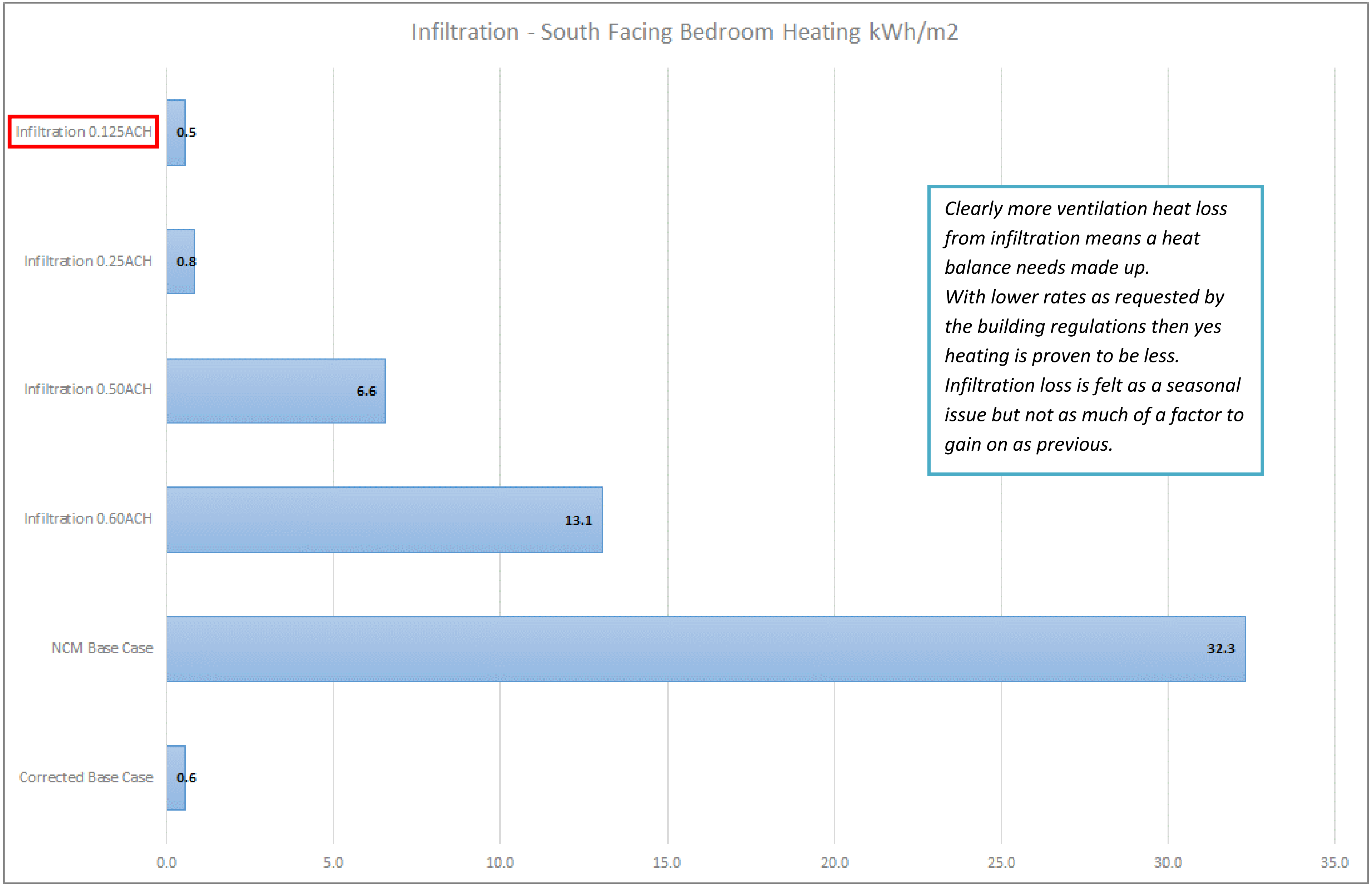


These cases looked at other void related measures at managing the risk. The possibility of adding insulation to contain ceiling void gain but this approach does not away from the fact it is still an attempt to cure and not prevent the gain occurring.

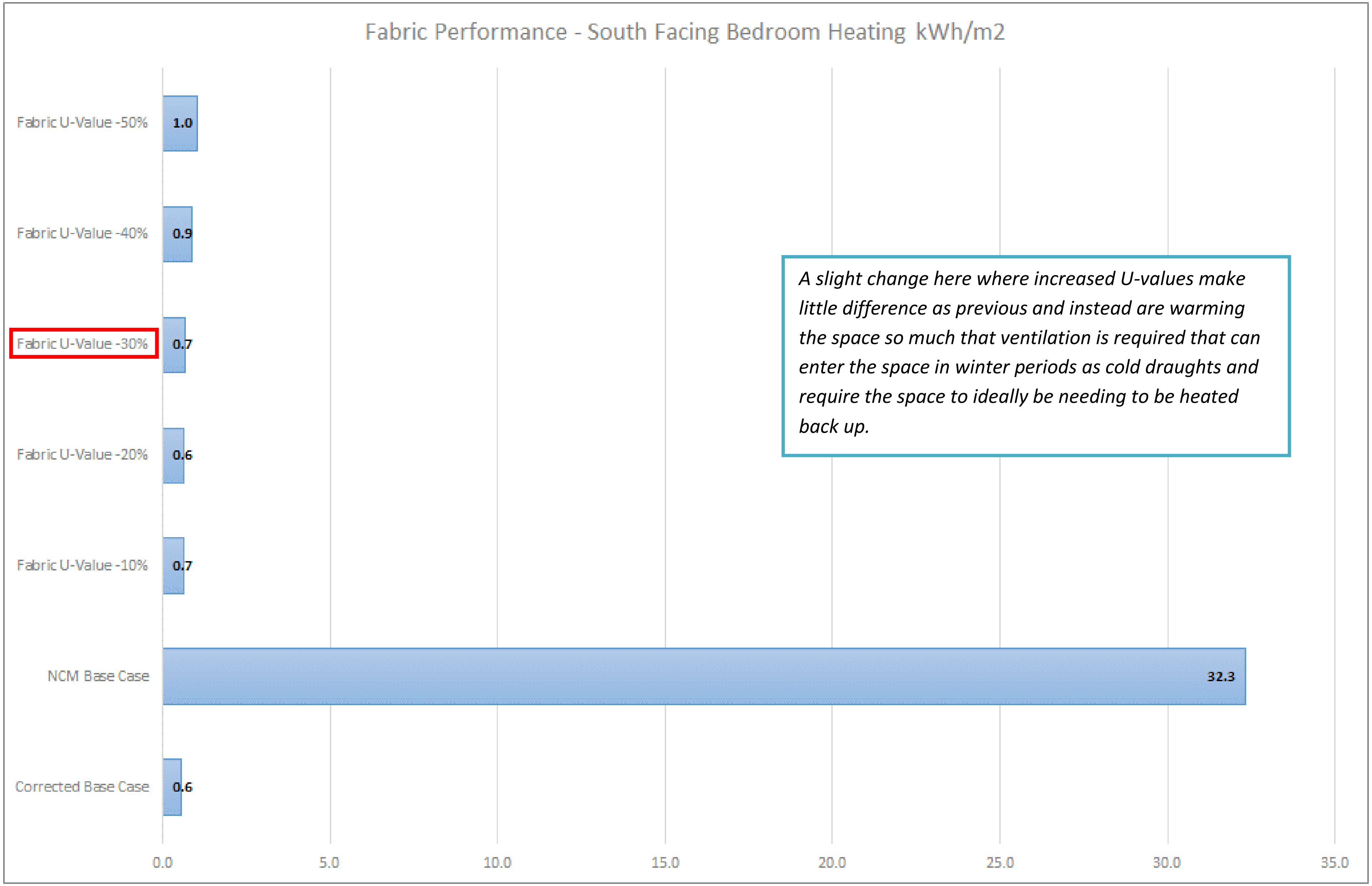
3.4.2.2 Heating Energy



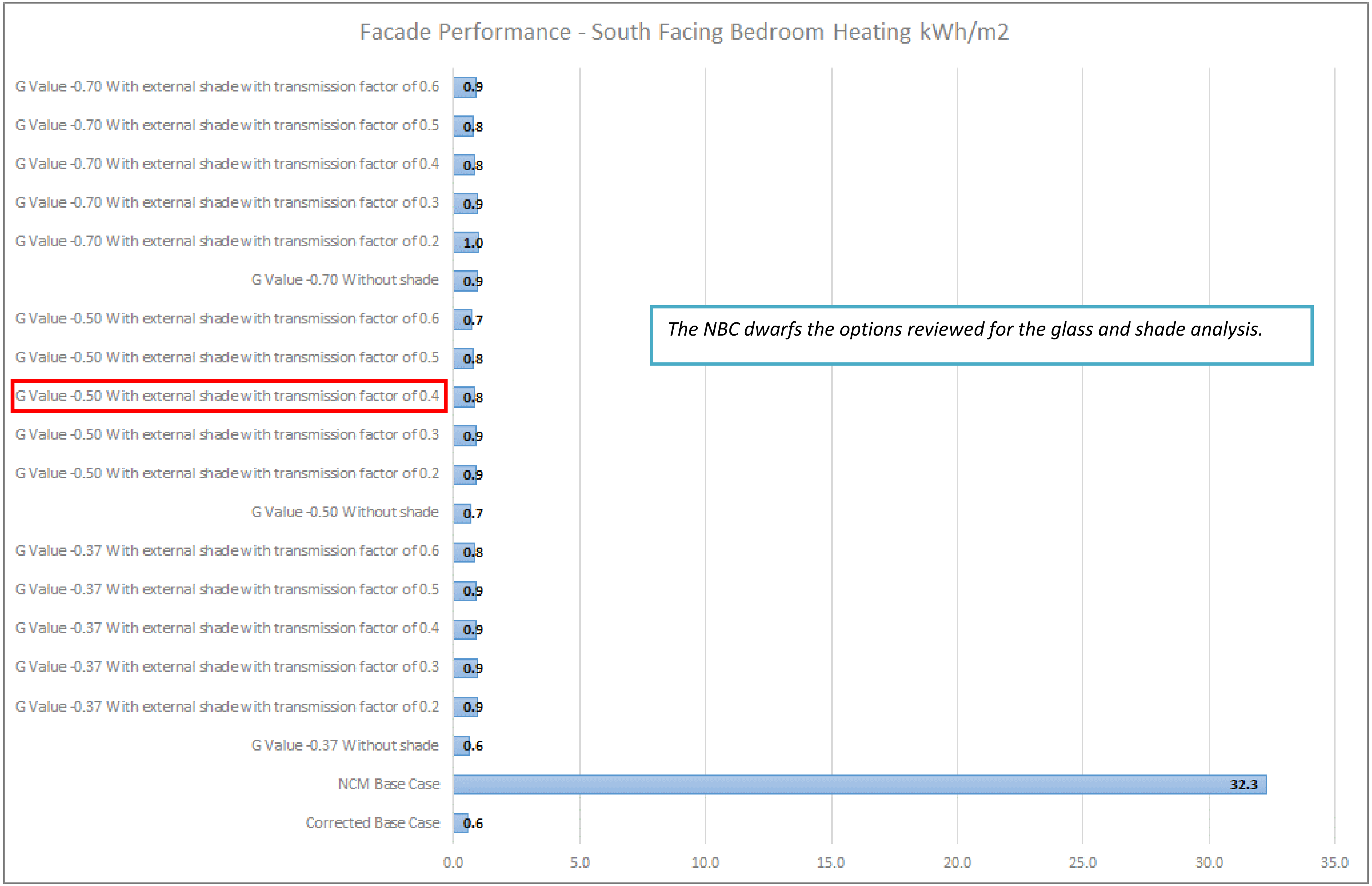
The NBC setup means it is not at as much risk of overheating as the other cases so heating consumption is higher even though it has a lower heating set point. This is primarily due to its lower level of internal gains and the fact a ceiling void does not need to be included in the way the CBC has attempted to accurately portray.



Clearly more ventilation heat loss from infiltration means a heat balance needs made up.
With lower rates as requested by the building regulations then yes heating is proven to be less.
Infiltration loss is felt as a seasonal issue but not as much of a factor to gain on as previous.



A slight change here where increased U-values make little difference as previous and instead are warming the space so much that ventilation is required that can enter the space in winter periods as cold draughts and require the space to ideally be needing to be heated back up.



Facade Performance - South Facing Bedroom Heating kWh/m2

The NBC dwarfs the options reviewed for the glass and shade analysis.

3.5 Optimised Approach

Utilising the modelling sensitivity scenarios tested against the CBC, a total of five optimised scenarios were modelled. The solutions forming these were selected based on their performance during the sensitivity tests and determined to be ideal candidates toward forming an optimised design.

Case-01 combines a series of optimisation solutions with Cases-02 to 04 introducing further enhancement on each step.

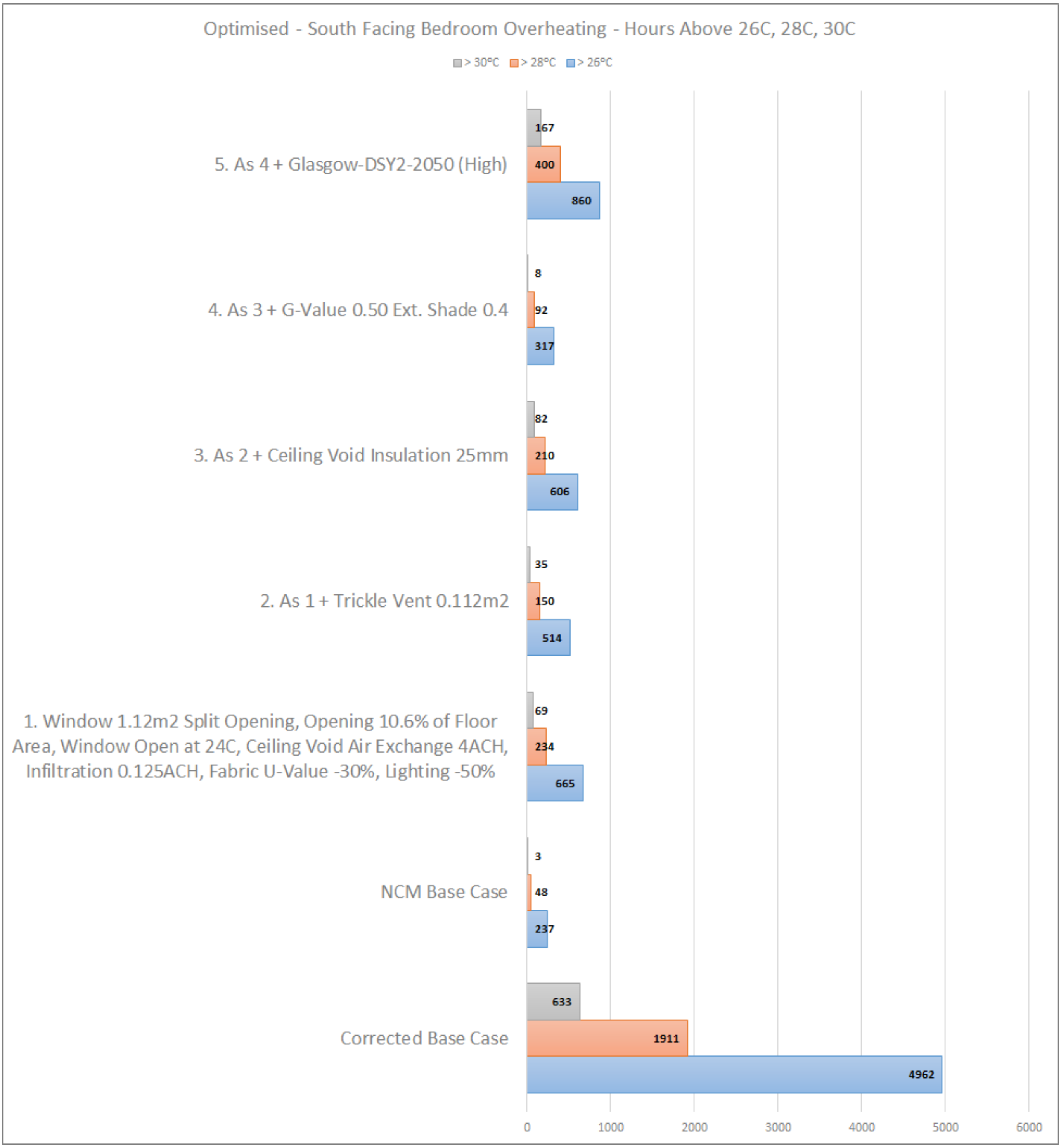
Case-05 then tests the complete optimised model against a future weather scenario to assess the potential for a regression back toward overheating.

Optimised Scenario	Window 1.12m2 Split Opening, Opening 10.6% of Floor Area, Window Open at 24°C, Ceiling Void Air Exchange 4ACH, Infiltration 0.125ACH, Fabric -30%, Lighting -50%	Trickle vent opening Area of 0.112m^2	Ceiling Void insulation 25mm	External window g-value of 0.50, external shade 0.40	Use of the future weather file Glasgow-DSY2-2050 (High)
Case-01	✓				
Case-02	✓	✓			
Case-03	✓	✓	✓		
Case-04	✓	✓	✓	✓	
Case-05	✓	✓	✓	✓	✓

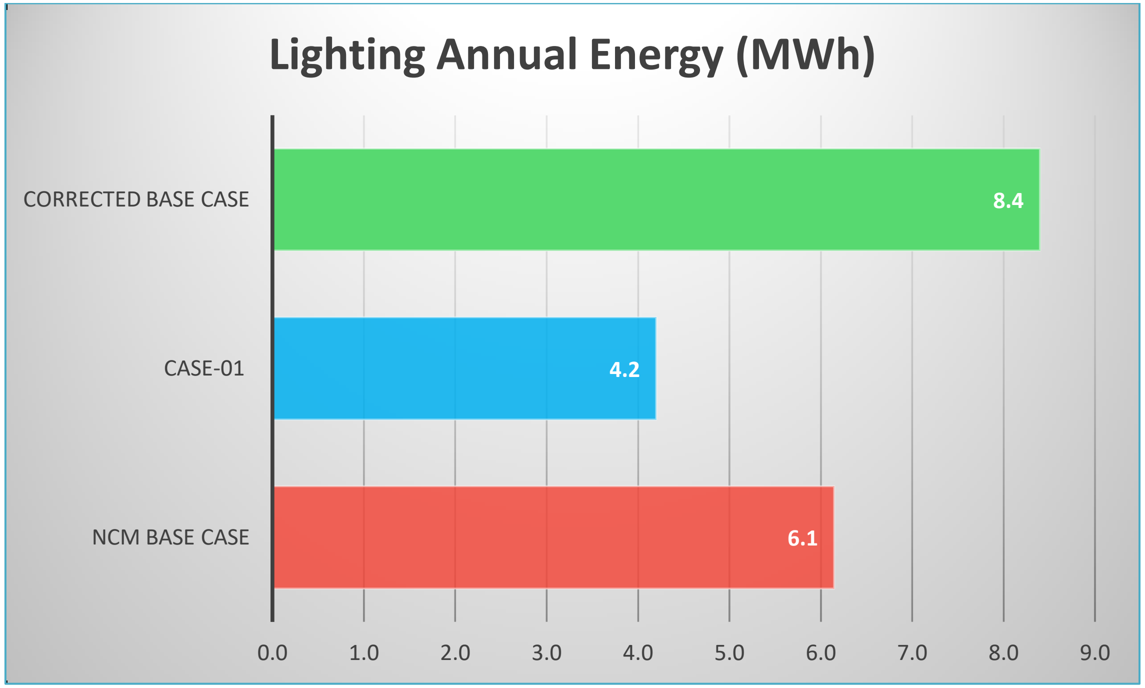
3.5.1.1 Bedroom Overheating

Following the optimisation case runs the modelling has demonstrated a substantial reduction and management of the overheating potential in the space to similar levels reported by the NBC.

At the same time the energy is managed to be similar to the CBC, described in the following sections.



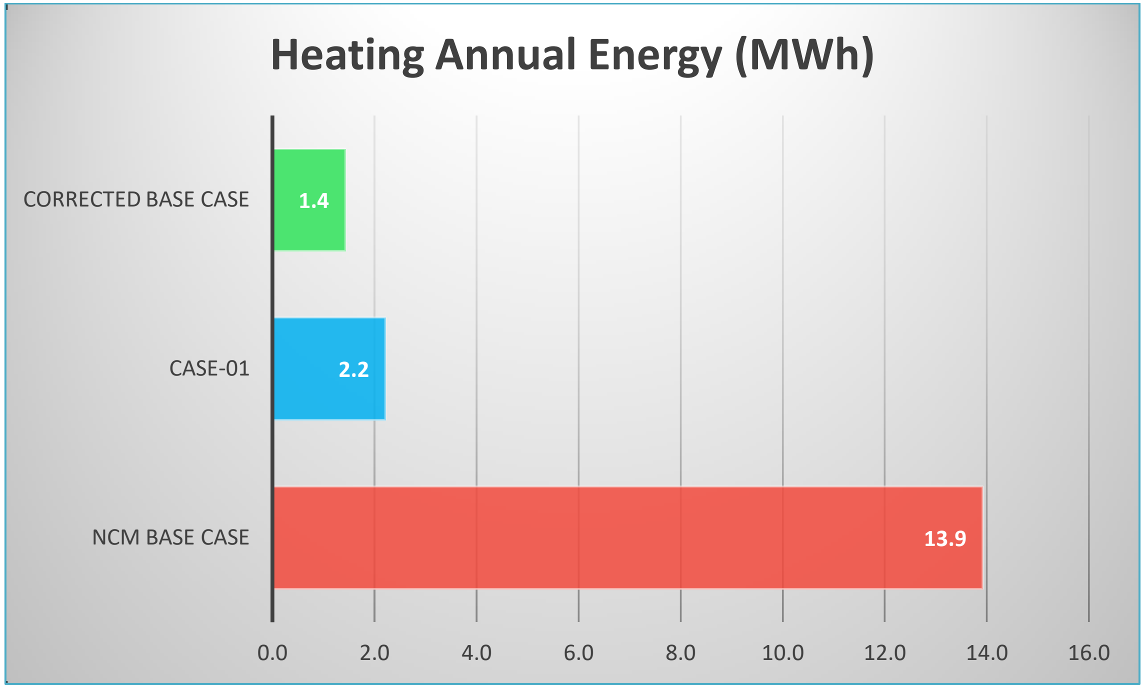
3.5.1.2 Bedroom Lighting Energy



- Cases 01-05 propose a 50% improvement on the lighting performance.
- This resulted in a significant decrease in the total lighting energy as more energy efficient lighting fixtures are employed.
- Case 01-05 lighting energy is less than the NBC by around 1/3.

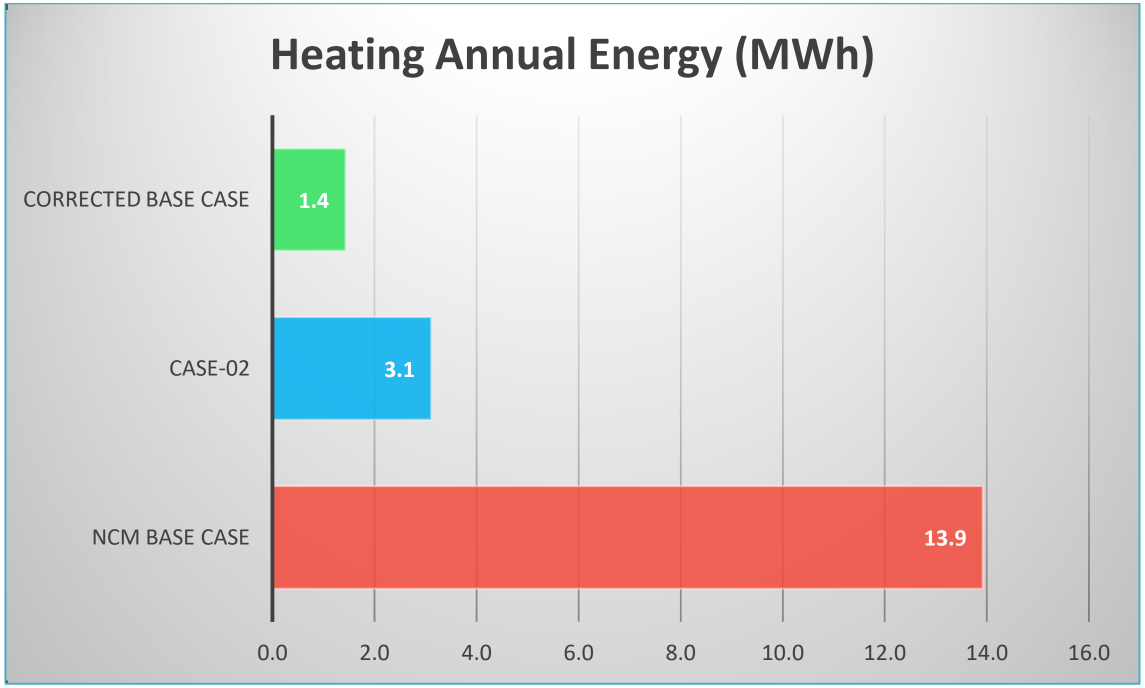
3.5.1.3 Bedroom Heating Energy

Case 01:



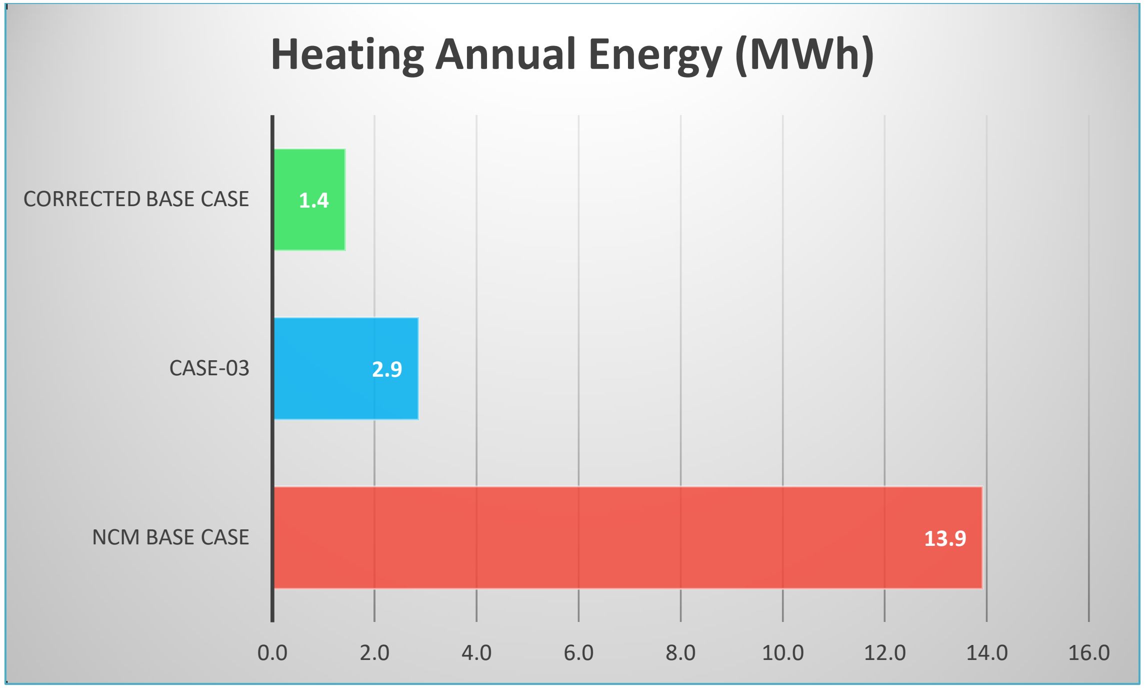
- Case 01 proposes the installation of windows with split openings of an area of 0.64m^2, 10.6% of the floor area and to open at 24C. The Ceiling void is to gain 4ACH, the infiltration rate the bedrooms is to be 0.125ACH whilst also improving the building fabric U-value by 30%.
- With the benefit of enhanced thermal comfort which reduces overheating then additional heating is required compared to the CBC to supplement.
- The heating energy is still substantially less than the predicted energy from an NBC scenario.

Case 02:



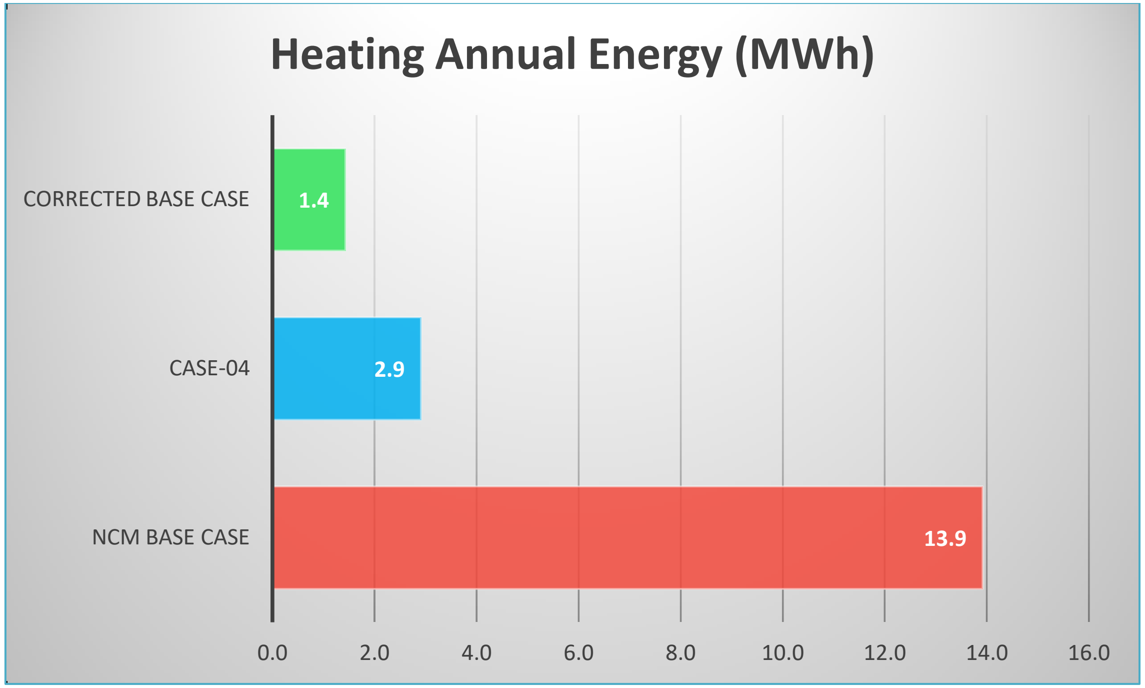
- In addition to the installations proposed in Case 01, Case 02 proposed the application of trickle vents of an area of 0.112m^2.
- Trickle vents introduces cool air in the form of natural ventilation and minimising the risk of spaces overheating which has been evidenced.
- The drawback is a small heating energy increase across the year which is still substantially less than the NBC.

Case 03:



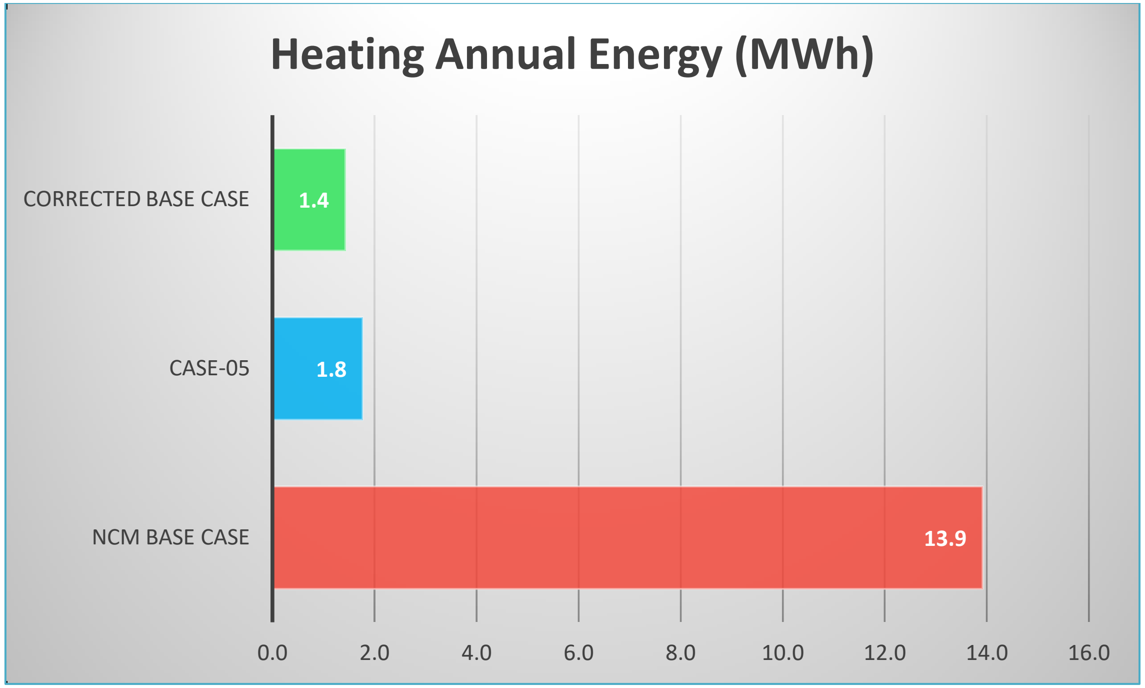
- In addition to the installations proposed in Case 02, Case 03 proposes a 25mm insulation around the ceiling void.
- This actually reduces the heating load because the heat loss to the void is reduced which is now acceptable to consider as ceiling void gain is less and is being controlled through the void’s purge ventilation.

Case 04:



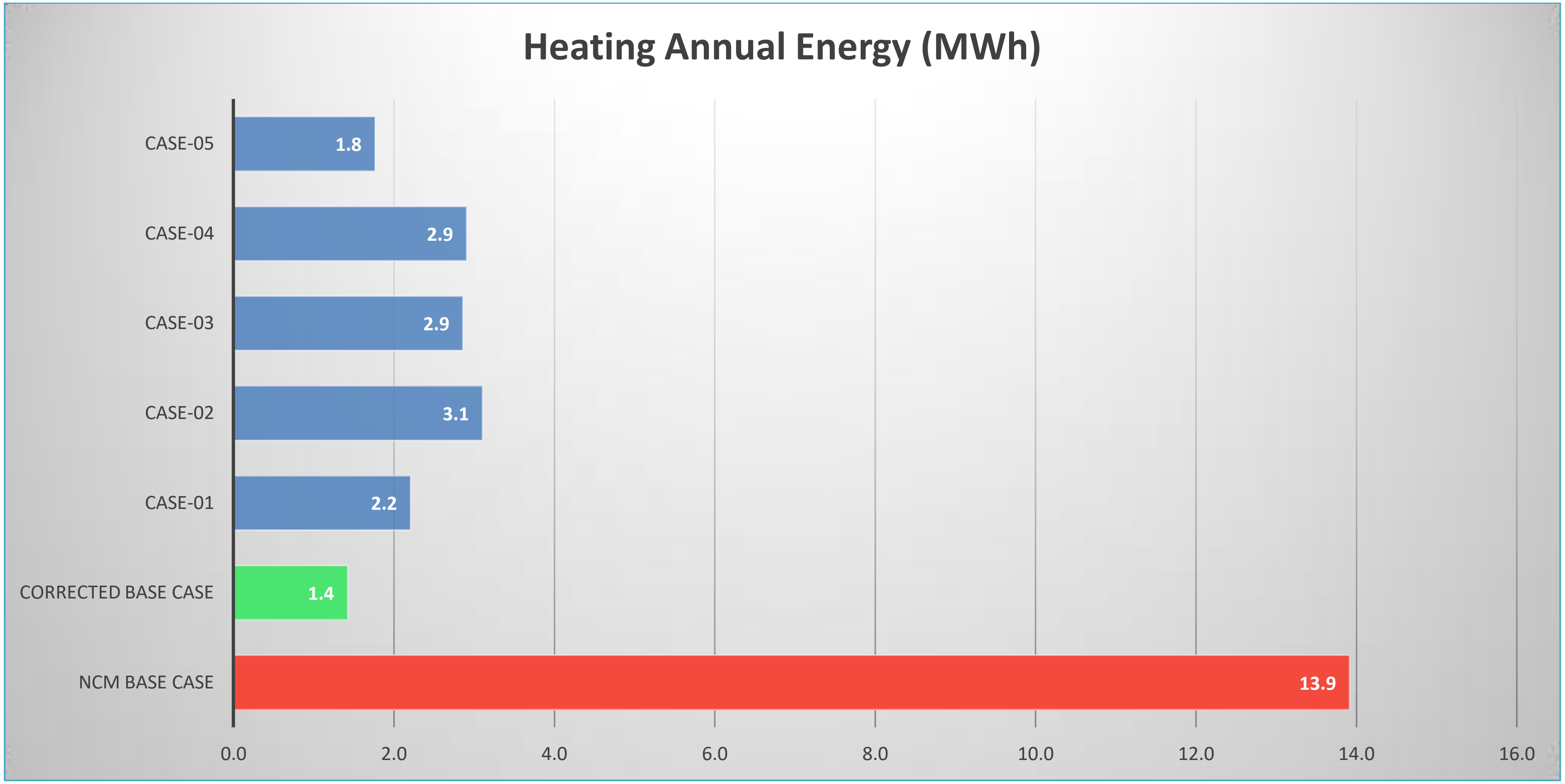
- In addition to installations proposed in Case 03, Case 04 proposes the installation of external windows of a g-value of 0.5 and external shading factor of 0.4
- This case proposes to limit solar gain during the summer period and therefore improves overheating performance.
- The drop in solar gain during the winter period is not significant for a change in the heating annual energy performance.

Case 05:



- Case 05 examines the installations proposed by Cases 01-04 in a future climate by utilising the Glasgow-DSY2-2050 (High) future weather file.
- Future climates are predicted to be warmer and heating energy is reduced as a result in comparison to optimised Case-04.
- The predicted risk of overheating in the future is greater, therefore the hospital must be able to adapt to the future climate even though there is a benefit to consumed heating energy.

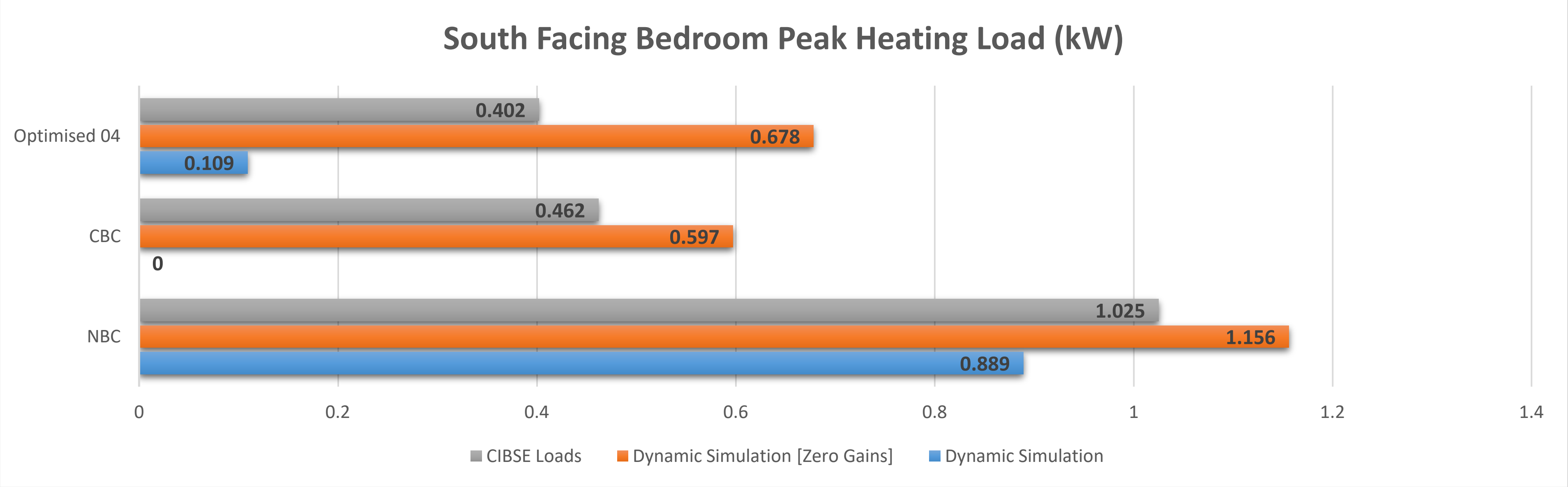
The graph below shows the impact of the optimised cases on heating side by side. There is however very little difference between the cases when compared to the NBC.



3.5.1.4 Bedroom Heating Loads

The peak heating load has been compared for the base building models and Case-04. Within this is a comparison of a static heating load calculated through the CIBSE Loads approach against the dynamic simulation route. With the static approach a number of factors are not included which may improperly influence the selection of plant equipment. For example internal gain heat loads are not included, profile variation is inherently not a factor due to the static nature of CIBSE Loads and this also means variation in natural ventilation heat loss cannot be accounted for. Additionally the comparison of the dynamic peak load with and without internal gains is noted.

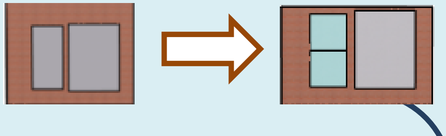
Heating Load (kW)			
	Dynamic Simulation	**Dynamic Simulation [Zero Gains]**	**CIBSE Loads**
NBC	0.889	1.156	1.025
CBC	0	0.597	0.462
Optimised 04	0.109	0.678	0.402



The same external design condition predicament between static model and dynamic model exists where the external design condition assumption can be different to the weather file used in the dynamic simulations.

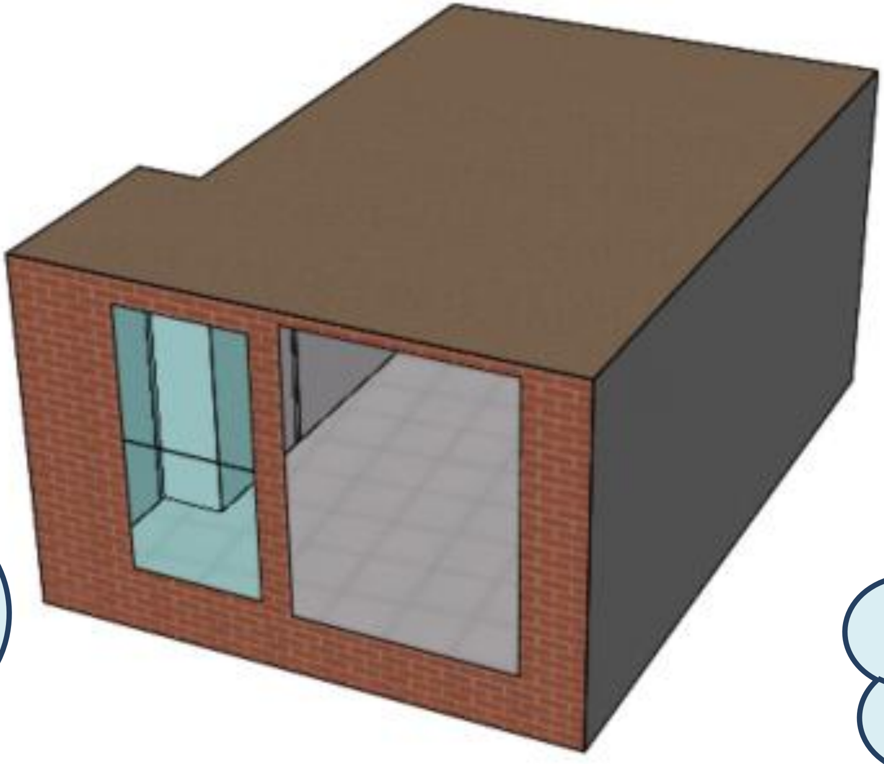
The accumulation of load differences could lead to a significant difference in the plant size design requirement for the building.

3.5.1.5 Bedroom Case-04 v CBC Summary View



Optimised Case -04 Ceiling voids are infused with 4ACH of air and 25mm of insulation are installed on the void surfaces whereas the CBC ceiling voids lack ventilation and are uninsulated.

Optimised Case-04 hospital's external building fabric is due to a 30% improvement in performance in comparison with the CBC model.



Increase in trickle ventilation opening area is increased in Case-04 from $0.02152m^2$ as included within the CBC to $0.112m^2$.

In Case 04, the Lighting System is further improved by 50% in comparison with the CBC model.

In the CBC, windows are configured to open when internal air temperature reaches 24°C and when outside air temperature is above 10°C

In Optimised Case-04 the window opens when the internal air temperature reaches 25°C.

CBC does not include any form of window shading although the façade performance is improved in Optimised Case-04 by the incorporation of window and external shading of g-values of 0.50 and 0.40 respectively.

3.6 Daylight Impact

Daylight capture was assessed for the bedroom space against the 4 standard orientations to test the sensitivity of harnessing natural daylight. A Climate Based Daylighting Modelling (CBDM) approach was employed, also known as dynamic daylighting, which models the annual illuminance performance and includes the impact of seasonal solar position, solar intensity, cloud cover from the weather file and building form. Modellers can assess attributes such as shades, surrounding topography, adjacent buildings, window layout including recesses and glass type are all factors that can be tested with this approach.

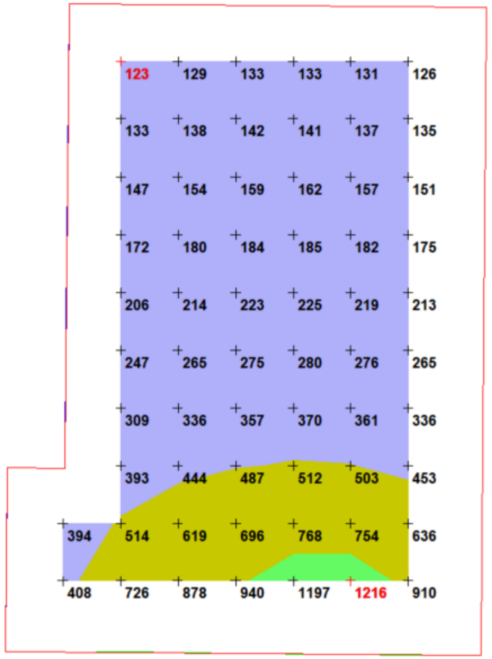
This is a more considered and accurate representation on the annual variation in daylight available and captured by building spaces, compared to say Daylight Factor (DF). Modellers can utilise CBDM from concept stage onwards to test sunlight performance and compare potential façade designs and space layouts for the captured illuminance. Using CBDM will provide modellers accurate feedback on how sunlight is not a constant for similar rooms on different orientations indicating bespoke approaches would need to be considered to optimise a space for its energy and environmental performance.

Alongside we have compared to DF, which has been the industry standard daylight metric. DF is calculated for an overcast sky and does not include for direct sunlight which is a significant limiting factor when testing true performance. The CBDM approach details the clear differences between each orientation whereas DF shows little change.

CBDM should be strongly considered as the daylight modelling approach to measure daylight capture and this extends to its ability to filter the hours of analysis. In the table below by filtering for the hours of occupancy usage this means the earlier and later hours of the day can be filtered which is when daylight levels are at their lowest. This approach is now assessing when daylight is actually being used and analysis can define more accurate benchmarks when assessing design scenarios. Designers can use CBDM to test their sunlight capture alongside their solar analysis performance which reports on the impact to the external façade.

Glass Transmittance at 70%	North	South	East	West
DF average	**3.64 %**	**3.46 %**	**3.64 %**	**3.47 %**
Annual Average Illuminance for Daylight Autonomy (*all sunlight hours*)	**274 lux**	**817 lux**	**655 lux**	**579 lux**
Annual Average Illuminance for Daylight Autonomy (*only occupied hours*)	**296 lux**	**978 lux**	**658 lux**	**616 lux**

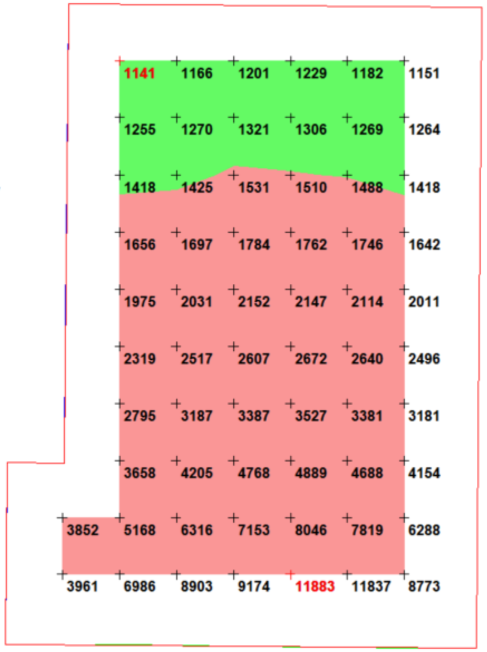
The images below demonstrate Climate Based Daylight Modelling outputs for the **South facing bedroom**:



1:[UDI] Average Lux for CIE O. Sky

Minimum = 123.10
Maximum = 1216.70
Average = 355.88

Lux	62
< 500	77.4 %
500 - 1000	19.4 %
1000 - 1500	3.2 %
> 1500	0.0 %



2:[UDI] Average Lux for Sunny Sky

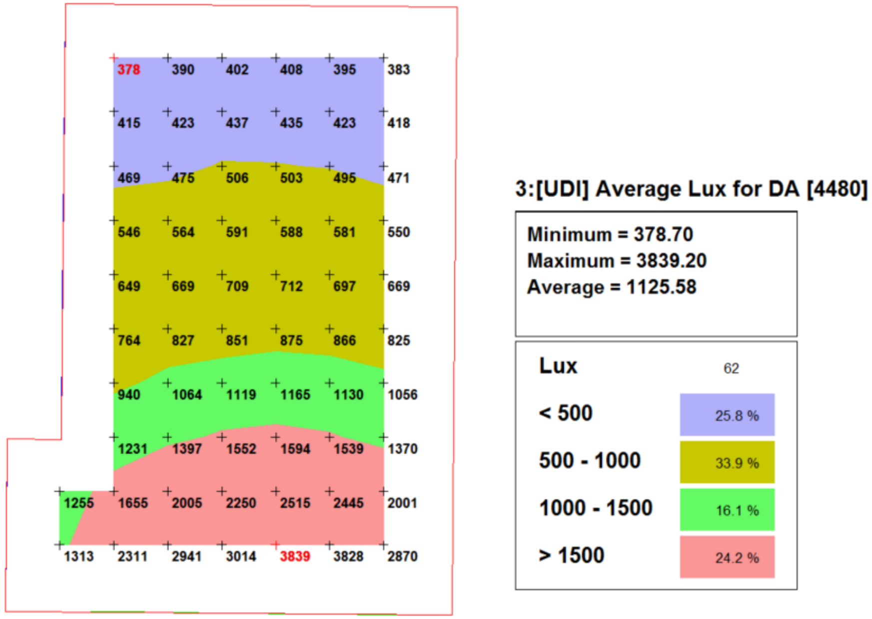
Minimum = 1141.10
Maximum = 11883.60
Average = 3443.85

Lux	62
< 500	0.0 %
500 - 1000	0.0 %
1000 - 1500	25.8 %
> 1500	74.2 %

The model first generates the potential minimum and maximum daylight capture for the space.

The **CIE Overcast Sky** represents the minimum available daylight capture across the full year whereas the **Sunny Sky** represents the maximum available daylight capture across the full year.

Both sky types are then taken to form a combined representation which is dependent on the weighting of cloud cover at each hourly time step for available daylight across the year.

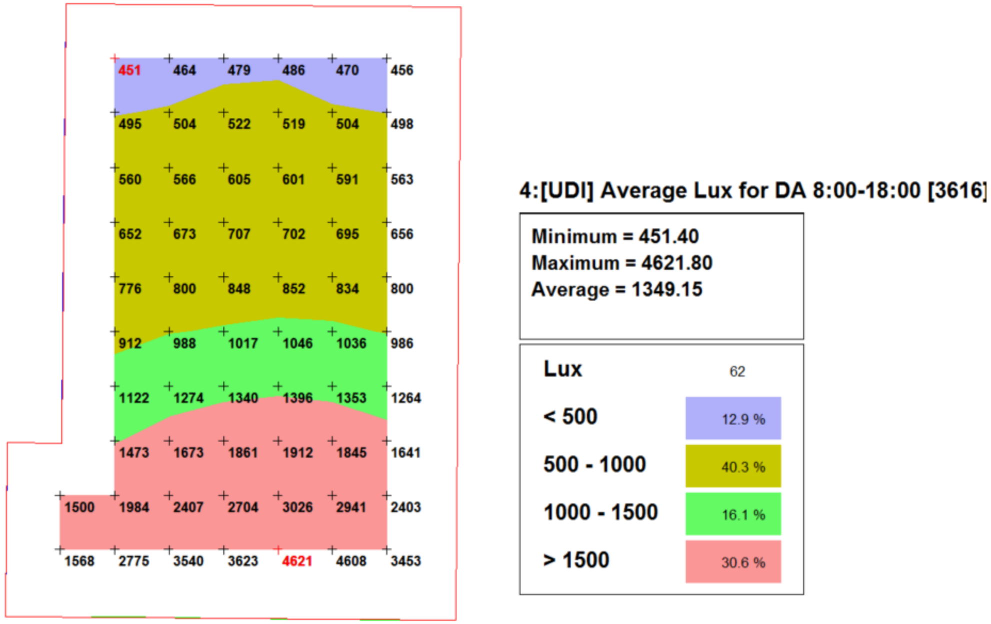


	378	390	402	408	395	383
	415	423	437	435	423	418
	469	475	506	503	495	471
	546	564	591	588	581	550
	649	669	709	712	697	669
	764	827	851	875	866	825
	940	1064	1119	1165	1130	1056
	1231	1397	1552	1594	1539	1370
1255	1655	2005	2250	2515	2445	2001
1313	2311	2941	3014	3839	3828	2870

3:[UDI] Average Lux for DA [4480]

Minimum = 378.70
Maximum = 3839.20
Average = 1125.58

Lux	62
< 500	25.8 %
500 - 1000	33.9 %
1000 - 1500	16.1 %
> 1500	24.2 %



	451	464	479	486	470	456
	495	504	522	519	504	498
	560	566	605	601	591	563
	652	673	707	702	695	656
	776	800	848	852	834	800
	912	988	1017	1046	1036	986
	1122	1274	1340	1396	1353	1264
	1473	1673	1861	1912	1845	1641
1500	1984	2407	2704	3026	2941	2403
1568	2775	3540	3623	4621	4608	3453

4:[UDI] Average Lux for DA 8:00-18:00 [3616]

Minimum = 451.40
Maximum = 4621.80
Average = 1349.15

Lux	62
< 500	12.9 %
500 - 1000	40.3 %
1000 - 1500	16.1 %
> 1500	30.6 %

The true annual illuminance performance is demonstrated by the **Average Lux for Daylight Autonomy** across the space at a working plane height. This *Daylight Autonomy* view is the mix of the two sky types previously described. Good and poorly performing illuminated areas of the space are then easily identifiable using the annual statistics, either in points or contours mode. The contours demonstrate illuminance bandings and can be configured to match the design illuminance for the space activity.

Assessing *Daylight Autonomy* during 'occupied hours only' then filters the hours where poorer sunlight levels are available during morning and evening. The space is then assessed for its usable sunlight capture, which typically demonstrates an enhanced average daylight performance compared to the DA across the full sunlight period.

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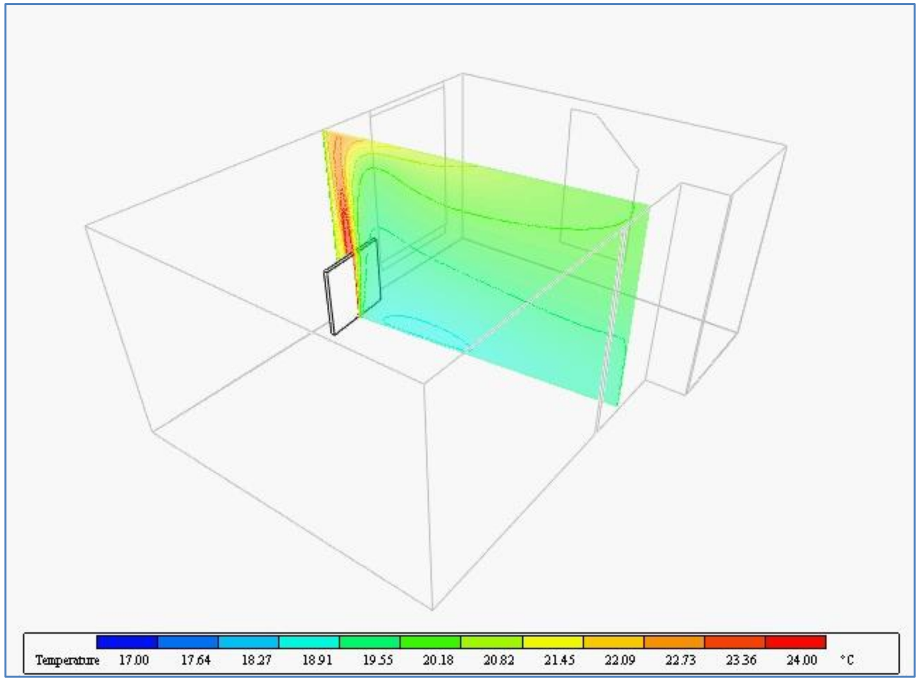
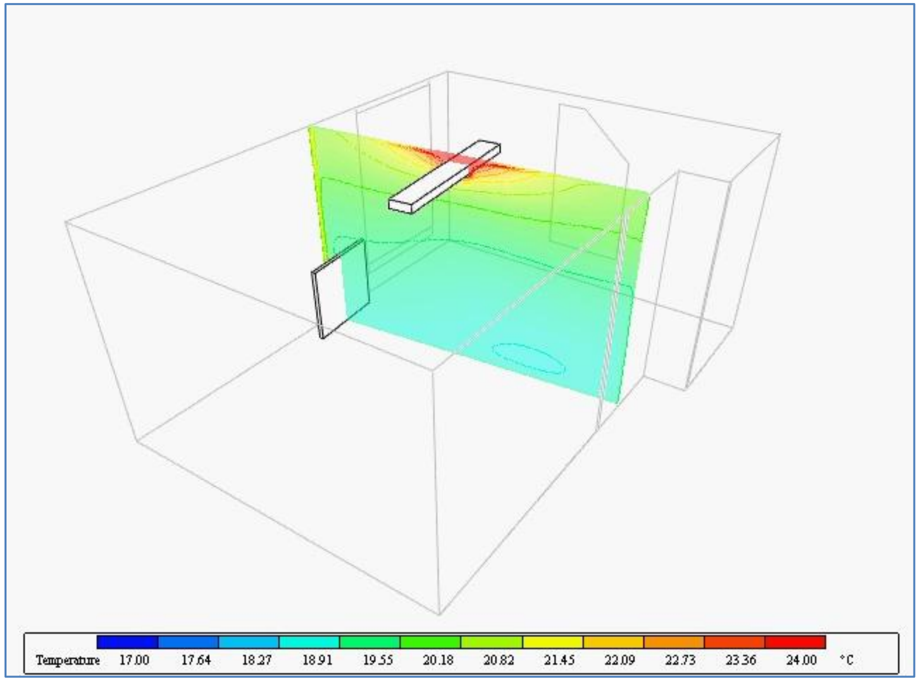
4 Appendix A: Bedroom Heating Design Approach - CFD Analysis: Wall Radiator v Ceiling Radiant Panel

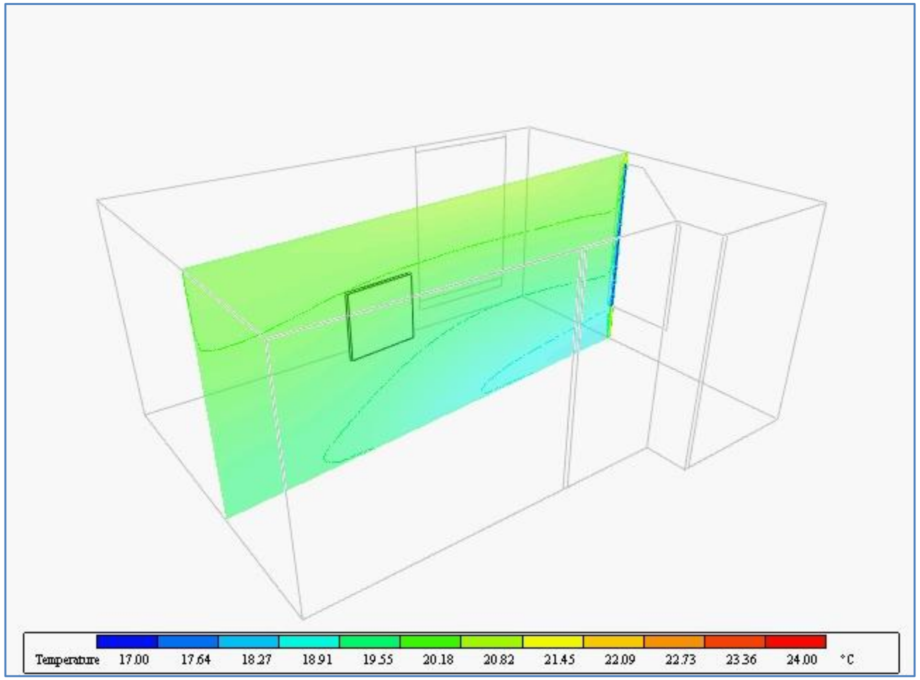
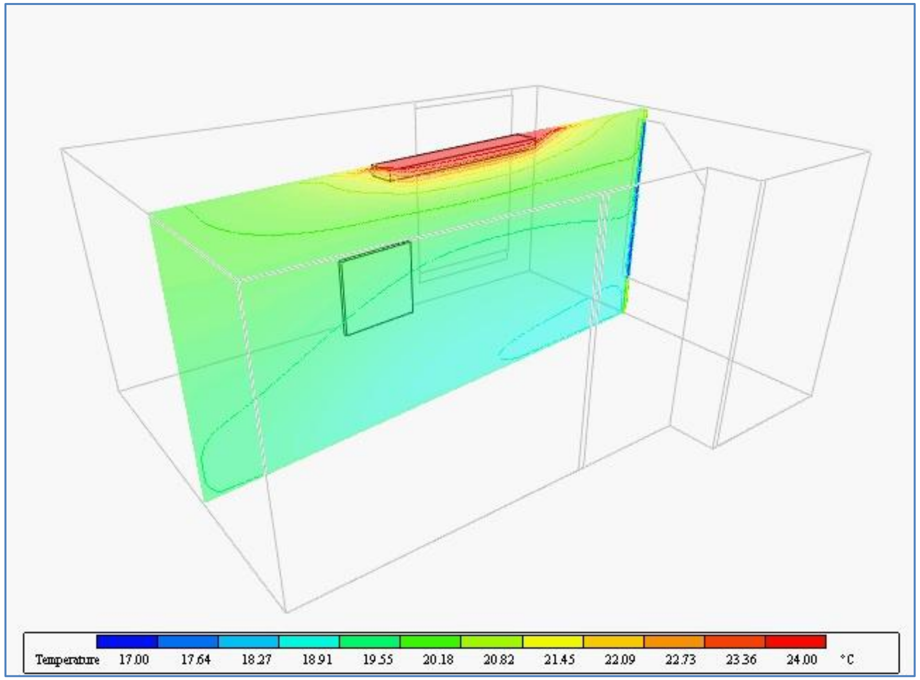
A CFD analysis was performed to compare the air temperature pattern in a typical ward single bedroom for a wall positioned radiator against a ceiling mounted radiant panel. The simulations were performed on a typical winter day assuming a heating load of 340W, an internal air temperature of 23°C and an average wall temperature of 22.5°C.

The following images show an airflow pattern comparison for installations of a wall positioned radiator and a ceiling mounted radiant panel.

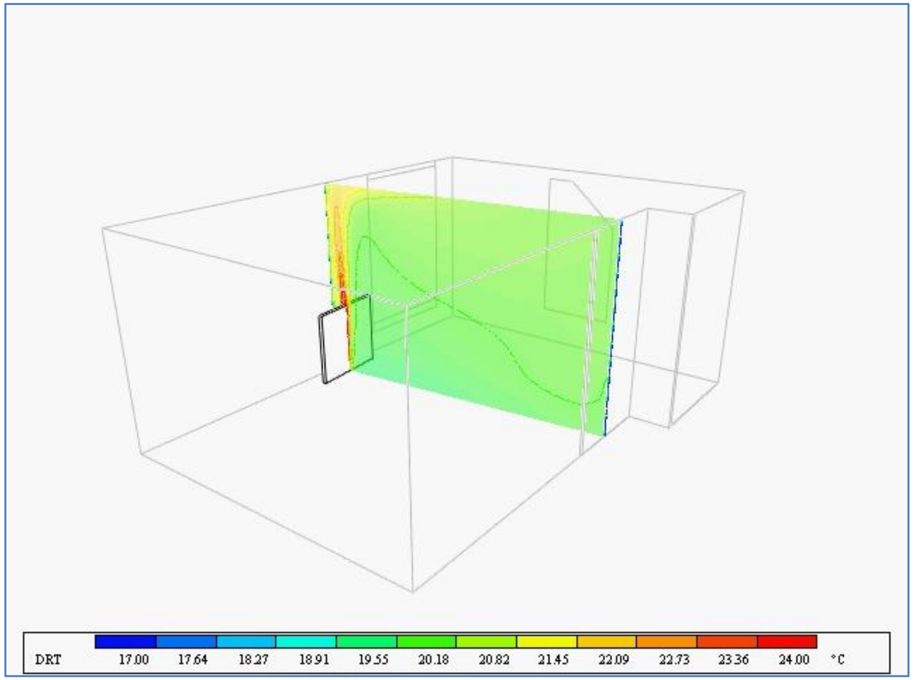
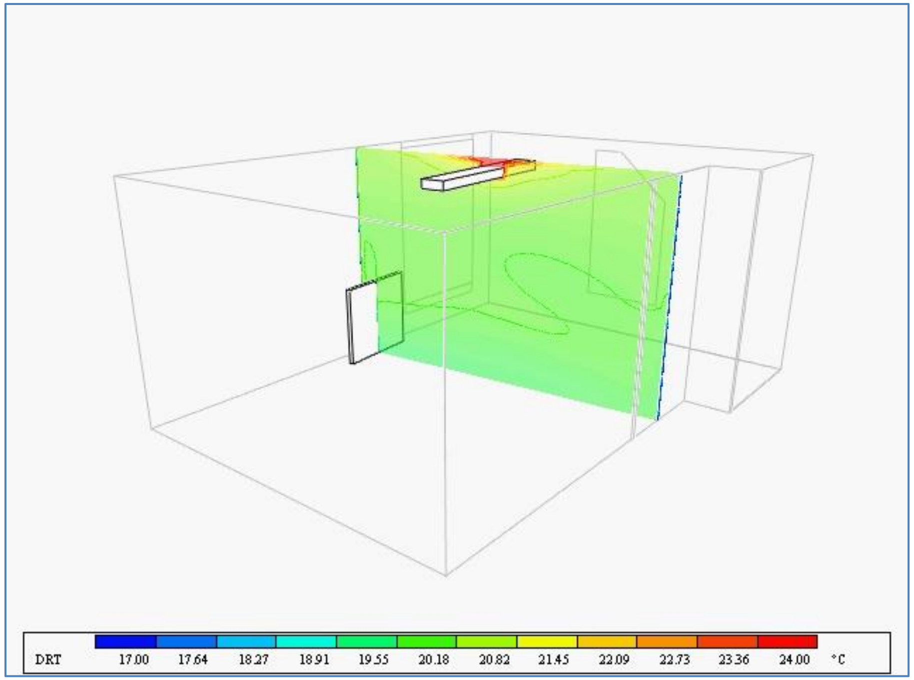
Air Temperature:

Wall Radiator	Ceiling Radiant Panel
	

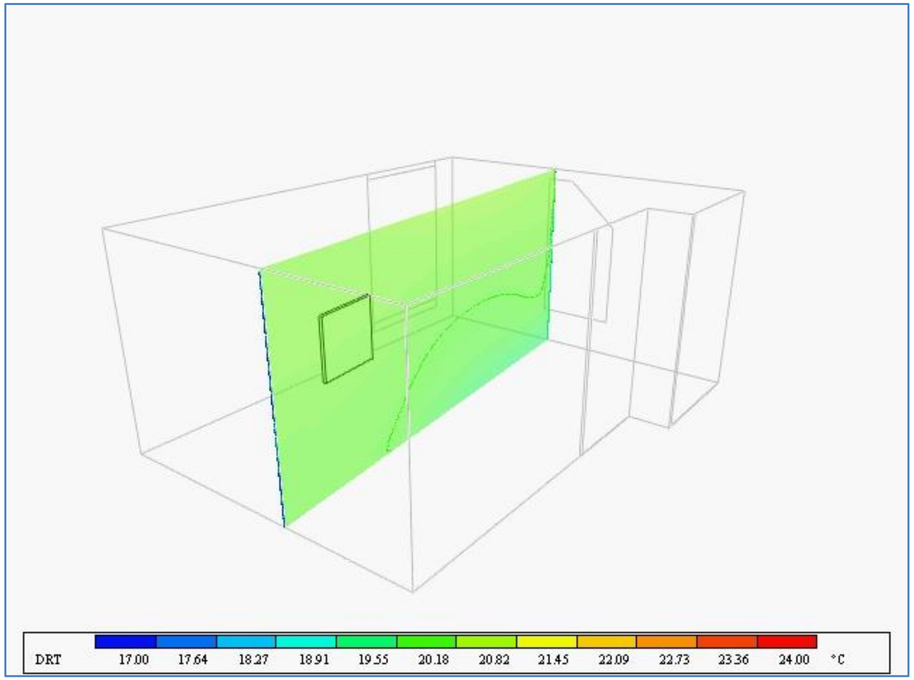
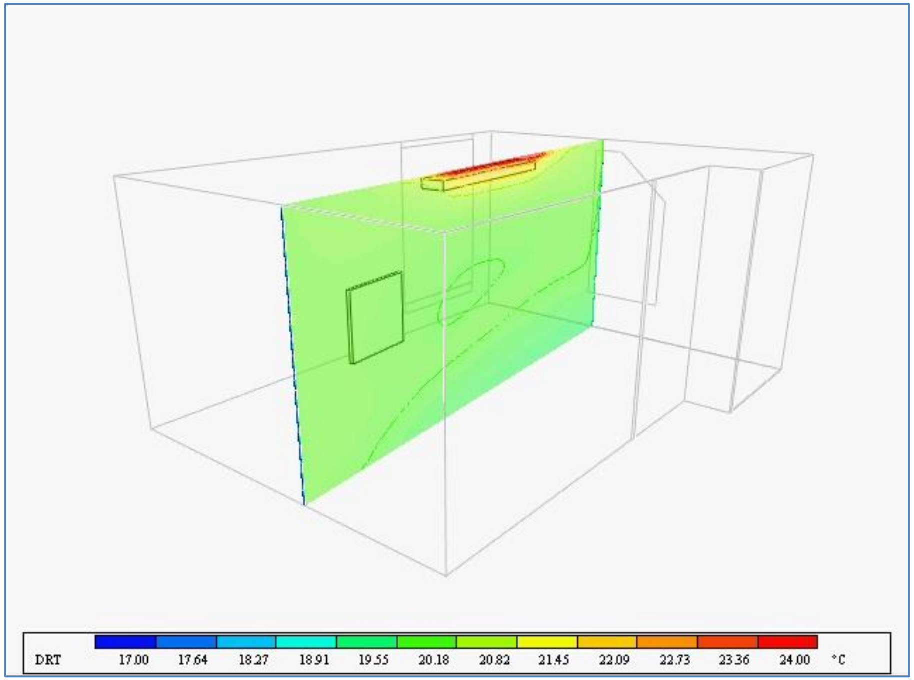
Air Temperature:

Wall Radiator	Ceiling Radiant Panel
	

Operative Temperature:

Wall Radiator	Ceiling Radiant Panel
	

Operative Temperature:

Wall Radiator	Ceiling Radiant Panel
	

In the radiator case, the thermal plume rises and distributes warm air across the room by traversing across the ceiling. The central volume of the room was observed to be between 18-20°C whereas near the walls was warmer at 22°C.

With the radiant panel, the entire room showed a defined vertical thermal gradient. With radiant panel the air is warmed near the ceiling and stays there due to natural buoyancy effects. Strong air movement was observed in the radiator case but not in the radiant panel case, instead heat transfer occurred by diffusion from the higher level rather than air movement.

Overall, the radiator cases performs better at mixing air across the room.

5 Appendix B: Room Data Sheets – Health Centre

Room Data Sheet				**RDS01**
Project	Typical Health Centre			
Room Type	Consulting Exam Room			
Area				
Space Data	**Area**	16 m^2	**Height**	2.4 m
Occupation	**Time**		**Number of Occupants**	
	0000 - 0900		0	
	0900 – 1200		1 inactive, 0.5 active	
	1200 - 1300		0	
	1300 – 1700		1 inactive, 0.5 active	
	1700 - 2400		0	
Note:	Some rooms may be occupied by 1 occupant between 07:00 and 09:00 and between 17:00 and 20:00			
Temperature	**Heating Season**		21 °C	
	Non-heating season		Maximum of 50 hours above 28°C	
Ventilation	**Type**		Natural	
	Infiltration Rate		5 m^3/h/m^2	
	Maximum required		1.9 ACH*	
	Trickle Vent		19,588 mm^2	
	Normally required		1.4 ACH*	
	Pressurisation		-	
Lighting	**Summer/Spring/Autumn**			
	0000 - 0900		0 W	
	0900 – 1230		53 W	
	1230 - 1300		0 W	
	1300 - 1700		53 W	
	1700 - 2400		0 W	
	Winter			
	0000 - 0900		0 W	
	0900 – 1230		106 W	
	1230 - 1300		0 W	
	1300 - 1700		106 W	
	1700 - 2400		0 W	
Equipment & Other	0000 - 0700		34 W	
	0900 – 1700		102 W	
	1800 - 2400		34 W	

**Based on 10l/s/p for 2 people.*

Room Data Sheet				**RDS02**
Project	Typical Health Centre			
Room Type	Ceiling Void – Consulting Exam Room			
Area				
Space Data	**Area**	16 m^2	**Height**	0.5 m
Ventilation	**Type**		Natural	
	Infiltration Rate		5 $m^3/h/m^2$	
	Trickle Vent		0 mm^2	
	Maximum required		N/A	
	Normally required		N/A	
	Pressurisation		N/A	
Lighting Gain to Void	**Summer/Spring/Autumn**			
	0000 - 0900		0 W	
	0900 – 1230		13.5 W	
	1230 - 1300		0 W	
	1300 - 1700		13.5 W	
	1700 - 2400		0 W	
	Winter			
	0000 - 0900		0 W	
	0900 – 1230		45.7 W	
	1230 - 1300		0 W	
	1300 - 1700		45.7 W	
	1700 - 2400		0 W	
Other heat	Summer		24 W	
	Winter/Spring/Autumn		124 W	

Room Data Sheet				**RDS03**
Project	Typical Health Centre			
Room Type	Corridor			
Area				
Space Data	**Area**		**Height**	2.4 m
Ventilation	**Type**		Natural	
	Infiltration Rate		0 $m^3/h/m^2$	
	Trickle Vent		0 mm^2	
	Maximum required		N/A	
	Normally required		N/A	
	Pressurisation		N/A	
Lighting	0000 - 0800		0 W	
	0800 – 2000		3.7 W/m^2	
	2000- 2400		0 W	

Room Data Sheet			**RDS04**	
Project	Typical Health Centre			
Room Type	Ceiling Void – Corridor			
Area				
Space Data	**Area**		**Height**	0.5 m
Ventilation	**Type**		Natural	
	Infiltration Rate		0 $m^3/h/m^2$	
	Trickle Vent		0 mm^2	
	Maximum required		N/A	
	Normally required		N/A	
	Pressurisation		N/A	
Lighting	0000 - 0800		0 W	
	0800 – 2000		1.6 W/m^2	
	2000- 2400		0 W	
Other heat	**Summer**			
	0000 - 2400		197 W	
	Winter/Spring/Autumn			
	0000 - 0800		197 W	
	0800 – 2000		469 W	
	2000- 2400		197 W	

6 Appendix C: Room Data Sheets – Hospital

Room Data Sheet			**RDS01**	
Project	Typical Hospital Ward Block			
Room Type	Bedroom - Single			
Area	First Floor, Inpatient Ward 3			
Space Data	**Area**	19 m^2	**Height**	2.7 m
Occupation	**Time**		**Number of Occupants**	
	0000 - 0800		1 inactive	
	0800 – 1000		2 inactive	
	1000 - 1200		1 inactive	
	1200 - 1500		2 inactive	
	1500 - 1800		1 inactive	
	1800 - 1900		2 inactive	
	1900 - 2400		1 inactive	
Temperature	**Heating Season**		22 – 24 °C	
	Non-heating season		Maximum of 50 hours above 28°C	
Ventilation	**Type**		Natural	
	Infiltration Rate		5 m^3/h/m^2	
	Trickle Vent		21,520 mm^2	
	Maximum required		3.5 ACH	
	Normally required		1.4 ACH	
	Pressurisation		0 or negative	
Lighting	**Summer**			
	0000 - 0900		1.5 W	
	0900 - 2000		73.5 W	
	2000 - 2200		99 W	
	2200 - 2400		56 W	
	Winter			
	0000 - 0700		1.5 W	
	0700 - 1600		73.5 W	
	1600 - 2200		99 W	
	2200 - 2400		56 W	
	Spring/Autumn			
	0000 - 0800		1.5 W	
	0800 - 1800		73.5 W	
	1800 - 2200		99 W	
	2200 - 2400		56 W	
Equipment & Other	**Time**		**Heat Gain**	
	0000 - 0700		90 W	
	0700 – 2300		140 W	
	2300 - 2400		90W	

Room Data Sheet			**RDS02**	
Project	Typical Hospital Ward Block			
Room Type	Ceiling Void – Bedroom - Single			
Area	First Floor, Inpatient Ward 3			
Space Data	**Area**	19 m^2	**Height**	0.5 m
Ventilation	**Type**		Natural	
	Infiltration Rate		5 $m^3/h/m^2$	
	Trickle Vent		0 mm^2	
	Maximum required		N/A	
	Normally required		N/A	
	Pressurisation		N/A	
Lighting loss to void	**Summer**			
	0000 - 0900		0.7 W	
	0900 - 2000		31 W	
	2000 - 2200		43 W	
	2200 - 2400		24 W	
	Winter			
	0000 - 0700		0.7 W	
	0700 - 1600		31 W	
	1600 - 2200		43 W	
	2200 - 2400		24 W	
	Spring/Autumn			
	0000 - 0800		0.7 W	
	0800 - 1800		31 W	
	1800 - 2200		43 W	
	2200 - 2400		24 W	
Other heat	Summer		0 W	
	Winter/Spring/Autumn		104 W	

Room Data Sheet				**RDS03**
Project	Typical Hospital Ward Block			
Room Type	En-Suite			
Area	First Floor, Inpatient Ward 3			
Space Data	**Area**	5.6 m^2	**Height**	2.4 m
Occupation	**Time**		**Number of Occupants**	
	0000 - 0800		0	
	0800 - 0900		1 inactive	
	0900 - 1700		0	
	1700 - 1800		1 inactive	
	1800 - 2400		0	
Temperature	**Heating Season**		26 – 27 °C	
	Non-heating season		Maximum of 50 hours above 28°C	
Ventilation	**Type**		Extract	
	Infiltration Rate		5 $m^3/h/m^2$	
	Trickle Vent		0 mm^2	
	Maximum required		10 ACH	
	Normally required		10 ACH	
	Pressurisation		negative	
Lighting	0000 - 0800		0 W	
	0800 - 0900		28 W	
	0900 - 1700		0 W	
	1700 - 1800		28 W	
	1800 - 2400		0 W	
Equipment & Other	**Time**		**Heat Gain**	
	0000 - 2400		22 W	

Room Data Sheet				**RDS04**
Project	Typical Hospital Ward Block			
Room Type	Ceiling Void – En-Suite			
Area	First Floor, Inpatient Ward 3			
Space Data	**Area**	5.6 m^2	**Height**	0.8 m
Ventilation	**Type**		Natural	
	Infiltration Rate		5 $m^3/h/m^2$	
	Trickle Vent		0 mm^2	
	Maximum required		N/A	
	Normally required		N/A	
	Pressurisation		N/A	
Lighting loss to void	0000 - 0800		0 W	
	0800 - 0900		12.1 W	
	0900 - 0000		0 W	
Other heat	22 W			

Room Data Sheet				**RDS05**
Project	Typical Hospital Ward Block			
Room Type	Bathroom			
Area	First Floor, Inpatient Ward 3			
Space Data	**Area**	14.6 m^2	**Height**	2.4 m
Occupation	**Time**		**Number of Occupants**	
	0000 - 0800		0	
	0800 – 1000		1 inactive, 1 active	
	1000 - 2400		0	
Temperature	**Heating Season**		26 – 27 °C	
	Non-heating season		Maximum of 50 hours above 28°C	
Ventilation	**Type**		Extract	
	Infiltration Rate		5 $m^3/h/m^2$	
	Maximum required		10 ACH	
	Normally required		10 ACH	
	Pressurisation		negative	
Lighting	0000 - 0800		0 W	
	0800 - 0900		120 W	
	0900 - 0000		0 W	
Equipment & Other	**Time**		**Heat Gain**	
	0000 - 0800		22 W	

Room Data Sheet			**RDS06**	
Project	Typical Hospital Ward Block			
Room Type	Clean Utility			
Area	First Floor, Inpatient Ward 3			
Space Data	**Area**	11.6 m^2	**Height**	2.7 m
Occupation	**Time**		**Number of Occupants**	
	0000 - 0800		0	
	0800 – 1200		1 active	
	1200 - 1300		0	
	1300 - 1700		1 active	
	1700 - 1800		0	
	1800 - 2100		1 active	
	2100 - 2400		0	
Temperature	**Heating Season**		18-20 °C	
	Non-heating season		Maximum of 50 hours above 28°C	
Ventilation	**Type**		Extract	
	Infiltration Rate		5 m^3/h/m^2	
	Maximum required		6 ACH	
	Normally required		6 ACH	
	Pressurisation		negative	
Lighting	0000 - 0800		0 W	
	0800 – 1200		60 W	
	1200 - 1300		0 W	
	1300 - 1700		60 W	
	1700 - 1800		0 W	
	1800 - 2100		60 W	
	2100 - 2400		0 W	
Equipment & Other	**Time**		**Heat Gain**	
	0000 - 2400		22 W	

<table>
<tr><td colspan="4">Room Data Sheet</td><td>RDS07</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Project</td><td colspan="4">Typical Hospital Ward Block</td></tr>
<tr><td>Room Type</td><td colspan="4">Communal Toilet</td></tr>
<tr><td>Area</td><td colspan="4">First Floor, Inpatient Ward 3</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Space Data</td><td>Average Area</td><td>12 m²</td><td>Height</td><td>2.4 m</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td rowspan="4">Occupation</td><td colspan="2">Time</td><td colspan="2">Number of Occupants</td></tr>
<tr><td colspan="2">0000 - 0800</td><td colspan="2">0</td></tr>
<tr><td colspan="2">0800 - 1700</td><td colspan="2">0.5 (average)</td></tr>
<tr><td colspan="2">1700 - 2400</td><td colspan="2">0</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td rowspan="2">Temperature</td><td colspan="2">Heating Season</td><td colspan="2">19 – 21 °C</td></tr>
<tr><td colspan="2">Non-heating season</td><td colspan="2">Maximum of 50 hours above 28°C</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td rowspan="6">Ventilation</td><td colspan="2">Type</td><td colspan="2">Extract</td></tr>
<tr><td colspan="2">Infiltration Rate</td><td colspan="2">5 m³/h/m²</td></tr>
<tr><td colspan="2">Trickle Vent</td><td colspan="2">0 mm²</td></tr>
<tr><td colspan="2">Maximum required</td><td colspan="2">10 ACH</td></tr>
<tr><td colspan="2">Normally required</td><td colspan="2">10 ACH</td></tr>
<tr><td colspan="2">Pressurisation</td><td colspan="2">negative</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td rowspan="3">Lighting</td><td colspan="2">0000 - 0800</td><td colspan="2">0 W</td></tr>
<tr><td colspan="2">0800 - 1700</td><td colspan="2">42 W</td></tr>
<tr><td colspan="2">1700 - 2400</td><td colspan="2">0 W</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td rowspan="2">Equipment & Other</td><td colspan="2">Time</td><td colspan="2">Heat Gain</td></tr>
<tr><td colspan="2">0000 - 2400</td><td colspan="2">22 W</td></tr>
</table>

Room Data Sheet			**RDS08**	
Project	Typical Hospital Ward Block			
Room Type	Corridor			
Area	First Floor, Inpatient Ward 3			
Space Data	**Area**	355 m^2	**Height**	2.7 m
Occupation	**Time**		**Number of Occupants**	
	0000 - 0800		1 active	
	0800 - 1500		3 active	
	1500 - 1700		5 active	
	1700 - 1900		3 active	
	1900 - 2100		5 active	
	2100 - 2400		1 active	
Temperature	**Heating Season**		19 – 21 °C	
	Non-heating season		Maximum of 50 hours above 28°C	
Ventilation	**Type**		Supply & Extract	
	Infiltration Rate		5 m^3/h/m^2	
	Maximum required		0.5 ACH	
	Normally required		0.2 ACH	
	Pressurisation		0	
Lighting	0000 - 2400		1,000 W	
Equipment & Other	**Time**		**Heat Gain**	
	0000 - 2400		150 W	

<table>
<tr><td colspan="4">Room Data Sheet</td><td>RDS09</td></tr>
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<tr><td>Project</td><td colspan="4">Typical Hospital Ward Block</td></tr>
<tr><td>Room Type</td><td colspan="4">Dirty Utility</td></tr>
<tr><td>Area</td><td colspan="4">First Floor, Inpatient Ward 3</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Space Data</td><td>Area</td><td>11.6 m^2</td><td>Height</td><td>2.7 m</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Occupation</td><td colspan="2">Time</td><td colspan="2">Number of Occupants</td></tr>
<tr><td></td><td colspan="2">0000 - 0800</td><td colspan="2">0</td></tr>
<tr><td></td><td colspan="2">0800 – 1200</td><td colspan="2">1 active</td></tr>
<tr><td></td><td colspan="2">1200 - 1300</td><td colspan="2">0</td></tr>
<tr><td></td><td colspan="2">1300 - 1700</td><td colspan="2">1 active</td></tr>
<tr><td></td><td colspan="2">1700 - 1800</td><td colspan="2">0</td></tr>
<tr><td></td><td colspan="2">1800 - 2100</td><td colspan="2">1 active</td></tr>
<tr><td></td><td colspan="2">2100 - 2400</td><td colspan="2">0</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Temperature</td><td colspan="2">Heating Season</td><td colspan="2">18-20 °C</td></tr>
<tr><td></td><td colspan="2">Non-heating season</td><td colspan="2">Maximum of 50 hours above 28°C</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Ventilation</td><td colspan="2">Type</td><td colspan="2">Extract</td></tr>
<tr><td></td><td colspan="2">Infiltration Rate</td><td colspan="2">5 $m^3/h/m^2$</td></tr>
<tr><td></td><td colspan="2">Maximum required</td><td colspan="2">6 ACH</td></tr>
<tr><td></td><td colspan="2">Normally required</td><td colspan="2">6 ACH</td></tr>
<tr><td></td><td colspan="2">Pressurisation</td><td colspan="2">negative</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Lighting</td><td colspan="2">0000 - 0800</td><td colspan="2">0 W</td></tr>
<tr><td></td><td colspan="2">0800 – 1200</td><td colspan="2">60 W</td></tr>
<tr><td></td><td colspan="2">1200 - 1300</td><td colspan="2">0 W</td></tr>
<tr><td></td><td colspan="2">1300 - 1700</td><td colspan="2">60 W</td></tr>
<tr><td></td><td colspan="2">1700 - 1800</td><td colspan="2">0 W</td></tr>
<tr><td></td><td colspan="2">1800 - 2100</td><td colspan="2">60 W</td></tr>
<tr><td></td><td colspan="2">2100 - 2400</td><td colspan="2">0 W</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Equipment & Other</td><td colspan="2">Time</td><td colspan="2">Heat Gain</td></tr>
<tr><td></td><td colspan="2">0000 - 0800</td><td colspan="2">44 W</td></tr>
<tr><td></td><td colspan="2">0800 – 1200</td><td colspan="2">1,044 W</td></tr>
<tr><td></td><td colspan="2">1200 - 1300</td><td colspan="2">44 W</td></tr>
<tr><td></td><td colspan="2">1300 - 1700</td><td colspan="2">1,044 W</td></tr>
<tr><td></td><td colspan="2">1700 - 1800</td><td colspan="2">44 W</td></tr>
<tr><td></td><td colspan="2">1800 - 2100</td><td colspan="2">1,044 W</td></tr>
<tr><td></td><td colspan="2">2100 - 2400</td><td colspan="2">44 W</td></tr>
</table>

Room Data Sheet				**RDS10**
Project	Typical Hospital Ward Block			
Room Type	DSR			
Area	First Floor, Inpatient Ward 3			
Space Data	**Area**	7 m^2	**Height**	2.4 m
Occupation	**Time**		**Number of Occupants**	
	0000 - 0600		0	
	0600 – 0800		1 active	
	0800 - 2400		0	
Temperature	**Heating Season**		15-18 °C	
	Non-heating season		Maximum of 50 hours above 28°C	
Ventilation	**Type**		Extract	
	Infiltration Rate		5 $m^3/h/m^2$	
	Maximum required		6 ACH	
	Normally required		6 ACH	
	Pressurisation		0 or negative	
Lighting	0000 - 0600		0 W	
	0600 – 0800		28 W	
	0800 - 2400		0 W	
Equipment & Other	**Time**		**Heat Gain**	
	0000 - 0700		66 W	
	0700 – 2300		66 W	
	2300 - 2400		66 W	

Room Data Sheet				**RDS11**
Project	Typical Hospital Ward Block			
Room Type	Interview Room			
Area	First Floor, Inpatient Ward 3			
Space Data	**Area**	8.4 m^2	**Height**	2.4 m
Occupation	**Time**		**Number of Occupants**	
	0000 - 0800		0	
	0800 – 1700		1 inactive	
	1700 - 2400		0	
Temperature	**Heating Season**		19 – 22 °C	
	Non-heating season		Maximum of 50 hours above 28°C	
Ventilation	**Type**		Natural	
	Infiltration Rate		5 m^3/h/m^2	
	Maximum required		1.4 ACH	
	Normally required		1.4 ACH	
	Pressurisation		0 or negative	
Lighting	0000 - 0800		0 W	
	0800 – 1700		60 W	
	1700 - 2400		0 W	
Equipment & Other	**Time**		**Heat Gain**	
	0000 - 0800		0 W	
	0800 – 1700		20 W	
	1700 - 2400		0W	

Room Data Sheet			**RDS12**	
Project	Typical Hospital Ward Block			
Room Type	Kitchen			
Area	First Floor, Inpatient Ward 3			
Space Data	**Area**	15.4 m^2	**Height**	2.7 m
Occupation	**Time**		**Number of Occupants**	
	0000 - 0800		0 inactive	
	0800 – 1000		2 active	
	1000 - 1200		0 inactive	
	1200 - 1500		2 active	
	1500 - 1700		0 inactive	
	1700 - 1900		2 active	
	1900 - 2400		0 inactive	
Temperature	**Heating Season**		19 – 24 °C	
	Non-heating season		Maximum of 50 hours above 28°C	
Ventilation	**Type**		Supply & Extract	
	Infiltration Rate		5 m^3/h/m^2	
	Maximum required		5.8 ACH	
	Normally required		5.8 ACH	
	Pressurisation		negative	
Lighting	0000 - 0800		0 W	
	0800 – 1000		120 W	
	1000 - 1200		0 W	
	1200 - 1500		120 W	
	1500 - 1700		0 W	
	1700 - 1900		120 W	
	1900 - 2400		0 W	
Equipment & Other	**Time**		**Heat Gain**	
	0000 - 0800		68 W	
	0800 – 1000		1,628 W	
	1000 - 1200		68 W	
	1200 - 1500		1,628 W	
	1500 - 1700		68 W	
	1700 - 1900		1,628 W	
	1900 - 2400		68 W	

Room Data Sheet			**RDS13**	
Project	Typical Hospital Ward Block			
Room Type	Kitchen Table & Circulation			
Area	First Floor, Inpatient Ward 3			
Space Data	**Area**	73.4 m^2	**Height**	2.7 m
Occupation	**Time**		**Number of Occupants**	
	0000 - 0800		0	
	0800 – 1000		4 inactive	
	1000 - 1200		1 inactive	
	1200 - 1400		4 inactive	
	1400 - 1700		1 inactive	
	1700 - 1900		2 inactive	
	1900 - 2400		0	
Temperature	**Heating Season**		22 – 24 °C	
	Non-heating season		Maximum of 50 hours above 28°C	
Ventilation	**Type**		Natural	
	Infiltration Rate		5 $m^3/h/m^2$	
	Trickle Vent		54,040 mm^2	
	Maximum required		1.9 ACH	
	Normally required		1.9 ACH	
	Pressurisation		0	
Lighting	**Summer**			
	0000 - 0900		300 W	
	0900 - 2100		150 W	
	2100 - 2400		300 W	
	Winter			
	0000 - 0700		300 W	
	0700 - 1600		150 W	
	1600 - 2400		300 W	
	Spring/Autumn			
	0000 - 0800		300 W	
	0800 - 1800		150 W	
	1800 - 2400		300 W	
Equipment & Other	**Time**		**Heat Gain**	
	0000 - 0700		0 W	
	0700 – 2300		100 W	
	2300 - 2400		0 W	

Room Data Sheet				**RDS14a**
Project	Typical Hospital Ward Block			
Room Type	Office (No. 35)			
Area	First Floor, Inpatient Ward 3			
Space Data	**Area**	20.3 m^2	**Height**	2.4 m
Occupation	**Time**		**Number of Occupants**	
	0000 - 0800		0	
	0800 - 1800		2 inactive	
	1800 - 2400		0	
Temperature	**Heating Season**		21 – 23 °C	
	Non-heating season		Maximum of 50 hours above 28°C	
Ventilation	**Type**		Supply & Extract	
	Infiltration Rate		0 $m^3/h/m^2$	
	Maximum required		2.4 ACH	
	Normally required		0.6 ACH	
	Pressurisation			
Lighting	0000 - 0800		0 W	
	0800 - 1800		120 W	
	1800 - 2400		0 W	
Equipment & Other	**Time**		**Heat Gain**	
	0000 - 0800		40 W	
	0800 - 1800		150 W	
	1800 - 2400		40W	

Room Data Sheet				**RDS14b**
Project	Typical Hospital Ward Block			
Room Type	Office (No. 68)			
Area	First Floor, Inpatient Ward 3			
Space Data	**Area**	13 m^2	**Height**	2.4 m
Occupation	**Time**		**Number of Occupants**	
	0000 - 0800		0	
	0800 - 1800		1 inactive	
	1800 - 2400		0	
Temperature	**Heating Season**		21 – 23 °C	
	Non-heating season		Maximum of 50 hours above 28°C	
Ventilation	**Type**		Natural	
	Infiltration Rate		5 $m^3/h/m^2$	
	Trickle Vent		17,800 mm^2	
	Maximum required		0.9 ACH	
	Normally required		0.9 ACH	
	Pressurisation			
Lighting	0000 - 0800		0 W	
	0800 - 1800		120 W	
	1800 - 2400		0 W	
Equipment & Other	**Time**		**Heat Gain**	
	0000 - 0800		40 W	
	0800 - 1800		100 W	
	1800 - 2400		40W	

Room Data Sheet				**RDS15**
Project	Typical Hospital Ward Block			
Room Type	Plant Room			
Area	First Floor, Inpatient Ward 3			
Space Data	**Area**	2.5 m^2	**Height**	2.7 m
Occupation	**Time**		**Number of Occupants**	
	0000 - 2400		0	
Temperature	**Heating Season**		Unconditioned	
	Non-heating season		Unconditioned	
Ventilation	**Type**		Natural	
	Infiltration Rate		5 $m^3/h/m^2$	
	Maximum required		0 ACH	
	Normally required		0 ACH	
	Pressurisation		0	
Lighting	0000 - 2400		0 W	
Equipment & Other	**Time**		**Heat Gain**	
	0000 - 2400		133 W	

Room Data Sheet				**RDS16**
Project	Typical Hospital Ward Block			
Room Type	Quiet Room			
Area	First Floor, Inpatient Ward 3			
Space Data	**Area**	21 m^2	**Height**	2.4 m
Occupation	**Time**		**Number of Occupants**	
	0000 - 0800		0	
	0800 – 1800		1 inactive	
	1800 - 2400		0	
Temperature	**Heating Season**		22 – 24 °C	
	Non-heating season		Maximum of 50 hours above 28°C	
Ventilation	**Type**		Natural	
	Infiltration Rate		5 $m^3/h/m^2$	
	Trickle Vent		22,600 mm^2	
	Maximum required		2.3 ACH	
	Normally required		0.6 ACH	
	Pressurisation		0	
Lighting	**Summer**			
	0000 - 0800		0 W	
	0800 - 1800		120 W	
	1800 - 2400		0 W	
	Winter			
	0000 - 0800		0 W	
	0800 - 1600		120 W	
	1600 - 1800		180 W	
	1800 - 2400		0 W	
	Spring/Autumn			
	0000 - 0800		0 W	
	0800 - 1800		120 W	
	1800 - 2400		0 W	

Room Data Sheet				**RDS17**
Project	Typical Hospital Ward Block			
Room Type	Riser			
Area	First Floor, Inpatient Ward 3			
Space Data	**Area**	4.6 m^2	**Height**	2.7 m
Occupation	**Time**		**Number of Occupants**	
	0000 - 2400		0	
Temperature	**Heating Season**		Unconditioned	
	Non-heating season		Unconditioned	
Ventilation	**Type**		Natural	
	Infiltration Rate		5 m^3/h/m^2	
	Maximum required		0 ACH	
	Normally required		0 ACH	
	Pressurisation		0	
Lighting	0000 - 0800		0 W	
Equipment & Other	**Time**		**Heat Gain**	
	0000 - 2400		132 W	

Room Data Sheet			**RDS18**	
Project	Typical Hospital Ward Block			
Room Type	Servery			
Area	First Floor, Inpatient Ward 3			
Space Data	**Area**	13.5 m^2	**Height**	2.4 m
Occupation	**Time**		**Number of Occupants**	
	0000 - 0800		0	
	0800 – 1000		2 active	
	1000 - 1200		0	
	1200 - 1500		2 active	
	1500 - 1700		0	
	1700 - 1900		2 active	
	1900 - 2400		0	
Temperature	**Heating Season**		15-18 °C	
	Non-heating season		Maximum of 50 hours above 28°C	
Ventilation	**Type**		Extract	
	Infiltration Rate		5 $m^3/h/m^2$	
	Maximum required		12 ACH	
	Normally required		12 ACH	
	Pressurisation		negative	
Lighting	0000 - 0800		0 W	
	0800 – 1000		120 W	
	1000 - 1200		0 W	
	1200 - 1500		120 W	
	1500 - 1700		0 W	
	1700 - 1900		120 W	
	1900 - 2400		0 W	
Equipment & Other	**Time**		**Heat Gain**	
	0000 - 0800		34 W	
	0800 – 1000		4,034 W	
	1000 - 1200		34 W	
	1200 - 1500		4,034 W	
	1500 - 1700		34 W	
	1700 - 1900		4,034 W	
	1900 - 2400		34 W	

Room Data Sheet				**RDS19**
Project	Typical Hospital Ward Block			
Room Type	Servery Utility			
Area	First Floor, Inpatient Ward 3			
Space Data	**Area**	8.3 m^2	**Height**	2.4 m
Occupation	**Time**		**Number of Occupants**	
	0000 - 0800		0	
	0800 – 1000		1 active	
	1000 - 1200		0	
	1200 - 1500		1 active	
	1500 - 1700		0	
	1700 - 1900		1 active	
	1900 - 2400		0	
Temperature	**Heating Season**		15-18 °C	
	Non-heating season		Maximum of 50 hours above 28°C	
Ventilation	**Type**		Extract	
	Infiltration Rate		5 $m^3/h/m^2$	
	Maximum required		6 ACH	
	Normally required		6 ACH	
	Pressurisation		negative	
Lighting	0000 - 0800		0 W	
	0800 – 1000		60 W	
	1000 - 1200		0 W	
	1200 - 1500		60 W	
	1500 - 1700		0 W	
	1700 - 1900		60 W	
	1900 - 2400		0 W	
Equipment & Other	**Time**		**Heat Gain**	
	0000 - 0800		94 W	
	0800 – 1000		3,214 W	
	1000 - 1200		94 W	
	1200 - 1500		3,214 W	
	1500 - 1700		94 W	
	1700 - 1900		3,214 W	
	1900 - 2400		94 W	

Room Data Sheet			**RDS20**	
Project	Typical Hospital Ward Block			
Room Type	Stair			
Area	First Floor, Inpatient Ward 3			
Space Data	**Area**	27.8 m^2	**Height**	13 m
Occupation	**Time**		**Number of Occupants**	
	0000 - 0800		0	
	0800 - 2100		0	
	2100 - 2400		0	
Temperature	**Heating Season**		19 – 24 °C	
	Non-heating season		Maximum of 50 hours above 28°C	
Ventilation	**Type**		Natural	
	Infiltration Rate		5 m^3/h/m^2	
	Maximum required		0 ACH	
	Normally required		0 ACH	
	Pressurisation		0	
Lighting	0000 - 2400		168 W	
Equipment & Other	**Time**		**Heat Gain**	
	0000 - 2400		0 W	

Room Data Sheet				**RDS21**
Project	Typical Hospital Ward Block			
Room Type	Stair Lobby			
Area	First Floor, Inpatient Ward 3			
Space Data	**Area**	9.4 m^2	**Height**	2.7 m
Occupation	**Time**		**Number of Occupants**	
	0000 - 0800		0	
	0800 - 2100		0	
	2100 - 2400		0	
Temperature	**Heating Season**		19 – 24 °C	
	Non-heating season		Maximum of 50 hours above 28°C	
Ventilation	**Type**		Natural	
	Infiltration Rate		5 $m^3/h/m^2$	
	Maximum required		0 ACH	
	Normally required		0 ACH	
	Pressurisation		0	
Lighting	0000 - 2400		56 W	
Equipment & Other	**Time**		**Heat Gain**	
	0000 - 2400		0 W	

Room Data Sheet				**RDS22**
Project	Typical Hospital Ward Block			
Room Type	Store			
Area	First Floor, Inpatient Ward 3			
Space Data	**Area**	11 m^2	**Height**	2.4 m
Occupation	**Time**		**Number of Occupants**	
	0000 - 2400		0	
Temperature	**Heating Season**		Unconditioned	
	Non-heating season		Unconditioned	
Ventilation	**Type**		Natural	
	Infiltration Rate		5 $m^3/h/m^2$	
	Maximum required		0 ACH	
	Normally required		0 ACH	
	Pressurisation		0	
Lighting	0000 - 2400		0 W	
Equipment & Other	**Time**		**Heat Gain**	
	0000 - 2400		0 W	

Room Data Sheet			**RDS23**	
Project	Typical Hospital Ward Block			
Room Type	Therapy			
Area	First Floor, Inpatient Ward 3			
Space Data	**Area**	45.8 m^2	**Height**	2.7 m
Occupation	**Time**		**Number of Occupants**	
	0000 - 0900		0	
	0900 – 1700		2 active	
	1700 - 2400		0	
Temperature	**Heating Season**		16 -18 °C	
	Non-heating season		< 20°C	
Ventilation	**Type**		Supply/Extract	
	Infiltration Rate		5 $m^3/h/m^2$	
	Trickle Vent		37,480 mm^2	
	Maximum required		10 ACH	
	Normally required		10 ACH	
	Pressurisation		positive	
Lighting	**Summer**			
	0000 - 1000		0 W	
	1000 - 1600		458 W	
	1600 - 2400		0 W	
	Winter/Spring/Autumn			
	0000 - 0900		0 W	
	0900 - 1700		458 W	
	1700 - 2400		0 W	
Equipment & Other	**Time**		**Heat Gain**	
	0000 - 0700		50 W	
	0700 – 2300		500 W	
	2300 - 2400		50 W	

Room Data Sheet				**RDS24**
Project	Typical Hospital Ward Block			
Room Type	Treatment Room			
Area	First Floor, Inpatient Ward 3			
Space Data	**Area**	15.5 m^2	**Height**	2.7 m
Occupation	**Time**		**Number of Occupants**	
	0000 - 0800		0	
	0800 – 1200		1 inactive, 1 active	
	1200 - 1300		0	
	1300 - 1630		1 inactive, 1 active	
	1630 - 2400		0	
Temperature	**Heating Season**		22 – 24 °C	
	Non-heating season		Maximum of 50 hours above 28°C	
Ventilation	**Type**		Mechanical	
	Infiltration Rate		0 $m^3/h/m^2$	
	Maximum required		10 ACH	
	Normally required		10 ACH	
	Pressurisation		Positive	
Lighting	0000 - 0800		0 W	
	0800 – 1200		120 W	
	1200 - 1300		0 W	
	1300 - 1630		120 W	
	1630 - 2400		0 W	
Equipment & Other	**Time**		**Heat Gain**	
	0000 - 0700		58 W	
	0700 – 2300		78 W	
	2300 - 2400		58 W	

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