DESIGN NOTE Revision: 01 Date: 09/05/2016 :: Purpose: For information		XCO2 Energy Ltd. 17-18 Hayward's Place :: Clerkenwell :: London :: EC1R 0EQ t: +44 (0) 20 7700 1000 :: f: +44 (0) 20 7183 6620 w: www.xco2energy.com	
Project:	Sondheim Theatre (Formerly Ambassador's Theatre), London		
Subject:	**Overheating risk assessment**		
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Executive Summary

This report details the overheating analysis for the proposed scheme at Sondheim (previously Ambassadors) Theatre located in the London Borough of Camden, based on the information provided by the design team. The purpose of this analysis is to assess the overheating risk, analyse the effectiveness of mitigating strategies in order to ensure the comfort of the occupants as well as future-proof the design taking into account projected climate changes.

In order to assess the thermal performance of the development, a complete model of the building was constructed within thermal simulation software and the internal temperature conditions were calculated for the various spaces via dynamic simulation.

In order to give the most robust consideration, the performance of the various occupied rooms were compared with CIBSE Technical Memorandum 52 (TM52) performance recommendations. These are rigorous targets that determine the acceptability of overheating based on the temperature differential between the internal and the external environment (ΔT), considering its frequency, its severity and an absolute peak difference beyond which the level of overheating is considered unacceptable.

The spaces analysed in detail with the thermal simulations are predominantly the ones where there is constant occupation and include:

- Auditorium and performance areas
- Reception areas, and General and Patron specific circulation spaces
- Eating and drinking areas
- Offices and workshop areas

The thermal simulations indicate the following:

- The building was not found to satisfy the overheating risk criteria for the historic weather data with the use of efficient lighting, reduction in heat gains and increased mechanical ventilation which are strategies in line with the cooling hierarchy.
- Energy efficient design and mechanical ventilation has shown to help reduce the number of hours during which overheating occurs, but not fully mitigate the overheating risk for most of the assessed spaces.
- Simulations using future weather files predict an increase in overheating risk in the future.

Based on the method of assessment adopted, XCO2 Energy would recommend the incorporation of the overheating reduction measures detailed within the report. It is proposed that space cooling be implemented to all the spaces to ensure satisfactory levels of thermal comfort for the future building users.

Introduction

The application proposes a new dedicated theatrical transfer house to accommodate productions that have come to the end of their run in the subsidised sector. The proposed theatre will provide the opportunity for subsidised productions that would not otherwise have the opportunity to transfer to the West End.

It is currently very difficult for successful subsidised productions to transfer to the West End because the internal arrangement of most West End theatres differs substantially from more modern arrangements of the subsidised sector. The vast majority of West End theatres have traditional 'proscenium arch' stages whilst most originating theatres in the subsidised sector have more modern arrangements, such as thrust stages or are arranged 'in the round'. This means that a transfer has to be restaged, often at huge cost to the originating subsidised theatre and eroding the original artistic intention of the director, to the detriment of the audience experience.

There are currently no dedicated theatres in the West End to which productions arising in the subsidised theatre sector can transfer in the event of critical acclaim or audience demand. Typically, publically subsidised productions are pre-programmed in advance at the originating playhouses and run for a period of 6-8 weeks only. The proposed new theatre would provide an opportunity for successful subsidised shows to transfer to the West End for a further 8-16 weeks.

This increased run would provide the subsidised sector with an opportunity to increase revenue at a time of consistently squeezed funding pressures and cuts. It will also diversify the offer for theatre goers and open up a range of quality productions to be viewed as originally intended, enhancing the range and quality of productions and cementing London's status as a world cultural capital in theatre.

Such is the shortage of space in the West End that very many successful subsidised productions are simply never seen again after their original run. Others, due to the physical difficulties of restaging in a proscenium setting simply have no prospect of transfer at all, even if a space in the West End were available.

In order to create a modern and flexible internal arrangement, it is proposed that much of the building is demolished and rebuilt behind the retained West Street façade and the stucco return onto Tower Court. Historically significant elements of plasterwork are to be relocated within the new theatre.

The proposed theatre will then provide a much needed resource for the transfer of productions from the subsidised sector. In turn, the subsidised sector will be able to secure a longer run for critically acclaimed productions that would otherwise close for good, frustrating a large unmet demand from the audience. Thus, the cultural life of the West End will be enhanced along with the audience's opportunity to see good quality subsidised productions for a longer period of time. In their turn, the subsidised sector will realise the opportunity to increase their revenue in an environment of constantly reduced funding.

The proposals have attracted wide ranging support from within the industry. Nicholas Hytner (former Artistic Director of the National Theatre) summarised the situation as:

> *"Over recent years, a large number of the most successful and ambitious productions in the subsidised theatre sector have been unable to find a venue for further life, leaving a significant potential audience without an opportunity to see work it would like to see. Very often this work would not justify the risks involved in a transfer to a large West End theatre. Cameron Mackintosh's plans for his new 450 seat theatre would greatly increase the chances of a future life for successful productions form theatres like the Dorfman, the Almeida, the Royal Court and the Donmar as well as offering a suitable venue for regional transfers."*

Full details of the need for a dedicated transfer house and how the proposed theatre meets that need is set out in the Design and Access Statement and Planning and Heritage Statement that accompany this application.

This report details the overheating analysis for the proposed scheme at Sondheim (previously Ambassadors) Theatre located within the London Borough of Camden, based on the information provided by the design team.

The site is located along the north side of West Street in central London, close to both Covent Garden and Leicester Square stations, within the London Borough of Camden. The project brief revolves primarily around the creation of a 450 seat theatre auditorium. Public areas and rehearsal facilities are also to be improved with the intention of retaining the facade and certain period features of the original architecture.

The study evaluates the overheating risk under historic and future weather conditions for key occupied spaces such as the theatre area, performance, circulation and other patron spaces. The purpose of this analysis is to influence the design to mitigate risks and future-proof the building in terms of potential overheating.

The analysis was undertaken by building a thermal model to assess the thermal performance of the development and investigate the impact of certain design measures on the predicted internal temperatures.

The London Plan Cooling Hierarchy

According to the London Plan's Policy 5.9 Overheating and Cooling, major development proposals should reduce potential overheating and reliance on air-conditioning systems, by demonstrating how the design, materials, construction and operation of the development would minimise overheating and also meet its cooling needs. This should be demonstrated in accordance with the following cooling hierarchy:

- Minimise internal heat generation through energy efficient design;
- Reduce the amount of heat entering a building in summer though orientation, shading, albedo, fenestration, insulation and green roofs and walls;
- Manage the heat within the building through exposed internal thermal mass and high ceilings;
- Passive ventilation;
- Mechanical ventilation;
- Active cooling systems (ensuring they are the lowest carbon options).

Using an iterative and progressive methodology, XCO2 developed a methodology to assess the above potential solutions for the different space types of Ambassador's theatre. The analysis considered in detail the measures that are applicable in each case considering the function of the various premises.

Methodology

A 3D thermal model was prepared in line with the architectural drawings. The model represents the office and restaurant area in the basement level of the development and the hotel in top levels together with all relevant adjacent spaces. Parts of the development not considered critical to the assessment, such as ancillary zones, were modelled as adiabatic adjacencies. Visualisation of the 3D thermal model is presented in the image below.

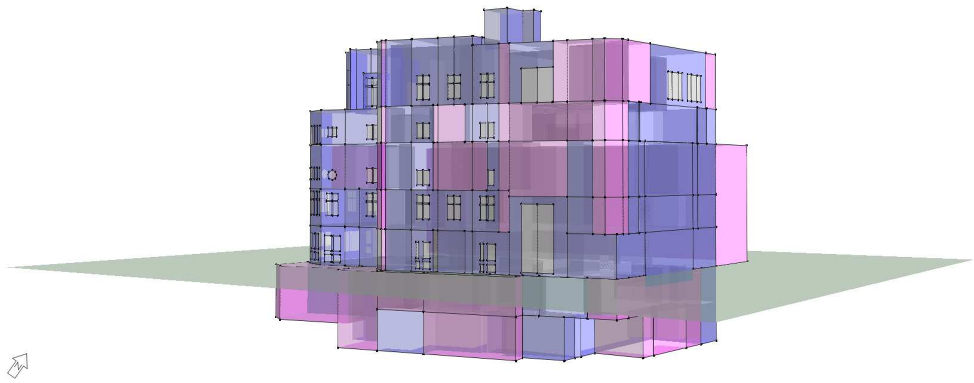

Figure 1: Visualization of 3D thermal model

The following diagram shows the main spaces that were tested as part of the overheating assessment, including spaces in the basement and mezzanine levels, and the theatre and other occupied areas. The majority of the spaces have been divided into smaller zones (excluding offices and public circulation spaces) with occupied and unoccupied zones separated to gain a better understanding of the predicted temperature distribution across the smaller zones rather than a single big space.

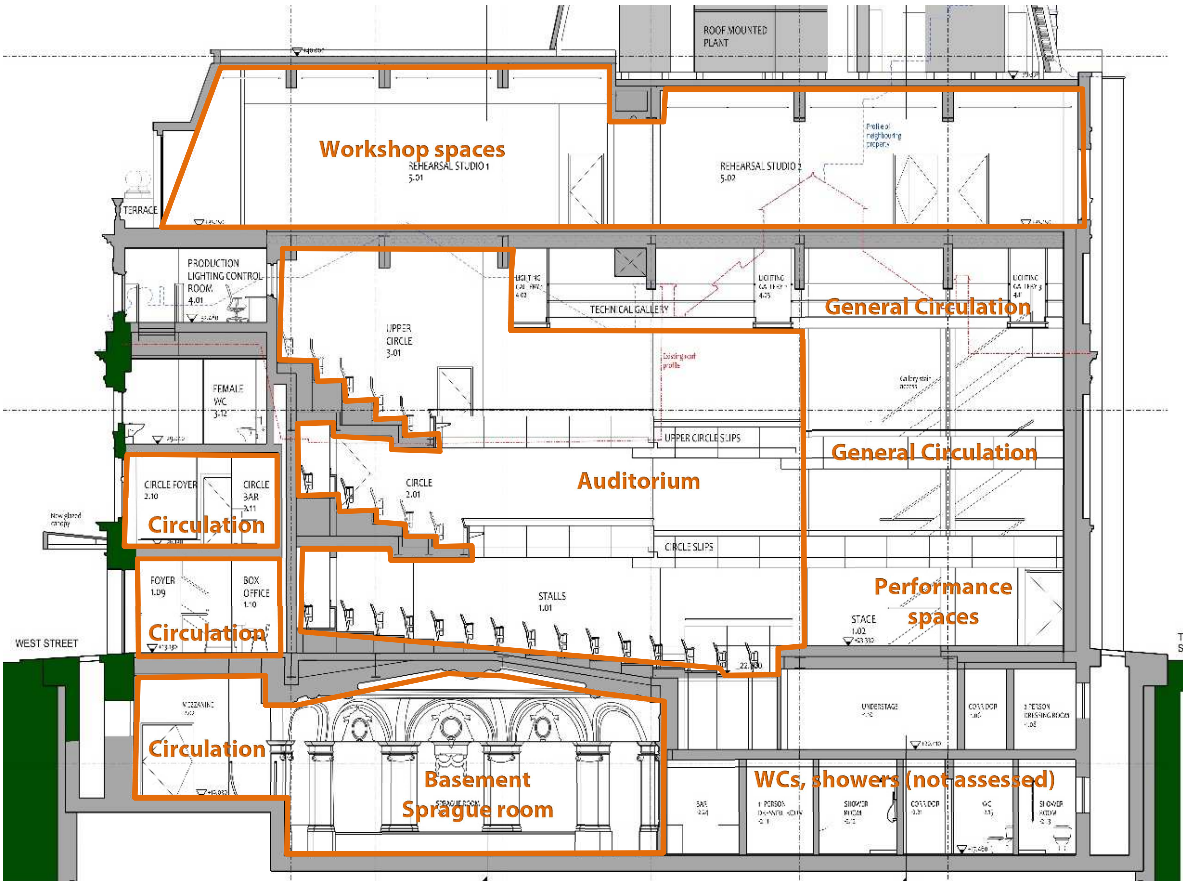

Figure 2: Section of proposed assessed spaces

The building has been modelled using dynamic thermal simulation software which is fully compliant with CIBSE Applications Manual AM11. The software can compute operative temperatures using CIBSE weather data sets, building fabric specification, window areas and opening, all aspects of solar and internal gains as well as natural and mechanical ventilation flows within buildings. Table 1 details the inputs inherent to the baseline model.

Table 1: Baseline thermal modelling inputs

Modelling Input	Design Criteria
Weather file	LondonDSY05
Fabric Specification	Wall U-Value - 0.15 W/m^2.K Retained Wall U-Value - 0.15 W/m^2.K Floor U-Value - 0.10 W/m^2.K Roof U-Value - 0.10 W/m^2.K
Window Specification	Windows U-Value - 1.6 W/m^2.K, Standard: g-value - 0.7
Internal Gains (design gains specified based on the National Calculation Methodology standard gains, unless stated otherwise)	Auditorium areas: (19 zones) *Lighting:* 15.6 W/m^2 *Occupancy:* 2.9 m^2/p Sensible 61W/p, Latent 39W/p *Equipment:* 1.7 W/m^2 sensible gains General circulation (theatre areas): (14 zones) *Lighting:* 5.2 W/m^2 *Occupancy:* 9.9 m^2/p Sensible 70W/p, Latent 70W/p *Equipment:* 1.7 W/m^2 sensible gains Eating and drinking areas: (2 zones) *Lighting:* 7.8 W/m^2 *Occupancy:* 4.5 m^2/p Sensible 67.1W/p, Latent 42.9W/p *Equipment:* 17.6 W/m^2 sensible gains

	Offices: (4 zones) *Lighting:* 15 W/m^2 *Occupancy:* 8.5 m^2/p Sensible 73 W/p, Latent 50 W/p *Equipment:* 13.4 W/m^2 sensible gains Performance areas: (3 zones) *Lighting:* 39 W/m^2 *Occupancy:* 20.2 m^2/p Sensible 85W/p, Latent 165W/p *Equipment:* 2.2 W/m^2 sensible gains Public Circulation: (14 zones) *Lighting:* 10.4W/m^2 *Occupancy:* 4.1 m^2/p Sensible 90 W/p, Latent 90 W/p *Equipment:* 4.0 W/m^2 sensible gains Reception areas: (8 zones) *Lighting:* 10.4 + 9 (display) W/m^2 *Occupancy:* 7.9 m^2/p Sensible 85.4 W/p, Latent 54.9 W/p *Equipment:* 5.4W/m^2 sensible gains Workshop areas: (8 zones) *Lighting:* 18.75W/m^2 *Occupancy:* 14.9 m^2/p Sensible 48.6 W/p, Latent 131.4W/p *Equipment:* 1.8W/m^2 sensible gains
Natural ventilation	Windows are only found in the peripheral circulation spaces and opening of windows is not possible due to acoustic reasons. No natural ventilation assumed.
Mechanical ventilation (in use)	ventilation rate of 10 l/s/p (CIBSE Guide A)

The CIBSE DSY weather dataset, used for the simulations, consists of hourly data for a complete year for which the average temperature of the summer months is at the centre of the upper quartile of the rankings obtained from approximately 20 years. There is therefore a 1-in-8 chance of the temperatures being exceeded over one year.

The method of assessment also included future weather files in order to assess the implications of future-proofing the design. These datasets have been developed based on different carbon emissions scenarios, the higher the emissions the greater the extent of the elevated temperatures. The ones used for this analysis are the following:

- CIBSE London DSY05, Design Summer Year based on historic data
- CIBSE Central London DSY2020 (1983-2020), High emission scenario, 50th percentile[1]
- CIBSE Central London DSY2050 (1983-2050), High emission scenario, 50th percentile

Iterations of the thermal simulation have been carried out in line with Policy 5.9 of the London Plan.

[1] Weather data sets are available for the 10th, 50th and 90th percentile, the 50th representing the 'best guess' climate projection for the given emissions scenario as it encompasses 50% of the projected changes to the climate.

Assessment criteria

The performance standards set out within CIBSE TM52 have been used to assess the overheating risk within the proposed development. For naturally ventilated spaces, at least two of the following criteria must be met:

1) Hours of exceedance (H_e): H_e<3% of occupied hours
The first criterion sets a limit for the number of hours that the operative temperature[2] can exceed the threshold comfort temperature by 1°C or more during the occupied hours of a typical non-heating season (1 May to 30 September).

2) Daily weighted exceedance (W_e): W_e<6
The second criterion deals with the severity of overheating within any one day, which can be as important as its frequency, the level of which is a function of both temperature rise and its duration. This criterion sets a daily limit for acceptability.

3) Upper limit temperature (T_{upp}): T_{op}[3]-T_{max}[4] <4°C
The third criterion sets an absolute maximum daily temperature for a room, beyond which the level of overheating is unacceptable.

All the criteria are evaluated in terms of the ΔT, which is the difference between the operative temperature T_{op} and the limiting maximum temperature T_{max}.
$\Delta T = T_{op} - T_{max}$

In order to estimate the T_{op}, dynamic thermal modelling is carried out to compute the predicted temperature distribution in the different thermal zones of the building. The maximum acceptable temperature is a function of the outdoor temperature and the design limits which are shown below. The table details the suggested acceptability in terms of the temperature range of naturally ventilated buildings. For the purposes of the assessment, we have used Category II limits.

Table 2: Acceptability range per building category

CATEGORY	EXPLANATION	SUGGESTED ACCEPTABLE RANGE (°C)
I	High level of expectation only used for spaces occupied by very sensitive and fragile persons	± 2
II	Normal expectation (for new buildings and renovations)	± 3
III	A moderate expectation (used for existing buildings)	± 4
IV	Values outside the criteria for the above categories (only acceptable for limited periods)	> 4

CIBSE does not specify the exact hours that the internal spaces are occupied and the BRE estimates that are inherited for the National Calculation Methodology (NCM) have been used as a closer prediction of the occupied hours of each of the areas.

[2] Operative temperature models the combined effect of convective and radiant heat transfer. It accounts for the combined effect of the temperature of the air, the temperature of the surfaces and the air speed.
[3] T_{op} = Operative temperature
[4] T_{max} is the maximum acceptable temperature and is dependent on the outdoor running mean temperature and the building category with each associated acceptability range

Results

This section presents the results summary for each of the tests carried out for the continually occupied spaces as described in Table 1. Since the auditorium, performance space and workshops are large open spaces, they have been subdivided into smaller thermal zones to provide a better temperature prediction distribution. Detailed results in relation to the overheating criterion for each different use can be found in the appendix.

The tables below show the results for the tests carried out for the London DSY05 weather file. Results are shown both in terms of the TM52 criteria and number of occupied hours in which internal temperature exceeds 28°C (or 25°C in the case of the auditorium spaces and patron areas). This metric was used as an additional metric to compare the results between the different iterations. It is important to note that the TM52 Overheating Criteria are based on the adaptive thermal comfort model for free running buildings, which may not be fully applicable for an auditorium where occupants would be expecting a fully conditioned environment. As such, a lower overheating threshold of 25°C has been applied for the simulations of the auditorium spaces and other patron areas.

Based on the results in Tables 3-10, the following observations can be made:

- Most of the tested spaces do not meet the required TM52 criteria
- Improved design though energy efficient lighting and presents a benefit to the internal conditions, but does not fully mitigate overheating risks.
- Solar control glazing cannot be used to mitigate risk of overheating due to the absence of any glazing in the basement levels, and the main occupied spaces such as the auditorium and performance areas.
- Improved design though increasing the mechanical ventilation rates presents a benefit to the internal conditions, but does not fully mitigate overheating risks. Although increased mechanical ventilation rates were found to improve the results, this is not necessarily more energy efficient than cooling which is dependent on the pressure drop within the ductwork. Therefore, a balanced analysis needs to be carried out (by the M&E designer) to determine whether providing cooling is more efficient than increasing mechanical ventilation flow rates in the building.
- Although the overheating risk to a few of the spaces is reduced using the strategies applied, simulations using London DSY2020 and DSY2050 weather files predict that these spaces are not likely meet the criteria in the future.

Auditorium

Table 3: Results for the London DSY05 weather file – Auditorium

Test	Iteration description	Energy efficient lighting (W/m^2)	Reduce heat entering building (g-value)[5]	Mech. Vent. (l/s/person)	N° of thermal zones failing	Average No. Of Hrs T>25°C (in °C)
0	Baseline	15.6		10	19/19	850
1	energy efficient design 01	10			19/19	764
2	energy efficient design 02	8			19/19	671
3	Reduce heat gain 01		0.5		19/19	632
4	Reduce heat gain 02		0.4		19/19	612
5	mechanical ventilation 01			15	19/19	449
6	mechanical ventilation 02			20	18/19	340
Results for the CIBSE London DSY2020 and DSY2050_High50pct weather file						
7	Iteration 6 with DSY2020	8	0.4	20	19/19	531
8	Iteration 6 with DSY2050	8	0.4	20	19/19	716

[5] G-value is the coefficient used to measure the solar energy transmittance through the glass. The solar transmission is lower (hence heat gained by the building is lower) if the g-value is lower.

General circulation (staff)

Table 4: Results for the London DSY05 weather file – General circulation

Test	Iteration description	Energy efficient lighting (W/m²)	Reduce heat entering building (g-value)	Mech. Vent. (l/s/person)	N° of thermal zones failing	Average No. of Hrs T>28°C (in °C)
0	Baseline	5.2		10	14/14	854
1	energy efficient design 01	4			14/14	644
2	energy efficient design 02	3			14/14	513
3	Reduce heat gain 01		0.5		14/14	427
4	Reduce heat gain 02		0.4		14/14	377
5	mechanical ventilation 01			15	5/14	193
6	mechanical ventilation 02			20	0/14	128
Results for the CIBSE London DSY2020 and DSY2050_High50pct weather file						
7	Iteration 6 with DSY2020	3	0.4	20	9/14	295
8	Iteration 6 with DSY2050	3	0.4	20	14/14	605

Eating and drinking spaces

Table 5: Results for the London DSY05 weather file – Eating and drinking spaces

Test	Iteration description	Energy efficient lighting (W/m²)	Reduce heat entering building (g-value)	Mech. Vent. (l/s/person)	N° of thermal zones failing	Average No. of Hrs T>25°C (in °C)
0	Baseline	7.8		10	2/2	466
1	energy efficient design 01	6			2/2	411
2	energy efficient design 02	4			2/2	365
3	Reduce heat gain 01		0.5		2/2	313
4	Reduce heat gain 02		0.4		2/2	278
5	mechanical ventilation 01			15	2/2	168
6	mechanical ventilation 02			20	1/2	118
Results for the CIBSE London DSY2020 and DSY2050_High50pct weather file						
7	Iteration 6 with DSY2020	4	0.4	20	1/2	268
8	Iteration 6 with DSY2050	4	0.4	20	2/2	382

Office spaces

Table 6 : Results for the London DSY05 weather file – Office spaces

Test	Iteration description	Energy efficient lighting (W/m²)	Reduce heat entering building (g-value)	Mech. Vent. (l/s/person)	N° of thermal zones failing	Average No. of Hrs T>28°C (in °C)
0	Baseline	15		10	4/4	1198
1	energy efficient design 01	10			4/4	1031
2	energy efficient design 02	8			4/4	922
3	Reduce heat gain 01		0.5		4/4	797
4	Reduce heat gain 02		0.4		4/4	719
5	mechanical ventilation 01			15	4/4	419
6	mechanical ventilation 02			20	1/4	279
Results for the CIBSE London DSY2020 and DSY2050_High50pct weather file						
7	Iteration 6 with DSY2020	8	0.4	20	4/4	584
8	Iteration 6 with DSY2050	8	0.4	20	4/4	901

Performance spaces

Table 7: Results for the London DSY05 weather file – Performance spaces

Test	Iteration description	Energy efficient lighting (W/m^2)	Reduce heat entering building (g-value)	Mech. Vent. (l/s/person)	N° of thermal zones failing	Average No. of Hrs T>28°C (in °C)
0	Baseline	39			3/3	640
1	energy efficient design 01	35			3/3	453
2	energy efficient design 02	30		10	3/3	350
3	Reduce heat gain 01		0.5		3/3	305
4	Reduce heat gain 02		0.4		3/3	287
5	mechanical ventilation 01			15	3/3	149
6	mechanical ventilation 02			20	2/3	100
Results for the CIBSE London DSY2020 and DSY2050_High50pct weather file						
7	Iteration 6 with DSY2020	30	0.4	20	3/3	218
8	Iteration 6 with DSY2050	30	0.4	20	3/3	466

Public circulation spaces

Table 8: Results for the London DSY05 weather file – Public Circulation spaces

Test	Iteration description	Energy efficient lighting (W/m^2)	Reduce heat entering building (g-value)	Mech. Vent. (l/s/person)	N° of thermal zones failing	Average No. of Hrs T>25°C (in °C)
0	Baseline	10.4			14/14	2201
1	energy efficient design 01	8			14/14	2065
2	energy efficient design 02	6		10	14/14	1958
3	Reduce heat gain 01		0.5		14/14	1870
4	Reduce heat gain 02		0.4		14/14	1822
5	mechanical ventilation 01			15	14/14	1177
6	mechanical ventilation 02			20	14/14	856
Results for the CIBSE London DSY2020 and DSY2050_High50pct weather file						
7	Iteration 6 with DSY2020	6	0.4	20	14/14	1318
8	Iteration 6 with DSY2050	6	0.4	20	14/14	1778

Reception spaces

Table 9: Results for the London DSY05 weather file – Reception Spaces

Test	Iteration description	Energy efficient lighting (W/m^2)	Reduce heat entering building (g-value)	Mech. Vent. (l/s/person)	N° of thermal zones failing	Average No. of Hrs T>25°C (in °C)
0	Baseline	19.4			8/8	1277
1	energy efficient design 01	17			8/8	1219
2	energy efficient design 02	15		10	8/8	1172
3	Reduce heat gain 01		0.5		8/8	1122
4	Reduce heat gain 02		0.4		8/8	1090
5	mechanical ventilation 01			15	8/8	880
6	mechanical ventilation 02			20	1/8	718
Results for the CIBSE London DSY2020 and DSY2050_High50pct weather file						
7	Iteration 6 with DSY2020	15	0.4	20	8/8	1019
8	Iteration 6 with DSY2050	15	0.4	20	8/8	1171

Workshop spaces

Table 10: Workshop spaces

Test	Iteration description	Energy efficient lighting (W/m ²)	Reduce heat entering building (g-value)	Mech. Vent. (l/s/person)	N° of thermal zones failing	Average No. of Hrs T>28°C (in °C)
0	Baseline	18.8		10	8/8	1127
1	energy efficient design 01	15			8/8	991
2	energy efficient design 02	12			8/8	862
3	Reduce heat gain 01		0.5		8/8	745
4	Reduce heat gain 02		0.4		8/8	675
5	mechanical ventilation 01			15	8/8	469
6	mechanical ventilation 02			20	8/8	325
Results for the CIBSE London DSY2020 and DSY2050_High50pct weather file						
7	Iteration 6 with DSY2020	12	0.4	20	8/8	730
8	Iteration 6 with DSY2050	12	0.4	20	8/8	957

It should be noted that relying on natural ventilation to meet the overheating criteria would mean that the internal temperatures of the various rooms would be heavily dependent on the external conditions. This suggests that during the hours when external temperatures are over 22°C, there may be periods when the internal temperatures could exceed the threshold of 25°C due to the additional internal heat gains.

Due to the building typology and the activity profiles of the spaces (such as the auditorium), it is unlikely that natural ventilation can be used to fully mitigate the overheating risk, which is also shown to be exacerbated in future weather predictions. Furthermore, due to the city centre location of the site, utilization of natural ventilation increases the impact of external noise and pollution and creates additional energy needs to improve indoor air and acoustic quality.

Based on the method of assessment adopted, XCO2 Energy would recommend the incorporation of the overheating reduction measures detailed within the report. It is proposed that space cooling be implemented to ensure satisfactory levels of thermal comfort for the future building users.

Conclusions

The Sondheim Theatre development has been modelled with dynamic thermal simulation software to assess the risk of overheating. The evaluation has been carried out against the performance standards set out within the CIBSE Technical Memorandum 52 and using both historic (measured) as well as future (predictive) weather files. The process of the overheating analysis is in line with Policy 5.9 of the London Plan.

The assessment indicates that the application of the London Plan cooling hierarchy strategies presents a benefit to the internal conditions, but does not fully mitigate overheating risks in occupied spaces at the theatre. Due to the building typology and the specific activity profiles of the spaces (such as the auditorium), it is unlikely that natural ventilation can be used effectively to decrease internal temperatures. Furthermore, due to the city centre location of the site, utilization of natural ventilation increases the impact of external noise and pollution and creates additional energy and construction needs to improve indoor air and acoustic quality.

As such, it will be impractical to fully apply natural ventilation strategies to mitigate overheating risks and that some level of space conditioning and cooling will be preferable for the control of internal temperatures during the non-heating season.

Recommendations:

Based on the method of assessment adopted, XCO2 Energy would recommend the design team to provide active cooling within the development, and consider incorporating the following recommendations as listed below to reduce the overheating risk and energy demand for space cooling in the development as far as practicable:

- Energy efficient lighting;
- Solar control glazing with a g-value of 0.4;
- Potentially increased mechanical ventilation capacity (to be confirmed with Mechanical Engineer).

Appendix – Detailed results

This appendix details the results for each overheating criterion for simulations for the Auditorium spaces as an example of the assessment conducted. The detailed results for all simulated spaces can be provided upon request.

Weather file: CIBSE London DSY05 for Auditorium spaces

Test	Room thermal zone name		Criteria 1 (%Hrs Top-Tmax>=1°C)	Criteria 2 (Max. Daily Deg.Hrs)	Criteria 3 (Max. DeltaT)	Criteria failing
Iteration 0	Auditoria	Sprague room	27.9	36	6	1 & 2 & 3
	Auditoria	Stalls-lower	41.6	44	7	1 & 2 & 3
	Auditoria	Stalls-upper	40.6	44	7	1 & 2 & 3
	Auditoria	BoxA	39.2	43	7	1 & 2 & 3
	Auditoria	BoxB	41.7	44	7	1 & 2 & 3
	Auditoria	Circle	40.9	43	7	1 & 2 & 3
	Auditoria	Slips	39.6	43	7	1 & 2 & 3
	Auditoria	BoxC	40	44	7	1 & 2 & 3
	Auditoria	BoxD	40.1	43	7	1 & 2 & 3
	Auditoria	Slips	39.2	43	7	1 & 2 & 3
	Auditoria	BoxE	42.8	44	7	1 & 2 & 3
	Auditoria	BoxF	41.5	44	7	1 & 2 & 3
	Auditoria	Upper-circle	42.5	44	7	1 & 2 & 3
	Auditoria	Slips	38.9	41	7	1 & 2 & 3
	Auditoria	BoxG	39.6	42	7	1 & 2 & 3
	Auditoria	BoxH	40.2	43	7	1 & 2 & 3
	Auditoria	Slips	39	42	7	1 & 2 & 3
	Auditoria	BoxJ	40.5	44	7	1 & 2 & 3
	Auditoria	BoxK	41.2	44	7	1 & 2 & 3
Iteration 1	Auditoria	Sprague room	16.8	29	5	1 & 2 & 3
	Auditoria	Stalls-lower	29	37	6	1 & 2 & 3
	Auditoria	Stalls-upper	28.2	37	6	1 & 2 & 3
	Auditoria	BoxA	27.3	36	6	1 & 2 & 3
	Auditoria	BoxB	29.4	38	6	1 & 2 & 3
	Auditoria	Circle	28.4	36	6	1 & 2 & 3
	Auditoria	Slips	27.4	36	6	1 & 2 & 3
	Auditoria	BoxC	28.1	37	6	1 & 2 & 3
	Auditoria	BoxD	27.8	36	6	1 & 2 & 3
	Auditoria	Slips	27.5	36	6	1 & 2 & 3
	Auditoria	BoxE	29.7	37	6	1 & 2 & 3
	Auditoria	BoxF	29.3	37	6	1 & 2 & 3
	Auditoria	Upper-circle	30	37	6	1 & 2 & 3
	Auditoria	Slips	26.7	35	6	1 & 2 & 3
	Auditoria	BoxG	27.6	35	6	1 & 2 & 3
	Auditoria	BoxH	28.3	37	6	1 & 2 & 3
	Auditoria	Slips	27	35	6	1 & 2 & 3
	Auditoria	BoxJ	28.7	37	6	1 & 2 & 3
	Auditoria	BoxK	29	37	6	1 & 2 & 3
Iteration 2	Auditoria	Sprague room	11.9	28	5	1 & 2 & 3
	Auditoria	Stalls-lower	22.4	34	6	1 & 2 & 3
	Auditoria	Stalls-upper	22.2	34	6	1 & 2 & 3
	Auditoria	BoxA	20.5	33	5	1 & 2 & 3
	Auditoria	BoxB	23.4	34	6	1 & 2 & 3

	Auditoria	Circle	21.9	34	6	1 & 2 & 3
	Auditoria	Slips	20.4	32	5	1 & 2 & 3
	Auditoria	BoxC	21	32	5	1 & 2 & 3
	Auditoria	BoxD	21.1	33	5	1 & 2 & 3
	Auditoria	Slips	20.6	33	5	1 & 2 & 3
	Auditoria	BoxE	23.9	34	6	1 & 2 & 3
	Auditoria	BoxF	23.1	34	6	1 & 2 & 3
	Auditoria	Upper-circle	23.7	34	6	1 & 2 & 3
	Auditoria	Slips	20.1	32	5	1 & 2 & 3
	Auditoria	BoxG	20.5	32	5	1 & 2 & 3
	Auditoria	BoxH	21	32	5	1 & 2 & 3
	Auditoria	Slips	20.4	32	5	1 & 2 & 3
	Auditoria	BoxJ	21.7	33	5	1 & 2 & 3
	Auditoria	BoxK	22.6	33	5	1 & 2 & 3
Iteration 3	Auditoria	Sprague room	10.7	27	5	1 & 2 & 3
	Auditoria	Stalls-lower	20	32	5	1 & 2 & 3
	Auditoria	Stalls-upper	19.8	32	5	1 & 2 & 3
	Auditoria	BoxA	18.4	30	5	1 & 2 & 3
	Auditoria	BoxB	20.2	33	5	1 & 2 & 3
	Auditoria	Circle	19.6	31	5	1 & 2 & 3
	Auditoria	Slips	17.9	30	5	1 & 2 & 3
	Auditoria	BoxC	18	30	5	1 & 2 & 3
	Auditoria	BoxD	18.3	30	5	1 & 2 & 3
	Auditoria	Slips	18.1	30	5	1 & 2 & 3
	Auditoria	BoxE	20	31	5	1 & 2 & 3
	Auditoria	BoxF	20	32	5	1 & 2 & 3
	Auditoria	Upper-circle	20.4	32	5	1 & 2 & 3
	Auditoria	Slips	16.6	30	5	1 & 2 & 3
	Auditoria	BoxG	17.3	30	5	1 & 2 & 3
	Auditoria	BoxH	18.1	30	5	1 & 2 & 3
	Auditoria	Slips	16.9	30	5	1 & 2 & 3
	Auditoria	BoxJ	18.6	30	5	1 & 2 & 3
	Auditoria	BoxK	19	30	5	1 & 2 & 3
Iteration 4	Auditoria	Sprague room	10	26	4	1 & 2
	Auditoria	Stalls-lower	18.8	30	5	1 & 2 & 3
	Auditoria	Stalls-upper	18.3	30	5	1 & 2 & 3
	Auditoria	BoxA	16.8	30	5	1 & 2 & 3
	Auditoria	BoxB	18.9	30	5	1 & 2 & 3
	Auditoria	Circle	18	30	5	1 & 2 & 3
	Auditoria	Slips	15.8	30	5	1 & 2 & 3
	Auditoria	BoxC	16.3	30	5	1 & 2 & 3
	Auditoria	BoxD	17	30	5	1 & 2 & 3
	Auditoria	Slips	15.9	30	5	1 & 2 & 3
	Auditoria	BoxE	18.4	30	5	1 & 2 & 3
	Auditoria	BoxF	18.6	30	5	1 & 2 & 3
	Auditoria	Upper-circle	18.7	30	5	1 & 2 & 3
	Auditoria	Slips	14.9	29	5	1 & 2 & 3
	Auditoria	BoxG	15.1	30	5	1 & 2 & 3
	Auditoria	BoxH	15.5	30	5	1 & 2 & 3
	Auditoria	Slips	14.9	29	5	1 & 2 & 3
	Auditoria	BoxJ	16.5	30	5	1 & 2 & 3
	Auditoria	BoxK	17.6	30	5	1 & 2 & 3

Iteration 5	Auditoria	Sprague room	4.7	21	4	1 & 2
	Auditoria	Stalls-lower	7	24	4	1 & 2
	Auditoria	Stalls-upper	7	24	4	1 & 2
	Auditoria	BoxA	6.3	23	4	1 & 2
	Auditoria	BoxB	7	24	4	1 & 2
	Auditoria	Circle	6.6	24	4	1 & 2
	Auditoria	Slips	6.3	22	4	1 & 2
	Auditoria	BoxC	6.3	22	4	1 & 2
	Auditoria	BoxD	6.3	22	4	1 & 2
	Auditoria	Slips	6.3	22	4	1 & 2
	Auditoria	BoxE	6.5	24	4	1 & 2
	Auditoria	BoxF	6.5	24	4	1 & 2
	Auditoria	Upper-circle	6.8	24	4	1 & 2
	Auditoria	Slips	5.8	22	4	1 & 2
	Auditoria	BoxG	6	22	4	1 & 2
	Auditoria	BoxH	6.2	22	4	1 & 2
	Auditoria	Slips	5.7	22	4	1 & 2
	Auditoria	BoxJ	6.2	22	4	1 & 2
	Auditoria	BoxK	6.4	22	4	1 & 2
Iteration 6	Auditoria	Sprague room	3	17	3	2
	Auditoria	Stalls-lower	4.7	19	4	1 & 2
	Auditoria	Stalls-upper	4.5	20	4	1 & 2
	Auditoria	BoxA	4.3	19	4	1 & 2
	Auditoria	BoxB	4.8	20	4	1 & 2
	Auditoria	Circle	4.5	19	4	1 & 2
	Auditoria	Slips	4.1	19	4	1 & 2
	Auditoria	BoxC	4.1	19	4	1 & 2
	Auditoria	BoxD	4.2	19	4	1 & 2
	Auditoria	Slips	4.1	19	4	1 & 2
	Auditoria	BoxE	4.5	20	4	1 & 2
	Auditoria	BoxF	4.5	19	4	1 & 2
	Auditoria	Upper-circle	4.7	20	4	1 & 2
	Auditoria	Slips	3.7	17	3	1 & 2
	Auditoria	BoxG	3.8	19	4	1 & 2
	Auditoria	BoxH	3.9	19	4	1 & 2
	Auditoria	Slips	3.8	19	4	1 & 2
	Auditoria	BoxJ	4	20	4	1 & 2
	Auditoria	BoxK	4.3	20	4	1 & 2

Weather file: CIBSE London DSY2020_High50pct

Test	Room thermal zone name		Criteria 1 (%Hrs Top-Tmax>=1°C)	Criteria 2 (Max. Daily Deg.Hrs)	Criteria 3 (Max. DeltaT)	Criteria failing
Iteration 7	Auditoria	Sprague room	4.5	22	4	1 & 2
	Auditoria	Stalls-lower	8.1	26	4	1 & 2
	Auditoria	Stalls-upper	7.8	26	4	1 & 2
	Auditoria	BoxA	7.2	24	4	1 & 2
	Auditoria	BoxB	8.2	26	4	1 & 2
	Auditoria	Circle	7.7	25	4	1 & 2
	Auditoria	Slips	6.5	24	4	1 & 2
	Auditoria	BoxC	6.8	24	4	1 & 2
	Auditoria	BoxD	6.9	25	4	1 & 2
	Auditoria	Slips	7.2	25	4	1 & 2
	Auditoria	BoxE	7.7	25	4	1 & 2
	Auditoria	BoxF	7.7	25	4	1 & 2
	Auditoria	Upper-circle	8.2	26	4	1 & 2
	Auditoria	Slips	6.3	24	4	1 & 2
	Auditoria	BoxG	6.4	24	4	1 & 2
	Auditoria	BoxH	6.6	24	4	1 & 2
	Auditoria	Slips	6.4	24	4	1 & 2
	Auditoria	BoxJ	6.8	24	4	1 & 2
	Auditoria	BoxK	7.2	25	4	1 & 2

Weather file: CIBSE London DSY2050_High50pct

Test	Room thermal zone name		Criteria 1 (%Hrs Top-Tmax>=1°C)	Criteria 2 (Max. Daily Deg.Hrs)	Criteria 3 (Max. DeltaT)	Criteria failing
Iteration 8	Auditoria	Sprague room	12	31	5	1 & 2 & 3
	Auditoria	Stalls-lower	20.6	35	6	1 & 2 & 3
	Auditoria	Stalls-upper	19.8	33	5	1 & 2 & 3
	Auditoria	BoxA	18.9	33	5	1 & 2 & 3
	Auditoria	BoxB	20.8	35	6	1 & 2 & 3
	Auditoria	Circle	19.5	33	5	1 & 2 & 3
	Auditoria	Slips	18.8	32	5	1 & 2 & 3
	Auditoria	BoxC	19.3	32	5	1 & 2 & 3
	Auditoria	BoxD	19.2	33	5	1 & 2 & 3
	Auditoria	Slips	19.3	33	5	1 & 2 & 3
	Auditoria	BoxE	20.8	33	5	1 & 2 & 3
	Auditoria	BoxF	20.1	33	5	1 & 2 & 3
	Auditoria	Upper-circle	20.8	33	5	1 & 2 & 3
	Auditoria	Slips	17.7	32	5	1 & 2 & 3
	Auditoria	BoxG	18.4	32	5	1 & 2 & 3
	Auditoria	BoxH	19.1	32	5	1 & 2 & 3
	Auditoria	Slips	18.2	32	5	1 & 2 & 3
	Auditoria	BoxJ	19.4	32	5	1 & 2 & 3
	Auditoria	BoxK	19.7	33	5	1 & 2 & 3