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A DYNAMIC THERMAL MODELLING STUDY OF A TYPICAL METAL CLAD BUILDING TO EVALUATE OVERHEATING IN THE UNITED KINGDOM

THE METAL CLADDING & ROOFING MANUFACTURERS ASSOCIATION

IN PARTNERSHIP WITH

NATIONAL ASSOCIATION OF ROOFLIGHT MANUFACTURERS

The Building Envelope Authority

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Contact:
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Report 090110BRE

A dynamic thermal modelling study of a typical metal clad building to evaluate overheating in the UK

Clients

Metal Cladding and Roofing Manufacturers Association (MCRMA) and National Association of Rooflight Manufacturers (NARM)

Oxford
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Summary

A typical modern portal frame warehouse building with in-plane GRP rooflights was modelled using Tas and Lumen Designer software to assess annual heating loads and summertime thermal comfort in the south of the UK. The effects of rooflight area, ventilation strategy and stratification were assessed.

Various combinations of ventilation strategy to reduce internal temperatures in the summer were investigated, including natural ventilation through cargo doors and/or ridge vents, and mechanical ventilation. The effect of ventilation was found to be critical, and by far the greatest effect on overheating risk.

The 'base case' building incorporated 10% rooflights; the effects of increasing rooflights to 14%, or eliminating rooflights were investigated. Use of daylight through rooflights offers major benefits to the internal environment within a metal clad building, as well as potential savings in energy use, running cost and CO_2 emissions. Use of 14% rooflights reduces lighting load by approximately 40% from that of a portal frame building with no rooflights, whilst beneficial solar gain also counteract the additional heat losses from the rooflights, resulting in heating loads only marginally greater. It was found that total CO_2 emissions (heating and lighting) are reduced by 30% (14% rooflights) when rooflights are used with dimmable lighting because the saving in lighting electricity far outweighs the additional heating. However, the daylighting benefit is at the expense of some increase in summertime overheating risk.

Stratification was investigated by assessing temperature on an imaginary mezzanine floor. Temperatures were found to be lower at floor level than at high level, but not to a high extent.

It was found that overheating occurred for the unventilated base case. However, introduction of some natural ventilation just by opening cargo doors and personnel doors was sufficient to avoid overheating, with temperatures kept down to acceptable levels (less than 1% of occupied hours above 28°C) at ground level.

It was found that rooflight area had some effect on overheating risk: eliminating rooflights reduces risk of overheating (although not a viable solution to most practical cases) whilst increasing rooflight area from 10% to 14% did show an increase in internal temperatures. However, this was a secondary effect in comparison to ventilation strategy, which had a far greater effect; a well ventilated building with good daylighting through 10-14% rooflights had lower risk of overheating than a non-ventilated building without rooflights.

Introduction of ventilation by leaving cargo doors open was found to have a significant effect on internal temperatures. Ridge vents had less effect on their own but offered more benefit when used with open cargo doors to allow increased throughput of air. Ridge vents that were left open at night had some effect, although this was minimal. Mechanical ventilation was found to offer some benefit, although less effective than cargo doors in conjunction with ridge vents, whilst plant size and consequent energy consumption is a deterrent to its use in practice.

The Building Regulations Solar Overheating criterion was investigated. ADL2 suggests total internal gains should not exceed 35W/m^{2}K when averaged over a specified period. Application of the approximate method in CIBSE TM37 (Design for Improved Solar Shading Control) indicated that this figure is not exceeded for a metal clad building with either 10% or 14% rooflights. The Tas modelling results agree closely.

However, buildings with higher internal loads, such as retail display lighting and/or much higher occupancy levels, can give risk of overheating unless alternative precautions are taken.

Introduction

The objective of this study was to better understand the extent of overheating likely with current metal clad portal frame buildings when rooflights are used. In particular, the temperature at different levels due to stratification within the occupied space needs to be determined. Various mitigation strategies will also be investigated using natural/mechanical ventilation at high and low level.

1. The Model: Weather, geometry and internal conditions

1.1 Weather/Location
The building is located in Southern England, so that CIBSE Design Summer Year (London DSY) weather file is used for thermal modelling.

1.2. Geometry
The building has two bays, each with a 6° duopitch roof, and is 60m in length, 40m in width and 7m height (floor to eave).

There is an office area in one corner of the building with a floor area of 120m^2 (6mx20m) with two storeys (floor height is 3m each).

Two cases are modelled: 10% and 14% nominal rooflight area, which are detailed in the table below. A 'frame' (overlap with opaque cladding) of 12.75% area was assumed.

Case	Nominal	Glazing	Glazing dimensions (m^2)	Number of rooflights
1	10%	8.75%	4.5m×0.925m	48
2	14%	12.25%	6.3m×0.925m	48

Table 1. Rooflight dimensions

Including frames, the total rooflight area for 10% case is 227m^2, for 14% case is 319m^2. There are no rooflights on the roof of the office area. External surfaces are all goosewing (mid) grey.

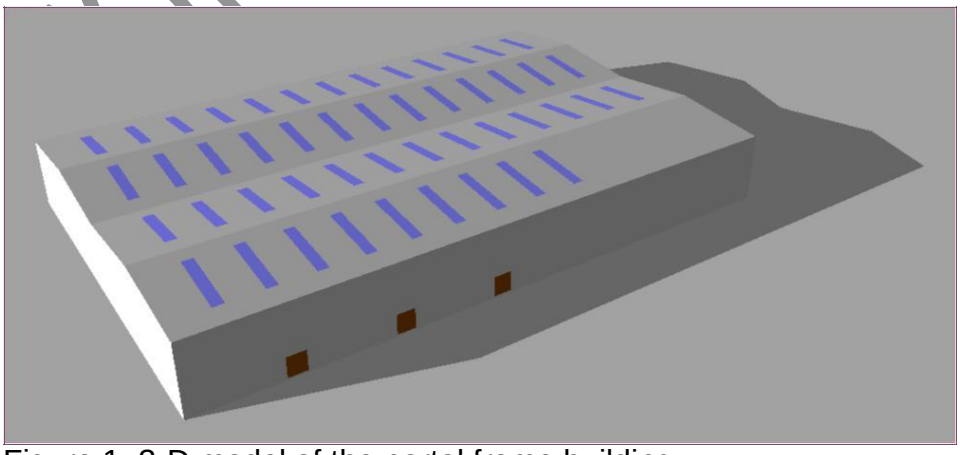


Figure 1. 3-D model of the portal frame building

1.3. Construction

The warehouse is of portal frame construction and is clad with profiled metal sheeting insulated as follows:

Roof cladding:	U-value = 0.25W/m^{2}K.
External wall cladding:	U-value = 0.35W/m^{2}K.
Ground floor (concrete floor):	U-value = 0.25 W/m^{2}K.
Internal wall (office use):	U-value = 0.83W/m^{2}K.

The rooflights consist of two layers of GRP with an intermediate insulating layer giving a U-value of 1.3 W/m^{2}K.

Optical properties of rooflight samples have been determined by an independent laboratory and combined by methods set out in BS EN ISO 410 to give properties for the rooflight construction: a visible light transmission of 0.47 and a solar gain factor (g-value) of 0.47 were calculated for the rooflight construction used.

1.4. Internal conditions

Twenty four hour, seven days per week occupation was assumed, with heating to 19°C (no heat mid-June to mid-September). There is no air conditioning. Air infiltration was calculated assuming an air permeability of 7.5 m^3/h per square metre total envelope area at 50Pa pressure differential.

1.4.1. Infiltration rate

7.5m3/h/m2@50Pa (Q_{50}/S)

$$I = \frac{1}{20} \frac{S}{V} Q_{50}$$

Inner Volume V = 17540m^3; Surface area S (excluding floor area) = 3855.2m^2
Thus air infiltration I=0.08 air changes per hour (ach). I=0.1 is used.

1.4.2. People

20 people, with heat outputs from CIBSE Guide A below (in table):

People	20°C		22°C	
Loads type (in W)	Apparent	Latent	Apparent	Latent
Light bench work (factory)	130	105	115	120
Medium bench work	140	125	125	140

Table 2. Heat gains from people (CIBSE Guide A)

For twenty people, apparent gain = 2600W, latent gain =2000W.
Portal frame building floor area = 2280m^2.
An apparent (sensible) heat gain of 1.2W/m^2 and latent gain of 0.9W/m^2 is used.

1.4.3. Lighting control

Auto control/dimmed;
Photocell control dimming;
Maximum light gain: 5.6W/m^2;
Target Room Illuminance: 350lux.

2. Daylight modelling

Lumen Designer was used to investigate the daylighting (illuminance distribution) on the floor.

2.1. Orientation of the building

There was found to be little difference of average daylight factor across whole building area (excluding offices) between different orientations of the building because of the very shallow slope of the roof. Therefore, thermal modelling was based on the long axis running **east-west.**

2.2. Daylight modelling results

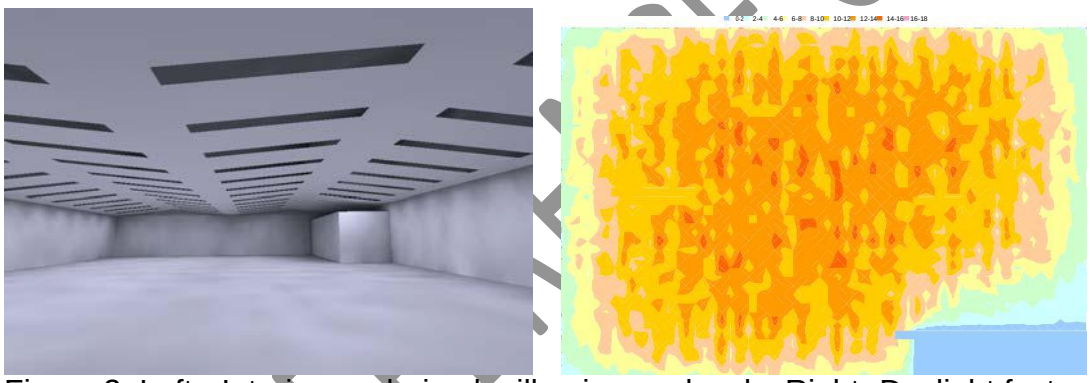


Figure 2. Left - Interior rendering by illuminance levels; Right -Daylight factor distribution on the floor (excluding the office at right bottom corner)

Nominal rooflight percentage	Average daylight factor (%)
14%	5.60
10%	3.41

Table 3. Daylight factor for different rooflight percentages

3. Thermal modelling

3.1. Method

A dynamic thermal model was created using TAS software, integrating daylight analysis results from Lumen Designer. A daylight availability analysis enabled the extent of artificial lighting to be controlled automatically to maintain 350lux. With realistic levels of interior heat gains from people, lights and equipment, and with solar radiation accounted for, the temperatures can be determined throughout the year at ground and mezzanine floor level.
Overheating is investigated by graphs showing percentage of temperature excess hours. Both mechanical ventilation and natural ventilation are investigated in this study.

3.2. Natural Ventilation

Natural ventilation includes cargo doors and ridge vents and the combination of these two. The temperature for opening cargo doors is set to 20ºC. The dimensions of natural ventilation openings are summarised in the following table.

Openings	Area (m^2)	Percentage of wall/floor area
Cargo doors	49.3	3.52% (of wall)
Personnel doors	10.8	0.77% (of wall)
Ridge vents	40.0	1.67% (of floor)

Table 4. Natural ventilation openings

An additional natural ventilation scheme allowed for ridge vents opening on summer nights.

3.3. Mechanical ventilation

Mechanical ventilation is set at 2.5ach, supplying outside air to the ground floor zone and exhausting from the roof zone.

4. Thermal modelling results for Case 1 (10% rooflights)

4.1. Summary of loads and CO_2 emissions

Table 5. Loads summary (kWh/m^2 per year): 10% rooflights

	Heating	Solar	People/ Equipment	Lighting
Base case	22.23	34.22	10.18	29.89
Base case without rooflights	16.85	0.00	10.18	49.06
Mechanical ventilation	22.32	34.22	10.18	29.89
Natural ventilation (by cargo doors)	22.50	34.22	10.18	29.89
Natural ventilation (by ridge openings)	22.57	34.22	10.18	29.89
Natural ventilation (cargo doors + ridge openings)	22.69	34.22	10.18	29.89
Natural ventilation (cargo doors + ridge NIGHT)	22.70	34.22	10.18	29.89

Table 6. CO_2 emissions (kg/m^2 per year): 10% rooflights

	Heating	Lighting
Base case	5.39	13.21
Base case without rooflights	4.17	21.68
Mechanical ventilation	5.41	13.21
Natural ventilation (by cargo doors)	5.46	13.21
Natural ventilation (by ridge openings)	5.47	13.21
Natural ventilation (cargo doors + ridge openings)	5.50	13.21
Natural ventilation (cargo doors + ridge NIGHT openings)	5.51	13.21

4.2. Monthly loads

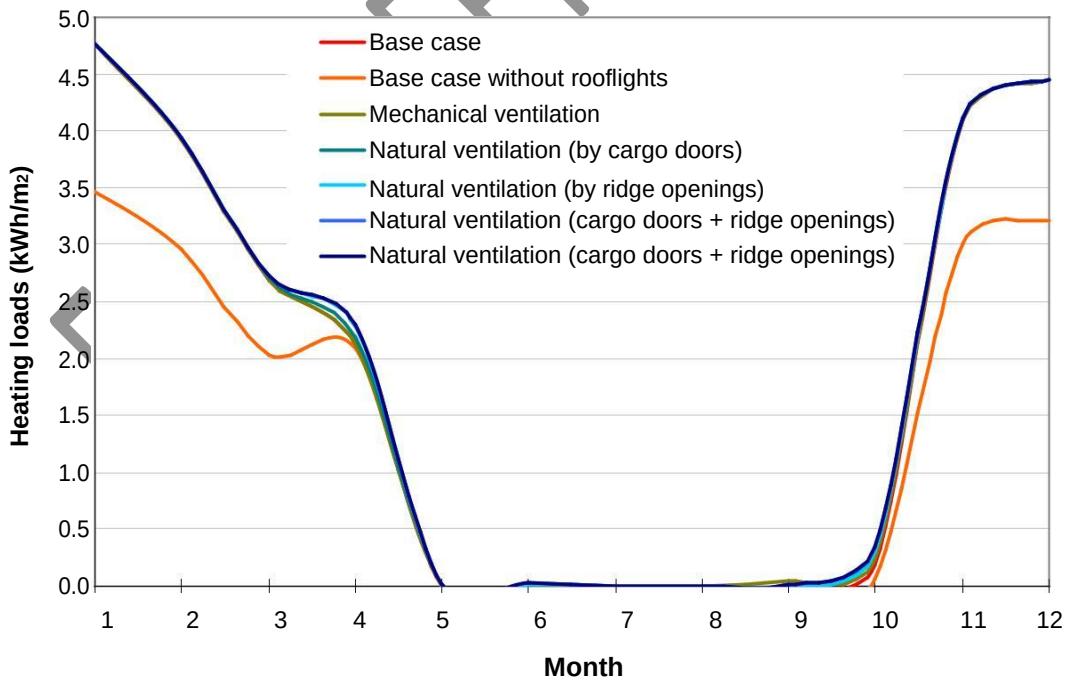


Figure 3.Monthly heating loads for different ventilation schemes: 10% rooflights

Ventilation scheme has little effect upon heating loads, and any variations can be ascribed to lack of optimisation of heating control (some heating may be applied at the same time as ventilation).

4.3. Overheating (ground floor)

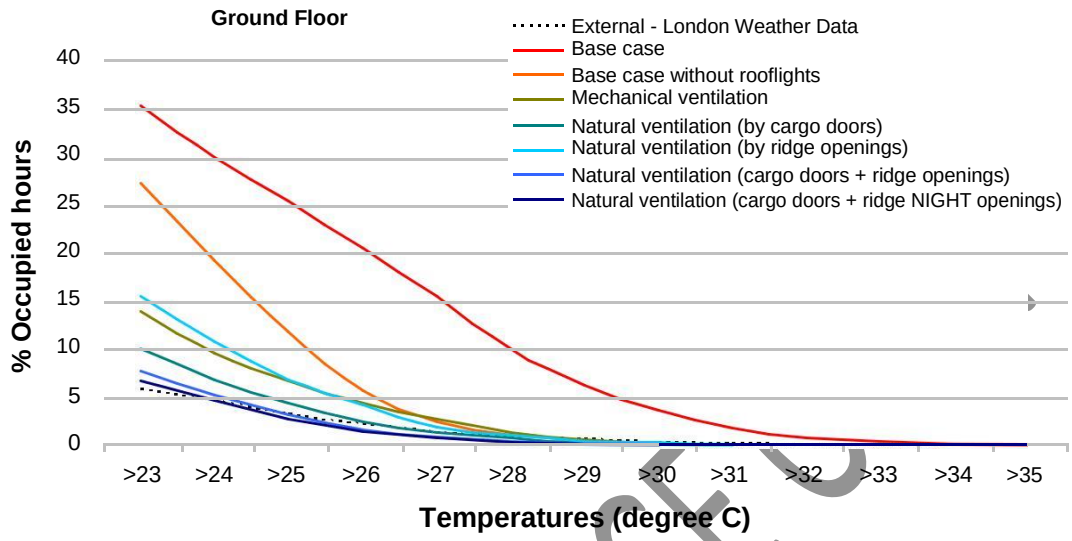


Figure 4. Ground floor overheating: 10% rooflights

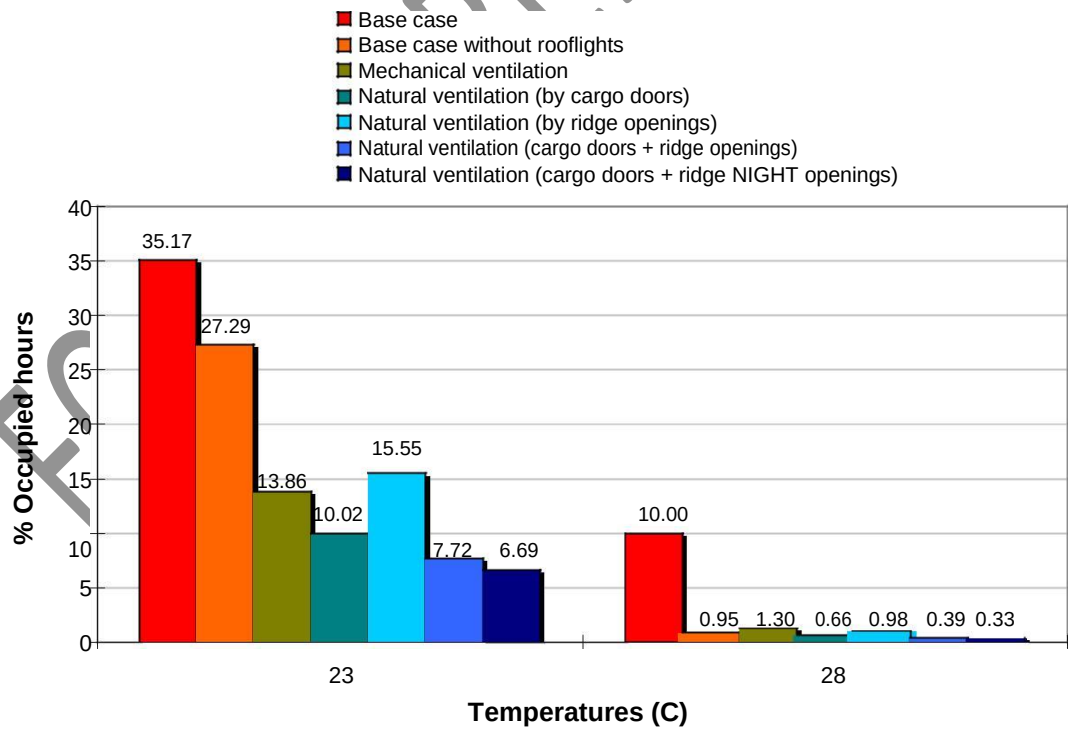


Figure 5. Percentage of occupied hours over certain temperatures: 10% rooflights

The base case shows significant risk of overheating when there is no ventilation. Elimination of rooflights does reduce the risk of overheating, although this would result in a significant increase in energy use, running costs and resultant CO_2 emissions and would have a serious effect upon the internal environment for occupants. Introduction of natural ventilation through open cargo doors has a much greater effect and ensures lower risk of overheating. This example building with 10% rooflights would not exceed 28°C for more than 1% of occupied hours. Ridge vents are less effective on their own, but would also substantially decrease overheating risk. However, ridge vents in conjunction with cargo doors allows cross-flow ventilation and gives the best results.

4.4. Overheating (mezzanine)

The effect of stratification was investigated by analysing temperatures at a notional mezzanine level.

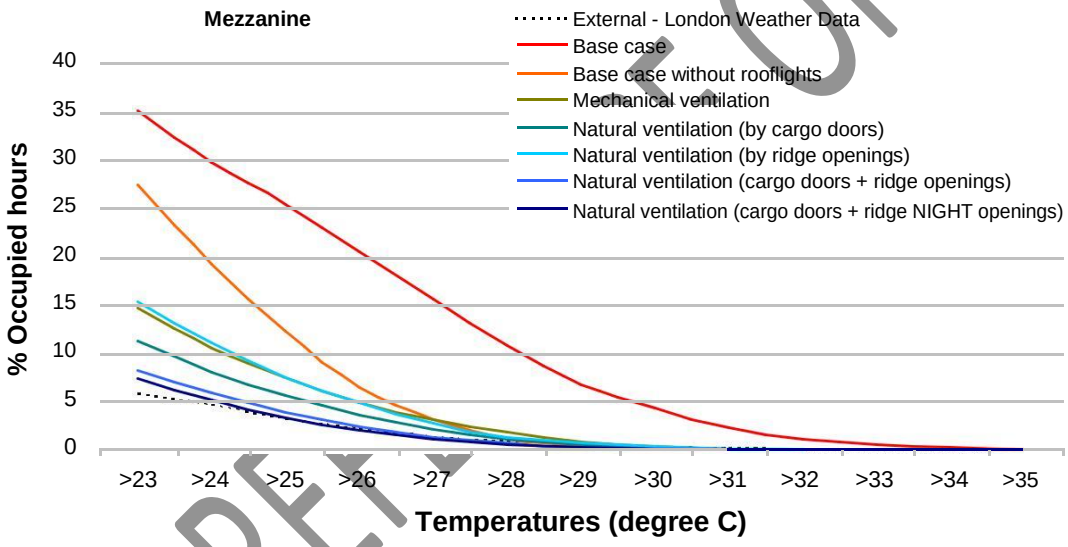


Figure 6. Mezzanine floor overheating: 10% rooflights

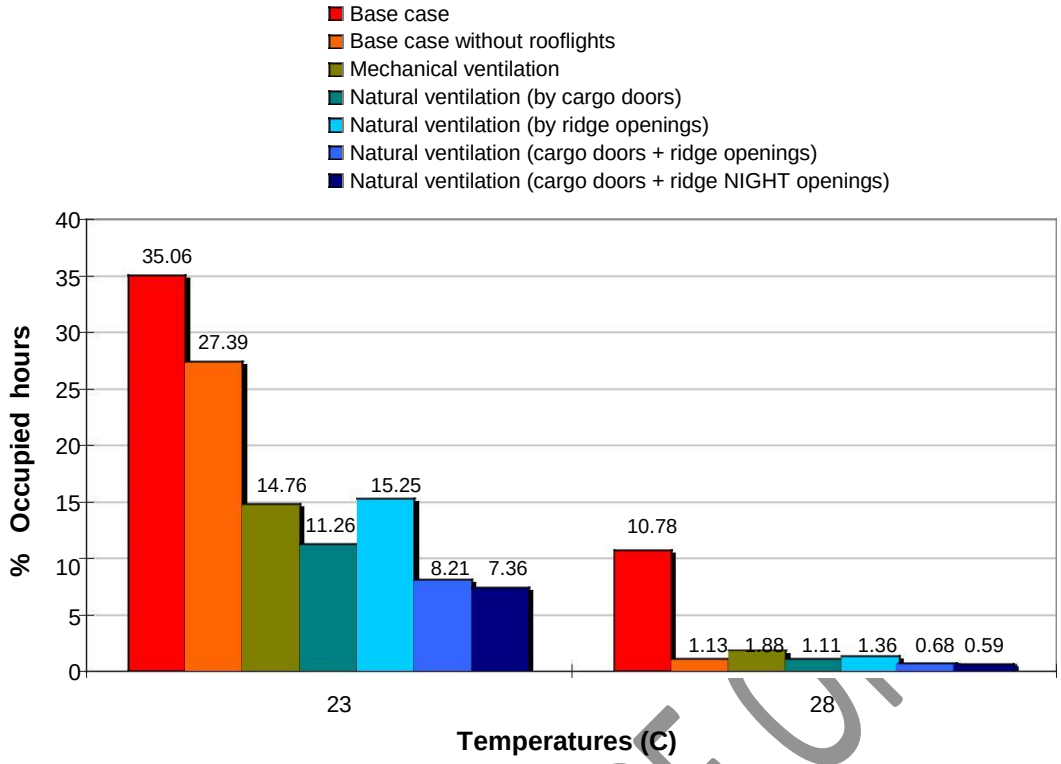


Figure 7.Percentage of occupied hours over certain temperatures: 10% rooflights

The mezzanine floor level is subject to higher temperatures than the ground floor, but thermal comfort remains close to an acceptable level.

4.5. Temperatures for three warmest days

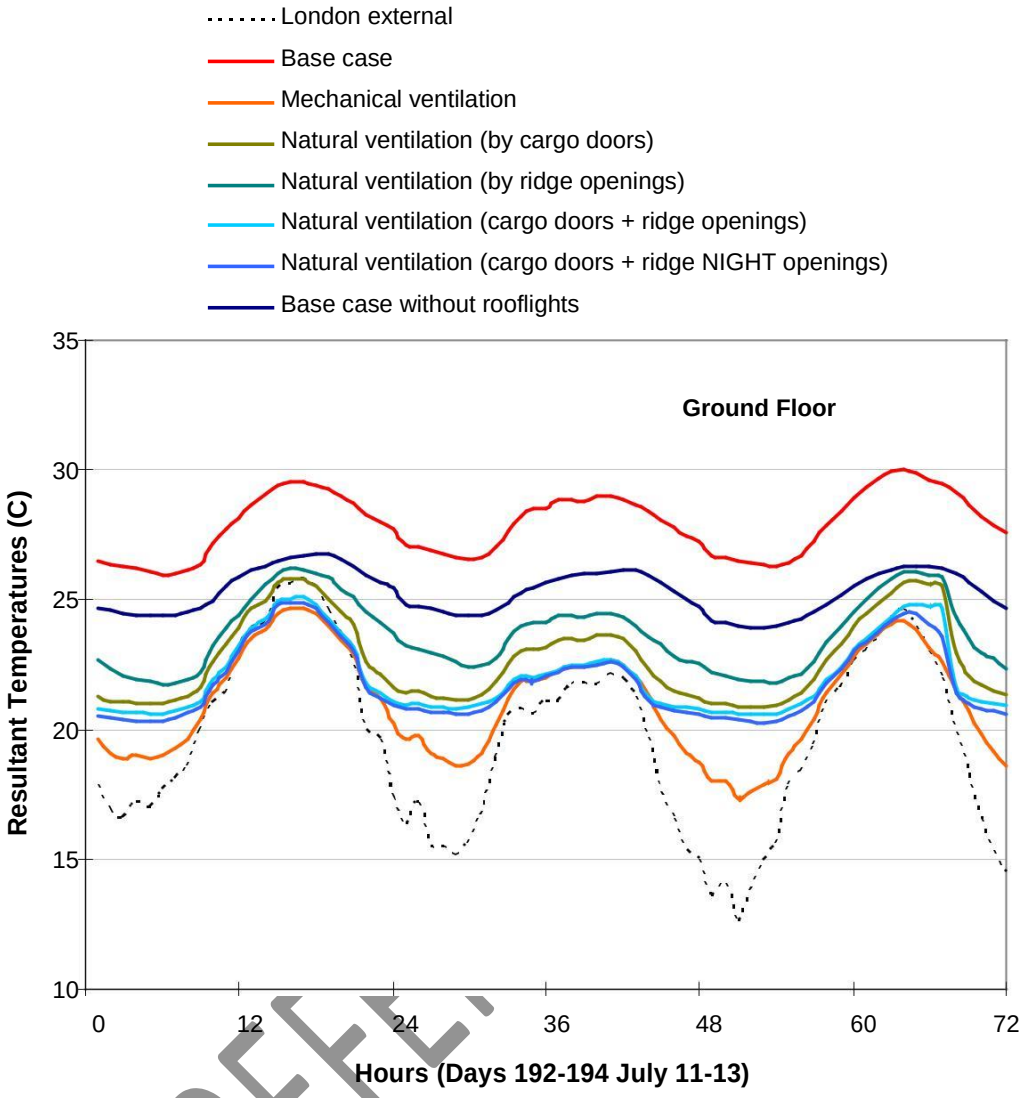


Figure 8. Resultant temperatures on ground floor for three warmest days: 10% rooflights

Mechanical ventilation is most effective at reducing temperatures overnight. However, using natural ventilation (cargo doors and ridge vents) keeps daytime peak resultant temperatures as low as achieved by mechanical ventilation. The unventilated building (with or without rooflights) gets significantly hotter than any of the ventilated cases, demonstrating that ventilation strategy is critical, and is of greater significance than rooflight area (up to a point) in avoiding overheating. The example building with 10% rooflights, ventilated with cargo doors and ridge vents, does not exceed 25°C resultant temperature of any of the three warmest days.

5. Thermal modelling results for Case 2 (14% rooflights)

5.1. Summary of loads and CO_2 emissions

Table 7. Loads summary (kWh/m^2 per year): 14% rooflights

	Heating	Solar	People/ Equipment	Lighting
Base case	22.69	48.09	10.18	28.14
Base case without rooflights	16.85	0.00	10.18	49.06
Mechanical ventilation	22.79	48.09	10.18	28.14
Natural ventilation (by cargo doors)	23.09	48.09	10.18	28.14
Natural ventilation (by ridge openings)	23.19	48.09	10.18	28.14
Natural ventilation (cargo doors + ridge openings)	23.32	48.09	10.18	28.14
Natural ventilation (cargo doors + ridge NIGHT)	23.33	48.09	10.18	28.14

Table 8.CO_2 emissions (kg/m^2 per year): 14% rooflights

	Heating	Lighting
Base case	5.50	12.44
Base case without rooflights	4.09	21.68
Mechanical ventilation	5.53	12.44
Natural ventilation (by cargo doors)	5.60	12.44
Natural ventilation (by ridge openings)	5.62	12.44
Natural ventilation (cargo doors + ridge openings)	5.65	12.44
Natural ventilation (cargo doors + ridge NIGHT openings)	5.66	12.44

5.2. Monthly loads

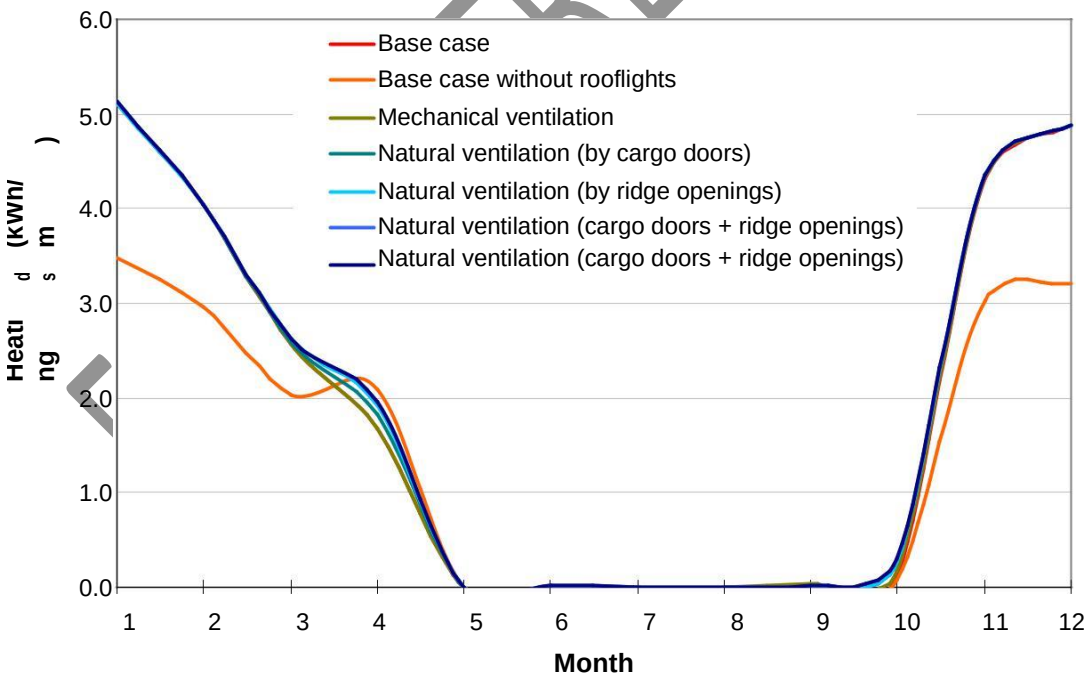


Figure 9. Monthly heating loads: 14% rooflights

This graph shows very similar results to Figure 3 (10% rooflights), as heating loads are not significantly affected by rooflight area.

5.3. Overheating (ground floor)

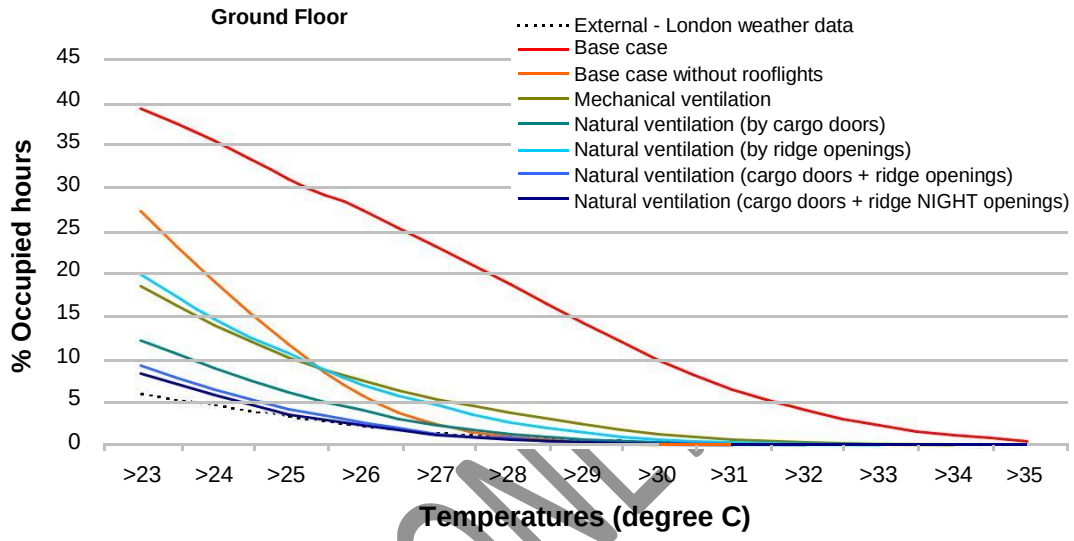


Figure 10. Ground floor overheating: 14% rooflights

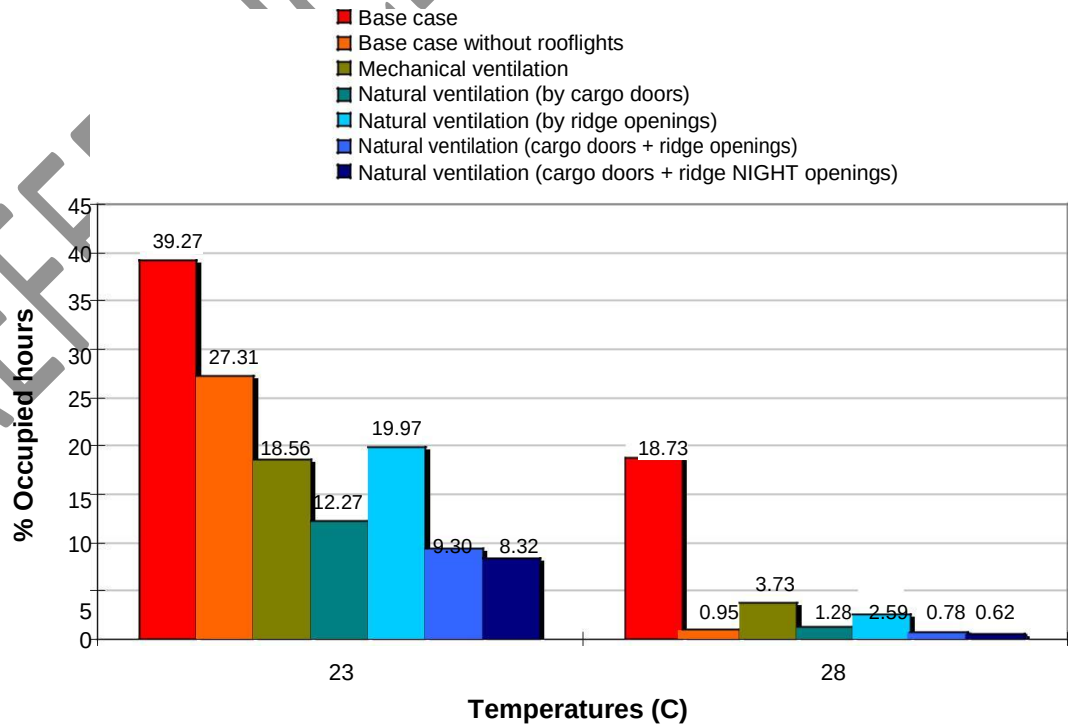


Figure 11.Percentage of occupied hours over certain temperatures: 14% rooflights

These graphs shows similar results to Figures 4 and 5 (10% rooflights). There is a significant risk of overheating in the unventilated base case. Eliminating rooflights does reduce the risk of overheating, but at the cost of increased energy consumption, running costs and CO2 emissions together with a poorer

internal environment. Even at 14% rooflights, natural ventilation through cargo doors has a greater effect and ensures lower risk of overheating. Ridge vents are less effective on their own, but, when combined with open cargo doors, give the best results, and this example building with 14% rooflights would not exceed 28C for more than 1% of occupied hours.

5.4. Overheating (mezzanine)

The effect of stratification was investigated by analysing temperatures at a notional mezzanine level.

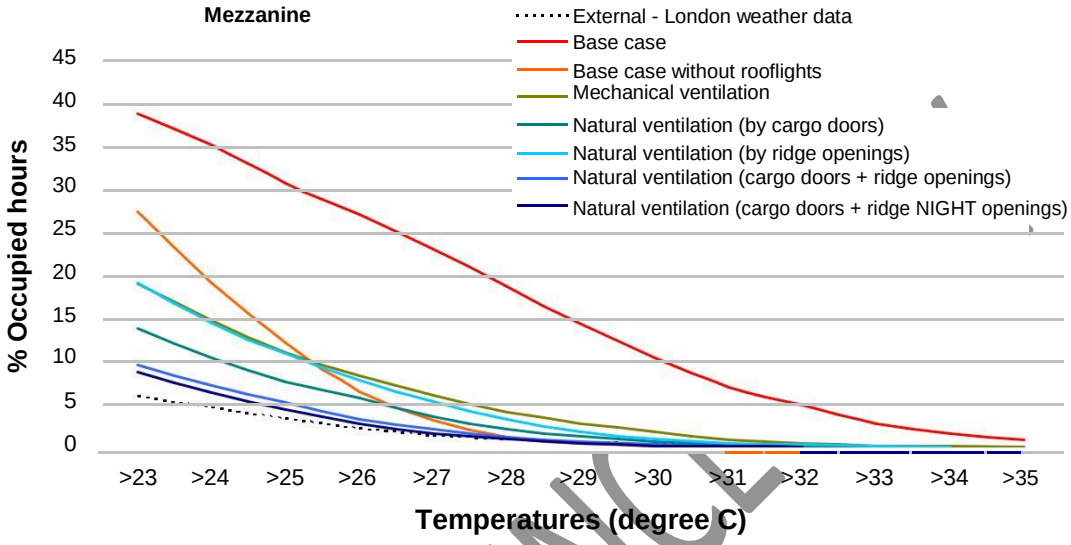


Figure 12. Mezzanine floor overheating: 14% rooflights

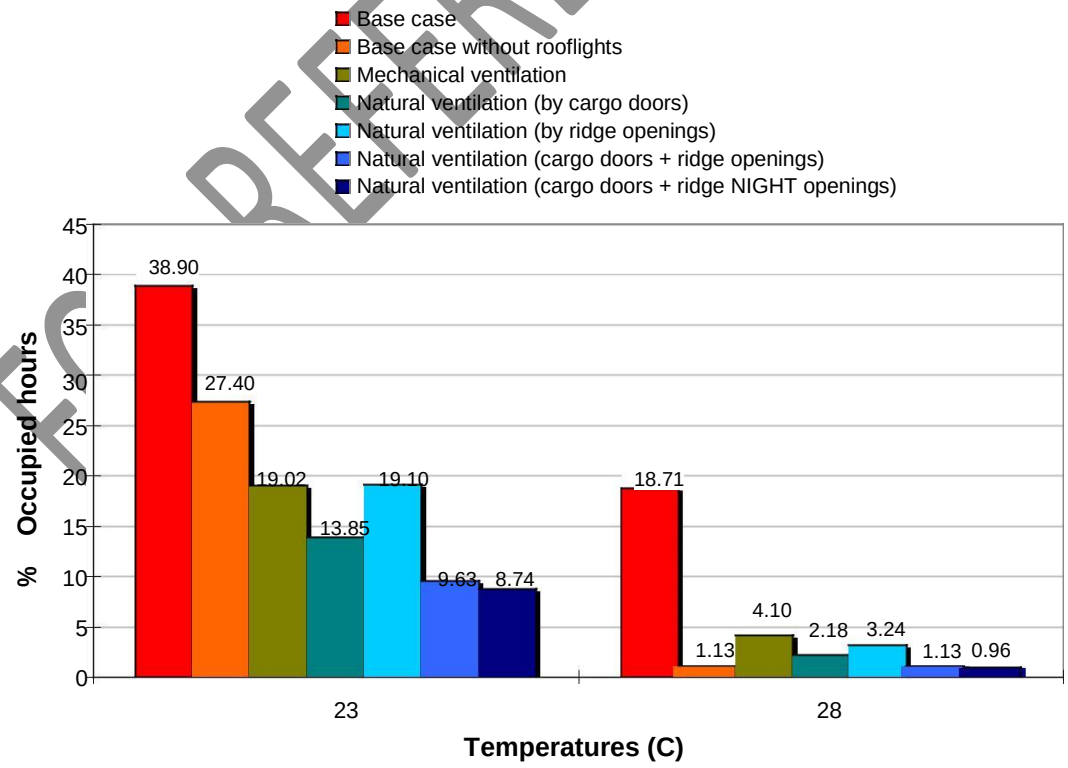


Figure 13.Percentage of occupied hours over certain temperatures: 14% rooflights

The model does show higher temperatures at mezzanine level, indicating some thermal stratification.

5.5. Temperatures for three warmest days

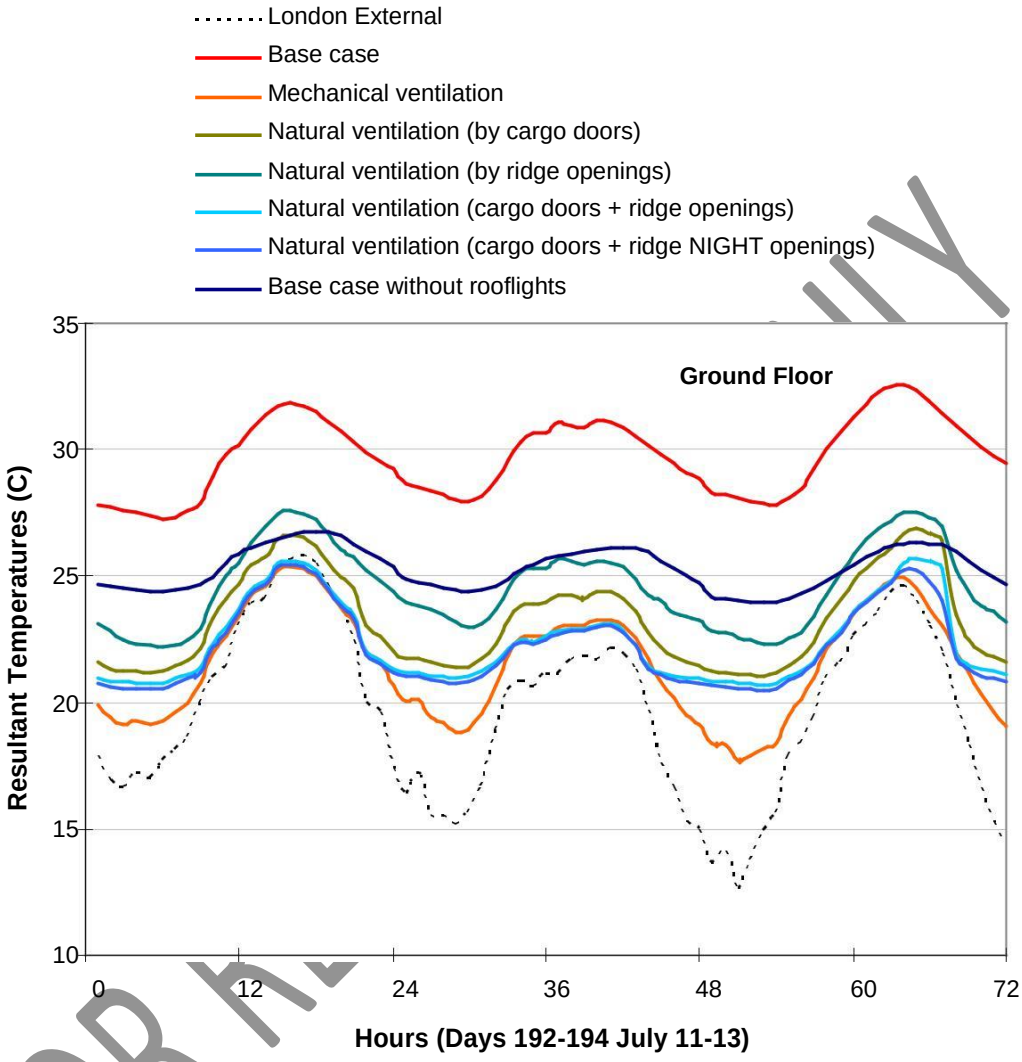


Figure 14.Resultant temperatures on ground floor for three warmest days: 14% rooflights

Mechanical ventilation is most effective at reducing temperatures overnight. However, using natural ventilation (cargo doors and ridge vents) keeps peak daytime resultant temperatures as low as achieved using mechanical ventilation. The unventilated example building gets significantly hotter than any of the ventilated cases, demonstrating that ventilation strategy is critical and of greater significance than rooflight area (up to a point) in avoiding overheating. A building with 14% rooflights does not exceed a resultant temperature of 26°C on any of the three warmest days.

6. Comparison between different rooflight percentages

The comparative analyses are based on cases of no ventilation at all and natural ventilation by opening cargo doors.

6.1. Loads and CO_2 emissions

Table 9.Loads (kWh/m^2 per year)

Ventilation schemes	Heating	Solar	People/ Equipment	Lighting
0% Base case	17.18	0	10.18	49.06
10% Base case	22.23	34.22	10.18	29.89
14% Base case	22.69	48.09	10.18	28.14
10% with cargo doors open	22.50	34.22	10.18	29.89
14% with cargo doors open	23.09	48.09	10.18	28.14

Table 10.CO_2 emissions (kg/m^2 per year)

Ventilation schemes	Heating	Lighting	Heating+Lighting
0% Base case	4.17	21.68	25.85
10% Base case	5.39	13.21	18.60
14% Base case	5.50	12.44	17.94
10% with cargo doors open	5.46	13.21	18.67
14% with cargo doors open	5.60	12.44	18.03

6.2. Monthly heating loads

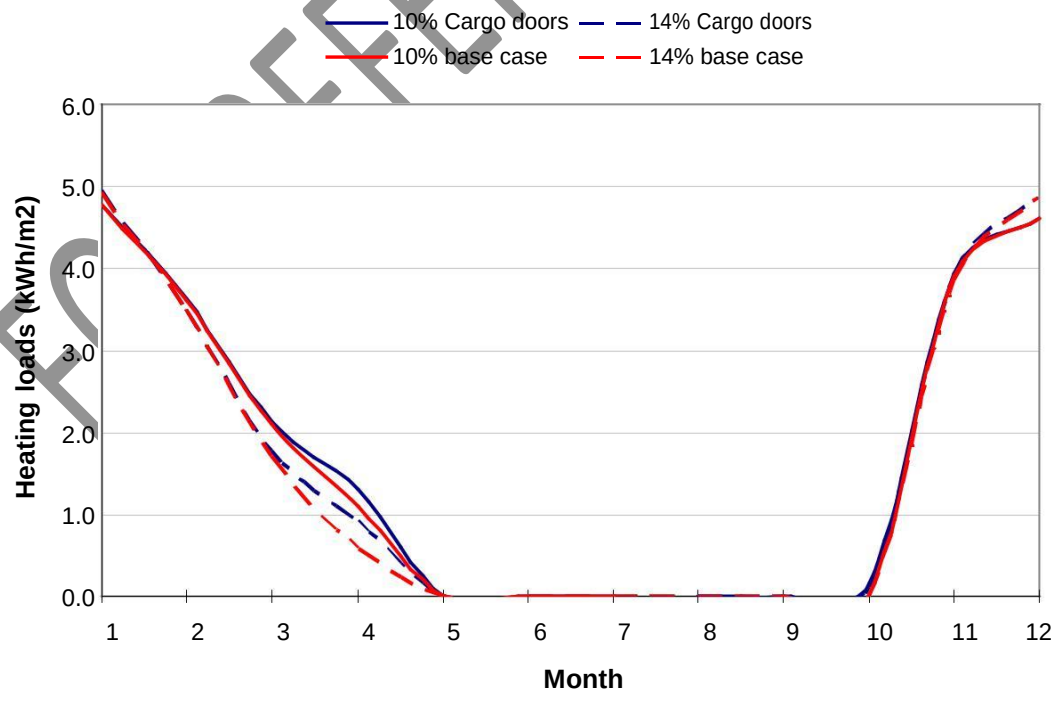


Figure 15.Heating loads for base case and natural ventilation (cargo doors open)

6.3. Overheating (ground floor)

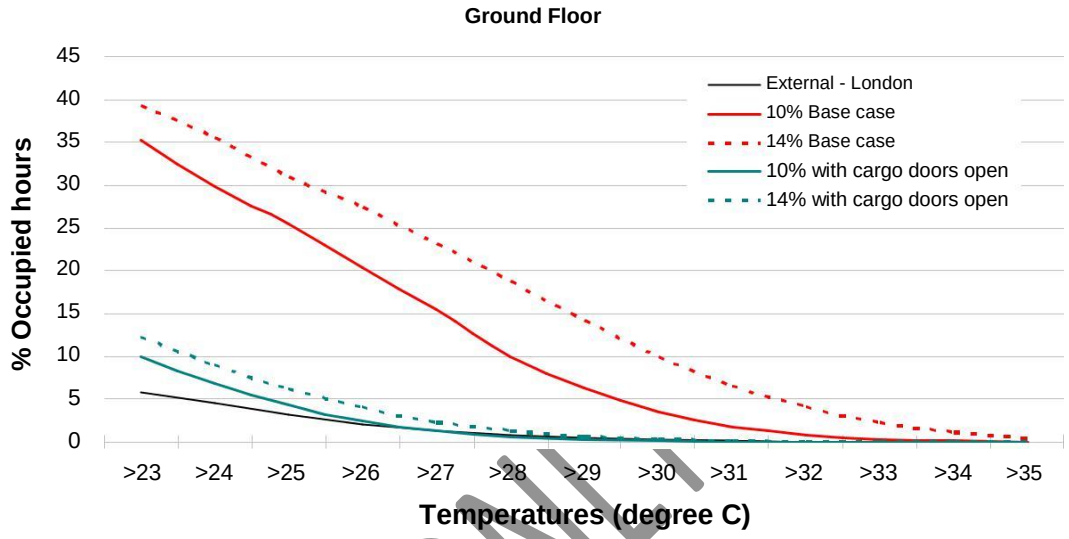


Figure 16.Ground floor overheating

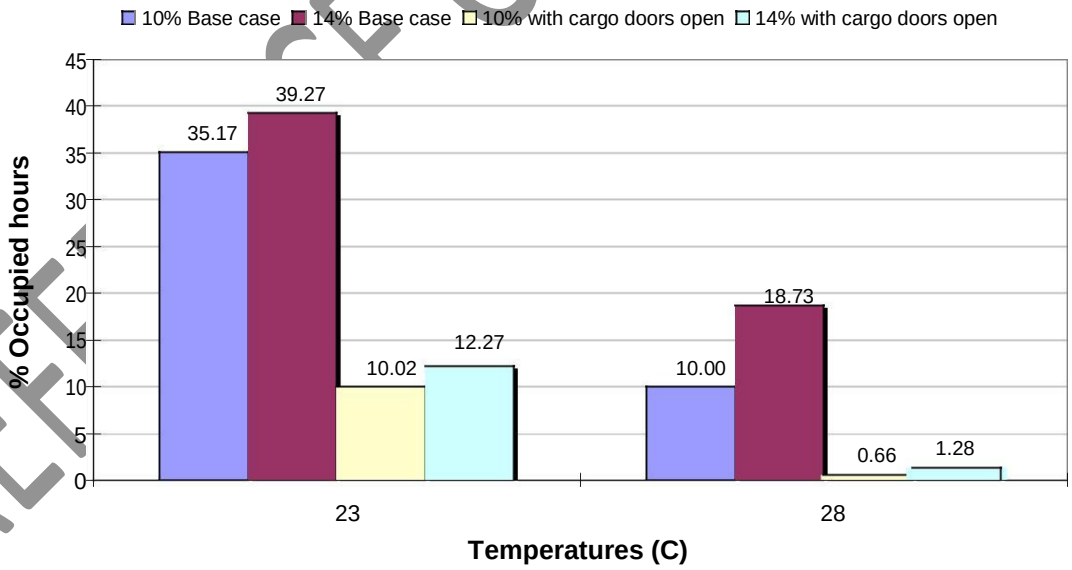


Figure 17.Percentage of occupied hours over certain temperatures

This clearly shows that use of natural ventilation has a very high impact, even when ventilation is only through cargo doors, whilst a change in rooflight area from 10% to 14% has a less dramatic effect upon overheating risk. The modelled building with 10-14% rooflights and effective natural ventilation has a low risk of overheating to uncomfortable levels.

6.4. Overheating (mezzanine)

The effect of stratification was investigated by introducing a notional mezzanine floor level.

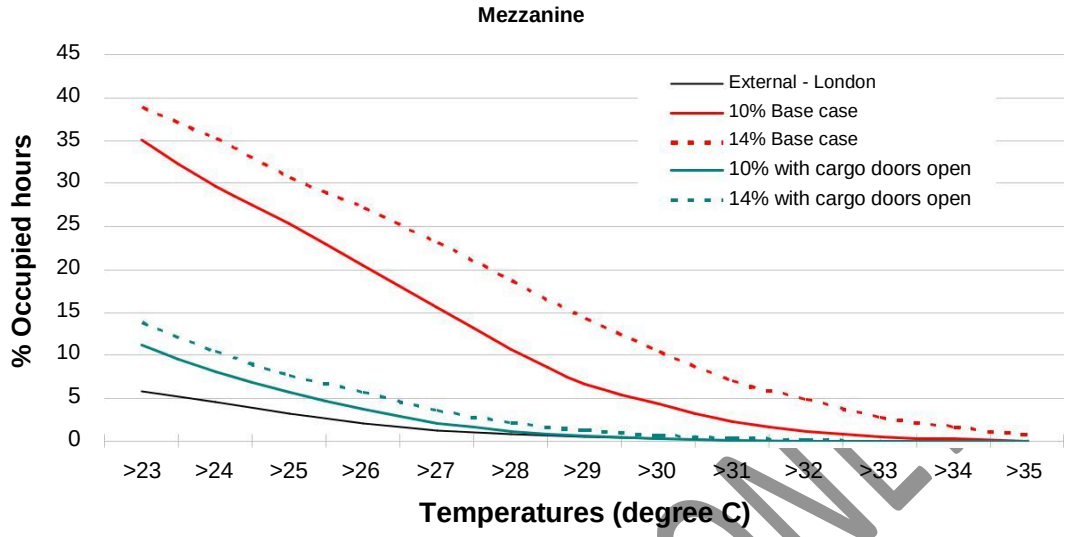


Figure 18.Mezzanine floor overheating

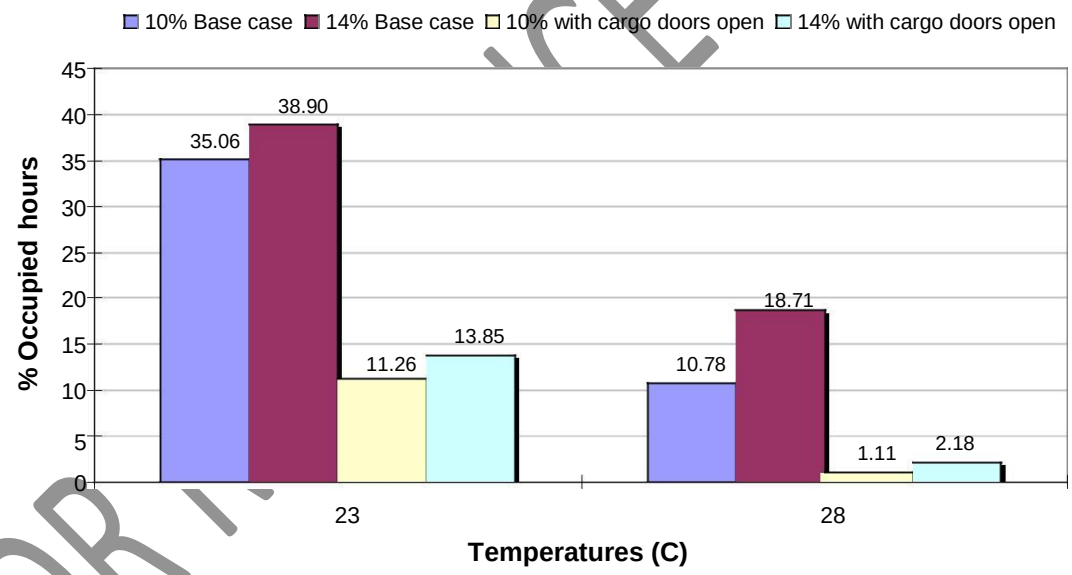


Figure 19.Percentage of occupied hours over certain temperatures

The model shows higher temperatures at the mezzanine level, indicating some thermal stratification.

6.5. Temperatures for three warmest days

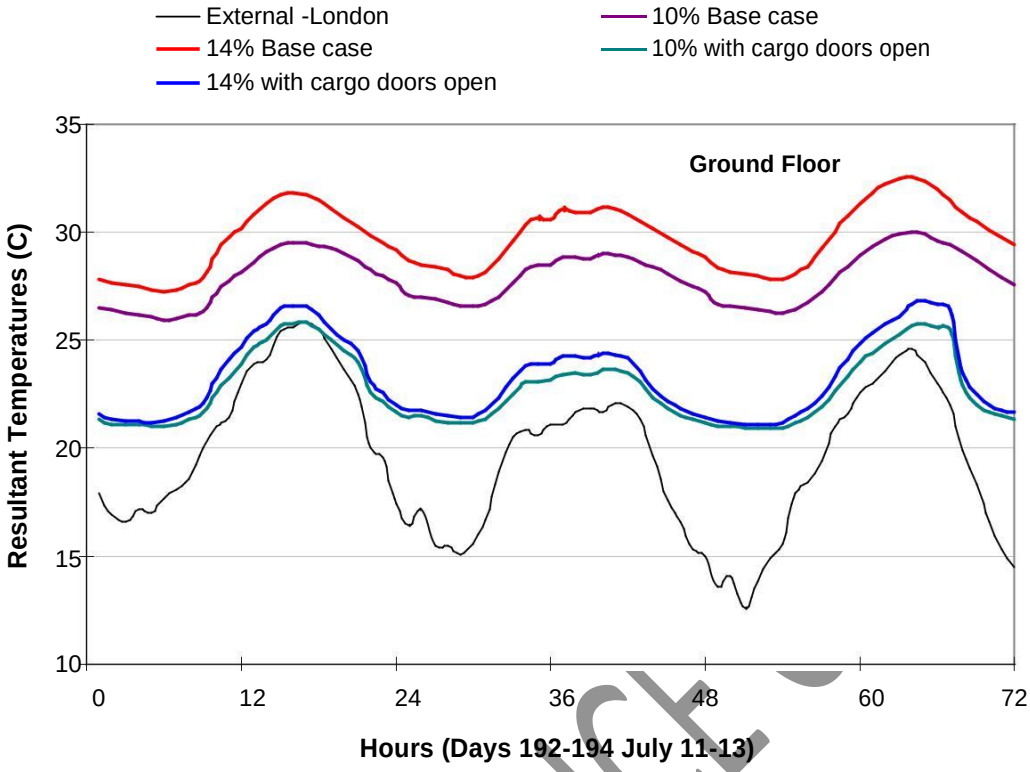


Figure 20.Resultant temperatures on ground floor for three warmest days

This graph shows that at the hottest point on the three warmest days of the year, unventilated buildings may overheat (reaching temperatures of over 30°C) but use of natural ventilation, if only through cargo doors, limits peak temperatures and significantly reduces overheating risk. Rooflight area (10-14% investigated) is a secondary effect for the example building studied, with an increase from 10% rooflights to 14% rooflights making less than 1°C difference to peak temperatures in the ventilated building.

7. Building Regulations Criterion 3: Limiting the effects of solar gains

Building Regulations Approved Document L2A states that reasonable provision could be:

a) when the building is subject to design irradiancies for July given in CIBSE Design Guide A, the combined solar and internal gains per unit floor area should not exceed 35W/m^2 when averaged between 0630 and 1630 GMT

b) the operative temperature does not exceed a threshold for more than a reasonable number of hours per year when the building is tested against the CIBSE Design Summer Year appropriate to the building location. For offices, a threshold of 1% over 28°C is suggested.

1% over 28°C may be considered unnecessarily onerous for many industrial and warehouse buildings, but it is still met by most of the cases analysed, except those without any ventilation

Analysis of the internal solar gains in the building with the CIBSE Design Summer Weather Year data used for July shows that the total average gains are never near 35W/m^2, even for 14% nominal rooflight area, as shown in the following graphs.

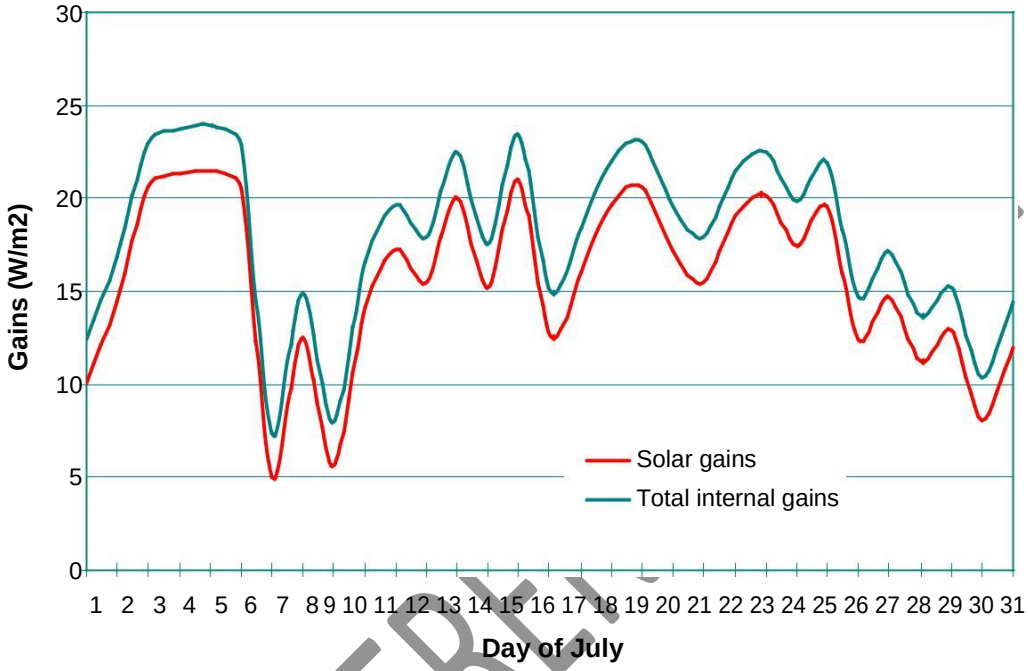


Figure 21. Total and solar gains for July (10% rooflights)

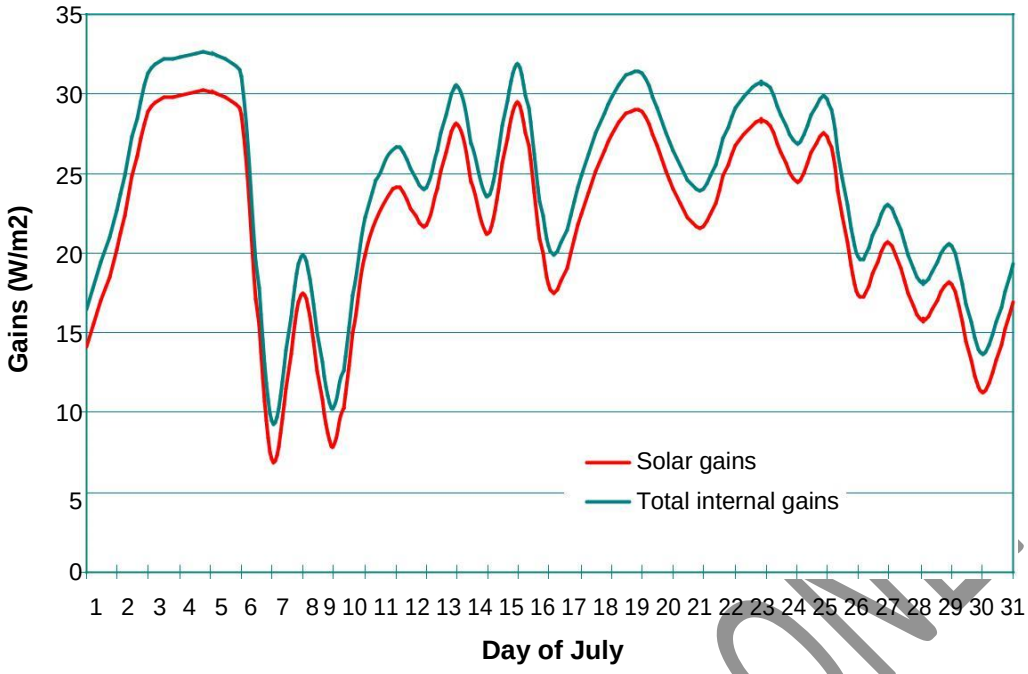


Figure 22. Total and solar gains for July (14% rooflights)

Using CIBSE Technical Memorandum TM37:2006 (Design for improved shading control), as recommended in ADL2, it is possible to calculate the approximate solar gain in a building from the location, the area and orientation of glazing, and the floor area. The solar load per unit floor area is given by:

$$\Phi_{sl} = (1/A_P)\sum(A_g \varphi_s g_{eff})$$

Where A_P = Perimeter floor area

A_g = Net area of glazing

φ_s = external solar radiation for the orientation of the opening

g_{eff} = effective g-value (gain) of the glazing

Applying this equation and using the tables in TM37 with an assumed g-value for the rooflights of 0.47 (as used in the modelling) and for London:

Perimeter area A_p = Total floor area – office area
= 2400 – 120
= 2280m^2

Glazing area A_g (10%) = 199.8m^2

Glazing Area A_g (14%) = 279.7m^2

Average outside solar irradiance for London on horizontal plane (Table 5.2 in TM37):

φ_S = 655 W/m^2

Effective g-value = g x 0.71 = 0.47 x 0.71 = 0.33

Rooflight percentage	Solar gain (TM37) W/m^2 for July 4th	Solar gain (TAS) W/m^2 for July 4th
10%	19.1	21.3
14%	26.7	29.9

Table 11. Average solar gains for TM37 method and TAS model

Internal gains add approximately 2.5W/m^2 to these figures, depending upon lighting load, taking the total load to over 23.8W/m^2 and 32.4W/m^2 for 10% and 14% rooflights respectively.

8. Conclusions

- Analysis shows there is an overheating risk with buildings that are totally unventilated
- Ventilation strategy and rooflight area both affect the risk of overheating, but ventilation strategy is by far the dominant effect.
- In a large open span metal clad building, cargo and personnel doors can be opened to provide effective cross ventilation as required. Opening cargo doors is common practice and is effectively self-regulating. Roof vents allow air to escape at high level and increase the effect of ventilation. They may also be left open at night to give secure night ventilation.
- Introduction of some natural ventilation (by opening cargo doors) has a significant effect, and ensures there is no overheating risk for buildings of this type incorporating 10% or 14% rooflights.
- The example building with either 10% or 14% rooflights with ridge vents and open cargo doors did not have total solar+internal gains exceeding 35W/m^2, and did not exceed 28^{o}C for more than 1% of occupied hours, thus complying with both main criteria in Building Regulations Approved Document L2A for demonstrating solar overheating will not occur. Modelling also showed that resultant temperature is not predicted to exceed 26^{o}C on the three warmest days of the year.
- Overheating risk can be reduced by eliminating rooflights altogether, but this would result in significant increases in overall energy use,

running costs, CO_2 emissions, and would give a significantly poorer internal environment inside the building.

- Rooflights save approximately 40% of lighting energy with only a small heating penalty, provided that appropriate controls are fitted to enable dimming in response to available daylight.
- Total CO_2 emissions (heating and lighting) are reduced by 30% (14% rooflights) when rooflights are used with dimmable lighting because the saving in lighting electricity far outweighs the additional heating gas required.
- Investigation of stratification shows this has some effect, particularly at higher rooflight areas, but the modelling suggest this is not a very significant factor.

The work demonstrates that there is no overheating problem at 14% rooflight area, for the warehouse considered. However, if other internal gains are higher (for example from significantly increased occupation density, or retail display lighting), it is possible that overall overheating criteria may be exceeded at lower rooflight areas.

APPENDIX

Base case

Value in kWh

Month	Heating	Solar	Internal (L,O,E)
1	10850.15	1568.14	9392.38
2	8961.61	2678.95	7783.01
3	6127.00	4806.03	7794.03
4	4838.49	7283.20	6821.25
5	18.96	13153.88	6446.94
6	0.00	11911.41	5901.03
7	0.00	13154.08	6275.40
8	0.00	10397.97	6792.32
9	0.00	6245.05	7248.68
10	427.54	3638.99	8269.09
11	9329.07	2114.36	8870.12
12	10132.26	1078.42	9761.11
Total	50685.07	78030.45	91355.38
Peak	43.99	65.39	15.42
Day	330	171	1
Hour	6	13	1

Heating Peaks Solar Peaks on Internal (L,O,E) Peaks on Day 1, Hour 1

Base case with no daylight windows

Value in kWh

Month	Heating	Solar	Internal (L,O,E)
1	7917.41	0.00	11440.96
2	6752.57	0.00	10333.77
3	4616.92	0.00	11440.96
4	4755.87	0.00	11071.89
5	12.92	0.00	11440.96
6	17.37	0.00	11071.89
7	0.00	0.00	11440.96
8	0.00	0.00	11440.96
9	0.00	0.00	11071.89
10	155.23	0.00	11440.96
11	6870.72	0.00	11071.89
12	7319.00	0.00	11440.96
Total	38418.02	0.00	134707.86
Peak	37.96	0.00	15.38
Day	330	0	1
Hour	6	0	1

Heating Peaks Solar Peaks on Internal (L,O,E) Peaks on Day 1, Hour 1

Mechanical ventilation

Value in kWh

Month	Heating	Solar	Internal (L,O,E)
1	10850.15	1568.14	9392.38
2	8961.61	2678.95	7783.01
3	6127.00	4806.03	7794.03
4	4838.49	7283.20	6821.25
5	18.96	13153.88	6446.94
6	0.00	11911.41	5901.03
7	0.00	13154.08	6275.40
8	0.00	10397.97	6792.32
9	94.07	6245.05	7248.68
10	526.08	3638.99	8269.09
11	9350.17	2114.36	8870.12
12	10134.12	1078.42	9761.11
Total	50900.66	78030.45	91355.38
Peak	44.00	65.39	15.42
Day	330	171	1
Hour	6	13	1

Heating Peaks Solar Peaks on Internal (L,O,E) Peaks on Day 1, Hour 1

Natural ventilation (by cargo doors)

Value in kWh

Month	Heating	Solar	Internal (L,O,E)
1	10856.48	1568.14	9392.38
2	8966.30	2678.95	7783.01
3	6169.56	4806.03	7794.03
4	4993.74	7283.20	6821.25
5	25.88	13153.88	6446.94
6	35.52	11911.41	5901.03
7	0.00	13154.08	6275.40
8	0.00	10397.97	6792.32
9	15.83	6245.05	7248.68
10	722.32	3638.99	8269.09
11	9374.88	2114.36	8870.12
12	10140.75	1078.42	9761.11
Total	51301.27	78030.45	91355.38
Peak	44.01	65.39	15.42
Day	330	171	1
Hour	6	13	1

Heating Peaks Solar Peaks on Internal (L,O,E) Peaks on Day 1, Hour 1

Natural ventilation (by ridge openings)

Value in kWh

Month	Heating	Solar	Internal (L,O,E)
1	10850.12	1568.14	9392.38
2	8973.08	2678.95	7783.01
3	6199.07	4806.03	7794.03
4	5178.10	7283.20	6821.25
5	27.59	13153.88	6446.94
6	44.01	11911.41	5901.03
7	0.00	13154.08	6275.40
8	0.00	10397.97	6792.32
9	5.80	6245.05	7248.68
10	675.80	3638.99	8269.09
11	9363.04	2114.36	8870.12
12	10134.41	1078.42	9761.11
Total	51451.02	78030.45	91355.38
Peak	44.00	65.39	15.42
Day	330	171	1
Hour	6	13	1

Heating Peaks Solar Peaks on Internal (L,O,E) Peaks on Day 1, Hour 1

Natural ventilation (cargo doors + ridge openings)

Value in kWh

Month	Heating	Solar	Internal (L,O,E)
1	10856.44	1568.14	9392.38
2	8977.76	2678.95	7783.01
3	6216.21	4806.03	7794.03
4	5225.68	7283.20	6821.25
5	44.52	13153.88	6446.94
6	88.50	11911.41	5901.03
7	0.00	13154.08	6275.40
8	0.00	10397.97	6792.32
9	20.61	6245.05	7248.68
10	779.80	3638.99	8269.09
11	9382.44	2114.36	8870.12
12	10140.97	1078.42	9761.11
Total	51732.93	78030.45	91355.38
Peak	44.01	65.39	15.42
Day	330	171	1
Hour	6	13	1

Heating Peaks Solar Peaks on Internal (L,O,E) Peaks on Day 1, Hour 1

Natural ventilation (cargo doors + ridge NIGHT openings)

Value in kWh

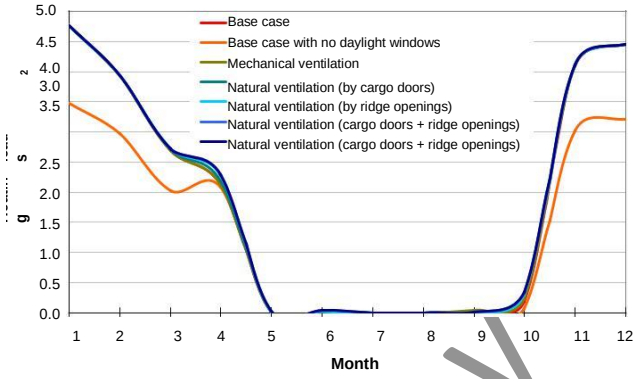
Month	Heating	Solar	Internal (L,O,E)
1	10856.44	1568.14	9392.38
2	8977.76	2678.95	7783.01
3	6216.21	4806.03	7794.03
4	5225.68	7283.20	6821.25
5	44.52	13153.88	6446.94
6	88.50	11911.41	5901.03
7	0.00	13154.08	6275.40
8	0.00	10397.97	6792.32
9	34.24	6245.05	7248.68
10	796.36	3638.99	8269.09
11	9385.90	2114.36	8870.12
12	10141.37	1078.42	9761.11
Total	51766.97	78030.45	91355.38
Peak	44.01	65.39	15.42
Day	330	171	1
Hour	6	13	1

Heating Peaks Solar Peaks on Internal (L,O,E) Peaks on Day 1, Hour 1

Shed floor area= ***2280 m2***

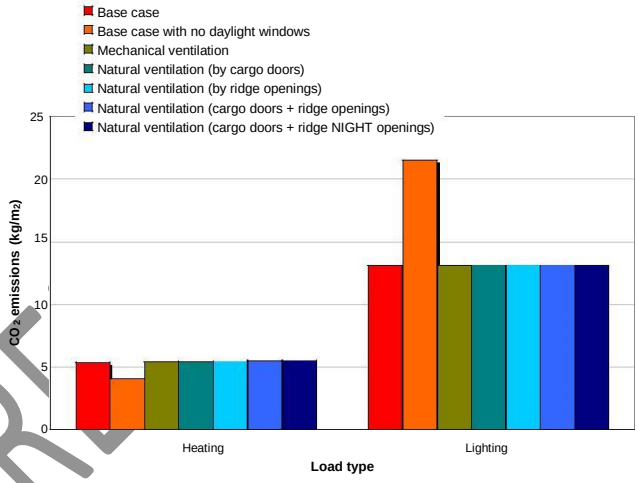
Base case

Value in kWh		Lighting electri	29.642
Month	Heating	Solar	Internal (L,O,E)
1	4.76	0.69	4.12
2	3.93	1.17	3.41
3	2.69	2.11	3.42
4	2.12	3.19	2.99
5	0.01	5.77	2.83
6	0.00	5.22	2.59
7	0.00	5.77	2.75
8	0.00	4.56	2.98
9	0.00	2.74	3.18
10	0.19	1.60	3.63
11	4.09	0.93	3.89
12	4.44	0.47	4.28
Total	22.23	34.22	40.07



Base case with no daylight windows

Value in kWh		Lighting electri	48.656
Month	Heating	Solar	Internal (L,O,E)
1	3.47	0.00	5.02
2	2.96	0.00	4.53
3	2.02	0.00	5.02
4	2.09	0.00	4.86
5	0.01	0.00	5.02
6	0.01	0.00	4.86
7	0.00	0.00	5.02
8	0.00	0.00	5.02
9	0.00	0.00	4.86
10	0.07	0.00	5.02
11	3.01	0.00	4.86
12	3.21	0.00	5.02
Total	16.85	0.00	59.08



Mechanical ventilation

Value in kWh		Lighting electri	29.642
Month	Heating	Solar	Internal (L,O,E)
1	4.76	0.69	4.12
2	3.93	1.17	3.41
3	2.69	2.11	3.42
4	2.12	3.19	2.99
5	0.01	5.77	2.83
6	0.00	5.22	2.59
7	0.00	5.77	2.75
8	0.00	4.56	2.98
9	0.04	2.74	3.18
10	0.23	1.60	3.63
11	4.10	0.93	3.89
12	4.44	0.47	4.28
Total	22.32	34.22	40.07

Natural ventilation (by cargo doors)

Value in kWh		Lighting electri	29.642
Month	Heating	Solar	Internal (L,O,E)
1	4.76	0.69	4.12
2	3.93	1.17	3.41
3	2.71	2.11	3.42
4	2.19	3.19	2.99
5	0.01	5.77	2.83
6	0.02	5.22	2.59
7	0.00	5.77	2.75
8	0.00	4.56	2.98
9	0.01	2.74	3.18
10	0.32	1.60	3.63
11	4.11	0.93	3.89
12	4.45	0.47	4.28
Total	22.50	34.22	40.07

Natural ventilation (by ridge openings)

Value in kWh		Lighting electri	29.642
Month	Heating	Solar	Internal (L,O,E)
1	4.76	0.69	4.12
2	3.94	1.17	3.41
3	2.72	2.11	3.42
4	2.27	3.19	2.99
5	0.01	5.77	2.83
6	0.02	5.22	2.59
7	0.00	5.77	2.75
8	0.00	4.56	2.98
9	0.00	2.74	3.18
10	0.30	1.60	3.63
11	4.11	0.93	3.89
12	4.44	0.47	4.28
Total	22.57	34.22	40.07

Natural ventilation (cargo doors + ridge openings)

Value in kWh		Lighting electri	29.642
Month	Heating	Solar	Internal (L,O,E)
1	4.76	0.69	4.12
2	3.94	1.17	3.41
3	2.73	2.11	3.42
4	2.29	3.19	2.99
5	0.02	5.77	2.83
6	0.04	5.22	2.59
7	0.00	5.77	2.75
8	0.00	4.56	2.98
9	0.01	2.74	3.18
10	0.34	1.60	3.63
11	4.12	0.93	3.89
12	4.45	0.47	4.28
Total	22.69	34.22	40.07

Natural ventilation (cargo doors + ridge NIGHT openings)

Value in kWh		Lighting electri	29.642
Month	Heating	Solar	Internal (L,O,E)
1	4.76	0.69	4.12
2	3.94	1.17	3.41
3	2.73	2.11	3.42
4	2.29	3.19	2.99
5	0.02	5.77	2.83
6	0.04	5.22	2.59
7	0.00	5.77	2.75
8	0.00	4.56	2.98
9	0.02	2.74	3.18
10	0.35	1.60	3.63
11	4.12	0.93	3.89
12	4.45	0.47	4.28
Total	22.70	34.22	40.07

Loads summary kWh/m2

	Heating	Solar	Internal	Lighting
Base case	22.23	34.22	40.07	29.64
Base case wit	16.85	0.00	59.08	48.66
Mechanical ve	22.32	34.22	40.07	29.64
Natural ventila	22.50	34.22	40.07	29.64
Natural ventila	22.57	34.22	40.07	29.64
Natural ventila	22.69	34.22	40.07	29.64
Natural ventila	22.70	34.22	40.07	29.64

CO2 emissions kg/m2

	Heating	Solar	Internal	Lighting
Base case	5.39	15.13	17.71	13.10
Base case wit	4.09	0.00	26.11	21.51
Mechanical ve	5.41	15.13	17.71	13.10
Natural ventila	5.46	15.13	17.71	13.10
Natural ventila	5.47	15.13	17.71	13.10
Natural ventila	5.50	15.13	17.71	13.10
Natural ventila	5.51	15.13	17.71	13.10

Base case
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Groun	8760	4078	3656	3427	3081	2614	2226	1789	1361	876	552	313	153	69	35	13	0

Base case without daylight
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Groun	8760	3940	3291	2976	2391	1672	1026	496	210	83	35	0	0	0	0	0	0

Mechanical ventilation
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Groun	8760	2847	2157	1685	1214	843	590	376	237	114	53	18	4	0	0	0	0

Natural ventilation (by cargo doors)
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Groun	8760	3696	2258	1270	878	593	384	218	111	58	28	11	4	0	0	0	0

Natural ventilation (by ridge openings)
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Groun	8760	3749	2808	1918	1362	937	591	367	171	86	43	25	5	0	0	0	0

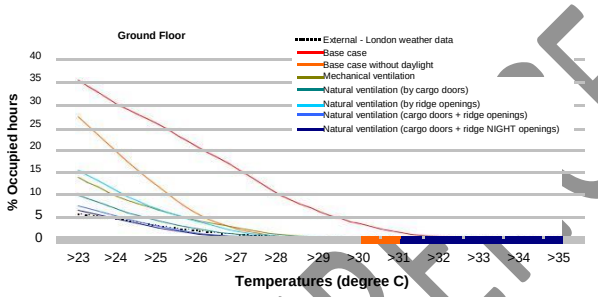
Natural ventilation (cargo doors + ridge openings)
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

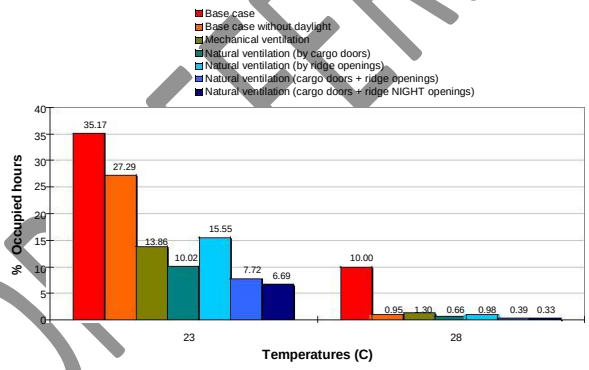
Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Groun	8760	3571	1772	973	676	458	277	142	72	34	13	5	1	0	0	0	0

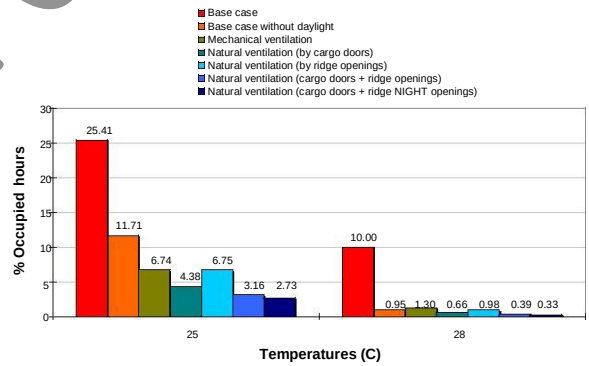
Natural ventilation (cargo doors + ridge NIGHT openings)
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Groun	8760	2930	1437	872	586	405	239	125	64	29	12	5	0	0	0	0	0

	>20	>21	>22	>23	>24	>25	>26	>27	>28	>29	>30	>31	>32	>33	>34	>35
External - L	11.95	9.59	7.53	5.83	4.62	3.23	2.15	1.28	0.82	0.51	0.25	0.14	0.06	0.03	0.00	0.00
Base case	46.55	41.74	39.12	35.17	29.84	25.41	20.42	15.54	10.00	6.30	3.57	1.75	0.79	0.40	0.15	0.00
Base case	44.98	37.57	33.97	27.29	19.09	11.71	5.66	2.40	0.95	0.40	0.00	0.00	0.00	0.00	0.00	0.00
Mechanical	32.50	24.62	19.24	13.86	9.62	6.74	4.29	2.71	1.30	0.61	0.21	0.05	0.00	0.00	0.00	0.00
Natural ven	42.19	25.78	14.50	10.02	6.77	4.38	2.49	1.27	0.66	0.32	0.13	0.05	0.00	0.00	0.00	0.00
Natural ven	42.80	32.05	21.89	15.55	10.70	6.75	4.19	1.95	0.98	0.49	0.29	0.05	0.00	0.00	0.00	0.00
Natural ven	40.76	20.23	11.11	7.72	5.23	3.16	1.62	0.82	0.39	0.15	0.06	0.01	0.00	0.00	0.00	0.00
Natural ven	33.45	16.40	9.95	6.69	4.62	2.73	1.43	0.73	0.33	0.14	0.06	0.00	0.00	0.00	0.00	0.00







Base case
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Groun	8760	4078	3656	3427	3081	2614	2226	1789	1361	876	552	313	153	69	35	13	0

Mechanical ventilation
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Groun	8760	2847	2157	1685	1214	843	590	376	237	114	53	18	4	0	0	0	0

Natural ventilation (by cargo doors)
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Groun	8760	3696	2258	1270	878	593	384	218	111	58	28	11	4	0	0	0	0

Natural ventilation (by ridge openings)
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Groun	8760	3749	2808	1918	1362	937	591	367	171	86	43	25	5	0	0	0	0

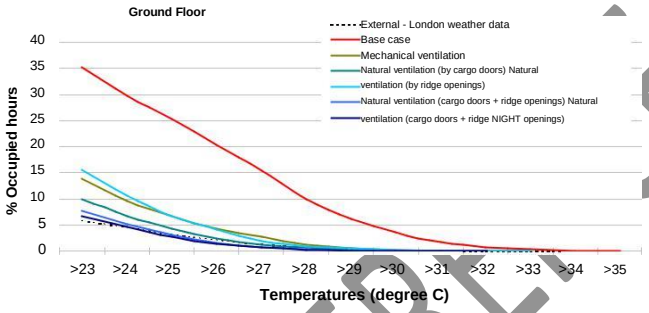
Natural ventilation (cargo doors + ridge openings)
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

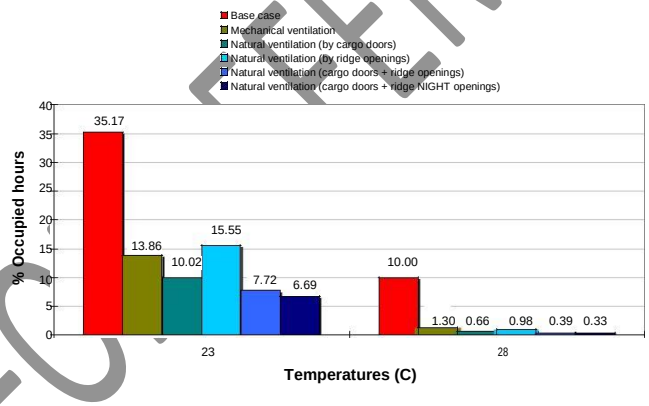
Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Groun	8760	3571	1772	973	676	458	277	142	72	34	13	5	1	0	0	0	0

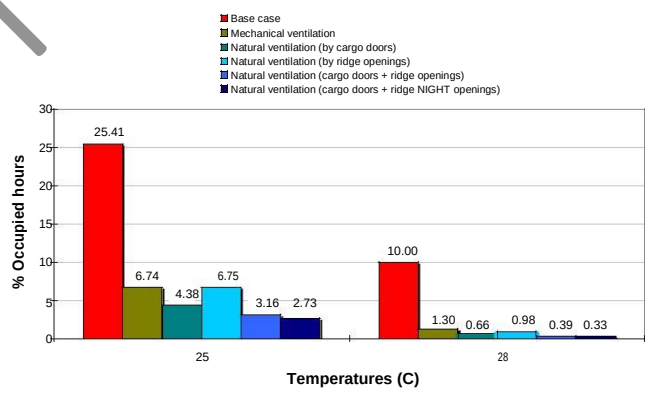
Natural ventilation (cargo doors + ridge NIGHT openings)
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Groun	8760	2930	1437	872	586	405	239	125	64	29	12	5	0	0	0	0	0

	>20	>21	>22	>23	>24	>25	>26	>27	>28	>29	>30	>31	>32	>33	>34	>35
External - L	11.95	9.59	7.53	5.83	4.62	3.23	2.15	1.28	0.82	0.51	0.25	0.14	0.06	0.03	0.00	0.00
Base case	46.55	41.74	39.12	35.17	29.84	25.41	20.42	15.54	10.00	6.30	3.57	1.75	0.79	0.40	0.15	0.00
Mechanical	32.50	24.62	19.24	13.86	9.62	6.74	4.29	2.71	1.30	0.61	0.21	0.05	0.00	0.00	0.00	0.00
Natural ven	42.19	25.78	14.50	10.02	6.77	4.38	2.49	1.27	0.66	0.32	0.13	0.05	0.00	0.00	0.00	0.00
Natural ven	42.80	32.05	21.89	15.55	10.70	6.75	4.19	1.95	0.98	0.49	0.29	0.06	0.00	0.00	0.00	0.00
Natural ven	40.76	20.23	11.11	7.72	5.23	3.16	1.62	0.82	0.39	0.15	0.06	0.01	0.00	0.00	0.00	0.00
Natural ven	33.45	16.40	9.95	6.69	4.62	2.73	1.43	0.73	0.33	0.14	0.06	0.00	0.00	0.00	0.00	0.00







Base case
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Mezza	8760	4087	3646	3397	3071	2610	2221	1798	1367	944	589	378	206	96	46	24	4

Base case without daylight
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Mezza	8760	3914	3293	2940	2399	1682	1071	567	273	99	40	14	0	0	0	0	0

Mechanical ventilation
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Mezza	8760	2866	2197	1717	1293	924	653	436	280	165	74	36	14	1	0	0	0

Natural ventilation (by cargo doors)
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Mezza	8760	3637	2268	1406	986	711	497	322	187	97	54	25	10	4	0	0	0

Natural ventilation (by ridge openings)
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Mezza	8760	3749	2647	1824	1336	975	660	431	235	119	58	34	15	2	0	0	0

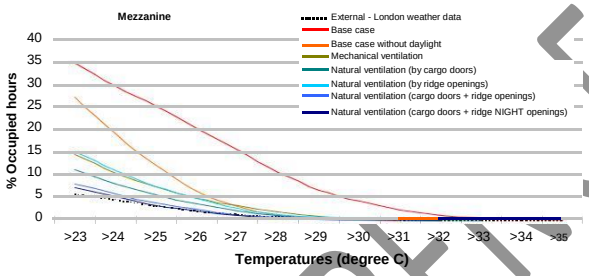
Natural ventilation (cargo doors + ridge openings)
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

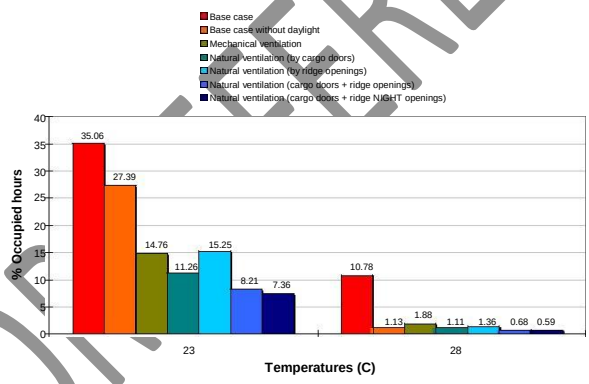
Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Mezza	8760	3468	1722	1003	719	518	340	211	108	60	30	11	5	1	0	0	0

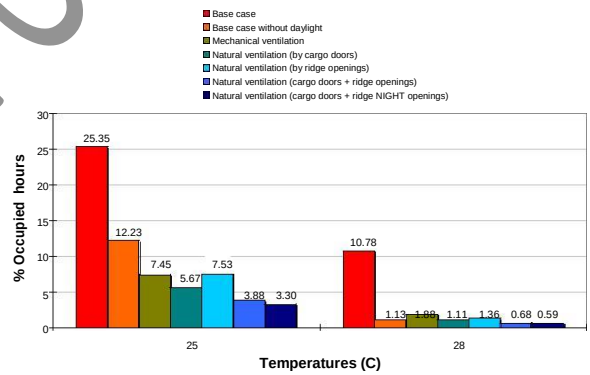
Natural ventilation (cargo doors + ridge NIGHT openings)
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Mezza	8760	2804	1427	899	645	461	289	183	95	52	23	11	5	0	0	0	0

	>20	>21	>22	>23	>24	>25	>26	>27	>28	>29	>30	>31	>32	>33	>34	>35
External - L	11.95	9.59	7.53	5.83	4.62	3.23	2.15	1.28	0.82	0.51	0.25	0.14	0.05	0.03	0.00	0.00
Base case	46.66	41.62	38.78	35.06	29.79	25.35	20.53	15.61	10.78	6.72	4.32	2.35	1.10	0.53	0.27	0.05
Base case	44.68	37.59	33.56	27.39	19.20	12.23	6.47	3.12	1.13	0.46	0.16	0.00	0.00	0.00	0.00	0.00
Mechanical	32.72	25.08	19.60	14.76	10.55	7.45	4.98	3.20	1.88	0.84	0.41	0.16	0.01	0.00	0.00	0.00
Natural vent	41.52	25.89	16.05	11.26	8.12	5.67	3.68	2.13	1.11	0.62	0.29	0.11	0.05	0.00	0.00	0.00
Natural vent	42.80	30.22	20.82	15.25	11.13	7.53	4.92	2.68	1.36	0.66	0.39	0.17	0.02	0.00	0.00	0.00
Natural vent	39.59	19.66	11.45	8.21	5.91	3.88	2.41	1.23	0.68	0.34	0.13	0.06	0.01	0.00	0.00	0.00
Natural vent	32.01	16.29	10.26	7.36	5.26	3.30	2.09	1.08	0.59	0.26	0.13	0.06	0.00	0.00	0.00	0.00







Base case
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Mezz	8760	4087	3646	3397	3071	2610	2221	1798	1367	944	589	378	206	96	46	24	4

Mechanical ventilation
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Mezz	8760	2866	2197	1717	1293	924	653	436	280	165	74	36	14	1	0	0	0

Natural ventilation (by cargo doors)
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Mezz	8760	3637	2268	1406	986	711	497	322	187	97	54	25	10	4	0	0	0

Natural ventilation (by ridge openings)
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Mezz	8760	3749	2647	1824	1336	975	660	431	235	119	58	34	15	2	0	0	0

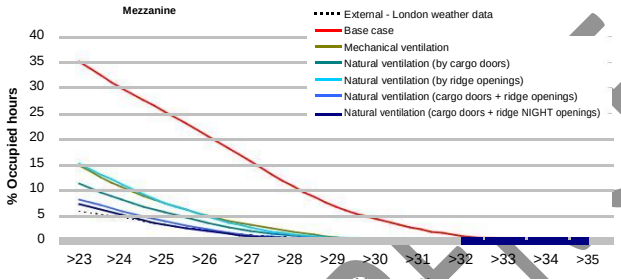
Natural ventilation (cargo doors + ridge openings)
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

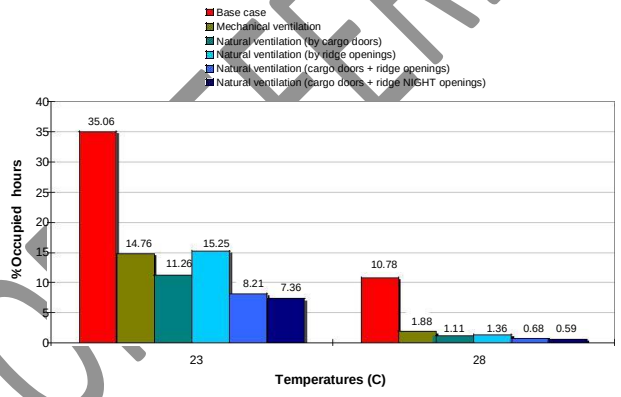
Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Mezz	8760	3468	1722	1003	719	518	340	211	108	60	30	11	5	1	0	0	0

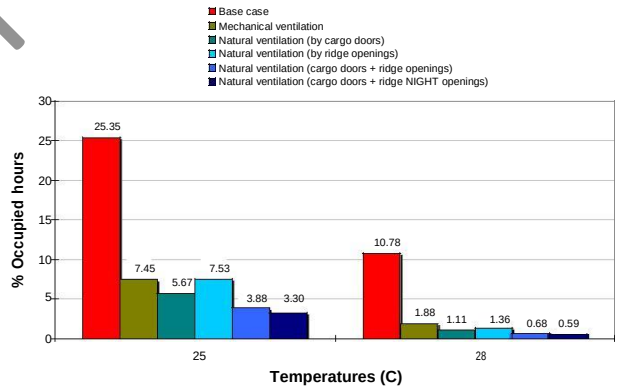
Natural ventilation (cargo doors + ridge NIGHT openings)
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

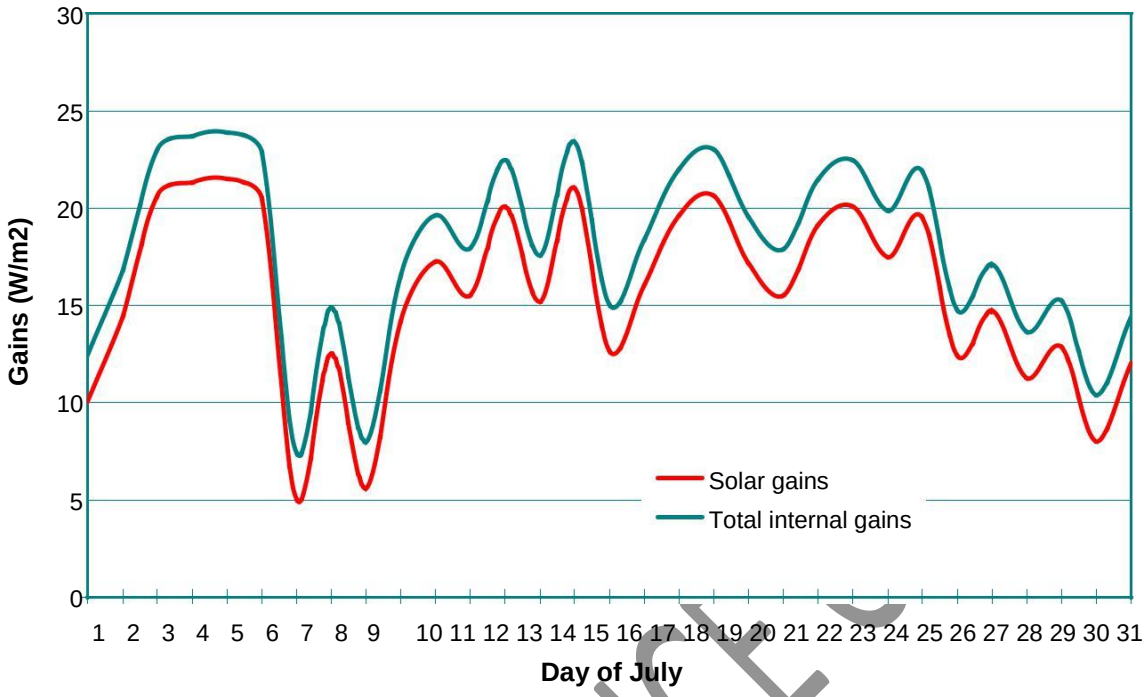
Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Mezz	8760	2804	1427	899	645	461	289	183	95	52	23	11	5	0	0	0	0

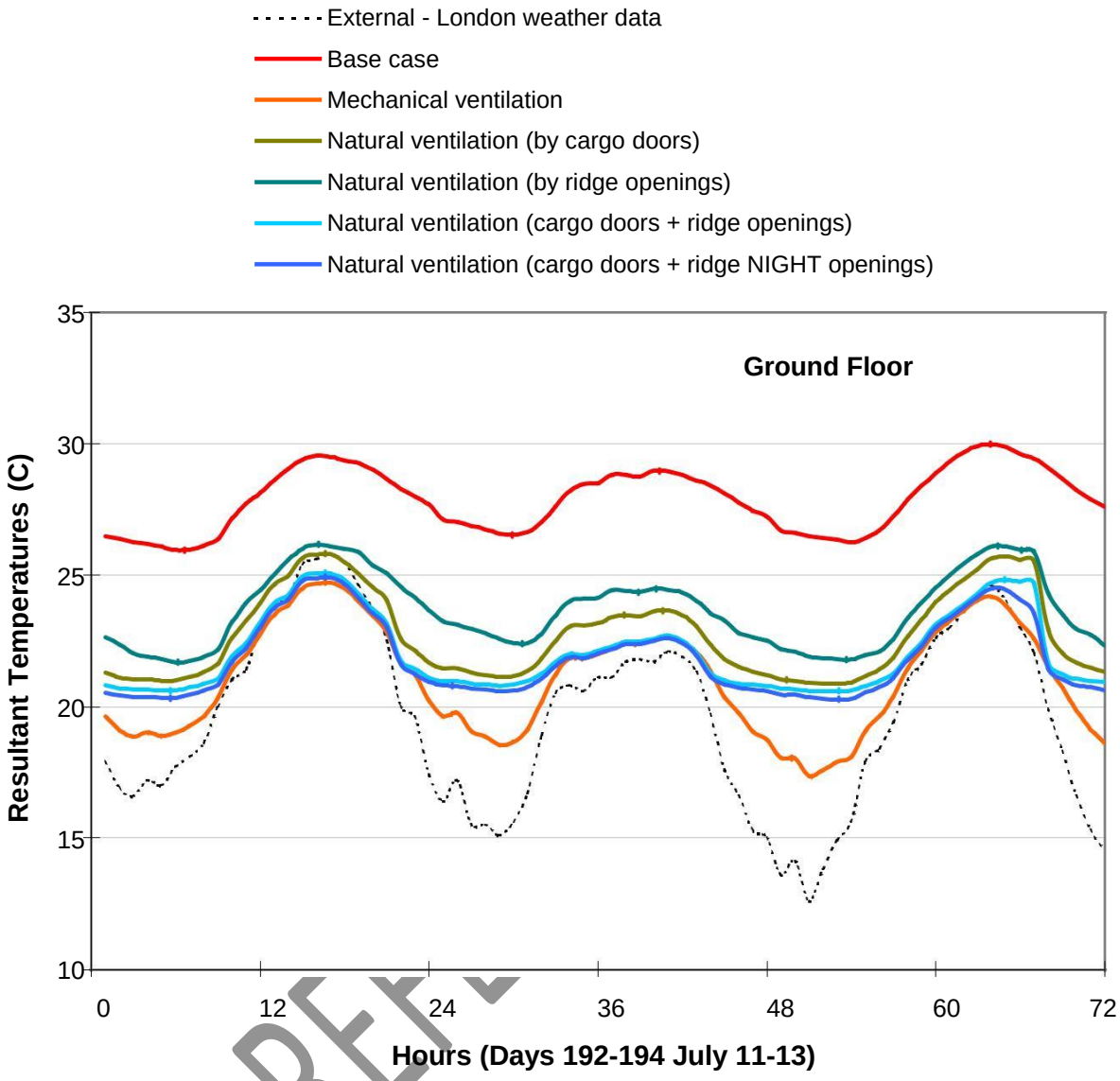
	>20	>21	>22	>23	>24	>25	>26	>27	>28	>29	>30	>31	>32	>33	>34	>35
External - L	11.95	9.59	7.53	5.83	4.62	3.23	2.15	1.28	0.82	0.51	0.25	0.14	0.06	0.03	0.00	0.00
Base case	46.66	41.62	38.78	35.06	29.79	25.35	20.53	15.61	10.78	6.72	4.32	2.35	1.10	0.53	0.27	0.05
Mechanical	32.72	25.08	19.60	14.76	10.55	7.45	4.98	3.20	1.88	0.84	0.41	0.16	0.01	0.00	0.00	0.00
Natural ven	41.52	25.89	16.05	11.26	8.12	5.67	3.68	2.13	1.11	0.62	0.29	0.11	0.05	0.00	0.00	0.00
Natural ven	42.80	30.22	20.82	15.25	11.13	7.53	4.92	2.68	1.36	0.66	0.39	0.17	0.02	0.00	0.00	0.00
Natural ven	39.59	19.66	11.45	8.21	5.91	3.88	2.41	1.23	0.68	0.34	0.13	0.06	0.01	0.00	0.00	0.00
Natural ven	32.01	16.29	10.26	7.36	5.26	3.30	2.09	1.08	0.59	0.26	0.13	0.06	0.00	0.00	0.00	0.00

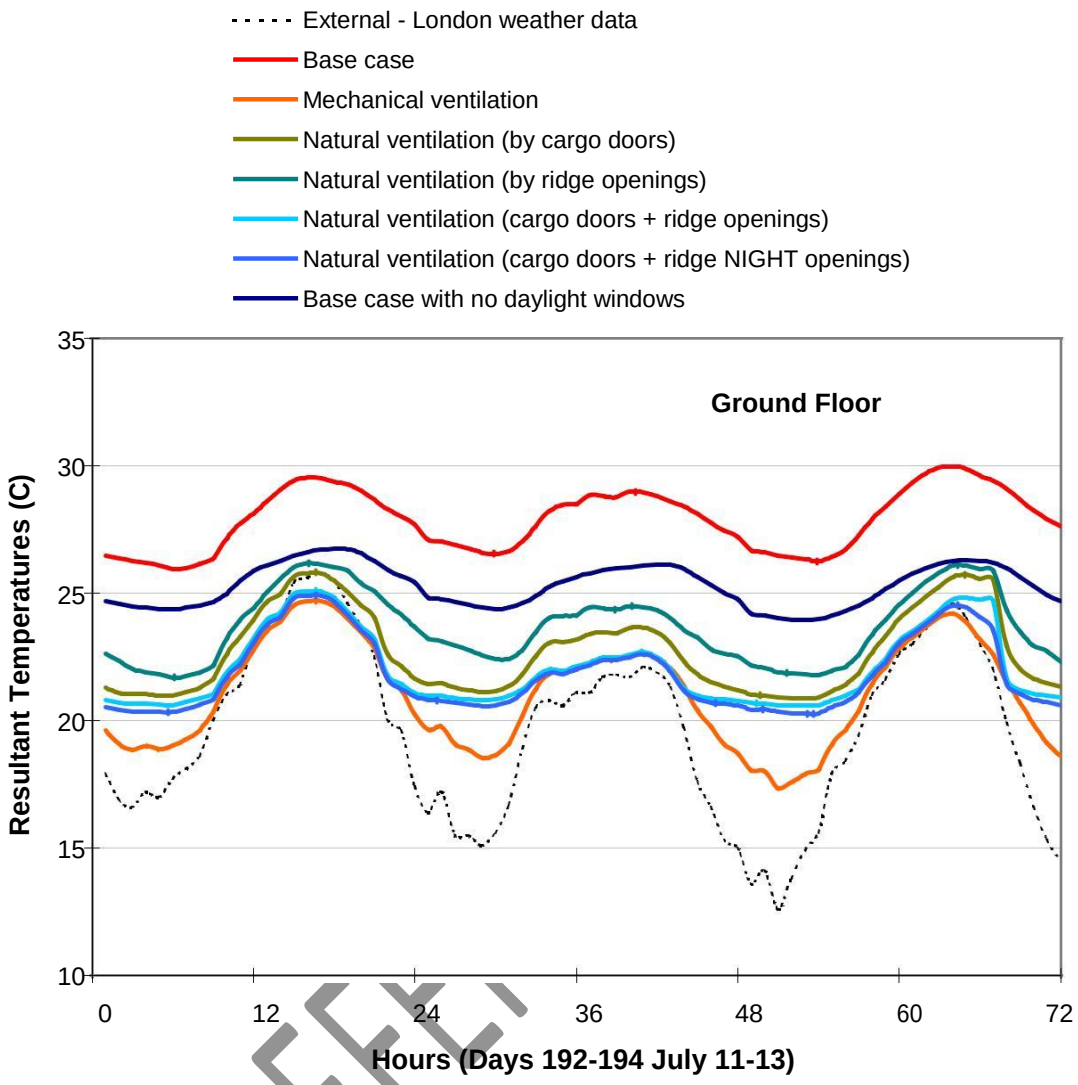









External - London weather data
Base case
Mechanical ventilation
Natural ventilation (by cargo doors)
Natural ventilation (by ridge openings)
Natural ventilation (cargo doors + ridge openings)
Natural ventilation (cargo doors + ridge NIGHT openings)
Ground Floor
Resultant Temperatures (C)
35
30
25
20
15
10
0
12
24
36
48
60
72
Hours (Days 192-194 July 11-13)


External - London weather data
Base case
Mechanical ventilation
Natural ventilation (by cargo doors)
Natural ventilation (by ridge openings)
Natural ventilation (cargo doors + ridge openings)
Natural ventilation (cargo doors + ridge NIGHT openings)
Base case with no daylight windows
Ground Floor
Resultant Temperatures (C)
35
30
25
20
15
10
0
12
24
36
48
60
72
Hours (Days 192-194 July 11-13)

Base case

Value in kWh

Month	Heating	Solar	Internal (L,O,E)
1	11662.80	2212.72	8928.51
2	9213.82	3767.13	7461.43
3	5830.31	6756.79	7493.34
4	3810.10	10240.99	6554.76
5	0.00	18465.93	6164.40
6	0.00	16723.07	5639.06
7	0.00	18456.22	5993.90
8	0.00	14602.03	6520.90
9	0.00	8781.80	6988.91
10	264.61	5120.08	7991.47
11	9835.13	2984.71	8436.70
12	11116.60	1529.96	9223.68
Total	51733.36	109641.38	87397.04
Peak	46.32	91.46	15.42
Day	330	171	1
Hour	6	13	1

Heating Peaks Solar Peaks o Internal (L,O,E) Peaks on Day 1, Hour 1

Base case with no daylight windows

Value in kWh

Month	Heating	Solar	Internal (L,O,E)
1	7917.09	0.00	11440.96
2	6752.31	0.00	10333.77
3	4616.67	0.00	11440.96
4	4753.11	0.00	11071.89
5	12.91	0.00	11440.96
6	17.36	0.00	11071.89
7	0.00	0.00	11440.96
8	0.00	0.00	11440.96
9	0.00	0.00	11071.89
10	155.08	0.00	11440.96
11	6870.38	0.00	11071.89
12	7318.68	0.00	11440.96
Total	38413.58	0.00	134707.86
Peak	37.96	0.00	15.38
Day	330	0	1
Hour	6	0	1

Heating Peaks Solar Peaks o Internal (L,O,E) Peaks on Day 1, Hour 1

Mechanical ventilation

Value in kWh

Month	Heating	Solar	Internal (L,O,E)
1	11662.80	2212.72	8928.51
2	9213.82	3767.13	7461.43
3	5830.31	6756.79	7493.34
4	3810.10	10240.99	6554.76
5	0.00	18465.93	6164.40
6	0.00	16723.07	5639.06
7	0.00	18456.22	5993.90
8	0.00	14602.03	6520.90
9	85.78	8781.80	6988.91
10	374.74	5120.08	7991.47
11	9860.06	2984.71	8436.70
12	11118.61	1529.96	9223.68
Total	51956.20	109641.38	87397.04
Peak	46.33	91.46	15.42
Day	330	171	1
Hour	6	13	1

Heating Peaks Solar Peaks o Internal (L,O,E) Peaks on Day 1, Hour 1

Natural ventilation (by cargo doors)

Value in kWh

Month	Heating	Solar	Internal (L,O,E)
1	11668.48	2212.72	8928.51
2	9218.60	3767.13	7461.43
3	5898.78	6756.79	7493.34
4	4172.31	10240.99	6554.76
5	13.40	18465.93	6164.40
6	8.88	16723.07	5639.06
7	0.00	18456.22	5993.90
8	0.00	14602.03	6520.90
9	14.26	8781.80	6988.91
10	612.22	5120.08	7991.47
11	9901.93	2984.71	8436.70
12	11125.59	1529.96	9223.68
Total	52634.47	109641.38	87397.04
Peak	46.34	91.46	15.42
Day	330	171	1
Hour	6	13	1

Heating Peaks Solar Peaks o Internal (L,O,E) Peaks on Day 1, Hour 1

Natural ventilation (by ridge openings)

Value in kWh

Month	Heating	Solar	Internal (L,O,E)
1	11662.81	2212.72	8928.51
2	9232.79	3767.13	7461.43
3	5957.96	6756.79	7493.34
4	4376.33	10240.99	6554.76
5	16.44	18465.93	6164.40
6	13.30	16723.07	5639.06
7	0.00	18456.22	5993.90
8	0.00	14602.03	6520.90
9	7.00	8781.80	6988.91
10	584.62	5120.08	7991.47
11	9893.89	2984.71	8436.70
12	11119.66	1529.96	9223.68
Total	52864.80	109641.38	87397.04
Peak	46.34	91.46	15.42
Day	330	171	1
Hour	6	13	1

Heating Peaks Solar Peaks o Internal (L,O,E) Peaks on Day 1, Hour 1

Natural ventilation (cargo doors + ridge openings)

Value in kWh

Month	Heating	Solar	Internal (L,O,E)
1	11668.47	2212.72	8928.51
2	9237.07	3767.13	7461.43
3	5976.64	6756.79	7493.34
4	4463.31	10240.99	6554.76
5	19.60	18465.93	6164.40
6	44.84	16723.07	5639.06
7	0.00	18456.22	5993.90
8	0.00	14602.03	6520.90
9	22.40	8781.80	6988.91
10	692.81	5120.08	7991.47
11	9917.13	2984.71	8436.70
12	11126.07	1529.96	9223.68
Total	53168.36	109641.38	87397.04
Peak	46.35	91.46	15.42
Day	330	171	1
Hour	6	13	1

Heating Peaks Solar Peaks o Internal (L,O,E) Peaks on Day 1, Hour 1

Natural ventilation (cargo doors + ridge NIGHT openings)

Value in kWh

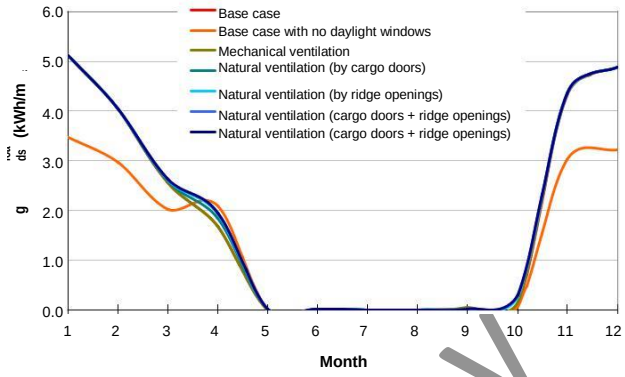
Month	Heating	Solar	Internal (L,O,E)
1	11668.47	2212.72	8928.51
2	9237.07	3767.13	7461.43
3	5976.64	6756.79	7493.34
4	4463.31	10240.99	6554.76
5	19.60	18465.93	6164.40
6	44.84	16723.07	5639.06
7	0.00	18456.22	5993.90
8	0.00	14602.03	6520.90
9	30.41	8781.80	6988.91
10	705.87	5120.08	7991.47
11	9920.33	2984.71	8436.70
12	11126.35	1529.96	9223.68
Total	53192.88	109641.38	87397.04
Peak	46.35	91.46	15.42
Day	330	171	1
Hour	6	13	1

Heating Peaks Solar Peaks o Internal (L,O,E) Peaks on Day 1, Hour 1

Shed floor area= ***2280 m2***

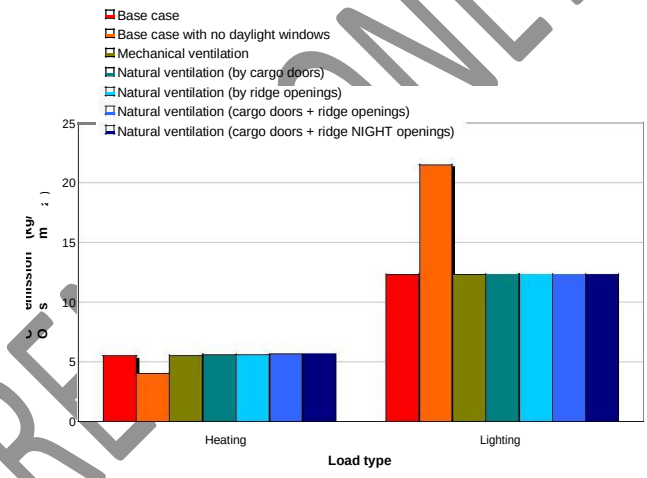
Base case

Value in kWh		Lighting electri	27.906
Month	Heating	Solar	Internal (L,O,E)
1	5.12	0.97	3.92
2	4.04	1.65	3.27
3	2.56	2.96	3.29
4	1.67	4.49	2.87
5	0.00	8.10	2.70
6	0.00	7.33	2.47
7	0.00	8.09	2.63
8	0.00	6.40	2.86
9	0.00	3.85	3.07
10	0.12	2.25	3.51
11	4.31	1.31	3.70
12	4.88	0.67	4.05
Total	22.69	48.09	38.33



Base case with no daylight windows

Value in kWh		Lighting electri	48.656
Month	Heating	Solar	Internal (L,O,E)
1	3.47	0.00	5.02
2	2.96	0.00	4.53
3	2.02	0.00	5.02
4	2.08	0.00	4.86
5	0.01	0.00	5.02
6	0.01	0.00	4.86
7	0.00	0.00	5.02
8	0.00	0.00	5.02
9	0.00	0.00	4.86
10	0.07	0.00	5.02
11	3.01	0.00	4.86
12	3.21	0.00	5.02
Total	16.85	0.00	59.08



Mechanical ventilation

Value in kWh		Lighting electri	27.906
Month	Heating	Solar	Internal (L,O,E)
1	5.12	0.97	3.92
2	4.04	1.65	3.27
3	2.56	2.96	3.29
4	1.67	4.49	2.87
5	0.00	8.10	2.70
6	0.00	7.33	2.47
7	0.00	8.09	2.63
8	0.00	6.40	2.86
9	0.04	3.85	3.07
10	0.16	2.25	3.51
11	4.32	1.31	3.70
12	4.88	0.67	4.05
Total	22.79	48.09	38.33

Natural ventilation (by cargo doors)

Value in kWh		Lighting electri	27.906
Month	Heating	Solar	Internal (L,O,E)
1	5.12	0.97	3.92
2	4.04	1.65	3.27
3	2.59	2.96	3.29
4	1.83	4.49	2.87
5	0.01	8.10	2.70
6	0.00	7.33	2.47
7	0.00	8.09	2.63
8	0.00	6.40	2.86
9	0.01	3.85	3.07
10	0.27	2.25	3.51
11	4.34	1.31	3.70
12	4.88	0.67	4.05
Total	23.09	48.09	38.33

Natural ventilation (by ridge openings)

Value in kWh		Lighting electri	27.906
Month	Heating	Solar	Internal (L,O,E)
1	5.12	0.97	3.92
2	4.05	1.65	3.27
3	2.61	2.96	3.29
4	1.92	4.49	2.87
5	0.01	8.10	2.70
6	0.01	7.33	2.47
7	0.00	8.09	2.63
8	0.00	6.40	2.86
9	0.00	3.85	3.07
10	0.26	2.25	3.51
11	4.34	1.31	3.70
12	4.88	0.67	4.05
Total	23.19	48.09	38.33

Natural ventilation (cargo doors + ridge openings)

Value in kWh		Lighting electri	27.906
Month	Heating	Solar	Internal (L,O,E)
1	5.12	0.97	3.92
2	4.05	1.65	3.27
3	2.62	2.96	3.29
4	1.96	4.49	2.87
5	0.01	8.10	2.70
6	0.02	7.33	2.47
7	0.00	8.09	2.63
8	0.00	6.40	2.86
9	0.01	3.85	3.07
10	0.30	2.25	3.51
11	4.35	1.31	3.70
12	4.88	0.67	4.05
Total	23.32	48.09	38.33

Natural ventilation (cargo doors + ridge NIGHT openings)

Value in kWh		Lighting electri	27.906
Month	Heating	Solar	Internal (L,O,E)
1	5.12	0.97	3.92
2	4.05	1.65	3.27
3	2.62	2.96	3.29
4	1.96	4.49	2.87
5	0.01	8.10	2.70
6	0.02	7.33	2.47
7	0.00	8.09	2.63
8	0.00	6.40	2.86
9	0.01	3.85	3.07
10	0.31	2.25	3.51
11	4.35	1.31	3.70
12	4.88	0.67	4.05
Total	23.33	48.09	38.33

Loads summary kWh/m2

	Heating	Solar	Internal	Lighting
Base case	22.69	48.09	38.33	27.91
Base case wit	16.85	0.00	59.08	48.66
Mechanical ve	22.79	48.09	38.33	27.91
Natural ventila	23.09	48.09	38.33	27.91
Natural ventila	23.19	48.09	38.33	27.91
Natural ventila	23.32	48.09	38.33	27.91
Natural ventila	23.33	48.09	38.33	27.91

CO2 emissions kg/m2

	Heating	Solar	Internal	Lighting
Base case	5.50	21.26	16.94	12.33
Base case wit	4.09	0.00	26.11	21.51
Mechanical ve	5.53	21.26	16.94	12.33
Natural ventila	5.60	21.26	16.94	12.33
Natural ventila	5.62	21.26	16.94	12.33
Natural ventila	5.65	21.26	16.94	12.33
Natural ventila	5.66	21.26	16.94	12.33

Base case
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Groun	8760	4407	3831	3636	3440	3114	2720	2393	2029	1641	1246	870	571	352	203	103	44

Base case without daylight
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Groun	8760	3940	3291	2977	2392	1672	1027	495	211	83	35	0	0	0	0	0	0

Mechanical ventilation
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Groun	8760	3284	2440	2048	1626	1227	896	664	471	327	208	113	50	22	10	1	0

Natural ventilation (by cargo doors)
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Groun	8760	4022	2670	1602	1075	791	544	353	207	112	61	31	11	3	0	0	0

Natural ventilation (by ridge openings)
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Groun	8760	4075	3180	2304	1749	1292	938	618	417	227	123	60	35	15	2	0	0

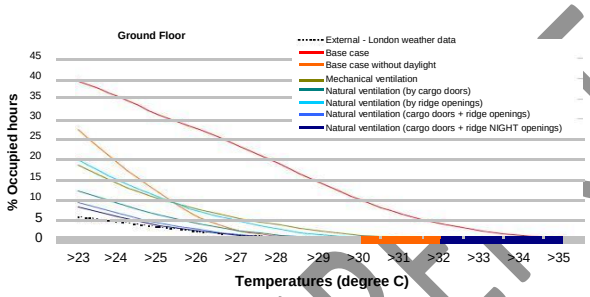
Natural ventilation (cargo doors + ridge openings)
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

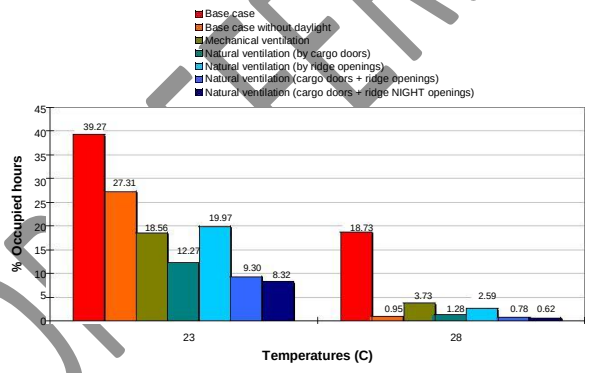
Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Groun	8760	3890	2243	1173	815	574	370	228	121	68	30	11	4	0	0	0	0

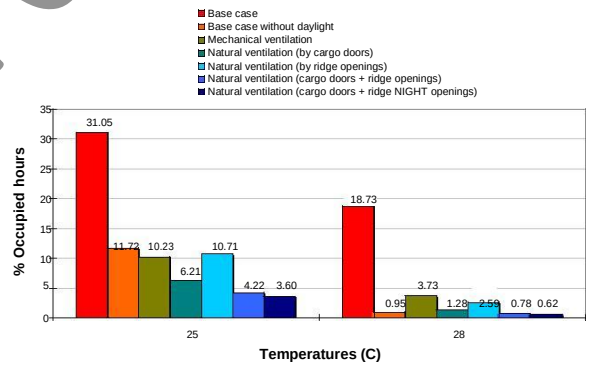
Natural ventilation (cargo doors + ridge NIGHT openings)
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Groun	8760	3374	1878	1047	729	508	315	193	100	54	23	11	4	0	0	0	0

	>20	>21	>22	>23	>24	>25	>26	>27	>28	>29	>30	>31	>32	>33	>34	>35
External - L	11.95	9.59	7.53	5.83	4.62	3.23	2.15	1.28	0.82	0.51	0.25	0.14	0.06	0.03	0.00	0.00
Base case	50.31	43.73	41.51	39.27	35.55	31.05	27.32	23.16	18.73	14.22	9.93	6.52	4.02	2.32	1.18	0.50
Base case	44.98	37.57	33.98	27.31	19.09	11.72	5.65	2.41	0.95	0.40	0.00	0.00	0.00	0.00	0.00	0.00
Mechanical	37.49	27.85	23.38	18.56	14.01	10.23	7.58	5.38	3.73	2.37	1.29	0.57	0.25	0.11	0.01	0.00
Natural ven	45.91	30.48	18.29	12.27	9.03	6.21	4.03	2.36	1.28	0.70	0.35	0.13	0.03	0.00	0.00	0.00
Natural ven	46.52	36.30	26.30	19.97	14.75	10.71	7.05	4.76	2.59	1.40	0.69	0.40	0.17	0.02	0.00	0.00
Natural ven	44.41	25.61	13.39	9.30	6.55	4.22	2.60	1.38	0.78	0.34	0.13	0.05	0.00	0.00	0.00	0.00
Natural ven	38.52	21.44	11.95	8.32	5.80	3.60	2.20	1.14	0.62	0.26	0.13	0.05	0.00	0.00	0.00	0.00







Base case
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Grou	8760	4407	3831	3636	3440	3114	2720	2393	2029	1641	1246	870	571	352	203	103	44

Mechanical ventilation
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Grou	8760	3284	2440	2048	1626	1227	896	664	471	327	208	113	50	22	10	1	0

Natural ventilation (by cargo doors)
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Grou	8760	4022	2670	1602	1075	791	544	353	207	112	61	31	11	3	0	0	0

Natural ventilation (by ridge openings)
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Grou	8760	4075	3180	2304	1749	1292	938	618	417	227	123	60	35	15	2	0	0

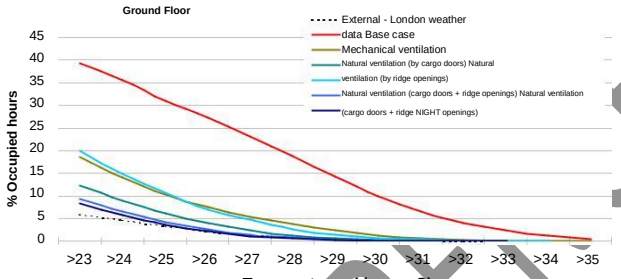
Natural ventilation (cargo doors + ridge openings)
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

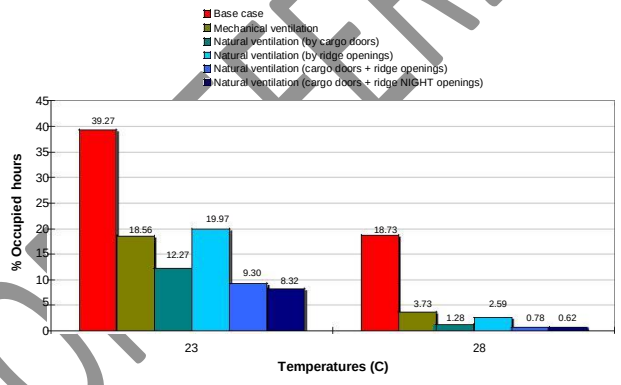
Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Grou	8760	3890	2243	1173	815	574	370	228	121	68	30	11	4	0	0	0	0

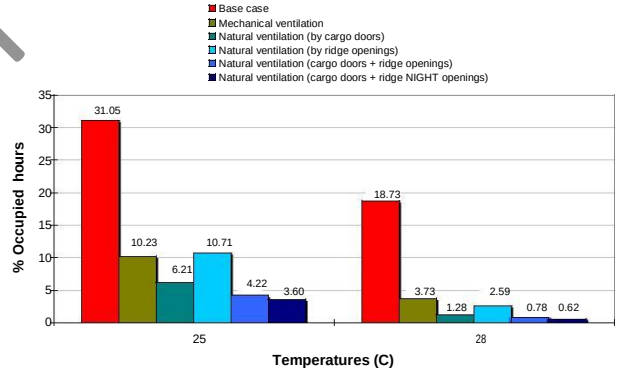
Natural ventilation (cargo doors + ridge NIGHT openings)
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Grou	8760	3374	1878	1047	729	508	315	193	100	54	23	11	4	0	0	0	0

	>20	>21	>22	>23	>24	>25	>26	>27	>28	>29	>30	>31	>32	>33	>34	>35
External - L	11.95	9.59	7.53	5.83	4.62	3.23	2.15	1.28	0.82	0.51	0.25	0.14	0.06	0.03	0.00	0.00
Base case	50.31	43.73	41.51	39.27	35.55	31.05	27.32	23.16	18.73	14.22	9.93	6.52	4.02	2.32	1.18	0.50
Mechanical	37.49	27.85	23.38	18.56	14.01	10.23	7.58	5.38	3.73	2.37	1.29	0.57	0.25	0.11	0.01	0.00
Natural ven	45.91	30.48	18.29	12.27	9.03	6.21	4.03	2.36	1.28	0.70	0.35	0.13	0.03	0.00	0.00	0.00
Natural ven	46.52	36.30	26.30	19.97	14.75	10.71	7.05	4.76	2.59	1.40	0.68	0.40	0.17	0.02	0.00	0.00
Natural ven	44.41	25.61	13.39	9.30	6.55	4.22	2.60	1.38	0.78	0.34	0.13	0.05	0.00	0.00	0.00	0.00
Natural ven	38.52	21.44	11.95	8.32	5.80	3.60	2.20	1.14	0.62	0.26	0.13	0.05	0.00	0.00	0.00	0.00







Base case
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Mezza	8760	4381	3847	3647	3408	3086	2696	2380	2015	1639	1247	907	608	420	245	148	74

Base case without daylight
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Mezza	8760	3916	3294	2940	2400	1682	1072	567	274	99	40	14	0	0	0	0	0

Mechanical ventilation
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Mezza	8760	3273	2481	2087	1666	1292	967	722	520	359	243	153	70	39	15	8	1

Natural ventilation (by cargo doors)
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Mezza	8760	3935	2616	1752	1213	916	674	491	311	191	112	62	33	14	5	0	0

Natural ventilation (by ridge openings)
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Mezza	8760	4043	3020	2178	1673	1268	956	689	470	284	162	89	49	27	12	2	0

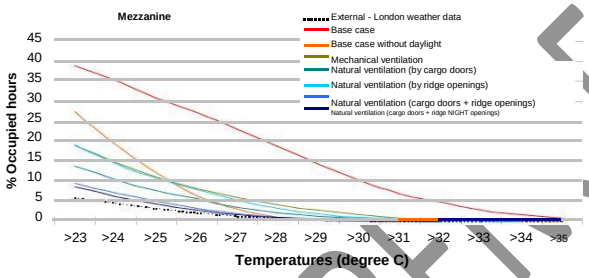
Natural ventilation (cargo doors + ridge openings)
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

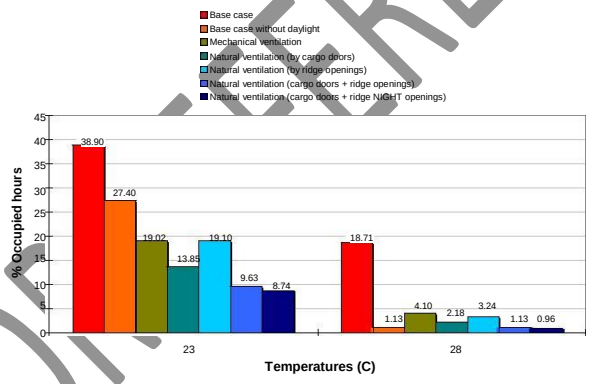
Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Mezza	8760	3788	2089	1204	844	620	454	285	180	99	52	26	10	3	0	0	0

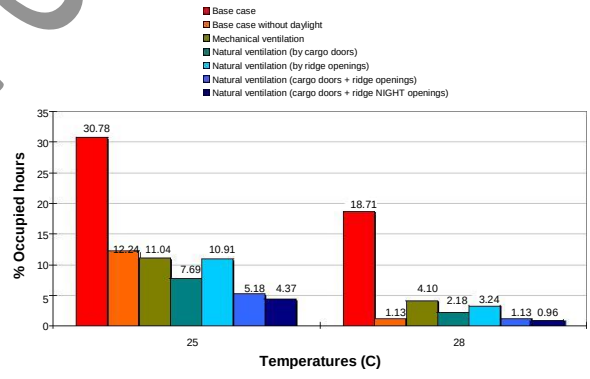
Natural ventilation (cargo doors + ridge NIGHT openings)
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Mezza	8760	3233	1799	1085	766	548	383	244	146	84	42	17	8	3	0	0	0

	>20	>21	>22	>23	>24	>25	>26	>27	>28	>29	>30	>31	>32	>33	>34	>35
External - L	11.95	9.59	7.53	5.83	4.62	3.23	2.15	1.28	0.82	0.51	0.25	0.14	0.05	0.03	0.00	0.00
Base case	50.01	43.92	41.63	38.90	35.23	30.78	27.17	23.00	18.71	14.24	10.35	6.94	4.79	2.80	1.69	0.84
Base case	44.70	37.60	33.56	27.40	19.20	12.24	6.47	3.13	1.13	0.46	0.16	0.00	0.00	0.00	0.00	0.00
Mechanical	37.36	28.32	23.82	19.02	14.75	11.04	8.24	5.94	4.10	2.77	1.75	0.80	0.45	0.17	0.09	0.01
Natural vent	44.92	29.86	20.00	13.85	10.46	7.69	5.61	3.55	2.18	1.28	0.71	0.38	0.16	0.06	0.00	0.00
Natural vent	46.15	34.47	24.86	19.10	14.47	10.91	7.87	5.37	3.24	1.85	1.02	0.56	0.31	0.13	0.02	0.00
Natural vent	43.24	23.85	13.74	9.63	7.08	5.18	3.25	2.05	1.13	0.59	0.30	0.11	0.03	0.00	0.00	0.00
Natural vent	36.91	20.54	12.39	8.74	6.26	4.37	2.79	1.67	0.96	0.48	0.19	0.09	0.03	0.00	0.00	0.00







Base case
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Mezz	8760	4381	3847	3647	3408	3086	2696	2380	2015	1639	1247	907	608	420	245	148	74

Mechanical ventilation
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Mezz	8760	3273	2481	2087	1666	1292	967	722	520	359	243	153	70	39	15	8	1

Natural ventilation (by cargo doors)
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Mezz	8760	3935	2616	1752	1213	916	674	491	311	191	112	62	33	14	5	0	0

Natural ventilation (by ridge openings)
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Mezz	8760	4043	3020	2178	1673	1268	956	689	470	284	162	89	49	27	12	2	0

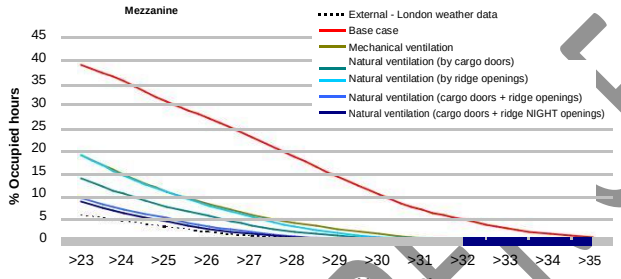
Natural ventilation (cargo doors + ridge openings)
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

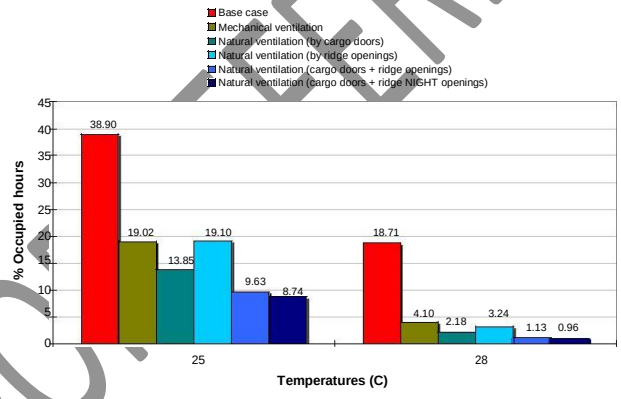
Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Mezz	8760	3788	2089	1204	844	620	454	285	180	99	52	26	10	3	0	0	0

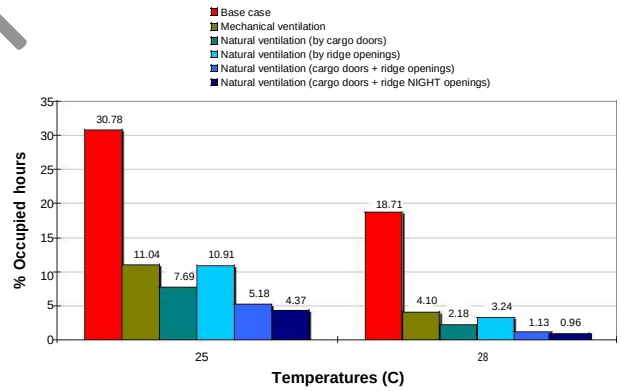
Natural ventilation (cargo doors + ridge NIGHT openings)
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

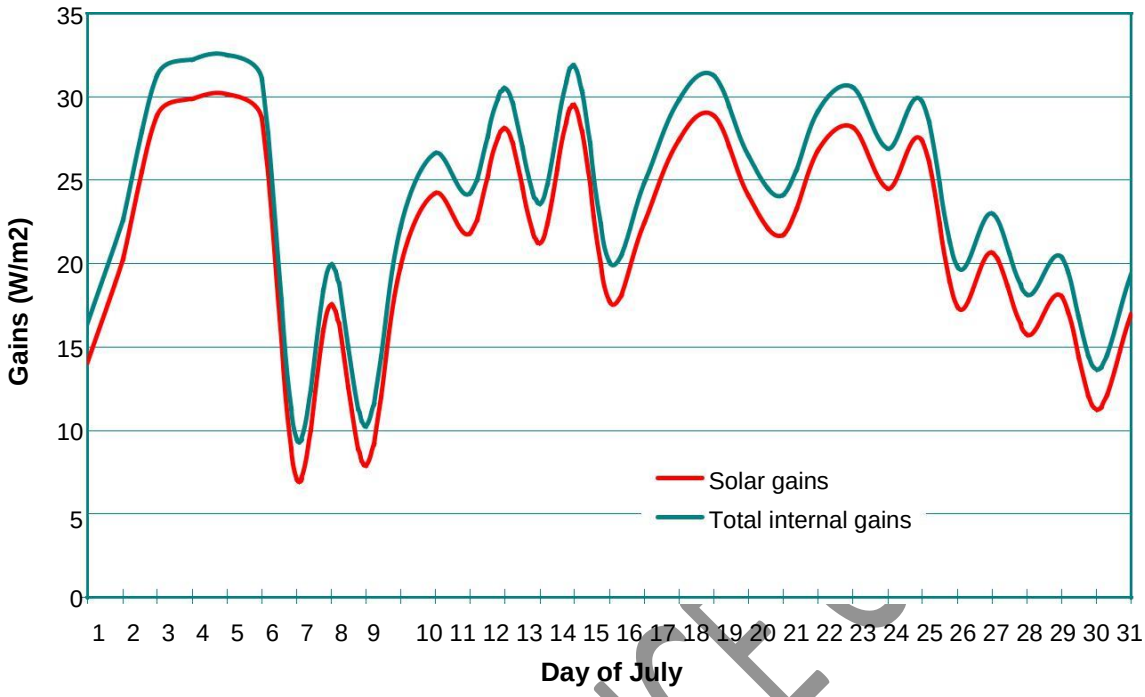
Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Mezz	8760	3233	1799	1085	766	548	383	244	146	84	42	17	8	3	0	0	0

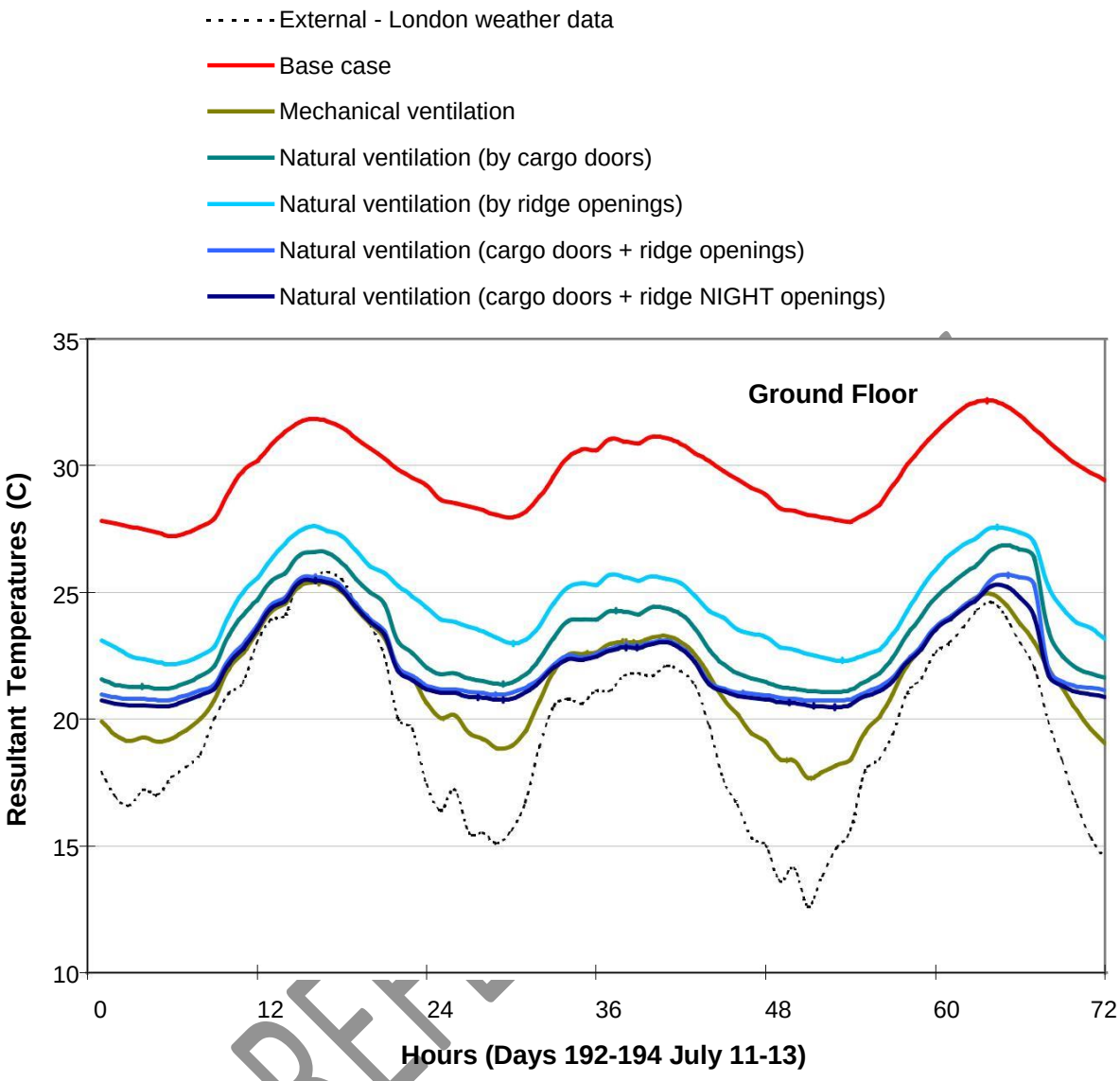
	>20	>21	>22	>23	>24	>25	>26	>27	>28	>29	>30	>31	>32	>33	>34	>35
External - L	11.95	9.59	7.53	5.83	4.62	3.23	2.15	1.28	0.82	0.51	0.25	0.14	0.06	0.03	0.00	0.00
Base case	50.01	43.92	41.63	38.90	35.23	30.78	27.17	23.00	18.71	14.24	10.35	6.94	4.79	2.80	1.69	0.84
Mechanical	37.36	28.32	23.82	19.02	14.75	11.04	8.24	5.94	4.10	2.77	1.75	0.80	0.45	0.17	0.09	0.01
Natural ven	44.92	29.86	20.00	13.85	10.46	7.69	5.61	3.55	2.18	1.28	0.71	0.38	0.16	0.06	0.00	0.00
Natural ven	46.15	34.47	24.86	19.10	14.47	10.91	7.87	5.37	3.24	1.85	1.02	0.56	0.31	0.14	0.02	0.00
Natural ven	43.24	23.85	13.74	9.63	7.08	5.18	3.25	2.05	1.13	0.59	0.30	0.11	0.03	0.00	0.00	0.00
Natural ven	36.91	20.54	12.39	8.74	6.26	4.37	2.79	1.67	0.96	0.48	0.19	0.09	0.03	0.00	0.00	0.00

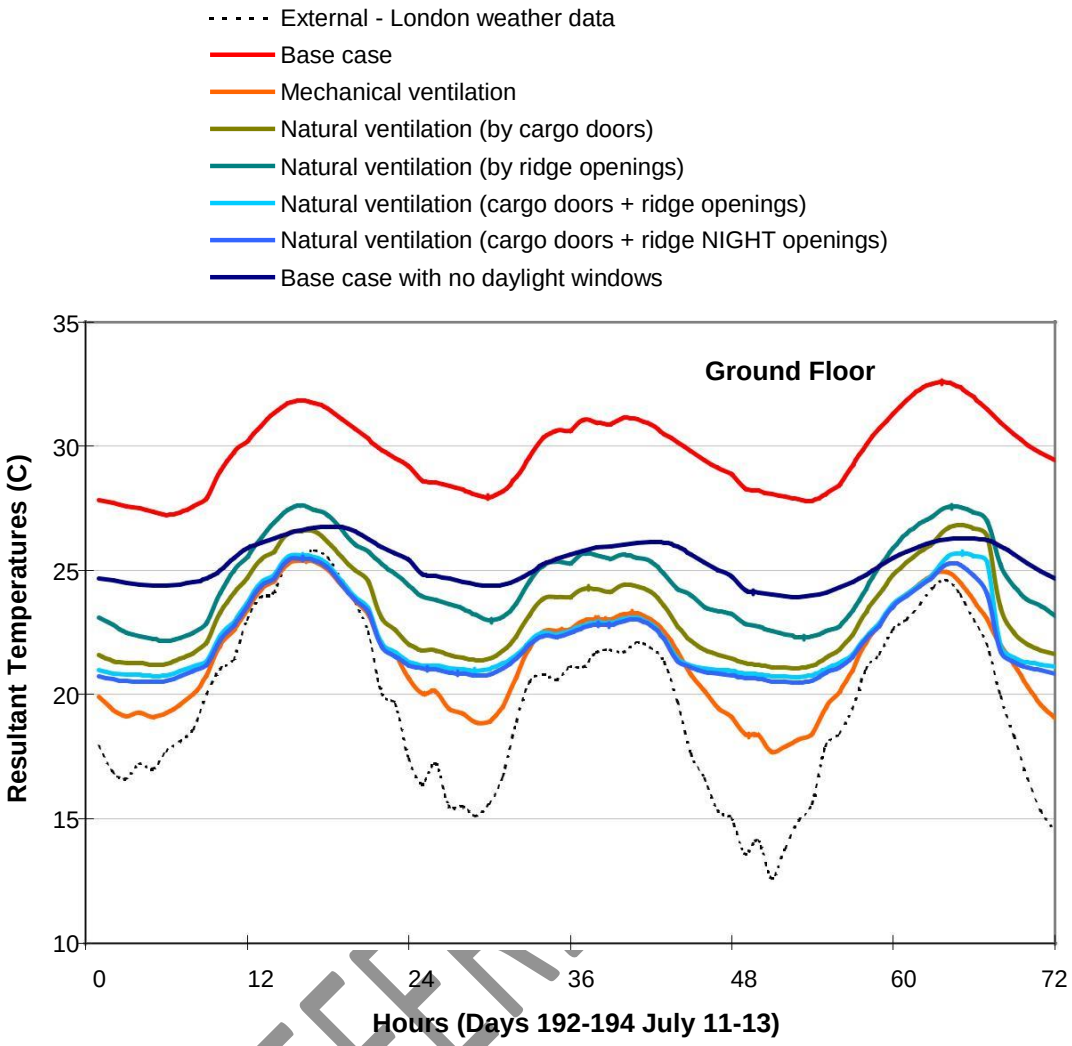









External - London weather data
Base case
Mechanical ventilation
Natural ventilation (by cargo doors)
Natural ventilation (by ridge openings)
Natural ventilation (cargo doors + ridge openings)
Natural ventilation (cargo doors + ridge NIGHT openings)
Ground Floor
Resultant Temperatures (C)
35
30
25
20
15
10
0
12
24
36
48
60
72
Hours (Days 192-194 July 11-13)



10% Base case

Value in kWh

Month	Heating	Solar	Internal (L,O,E)
1	10850.15	1568.14	9392.38
2	8961.61	2678.95	7783.01
3	6127.00	4806.03	7794.03
4	4838.49	7283.20	6821.25
5	18.96	13153.88	6446.94
6	0.00	11911.41	5901.03
7	0.00	13154.08	6275.40
8	0.00	10397.97	6792.32
9	0.00	6245.05	7248.68
10	427.54	3638.99	8269.09
11	9329.07	2114.36	8870.12
12	10132.26	1078.42	9761.11
Total	50685.07	78030.45	91355.38
Peak	43.99	65.39	15.42
Day	330	171	1
Hour	6	13	1

Heating Peaks Solar Peaks o Internal (L,O,E) Peaks on Day 1, Hour 1

14% Base case

Value in kWh

Month	Heating	Solar	Internal (L,O,E)
1	11662.80	2212.72	8928.51
2	9213.82	3767.13	7461.43
3	5830.31	6756.79	7493.34
4	3810.10	10240.99	6554.76
5	0.00	18465.93	6164.40
6	0.00	16723.07	5639.06
7	0.00	18456.22	5993.90
8	0.00	14602.03	6520.90
9	0.00	8781.80	6988.91
10	264.61	5120.08	7991.47
11	9835.13	2984.71	8436.70
12	11116.60	1529.96	9223.68
Total	51733.36	109641.38	87397.04
Peak	46.32	91.46	15.42
Day	330	171	1
Hour	6	13	1

Heating Peaks Solar Peaks o Internal (L,O,E) Peaks on Day 1, Hour 1

10% with cargo doors open

Value in kWh

Month	Heating	Solar	Internal (L,O,E)
1	10856.48	1568.14	9392.38
2	8966.30	2678.95	7783.01
3	6169.56	4806.03	7794.03
4	4993.74	7283.20	6821.25
5	25.88	13153.88	6446.94
6	35.52	11911.41	5901.03
7	0.00	13154.08	6275.40
8	0.00	10397.97	6792.32
9	15.83	6245.05	7248.68
10	722.32	3638.99	8269.09
11	9374.88	2114.36	8870.12
12	10140.75	1078.42	9761.11
Total	51301.27	78030.45	91355.38
Peak	44.01	65.39	15.42
Day	330	171	1
Hour	6	13	1

Heating Peaks Solar Peaks o Internal (L,O,E) Peaks on Day 1, Hour 1

14% with cargo doors open

Value in kWh

Month	Heating	Solar	Internal (L,O,E)
1	11668.48	2212.72	8928.51
2	9218.60	3767.13	7461.43
3	5898.78	6756.79	7493.34
4	4172.31	10240.99	6554.76
5	13.40	18465.93	6164.40
6	8.88	16723.07	5639.06
7	0.00	18456.22	5993.90
8	0.00	14602.03	6520.90
9	14.26	8781.80	6988.91
10	612.22	5120.08	7991.47
11	9901.93	2984.71	8436.70
12	11125.59	1529.96	9223.68
Total	52634.47	109641.38	87397.04
Peak	46.34	91.46	15.42
Day	330	171	1
Hour	6	13	1

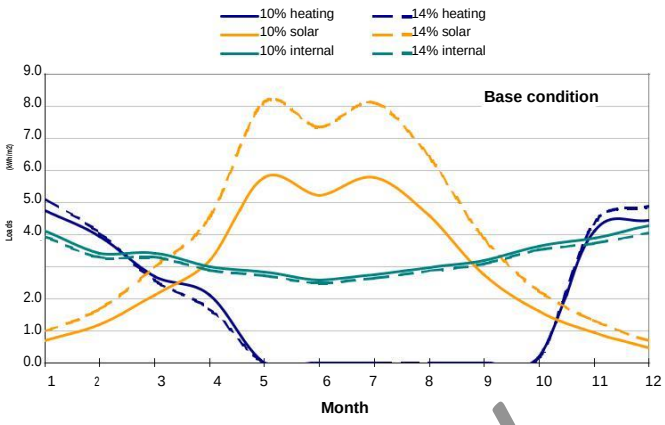
Heating Peaks Solar Peaks o Internal (L,O,E) Peaks on Day 1, Hour 1

Shed floor area= ***2280 m2***

10% Base case

Value in kWh — Lighting electri 29.642

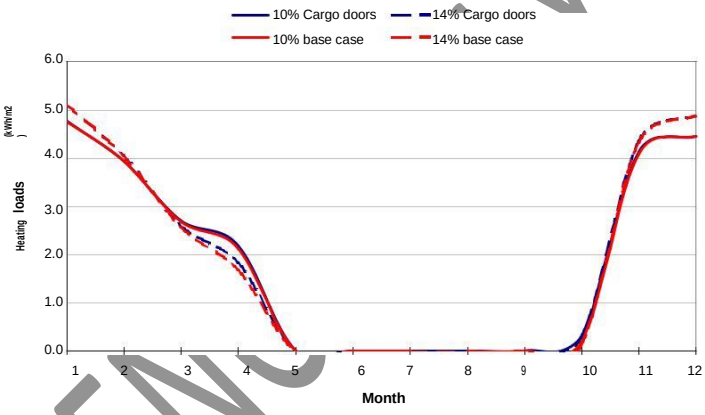
Month	Heating	Solar	Internal (L,O,E)
1	4.76	0.69	4.12
2	3.93	1.17	3.41
3	2.69	2.11	3.42
4	2.12	3.19	2.99
5	0.01	5.77	2.83
6	0.00	5.22	2.59
7	0.00	5.77	2.75
8	0.00	4.56	2.98
9	0.00	2.74	3.18
10	0.19	1.60	3.63
12	4.44	0.47	4.28
Total	22.23	34.22	40.07



14% Base case

Value in kWh — Lighting electri 27.906

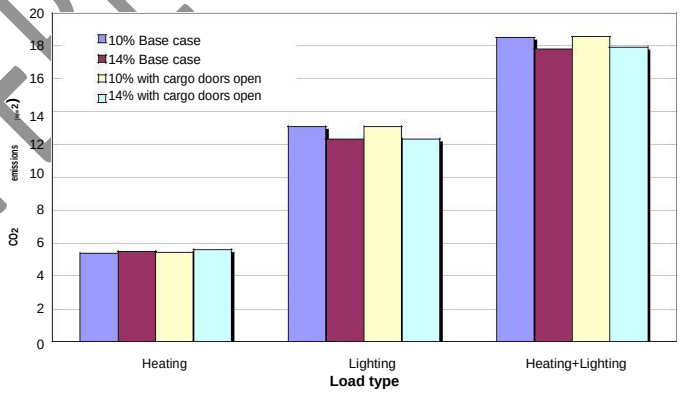
Month	Heating	Solar	Internal (L,O,E)
1	5.12	0.97	3.92
2	4.04	1.65	3.27
3	2.56	2.96	3.29
4	1.67	4.49	2.87
5	0.00	8.10	2.70
6	0.00	7.33	2.47
7	0.00	8.09	2.63
8	0.00	6.40	2.86
9	0.00	3.85	3.07
10	0.12	2.25	3.51
11	4.31	1.31	3.70
12	4.88	0.67	4.05
Total	22.69	48.09	38.33



10% with cargo doors open

Value in kWh — Lighting electri 29.642

Month	Heating	Solar	Internal (L,O,E)
1	4.76	0.69	4.12
2	3.93	1.17	3.41
3	2.71	2.11	3.42
4	2.19	3.19	2.99
5	0.01	5.77	2.83
6	0.02	5.22	2.59
7	0.00	5.77	2.75
8	0.00	4.56	2.98
9	0.01	2.74	3.18
10	0.32	1.60	3.63
11	4.11	0.93	3.89
12	4.45	0.47	4.28
Total	22.50	34.22	40.07



14% with cargo doors open

Value in kWh — Lighting electri 27.906

Month	Heating	Solar	Internal (L,O,E)
1	5.12	0.97	3.92
2	4.04	1.65	3.27
3	2.59	2.96	3.29
4	1.83	4.49	2.87
5	0.01	8.10	2.70
6	0.00	7.33	2.47
7	0.00	8.09	2.63
8	0.00	6.40	2.86
9	0.01	3.85	3.07
10	0.27	2.25	3.51
11	4.34	1.31	3.70
12	4.88	0.67	4.05
Total	23.09	48.09	38.33

Loads summary kWh/m2

	Heating	Solar	Internal	Lighting
10% Base cas	22.23	34.22	40.07	29.64
14% Base cas	22.69	48.09	38.33	27.91
10% with carg	22.50	34.22	40.07	29.64
14% with carg	23.09	48.09	38.33	27.91

CO2 emissions kg/m2

	Heating	Solar	Internal	Lighting	Heating+Lighting
10% Base cas	5.39	15.13	17.71	13.10	18.49
14% Base cas	5.50	21.26	16.94	12.33	17.84
10% with carg	5.46	15.13	17.71	13.10	18.56
14% with carg	5.60	21.26	16.94	12.33	17.93

10% Base case
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Groun	8760	4078	3656	3427	3081	2614	2226	1789	1361	876	552	313	153	69	35	13	0

14% Base case
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Groun	8760	4407	3831	3636	3440	3114	2720	2393	2029	1641	1246	870	571	352	203	103	44

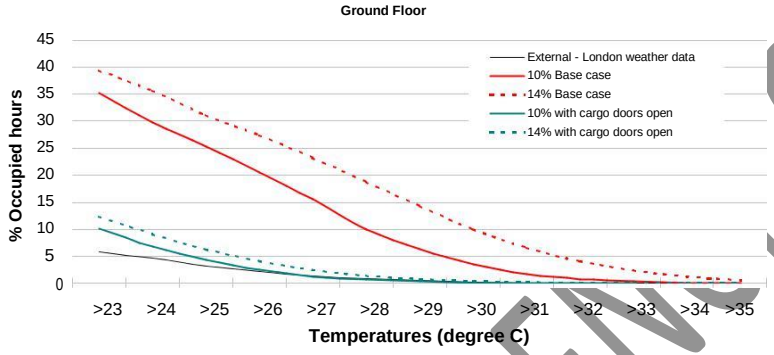
10% with cargo doors open
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

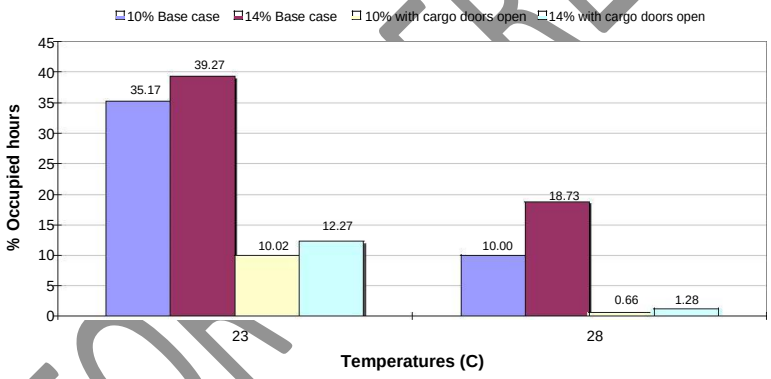
Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Groun	8760	3696	2258	1270	878	593	384	218	111	58	28	11	4	0	0	0	0

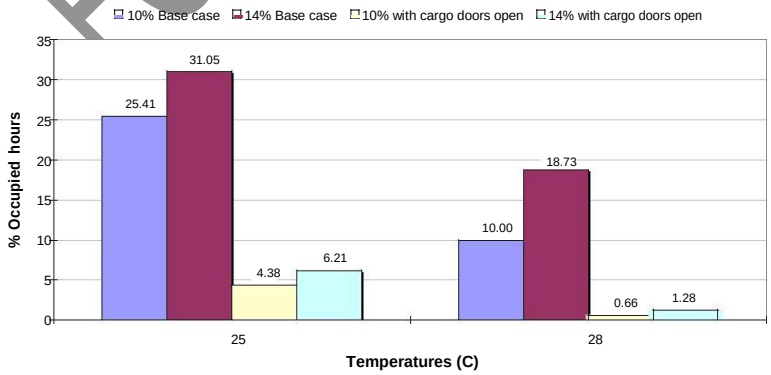
14% with cargo doors open
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Groun	8760	4022	2670	1602	1075	791	544	353	207	112	61	31	11	3	0	0	0

	>20	>21	>22	>23	>24	>25	>26	>27	>28	>29	>30	>31	>32	>33	>34	>35
External - L	11.95	9.59	7.53	5.83	4.62	3.23	2.15	1.28	0.82	0.51	0.25	0.14	0.06	0.03	0.00	0.00
10% Base c	46.55	41.74	39.12	35.17	29.84	25.41	20.42	15.54	10.00	6.30	3.57	1.75	0.79	0.40	0.15	0.00
14% Base c	50.31	43.73	41.51	39.27	35.55	31.05	27.32	23.16	18.73	14.22	9.93	6.52	4.02	2.32	1.18	0.50
10% with ca	42.19	25.78	14.50	10.02	6.77	4.38	2.49	1.27	0.66	0.32	0.13	0.05	0.00	0.00	0.00	0.00
14% with ca	45.91	30.48	18.29	12.27	9.03	6.21	4.03	2.36	1.28	0.70	0.35	0.13	0.03	0.00	0.00	0.00







10% Base case
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Mezz	8760	4087	3646	3397	3071	2610	2221	1798	1367	944	589	378	206	96	46	24	4

14% Base case
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Mezz	8760	4381	3847	3647	3408	3086	2696	2380	2015	1639	1247	907	608	420	245	148	74

10% with cargo doors open
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Mezz	8760	3637	2268	1406	986	711	497	322	187	97	54	25	10	4	0	0	0

14% with cargo doors open
Cumulative Frequency (Hours) of Resultant Temperature for Year, Days 1 to 365

Band (C)	Total	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
External - L	8760	1047	840	660	511	405	283	188	112	72	45	22	12	5	3	0	0
Shed Mezz	8760	3935	2616	1752	1213	916	674	491	311	191	112	62	33	14	5	0	0

	>20	>21	>22	>23	>24	>25	>26	>27	>28	>29	>30	>31	>32	>33	>34	>35
External - L	11.95	9.59	7.53	5.83	4.62	3.23	2.15	1.28	0.82	0.51	0.25	0.14	0.06	0.03	0.00	0.00
10% Base c	46.66	41.62	38.78	35.06	29.79	25.35	20.53	15.61	10.78	6.72	4.32	2.35	1.10	0.53	0.27	0.05
14% Base c	50.01	43.92	41.63	38.90	35.23	30.78	27.17	23.00	18.71	14.24	10.35	6.94	4.79	2.80	1.69	0.84
10% with ca	41.52	25.89	16.05	11.26	8.12	5.67	3.68	2.13	1.11	0.62	0.29	0.11	0.05	0.00	0.00	0.00
14% with ca	44.92	29.86	20.00	13.85	10.46	7.69	5.61	3.55	2.18	1.28	0.71	0.38	0.16	0.06	0.00	0.00