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ROBUST Building Energy Simulation Results

Client

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ROBUST Building Energy Simulation Results

1. Introduction

A 10 storey residential building of 14m×24m floor area and a 7 storey office/commercial building of similar floor area were modelled based on the location of London. For comparison, the residential building was also modelled by applying Edinburgh, Berlin and Helsinki climates. The heating loads for both building, together with cooling loads for only the commercial building, were calculated using the modelling. The effects of percentage openings, façade insulations, air-tightness on energy consumption were also investigated and the results are discussed in this report. As an extra case, a 4 storey residential building with floor space of 12m×30m was also thermally simulated. Orientation, as an influencing factor, was also modelled by using 10 storey residential building and London climate.

Table 1 shows the thermal properties of building elements for either existing building and improved/overcladded building.

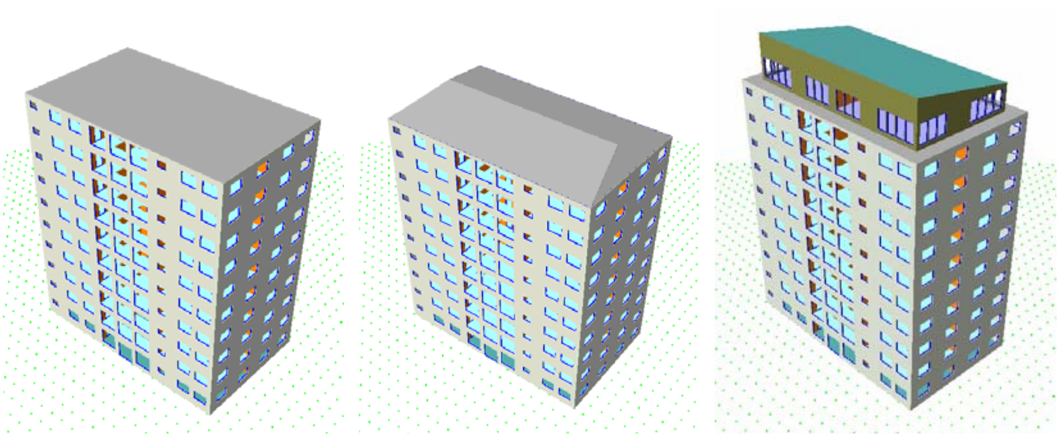
Table 1 Summary of thermal properties

Thermal properties	**Original**	**Improved**
U-value of external walls	1.5W/m^2 ºC	0.3W/m^2 ºC
U-value of windows	5.8W/m^2 ºC	1.8W/m^2 ºC
U-value of roof	1.5W/m^2 ºC	0.24W/m^2 ºC
U-value of ground floor	2.9W/m^2 ºC	0.5W/m^2 ºC
Air-tightness of the building (at 50Pa)	15m^3/m^2/h	5m^3/m^2/h

The original means the values for the building as it is without overcladding; the improved indicates the improved values by overcladding the building.

2. Ten-storey residential building: different climates and different roof extensions

Four different locations were used in the modelling: London, Edinburgh, Berlin and Helsinki. Roof-top extensions were also modelled. Details are given in Figure 1.



(a) original (b) pitched roof (c) penthouse

Figure 1 Three-dimensional view of residential building (10 storeys)

Each floor of the building is divided into 5 flats (there is also a landing/stair area each floor) with average floor area of around 55m^2. The total floor area for 50 flats in the building is measured as 2714.69m^2. The building is located with long axis east-west so that the main entrance of the building faces south.

Pitched roof is an extension on top of existing building, which is a hip roof with roof angle 15º. Penthouse is another type roof extension, taking floor space of 11m$\times$21m (1.5m access around perimeter) and height of 3m with 30% glazing on side elevations.

In winter, the flats are heated to 22ºC daily from 1500h to 2300h. In summer, natural ventilation is applied for the model that is controlled by opening windows (if internal temperature is higher than 24ºC).

The internal gains for flats are summarised in Table 2 below.

Table 2 Internal gains

Internal gains	**Value**	**Time schedule**
Lighting gain	2.0W/m^2	1500h-2300h
Occupancy Sensible	3.0W/m^2	1800h-0800h
Occupancy Latent	1.5W/m^2	1800h-0800h
Equipment Sensible	3.0W/m^2	1500h-2300h

These conditions will apply for the following sections of this document unless stated otherwise.

Following shows the terms used in graphs in this section:

- 1960: building as it is without overcladding
- 2008: building is overcladded/improved
- 2008 no roof cladding: improvement applied on the existing building except roof
- 2008 pitched: overcladded building with roof extension of pitched roof
- 2008 penthouse: overcladded building with roof extension of a penthouse

2.1. London case

Annual heating loads for whole building and per floor area are plotted in Figure 2 and Figure 3 below, showing the figures for different building improvement options.

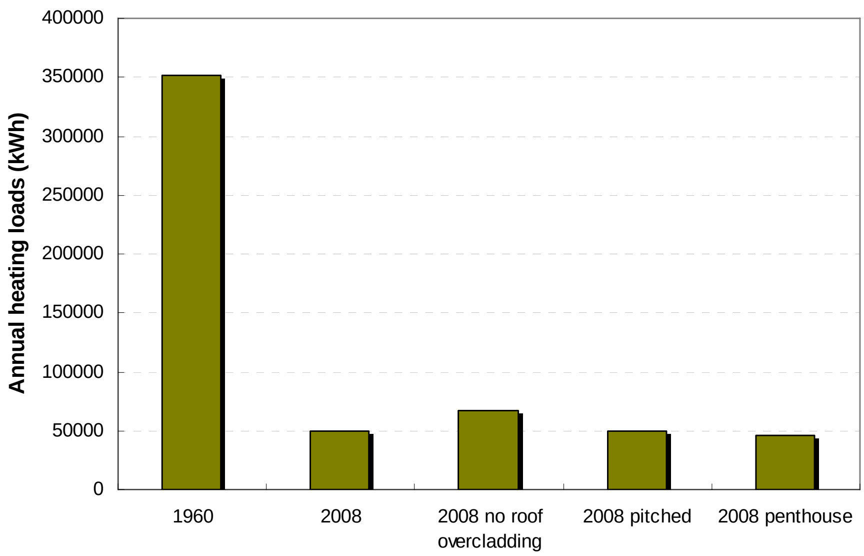


Figure 2 Annual heating loads for whole building

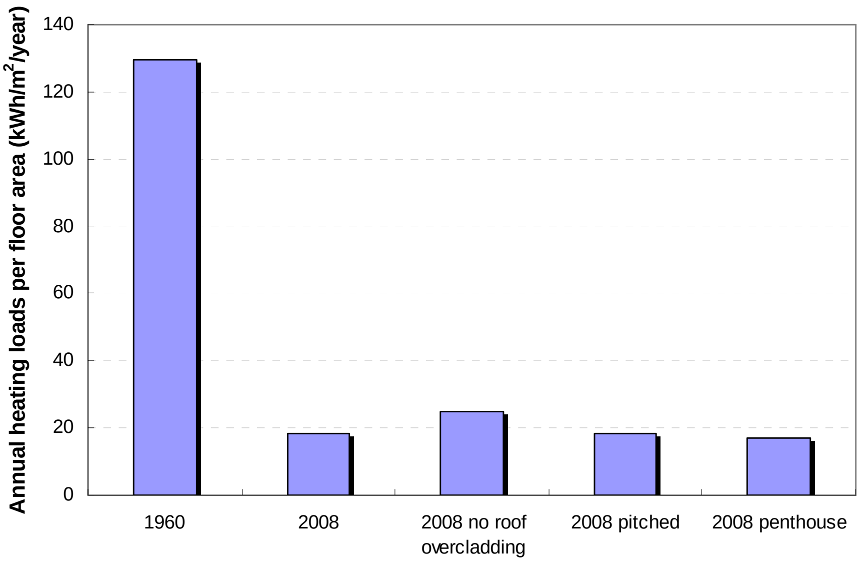


Figure 3 Annual heating loads per floor area

About 85% heating energy saving can be obtained by overcladding the building. In addition, less than 20kWh/m^2 heating load per annum can be achieved after overcladding. If improvement only applied to the building except roof, the heating energy saving becomes 82%. There is almost no change by adding roof extensions on existing building.

Monthly heating loads and solar gains are shown in Figure 4.

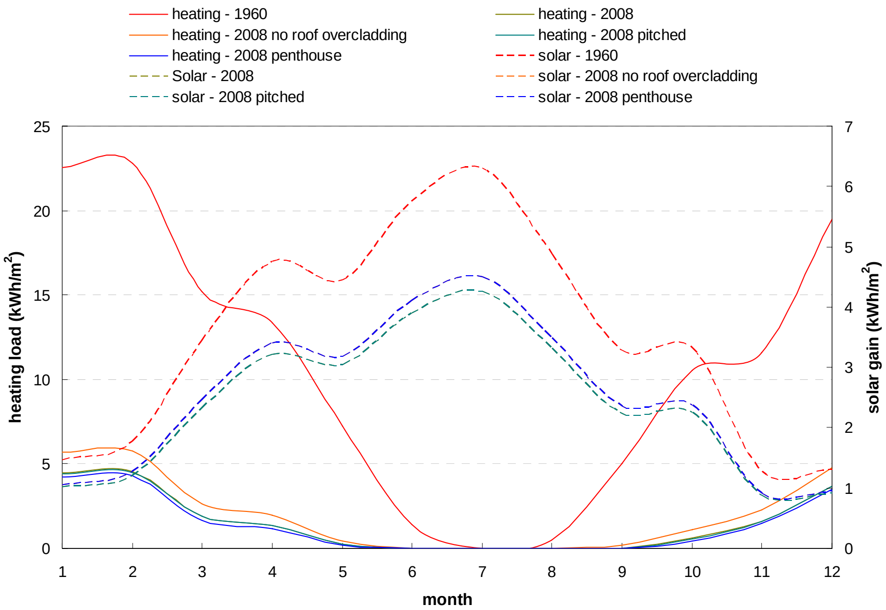


Figure 4 Monthly heating load and solar gains

These are the figures for per floor area. The solar gains are not very much reduced by using double glazing instead of single glazing, but great reduction on heating demand can be observed by improving thermal properties of building elements.

2.2. Edinburgh case

Annual heating loads for whole building and per floor area were plotted in Figure 5 and Figure 6 below, showing the figures for different building improvement options.

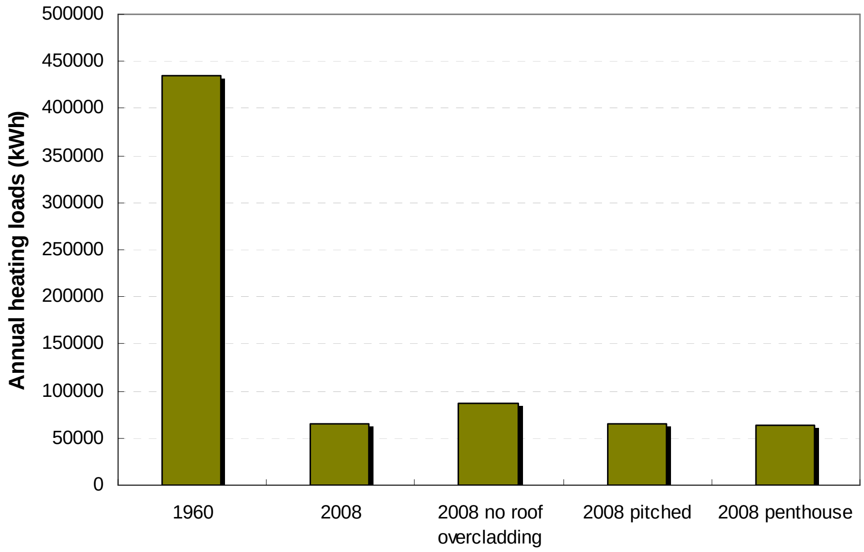


Figure 5 Annual heating loads for whole building

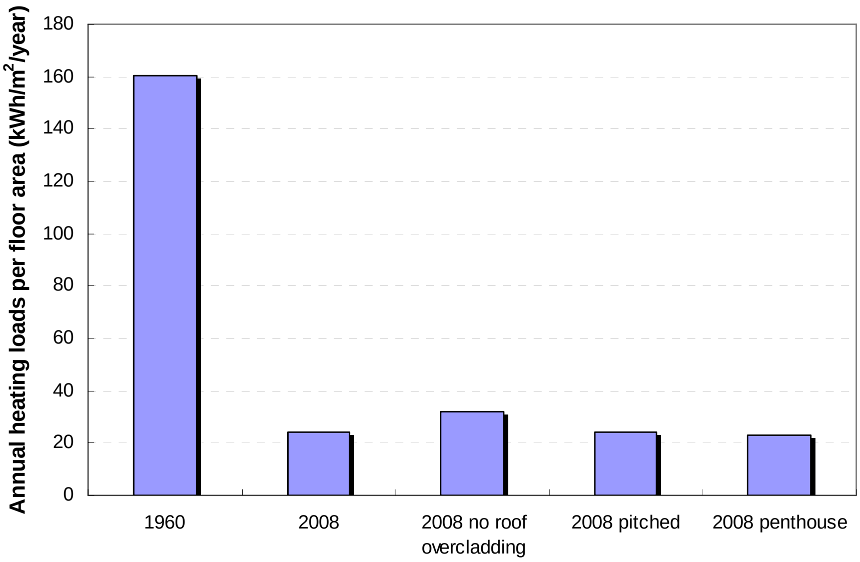


Figure 6 Annual heating loads per floor area

Again, the heating energy saving of 85% can be achieved by overcladding the building. Slightly less heating demands can be found by adding roof extensions. But if no overcladding on roof, the energy saving compared to existing building will be 80% only.

Monthly heating loads and solar gains are shown in Figure 7.

The solar gains are not very much reduced by using double glazing instead of single glazing, but great reduction on heating demand can be observed by improving thermal properties of building elements.

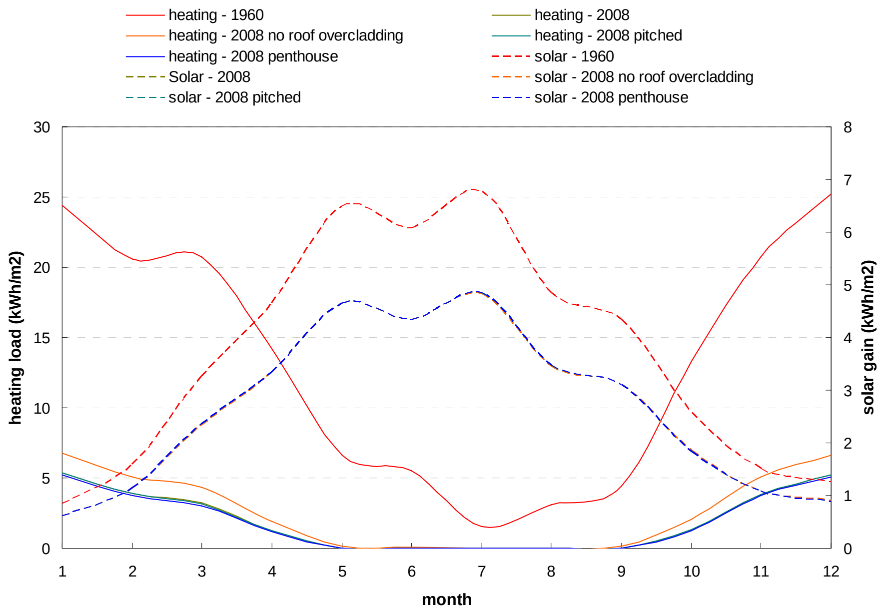


Figure 7 Monthly heating load and solar gains

2.3. Berlin case

Annual heating loads for whole building and per floor area were plotted in Figure 8 and Figure 9 below, showing the figures for different building improvement options.

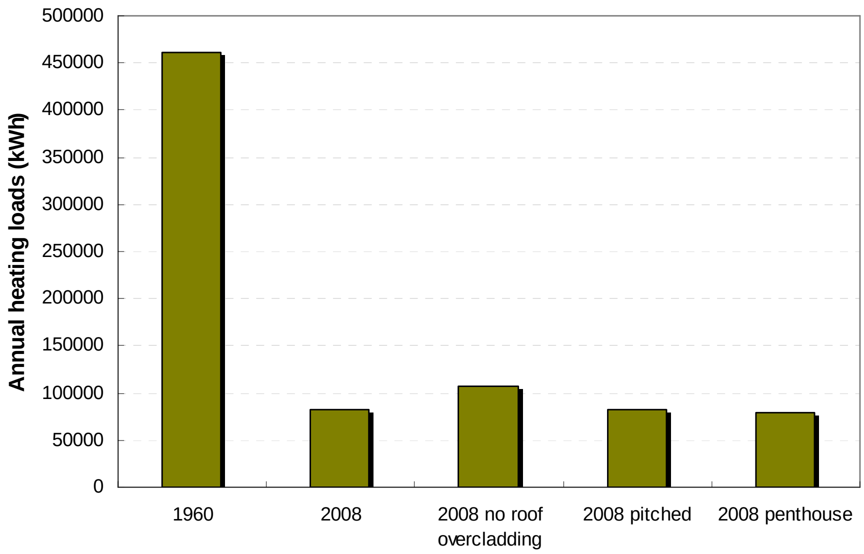


Figure 8 Annual heating loads for whole building

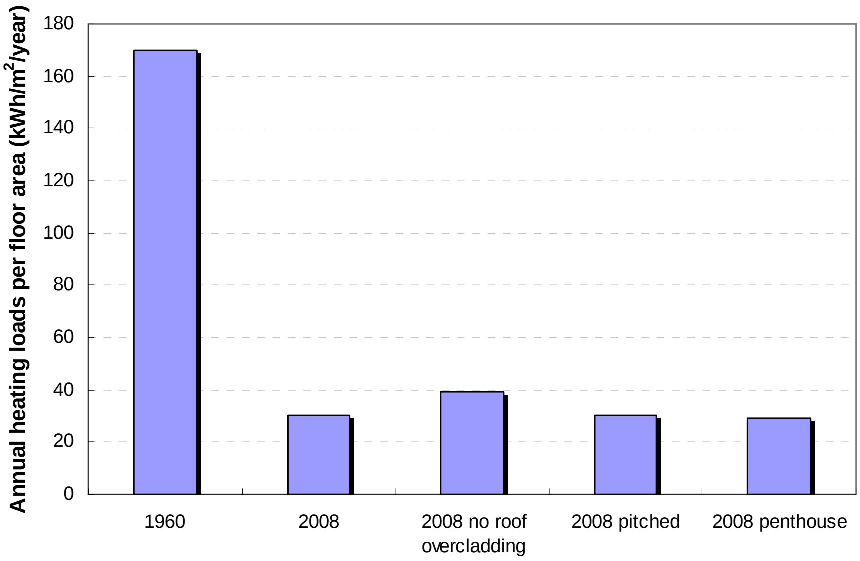


Figure 9 Annual heating loads per floor area

Figure 8 and Figure 9 show that over 80% heating energy saving is achieved in Berlin case. There is almost no change by adding roof extensions on existing building.

Monthly heating loads and solar gains are shown in Figure 10.

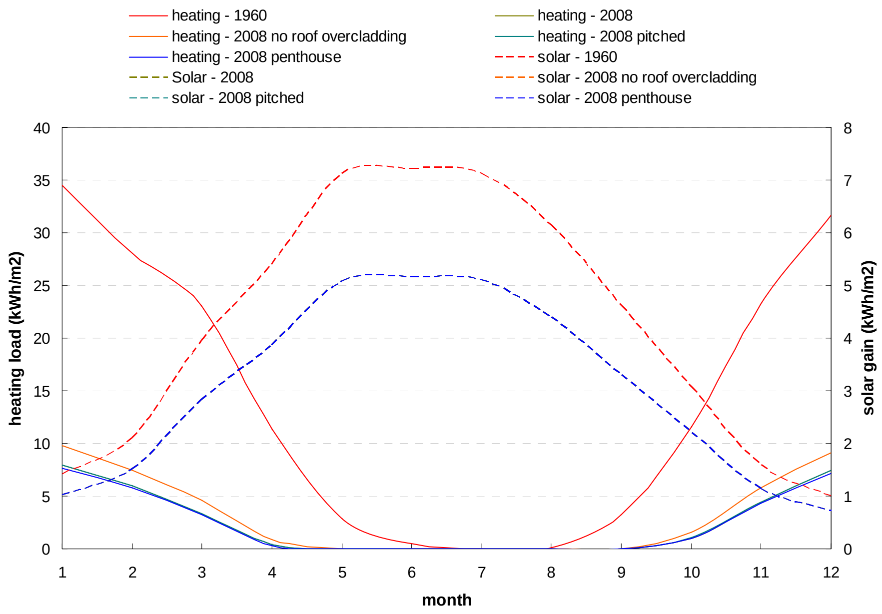


Figure 10 Monthly heating load and solar gains

2.4. Helsinki case

Annual heating loads for whole building and per floor area were plotted in Figure 11 and Figure 12 below, showing the figures for different building improvement options.

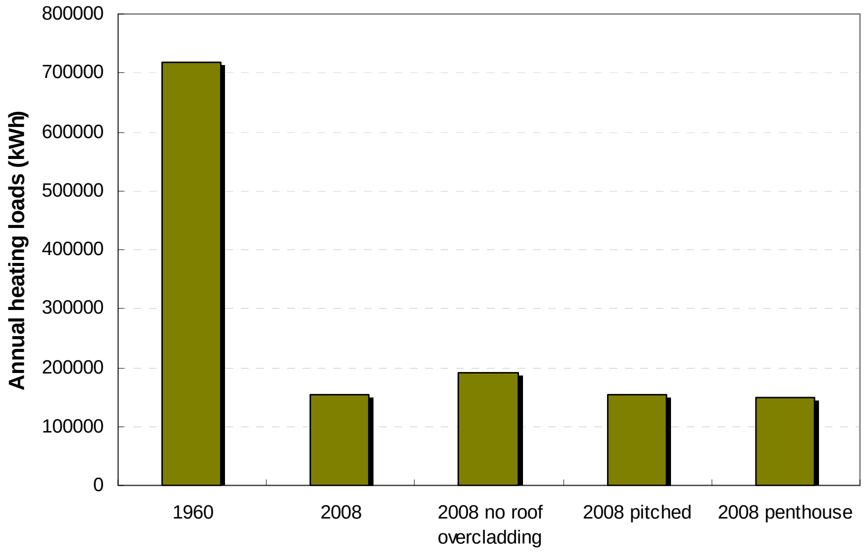


Figure 11 Annual heating loads for whole building

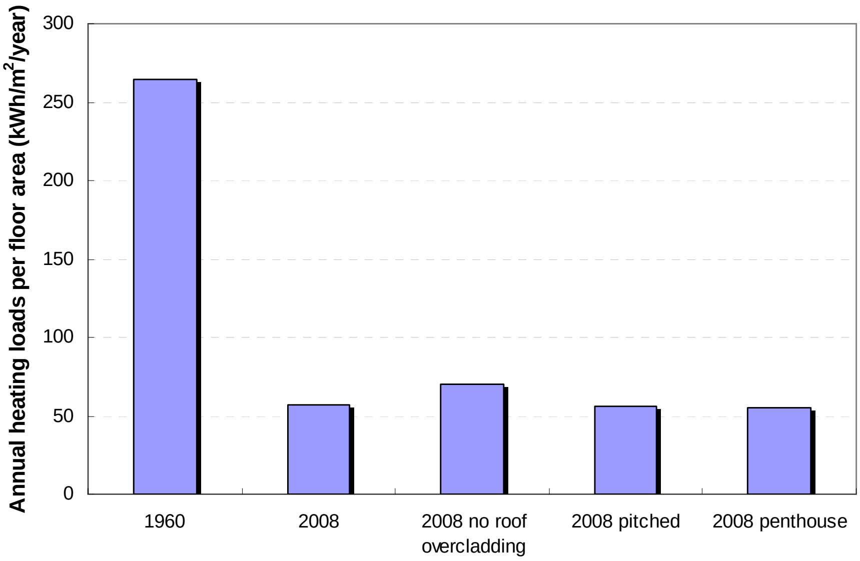


Figure 12 Annual heating loads per floor area

Figure 11 and Figure 12 show that over 75% heating energy saving can be achieved in Helsinki case. But the heating energy per floor area for overcladded building is over 55kWh per annum, as a contrast, the figure for London is less than 20kWh per annum due to the warmer weather. There is almost no change by adding roof extensions on existing building.

Monthly heating loads and solar gains are shown in Figure 13.

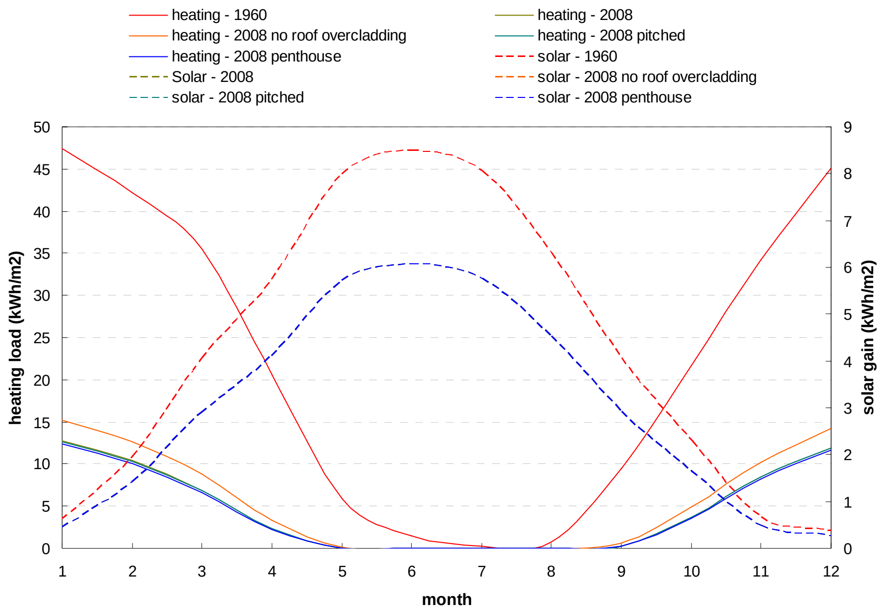


Figure 13 Monthly heating load and solar gains

3. Ten-storey residential building: percentage openings

The thermal simulation is for London climate only. The comparison is performed between existing building (1960) and overcladded/improved building (2008). Other options like no roof overcladding and roof extensions are not included into the simulation.

17%, 20%, 23% and 27% percentage openings were modelled based on 10-storey residential building that is located in London.

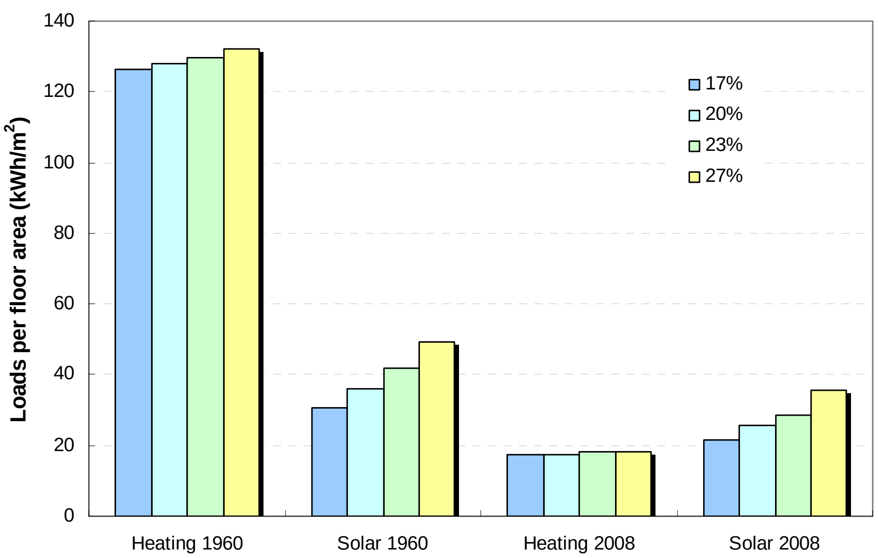


Figure 14 Breakdown of heating loads and solar gains

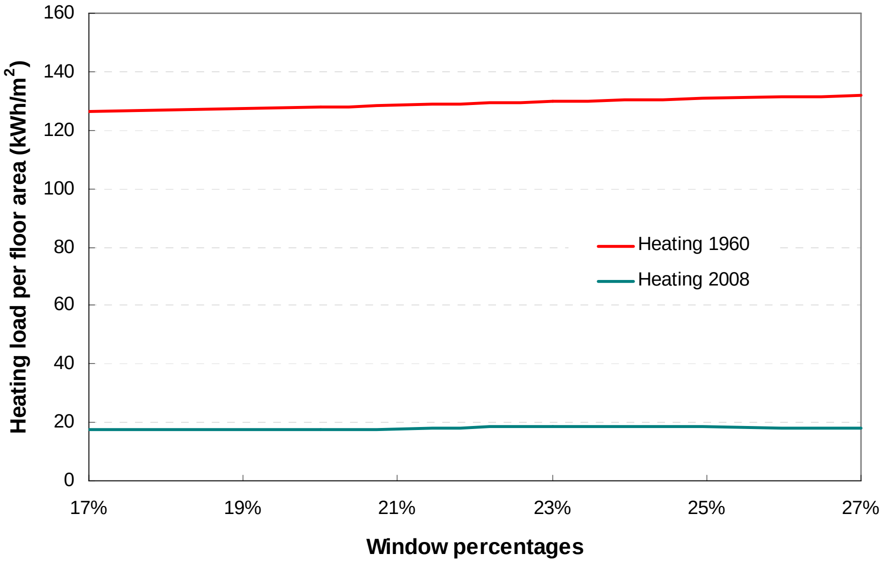


Figure 15 Heating load against percentage opening

It is possible to enlarge the window opening, thus increasing the percentage openings, to get more benefit from daylight (saving artificial lighting, investigation on lighting is not included in this modelling), because only about 5% increment of heating load was reached when enlarging percentage opening from 17% to 27%.

4. Ten-storey residential building: façade insulation properties

The thermal simulation is for one London climate only. The model uses 10-storey residential building. The influence of façade insulation properties (U-values for this estimation, say 0.20W/m^2 ºC, 0.25W/m^2 ºC and 0.30W/m^2 ºC) on heating loads was conducted.

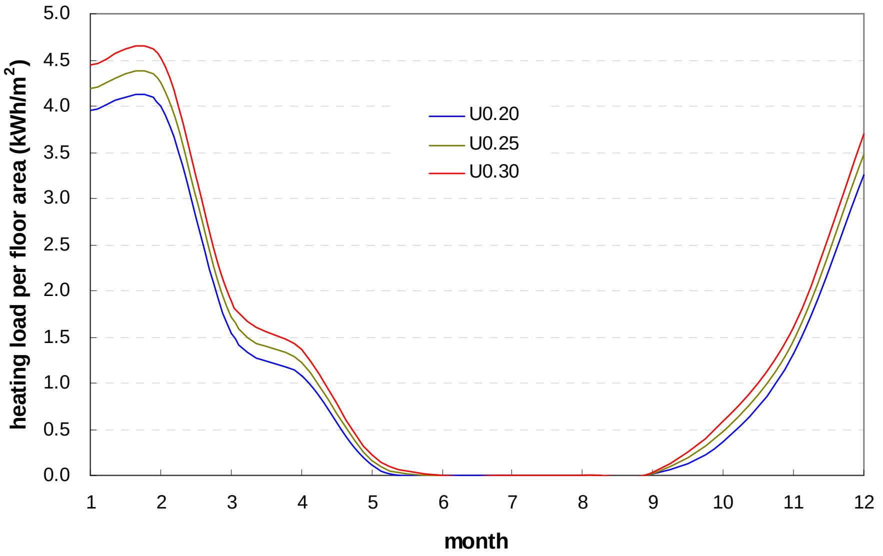
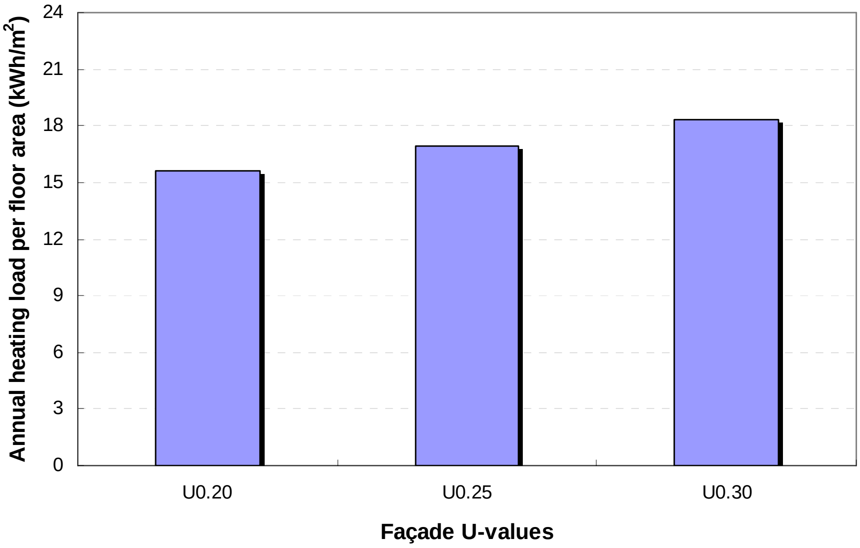
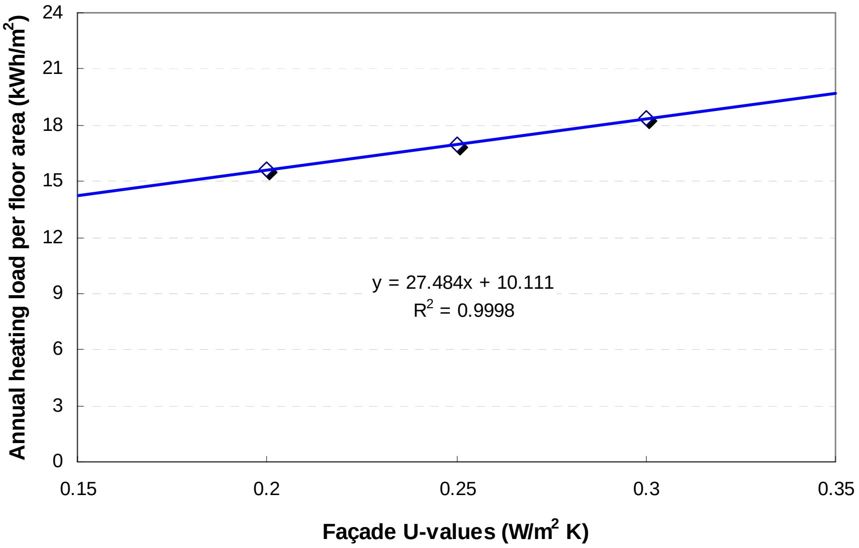


Figure 16 Monthly heating loads for different façade U-values

Figure 16 shows heating loads per floor area changes with the month of the year with peak value changes from 4.2kWh/m^2 in February for façade U-value of 0.30W/m^2 ºC to 4.7kWh/m^2 for façade U-value of 0.20W/m^2 ºC.



(a)



(b)

Figure 17 Annual heating loads for different façade U-values

The observation shows that it is important to improve the façade insulation level to at least 0.25W/m^2 ºC U-value (40% heating energy saving was achieved compared to 0.30W/m^2 ºC U-value). By regressing the data of annual heating loads to façade U-values, a perfect straight line can be reached; there is a proportional variation for heating loads against façade U-values.

5. Ten-storey residential building: air-tightness

The thermal simulation is for London climate only. The model uses 10-storey residential building. Investigation on the effect of air-tightness levels (3m^3/m^2/h, 5m^3/m^2/h and 7m^3/m^2/h) on heating energy was carried out by using thermal modelling.

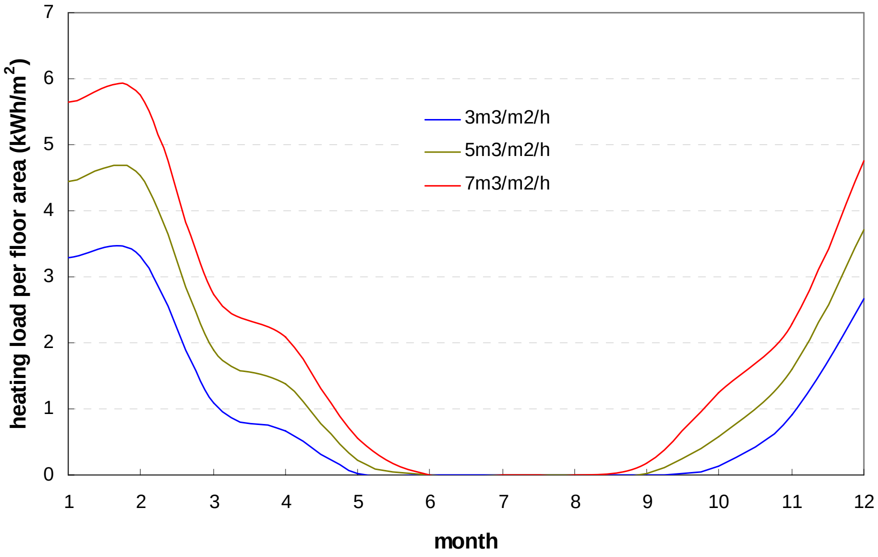
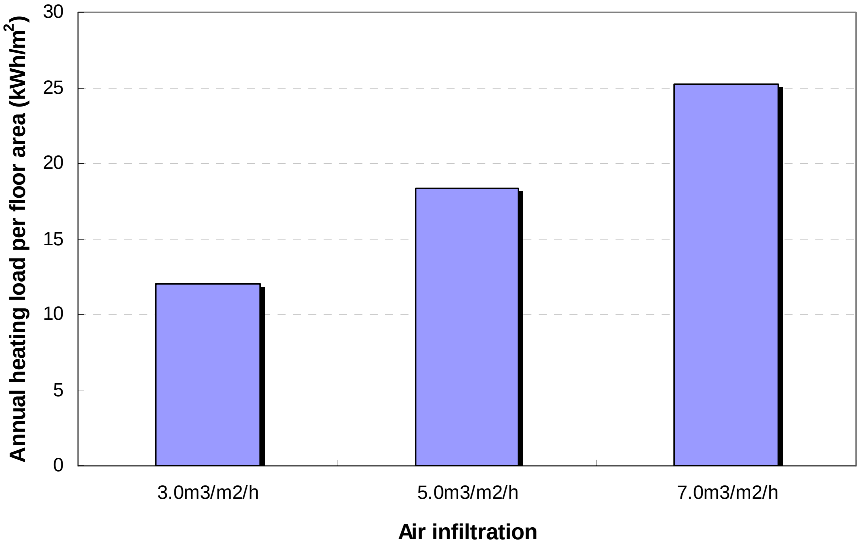
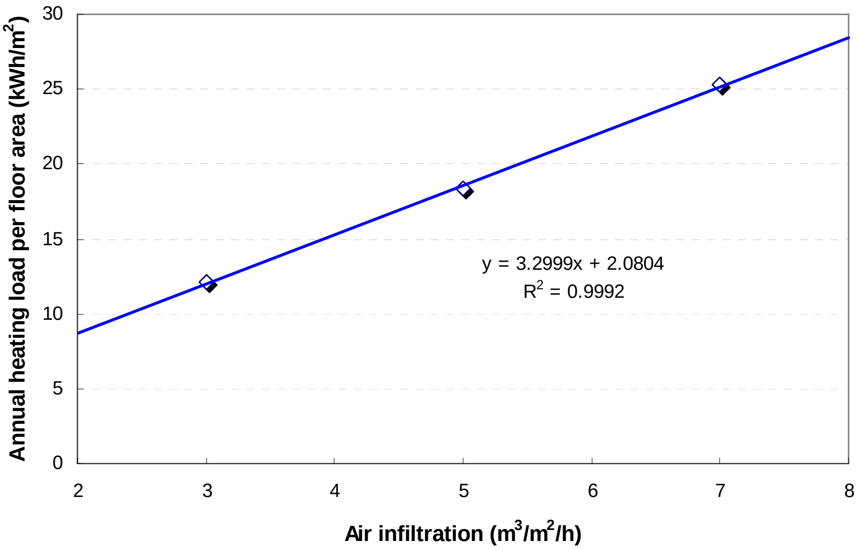


Figure 18 Monthly heating loads for different air-tightness

Air-tightness has strong influence on building energy, increasing infiltration level from $3m^3/m^2/h$ at 50Pa to 7 $m^3/m^2/h$ at 50Pa yields almost doubled heating energy demands, which can be found from Figure 18.



(a)



(b)

Figure 19 Annual heating loads for different air-tightness

A perfect line of heating loads against air-tightness was also obtained by regression. Annual heating loads change proportional with air-tightness levels.

6. Ten-storey residential building: over-roofing and over-cladding options

The thermal simulation is for London climate only. The model uses 10-storey residential building.

6.1. Over-roofing and over-cladding

Three different roof overcladding U-values of 0.15W/m^2 ºC, 0.20W/m^2 ºC and 0.25W/m^2 ºC were used for this estimation.

Figure 20 Monthly heating loads for different roof U-values

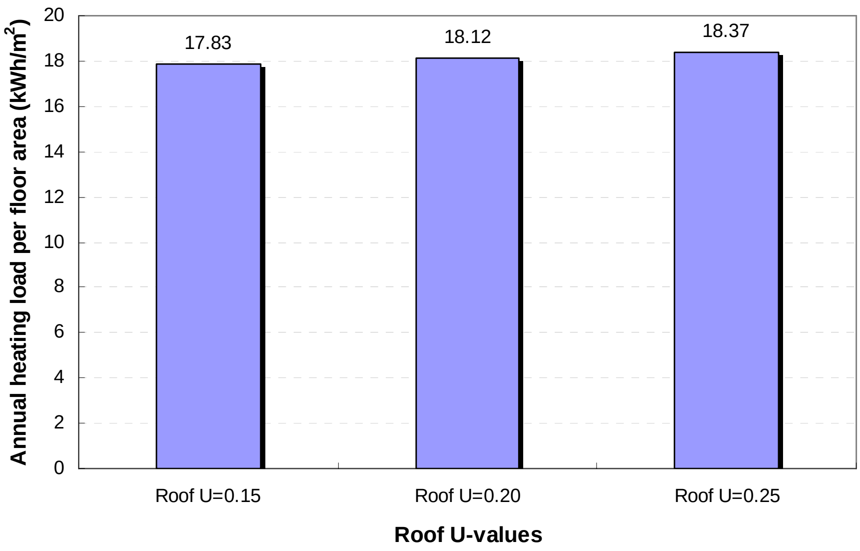


Figure 21 Annual heating loads for different roof U-values

No significant difference was found on heating load by changing over-roofing U-value.

6.2. Over-roofing existing-cladding

This section investigates the effect of using just overcladding on roof but keeping existing envelope. The results are shown in Figure 22 (monthly figures per floor area) and Figure 23 (annual figures per floor area).

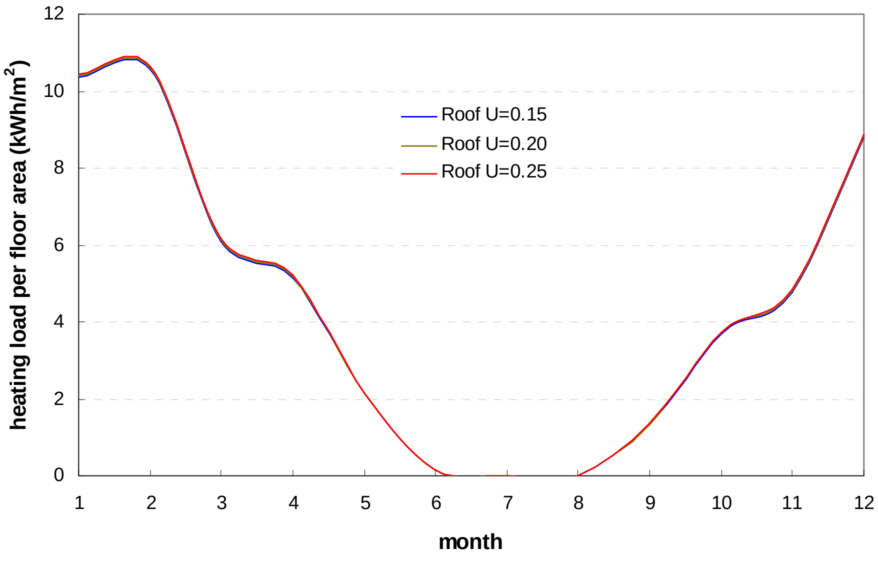


Figure 22 Monthly heating loads for different roof U-values

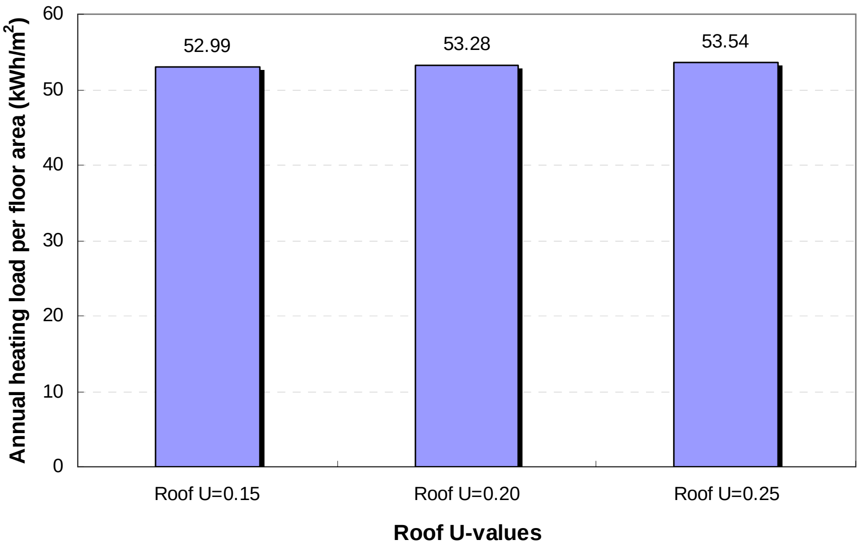


Figure 23 Annual heating loads for different roof U-values

Changing over-roofing U-value creates almost identical heating demands.

7. Residential building: extra building shape

A four-storey residential building with dimensions of 12m×30m was modelled as an extra case by using London climate. The model is shown on Figure 24. The model uses the same internal conditions as ten-storey residential building. The total floor area for 20 flats in this building is measured as 1165.60m^2. The comparison is performed between existing building (1960) and overcladded/improved building (2008). Other options like no roof overcladding and roof extensions are not included into the simulation.

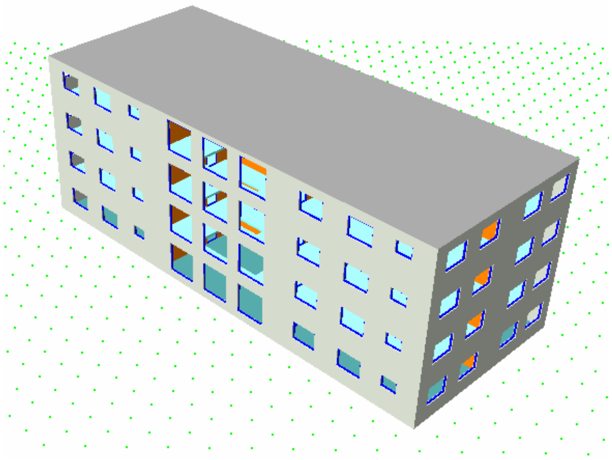


Figure 24 Three-dimensional view of four-storey residential building

7.1. Heating loads

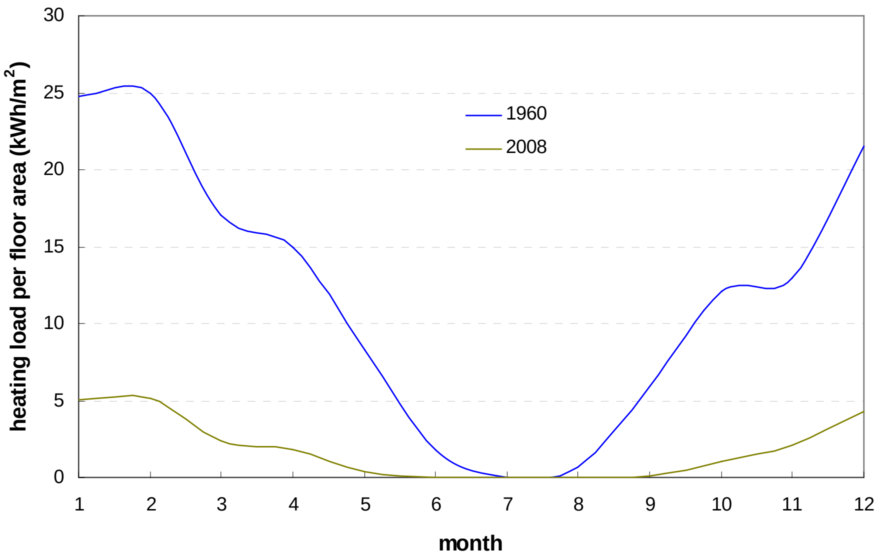


Figure 25 Monthly heating load on per floor area

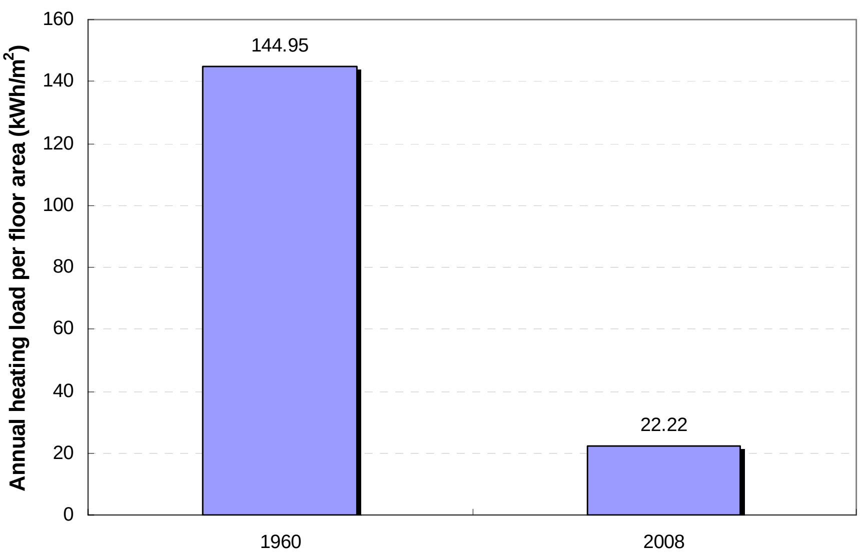


Figure 26 Comparison of annual heating loads

The figures show 85% heating energy savings can be reached by overcladding the building.

7.2. Comparison of building forms

Table 3 shows the heating demand comparison for residential buildings with different shapes and heights.

Table 3 Heating demand comparison

Building form	Heating (1960)	Heating (2008)	Savings
14m×24m 10 storeys	129.66	18.37	85.8%
12m×30m 4 storeys	144.95	22.22	84.7%

Table 3 shows there is no strong influence of building forms on savings of improved building over existing building, but they do affect the figure of heating load per floor area due to being big portion about heat loss through roof and ground floor for lower building.

8. Seven-storey commercial building

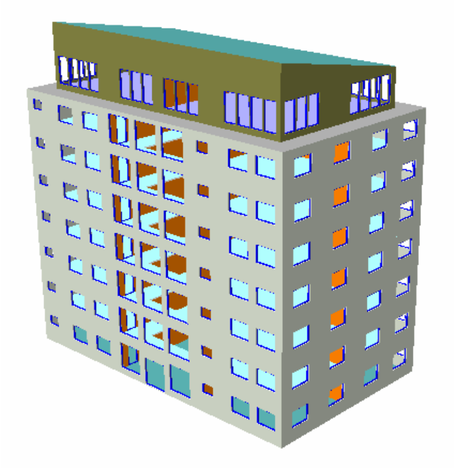


Figure 27 Three-dimensional view of seven-storey office building with a penthouse

The thermal simulation is for London climate only.

The building, which is only occupied as offices during daytime (0700h – 2000h) on weekdays, is supposed to be heated to 21ºC in winter and air-conditioned (cooled) to 24ºC in summer, therefore there is not natural ventilation applied to this building in the modelling.

The comparison on energy consumption between 2008 (improved) and 1960 (existing) was performed using thermal modelling, taking into account different roof-top extensions (pitched roof and penthouse).

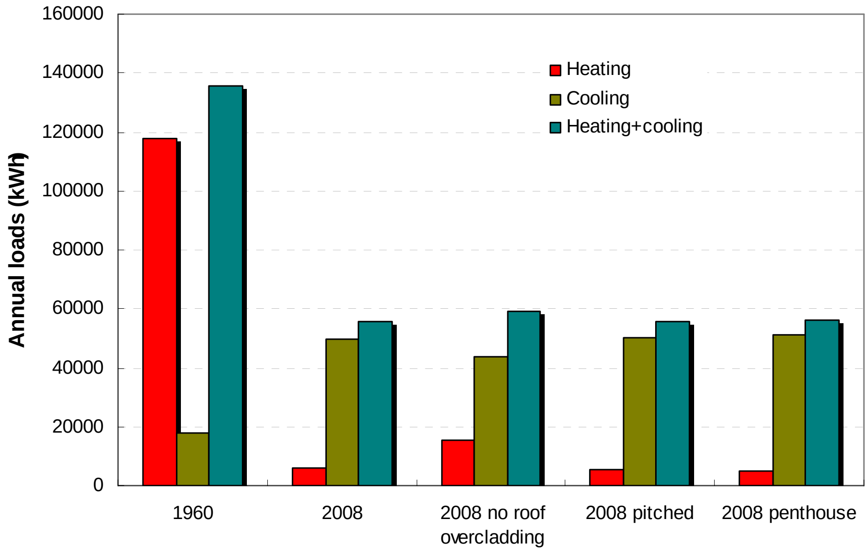


Figure 28 Annual loads for whole building

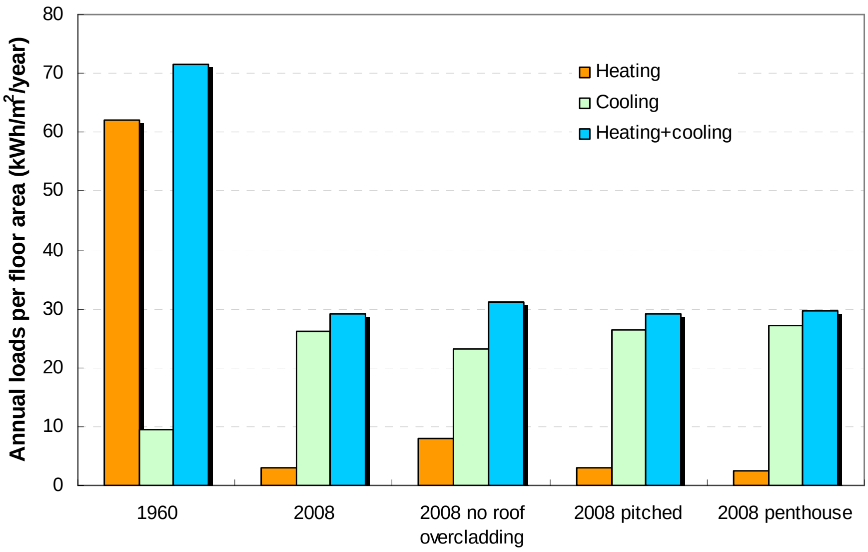


Figure 29 Annual loads per floor area

Figure 28 and Figure 29 show that more than 50% of the total loads saving is achieved by overcladding the building. Also, the building used as office incurs more cooling requirements due to less heat loss through envelope for improved building. If considering the primary energy consumption of the building, cooling has less contribution because the coefficient of performance for air-conditioning system is close or greater than 2.

9. Orientation

The thermal simulation is for London climate only. Building forms of one 10 storey 14m×24m residential building and another 4 storey 12m×30m residential building were used for the estimation. The comparison is performed between existing building (1960) and overcladded/improved building (2008). Other options like no roof overcladding and roof extensions are not included into the simulation.

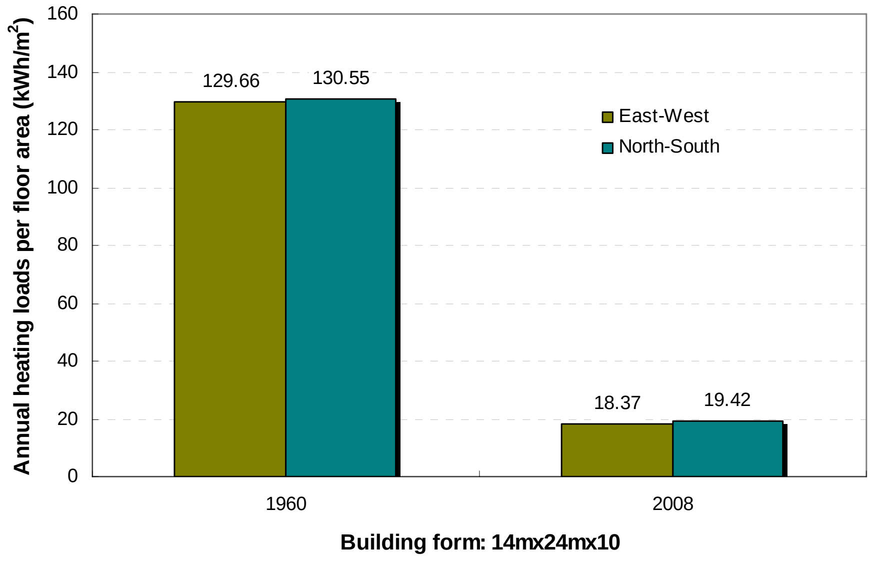


Figure 30 Heating loads against orientation for 10 storey residential building

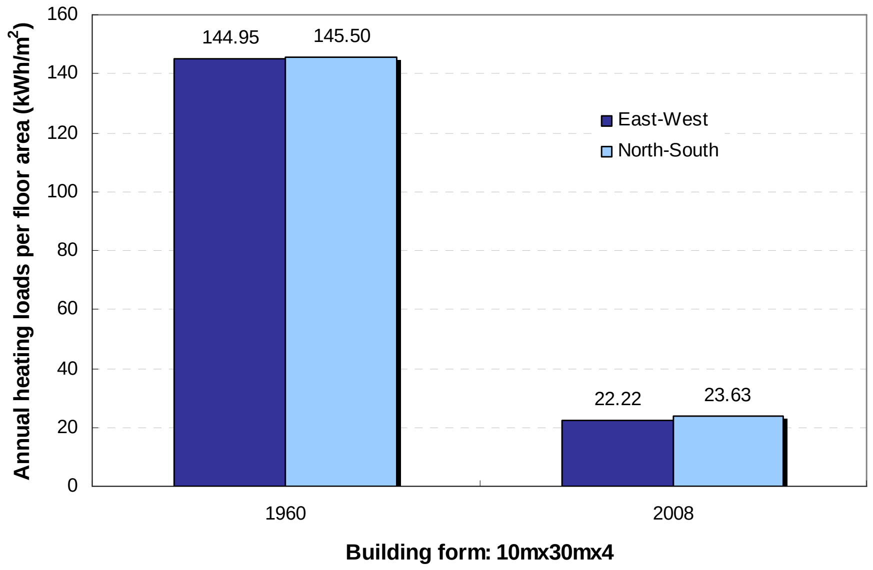


Figure 31 Heating loads against orientation for 4 storey residential building

Comparing two different building forms, there is no significant difference for annual heating loads was found for two different orientations.