# DAYLIGHTING THE PAST

*Even though lighting designers will inevitably be more constrained in what they can do, older and historic buildings can still lend themselves well to daylight harvesting, as a study by Historic England and Hoare Lea has shown. This means substantial savings on energy and carbon may be able to be made without upsetting the historic fabric*

**By Geraldine O'Farrell**

The impact of daylighting on our health and sense of well-being is now well understood. As diurnal animals (in other words, that we are awake during the day), sunlight supports our biological requirements by triggering our circadian rhythms or body clock via non-visual receptors in the eye. By increasing daylight within our working environments, we can create better, happier, healthier and more productive spaces.

CIBSE has produced Technical Memorandum 40:2020 *Health and well-being in building services* to demonstrate how these, along with other performance parameters such as acoustic, thermal and humidity can impact our health [1]. Also, by utilising more natural daylight we reduce our reliance on artificial electric lighting which in turn saves energy.

As part of Historic England's commitment to reducing its carbon emissions, we decided to carry out daylight studies in two of our older, listed regional offices to see how they performed.

## COMPARATIVE MODELLING PROCESS

For the initial study we chose the Grade I listed Bessie Surtees House in Newcastle upon Tyne. This site, comprising sixteenth and seventeenth century merchants' houses, was picked because of the impending need to upgrade the services, including the lighting.

We asked consultants Hoare Lea to carry out this study on our behalf. It did this by creating a model of the rooms chosen using a commercially available programme called Rhino 3D with a suite of

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Figure 1. An illustration of some of the modelling process for the Grade I listed Bessie Surtees House in Newcastle

daylight analysis plug-ins. In addition to the models, the context in which the building is located was also modelled, as shown in figure 1 above.

We were also able to provide Hoare Lea with a great deal on information to assist in this exercise from our own Matterport camera scans to the plans and listing records from the Historic England Archive in Swindon. Also, we furnished Hoare Lea with details of the existing lighting installation and desk layouts plus the current office usage.

The rooms chosen at our Newcastle offices were in two distinct parts of the building. Each was considered typical of all the rooms on the main façade. The first was in the sixteenth century Tudor half, which gives the site its name, and the second in the later seventeenth century Jacobean building called Millbank House.

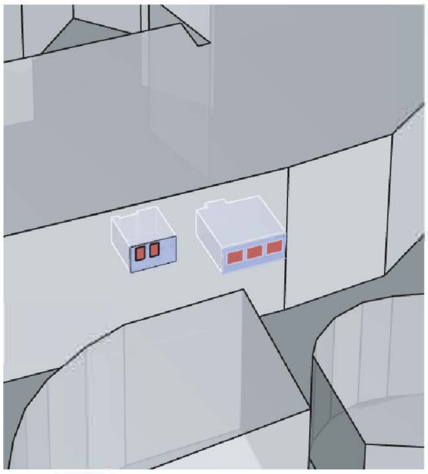
The room and window proportions are different, with the Tudor room having a higher ceiling but deeper footprint to the office space chosen in Millbank House. In addition, the window designs of the two rooms were also substantially different.

## POTENTIAL FOR ENERGY SAVINGS

The first part of the analysis looked at the internal daylight in relation to current best practice standards and the second looked at the potential for energy savings with daylight dimming incorporated into the lighting controls for each room.

Each of the detailed 3D models for the two rooms employed the same assumed material properties to be used in the daylight calculations. For light reflectance value, these were:

- Ground 20%
- Surrounding buildings 20%
- Floors 20%
- Walls and partitions 30%
- Ceilings 50%
- Glazing visible light transmittance (VLT) 0.8



The analysis of the two rooms chosen for assessment used Climate-Based Daylight Modelling (CBDM). CBDM, for those who are unfamiliar with the term, is the prediction of various radiant or luminous quantities using daylight conditions derived from standard meteorological datasets.

The metric used for the study was 'Spatial Autonomy' (sDA). This is a measure of how much of the room achieves daylight autonomy, in other words how much can be illuminated by daylight alone without artificial lighting. sDA measures how much of the space receives a given illuminance level from daylight alone for a given proportion of the occupied hours over an entire year.

sDA targets also vary with the application, but the WELL Building Standard (IWBI 2020) recommends the following in order to ensure that a room is sufficiently well lit:

- Good sDA 300.50 ≥ 55%
- Excellent sDA 300.50 ≥ 75%
- The target illuminance was set at 300 lux at desk height

The above statements mean that, if 55% of the space achieves 300 lux for 50% of the occupied hours, then the room can be considered to have 'good' daylighting. If 75% of the space achieves 300 lux for 50% of the occupied hours it can be considered to have achieved 'excellent' daylighting.

The results that came back for Millbank House, with its lower ceilings and shallower footplate, were very encouraging. For the purposes of this study an energy consumption density figure of 9 W/m2 was used for the existing fluorescent lighting. As a comparison the typical energy density figure for LED lighting is 3W/m2 and for incandescent lighting it is 15W/m2.

The total energy consumption without daylight linking was 619 kWh per year. By comparison, the total energy consumption with daylight linking was 316 kWh per year.

The daylight results indicated that the Millbank House room has an sDA 300.50 of 62.5%, which exceeds the minimum WELL standard of 55%. It has a favourable height-to-depth ratio, making it good for daylighting and, although it faces the Newcastle Guildhall across the street, its elevated position on the third floor makes it less susceptible to overshadowing.

The results for Bessie Surtees House gave the following results. The total energy consumption without daylight linking was 1,184 kWh per year, while the total energy consumption with daylight linking was 602 kWh per year. The daylight results gave an sDA 300.50 of 37.9%, which falls short of the 55% target recommended by WELL.

Although the façade is south east-orientated and the space chosen has ample glazing, the room's layout makes it more challenging with its greater depth-to-window height and the position on the second floor means it is overshadowed by the building opposite.

This has an obvious negative impact on the amount of daylight that the back third of the room receives. However, as the

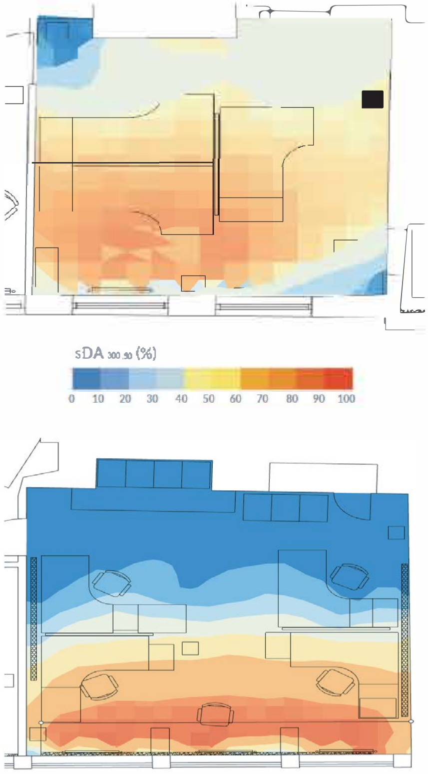



Figure 2. Daylight modelling (showing sDA) comparisons for Millbank House (top) and Bessie Surtees House

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following figures illustrate, considerable savings can still be achieved for both typical rooms. In terms of financial beneficial, based on the current average cost of electricity of 16.3p/kWh, the achievable savings for each room would be:

- Millbank House = approx £50year
- Bessie Surtees House = approx £95/year

In terms of carbon reduction and using a carbon factor of 0.233kg.$CO_2$/kWh, the following is achieved:

- MillbankHouse = 71kg.$CO_2$ per year
- Bessie Surtees House = 136kg.$CO_2$ per year.

These figures all confirm that, even with an sDA figure that does not meet any of the WELL standards, substantial savings can be made.

The main contributing factor is the different architectural styles of the two parts of the building. Millbank has sash windows and a shallower room depth; Bessie Surtees has greater room depth and, although a higher density of fenestration, has associated finishes such as dark wood panelling (typical for the period) which absorbs more light than it reflects.

The light reflectance values cannot be easily improved with such historic interiors and so the only avenue for improvement would be with the maintenance of the glazing and ensuring that the windows are not covered during daylight hours as much as is possible.

These two rooms could be used to develop a larger daylight study of the building and, with it, hopefully expand our knowledge about the relationship between historic architecture, period interiors, artificial lighting usage and the present-day use to which these buildings are put.

## ANALYSIS OF SWINDON HISTORIC ENGLAND OFFICES

As we had such surprisingly good results, we asked Hoare Lea to carry out a more detailed study at our Grade II listed offices at Swindon. In this second study, as shown in figure 3 above, we had them look at much larger spaces on two floors, one floor having the added complication of existing skylights. These offices would all be of the same general style and of the same period.

Our Swindon offices (now called The Engine House) were originally started in 1842-43, with extensions added in 1869-70, followed by more alterations in the 1890s and in 1904-05. The building is therefore Victorian in design with high ceilings and large sash windows down both sides of the office space. The general colour of all the surfaces is white, apart from the floor.

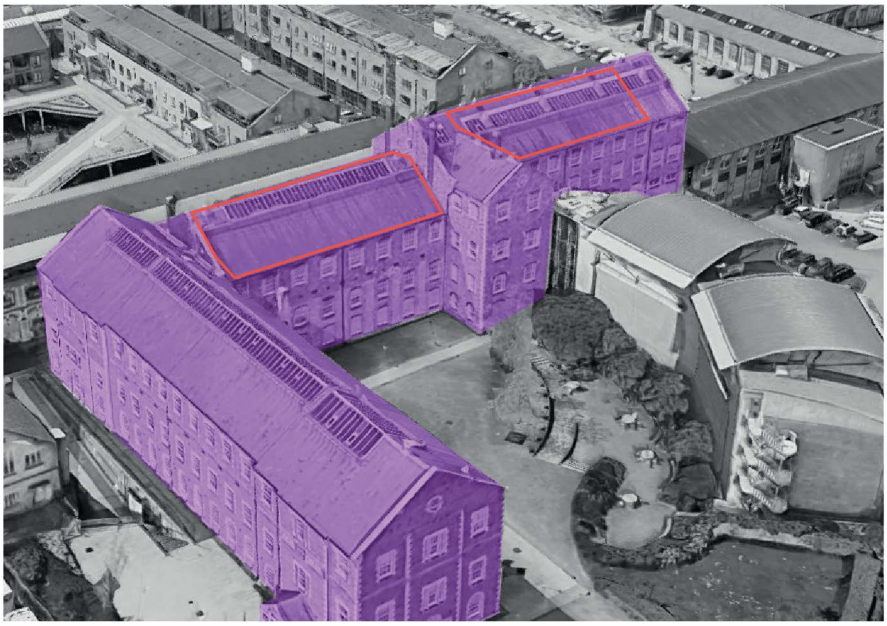

Figure 3. An illustration of the modelling process at the Historic England Grade II listed offices in Swindon

As this was a more detailed study, additional metrics were used, including Useful Daylight Illuminance (UDI), which is the percentage of occupied time that a space can achieve useful daylight illuminances within a given range. The range chosen was 300-3,000 lux, graded as follows, and are also shown in figures below and overleaf:

- UDI-a. Where light levels stayed between the range chosen of 300 lux and 3,000 lux
- UDI-s. Where the light levels did not reach 300 lux and supplementary lighting would be needed
- UDI-e. Where light levels were excessive and reached values over 3,000 lux

'Cumulative annual sunlight hours' were used to measure the summative number of hours of direct sunlight on each floor area. This assists in identifying which parts of the building receive the most direct sunlight throughout the year.

'Temporal analysis' of the sunlight was then carried out in sections of the space to identify the times of day and year when direct sunlight reached various parts of the rooms in the study and when glare was likely to occur. For this calculation, the working plane was raised to 1.2m, in other words to where most people's eye level would be when seated.

Finally, 'annual daylight glare probability' (DGP) was used. This is an analysis that helps us understand which of the desk positions would be likely to experience glare and for what proportion of the occupied hours they would likely experience this discomfort.

Again, for this second study we were able to provide Hoare Lea with a lot of information on the use of the space and the furniture layouts. The first set of

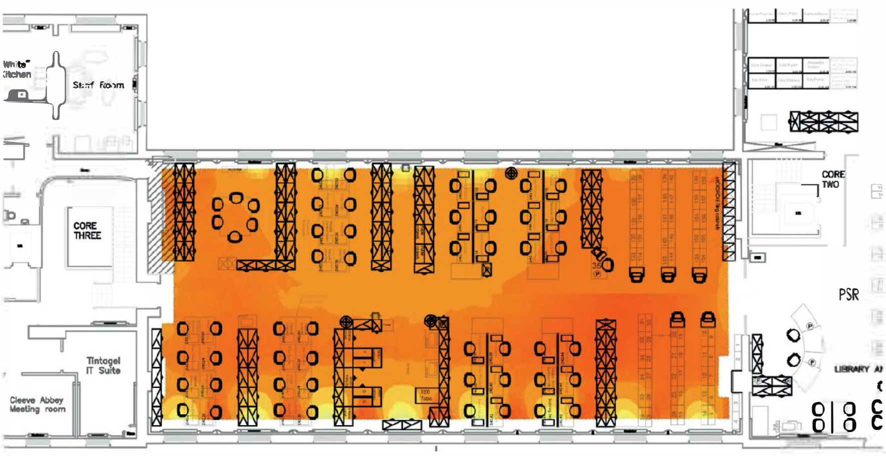


Figure 4. UDI-a on level 2 without blinds

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results that were analysed involve the daylight illuminance values with and without blinds.

As expected, without blinds the third floor with the skylights had a consistent level of UDI-e, all above 20%.

The results achieved when simulating the use of sensor-controlled blinds were also predictable, with the levels of UDI-a for the third floor increasing. However, for the second floor (where there was very little excessive light) they decreased, indicating that the office lighting would likely be switched on.

Next the areas that would likely experience glare were established. For this, as already highlighted, the working plane was adjusted to 1.2m above the floor, where generally most people's eye level would be when seated at their desk.

Both levels two and three receive high levels of direct sunlight through the year, although the second floor receives less because of external factors such as surrounding buildings and internal factors such as the height of the room and the absence of skylights.

The direct sunlight is concentrated along the south west façade and it is here that occupants are likely to experience glare more often. After temporal analysis was carried out, it was established that this would occur between midday and 3pm throughout the year and between 7am and 11am between April and August, thus demonstrating that the time of year as well as the time of day is also an important factor. The daylight results for the second floor of The Engine House were as follows:

- The total energy consumption without daylight linking = 4,211 kWh per year.
- The total energy consumption with daylight linking = 1,941 kWh per year.
- A saving of 2,270 kWh per annum for one small area of level two, and based on the same unit price of electricity of 16.3p/kWh, the financial savings could amount to £370 per year for just the level 2 area. For the areas on both floors this increases to £640 per annum.
- In terms of carbon reduction, and again using a carbon factor of 0.233kg. $CO_2$/kWh, this would reduce carbon emissions by 930 kg.$CO_2$ per year.

It should be noted that the energy savings outlined are based on daylighting the spaces without blinds. However, blinds are used by the occupants and therefore the quantity of daylight in the rooms will be reduced and, therefore in turn, supplementary lighting will be needed more of the time.

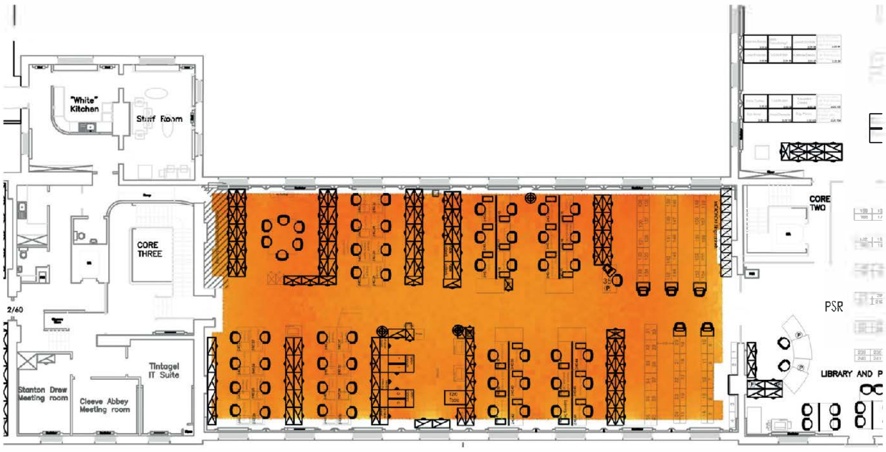


**Figure 5. UDI-a on level 2 with blinds, with UDI-a being within the 300-3,000 lux range**

Nonetheless the addition of daylight-linked controls would still deliver significant savings and, when mapped with temporal analysis that has identified the time and areas where blinds are needed to operate, would also help to prevent glare.

We knew that the Swindon offices received a high amount of daylight throughout the year and that this has disadvantages as well as advantages. Thanks to the modelling and analysis, we now know where and when occupants are likely to experience glare and we know which areas will need the most use of blinds. We have also established that we can make significant savings and reduce the need for artificial lighting for substantial periods of time throughout the year.

## CONCLUSIONS

In sum, the conclusions we reached are:

- Retain the roller binds for the vertical glazing and possibly adjust the design so that only the lower portion of the window is covered
- Utilise the venetian blinds for the skylights
- Install automated blind control to use the full potential of the available daylight
- Install a manual override switch to give occupants the facility to take control for two hours to maximise their comfort and acceptance of the system
- Make changes to the furniture layout to assist with the potential for glare on the south west façade and thus reduce the need for blinds – instead make the perimeter of the office the circulation route

The large sash windows at The Engine House coupled with a shallow footplate means that daylight can penetrate deeper into the office. However, any adjustment to the glazing and windows must always be with the heritage of the building foremost in mind.

Ultimately, this study shows that older buildings still lend themselves well to daylight harvesting and that substantial savings on both energy and carbon can be made without having to making much in the way of intrusion into the historic fabric.

Control sensors for a daylight harvesting system would normally be installed within the luminaires, however other alternatives to automated blinds such as electrochromatic glazing would not be suitable for listed buildings if visible externally. They might yet be permitted in concealed skylights if the original glazing did not still exist.

### FIND OUT MORE

Both Geraldine and Ruth Kelly Waskett, senior associate at Hoare Lea (who advised on the project), have said they are happy to be contacted by ILP members who wish to find out more about this project, or simply daylighting of historic buildings in general.

They can be contacted on **Geraldine.OFarrell@HistoricEngland.org.uk** and **ruthkellywaskett@hoarelea.com**

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[1] 'Technical Memorandum 40:2020 Health and wellbeing in building services', CIBSE, https://www.cibse.org/Knowledge/CIBSE-TM/TM40-2019-Health-Issues-and-Wellbeing-in-Building-Services