# The Investigation of a NZEB Retrofit to a 1960s Head Office Building

ARCH2280 DT774b 2013-2014

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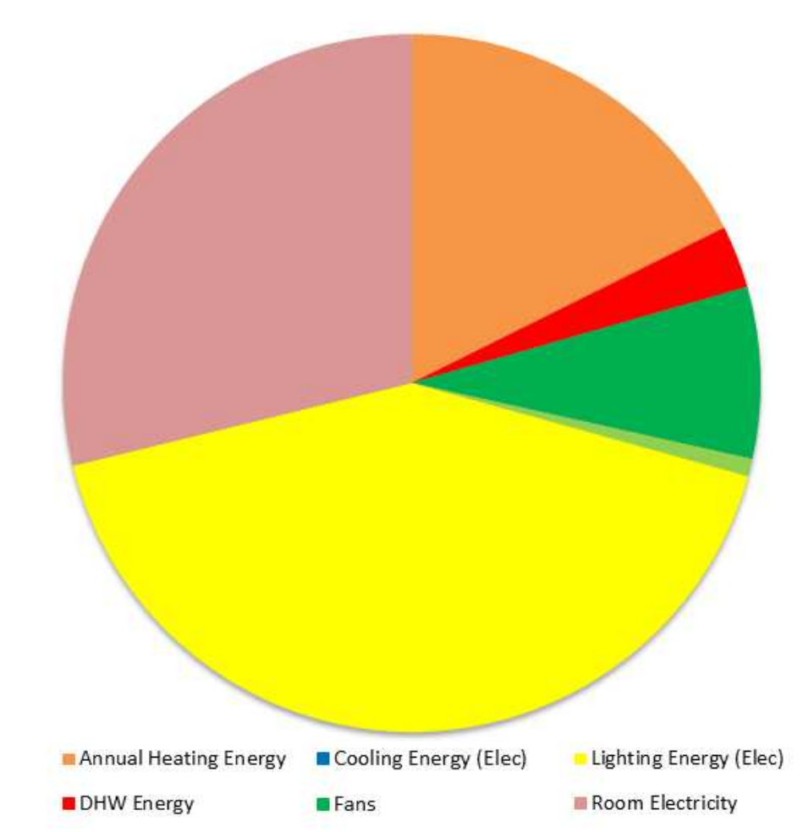
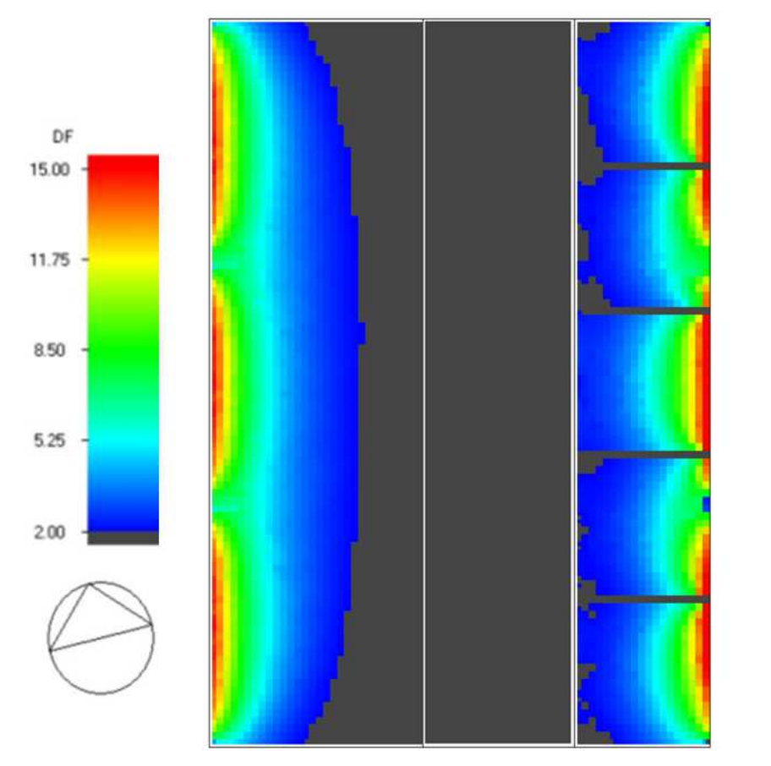
DIT BOLTON STREET
DT774b - SESSION 2013-2014

Postgraduate Diploma in
Digital Analysis and Energy Retrofit

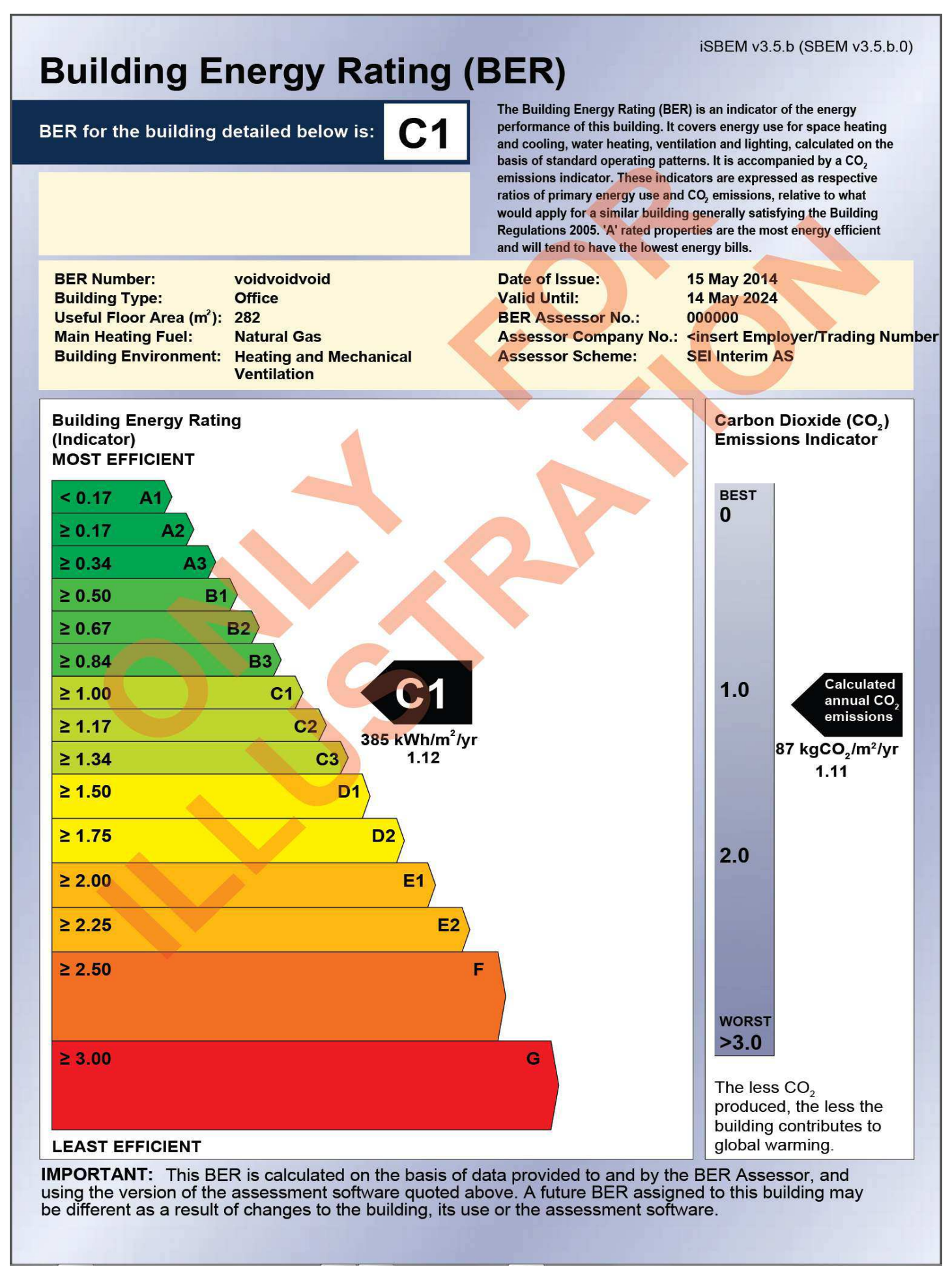
Methodology:
The main focus of the study was on a 3-Bay typical section of the building which represents the majority of floor space. The existing baseline building model definition is based on the geometry from the survey, building drawings provided and specifications from the investigations on site.

Existing Baseline:
U-value and condensation risk assessments of the major envelope build-ups using the Build Desk U software and the values obtained were input into the DesignBuilder model. The software predicted that there would be some interstitial condensation and the u-values were poor. Linear thermal bridges were modelled using the Therm software and the Psi Values were calculated for the junctions. The Psi values indicate that the junctions perform quite poorly and there is likely a surface condensation risk at each of the junctions studied.





Baseline Proportional Energy Use Diagram (Left) and Daylighting Map (Above)



**Building Energy Rating (BER)**

iSBEM v3.5.b (SBEM v3.5.b.0)

BER for the building detailed below is: **C1**

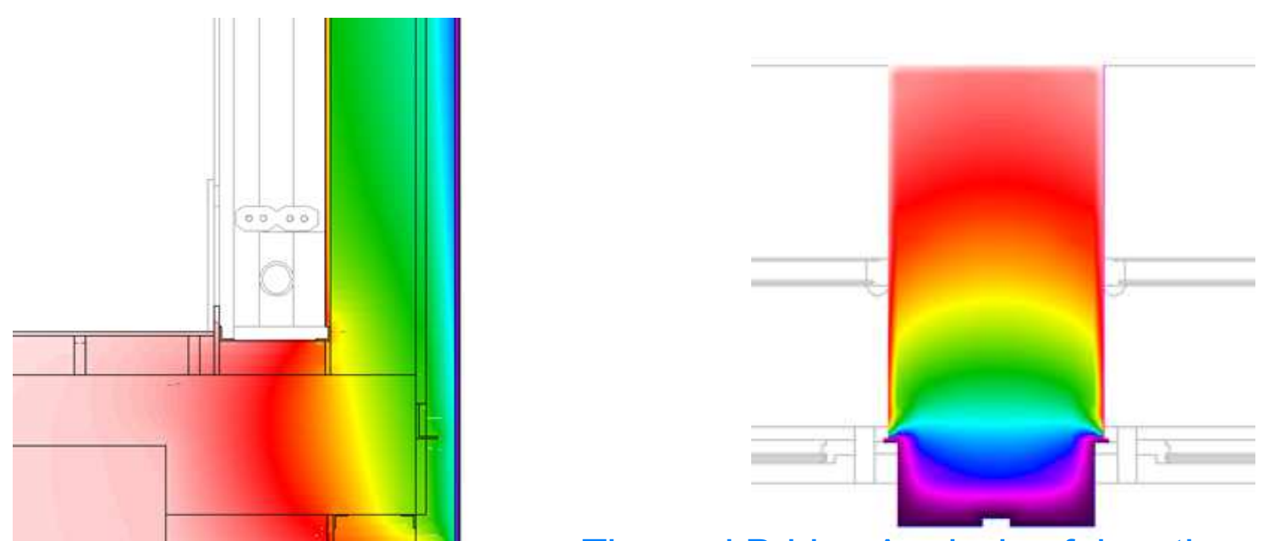
The Building Energy Rating (BER) is an indicator of the energy performance of this building. It covers energy use for space heating and cooling, water heating, ventilation and lighting, calculated on the basis of standard operating patterns. It is accompanied by a $CO_2$ emissions indicator. These indicators are expressed as respective ratios of primary energy use and $CO_2$ emissions, relative to what would apply for a similar building generally satisfying the Building Regulations 2005. 'A' rated properties are the most energy efficient and will tend to have the lowest energy bills.

| | | | |
|---|---|---|---|
| BER Number: | voidvoidvoid | Date of Issue: | 15 May 2014 |
| Building Type: | Office | Valid Until: | 14 May 2024 |
| Useful Floor Area (m²): | 282 | BER Assessor No.: | 000000 |
| Main Heating Fuel: | Natural Gas | Assessor Company No.: | <insert Employer/Trading Number |
| Building Environment: | Heating and Mechanical Ventilation | Assessor Scheme: | SEI Interim AS |

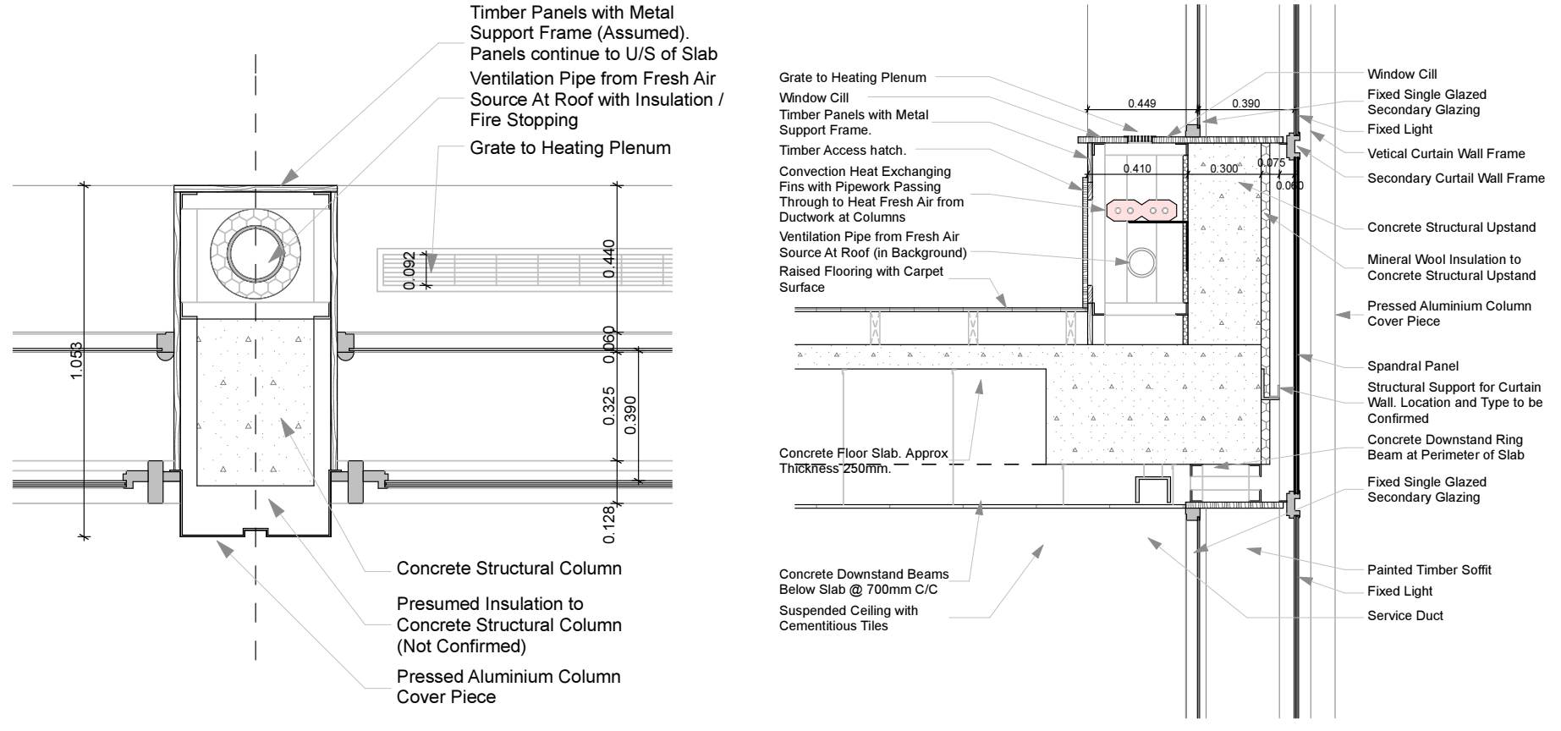
The less $CO_2$ produced, the less the building contributes to global warming.

IMPORTANT: This BER is calculated on the basis of data provided to and by the BER Assessor, and using the version of the assessment software quoted above. A future BER assigned to this building may be different as a result of changes to the building, its use or the assessment software.

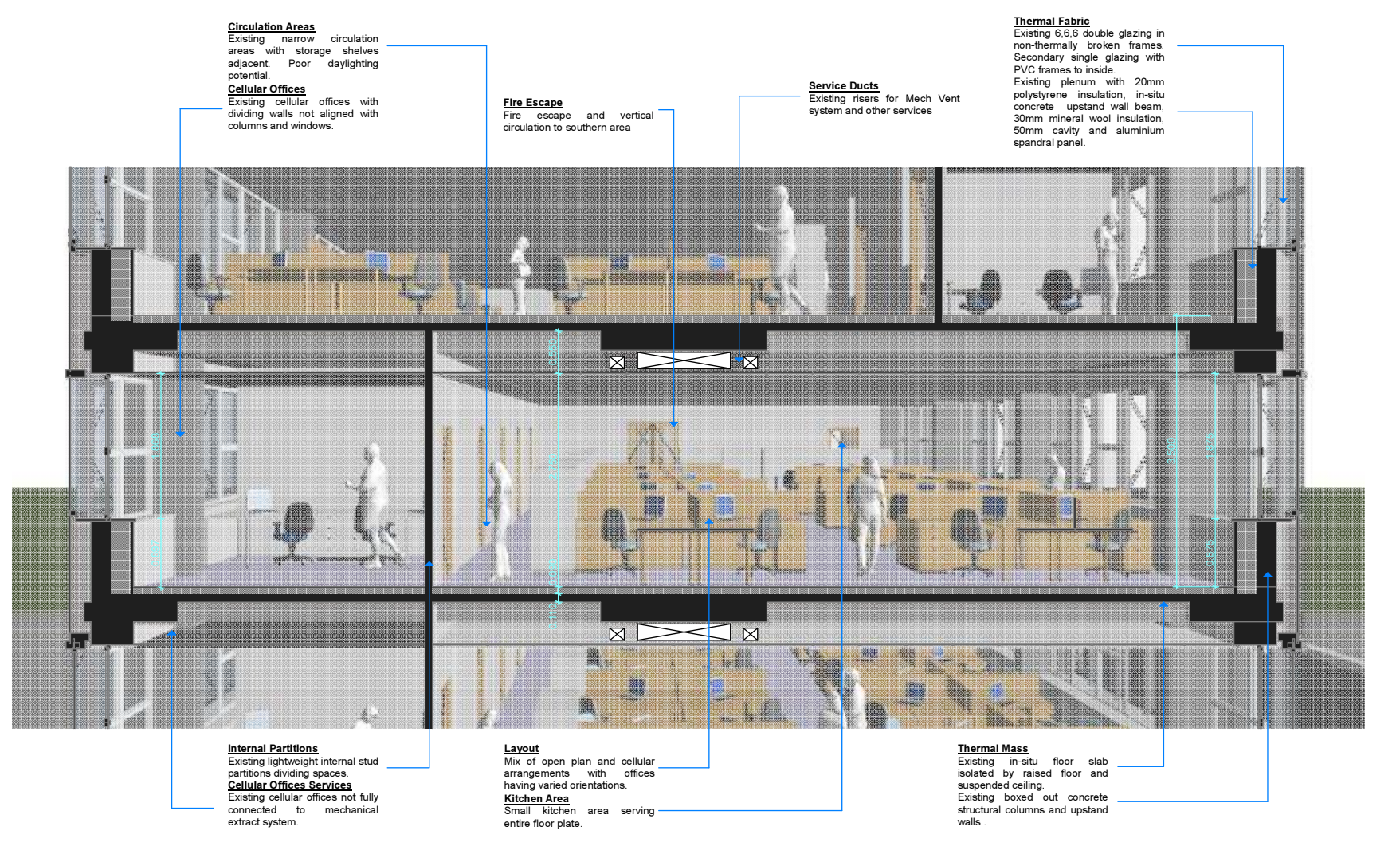
BER Cert for Baseline Generated Using iSBEM



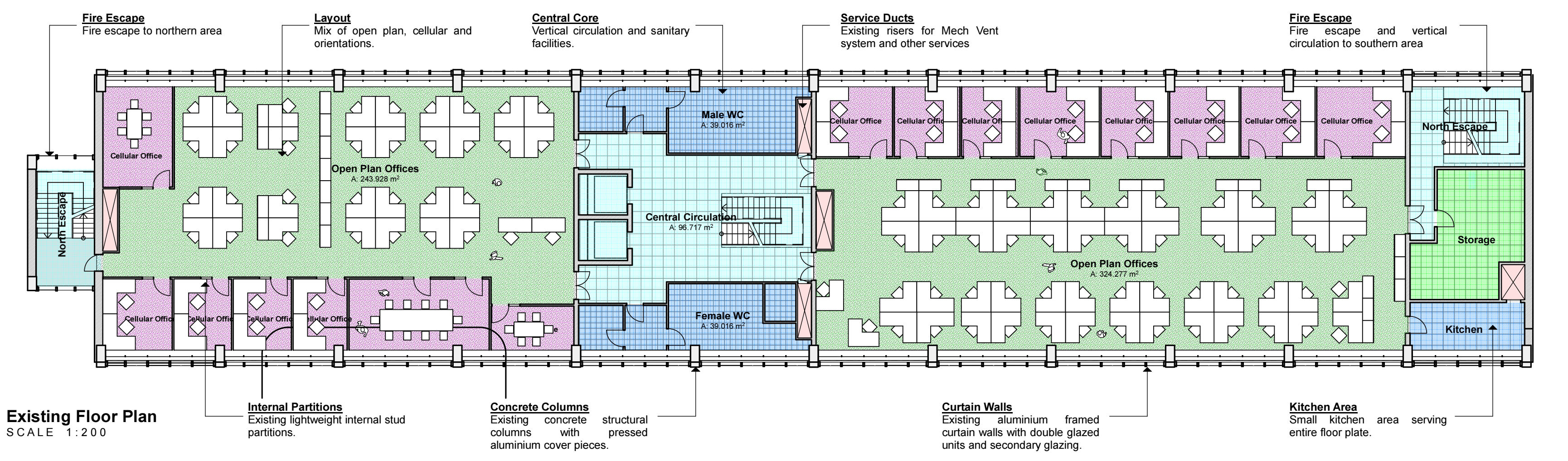
Thermal Bridge Analysis of Junction Floor to Wall (Left) and Column (Above)



Typical DetailsWall, Cill and Head (Above Right) & Column (Above Left)



The 3-Bay baseline model was examined using DesignBuilder for annual, summer and winter design weeks. Results were generated for energy expenditure, gains, overheating/discomfort and the daylighting provision. The total energy load was 47.57W/m² (annual), 40.33W/m² (summer) and 87.83W/m² (winter) for 3-Bay model. Internal gains from solar, lighting and equipment (13.76W/m², 20W/m² and 13.76W/m² annually) were quite high when compared to the annual heating demand (8.43W/m²). The gains contributed to the overheating which between 5.2% and 9.9% with discomfort hours between 155hours and 187hours. Average daylighting provision ranged between 0.886%, 3.952% and 5.03% for the central, west and east areas respectively.

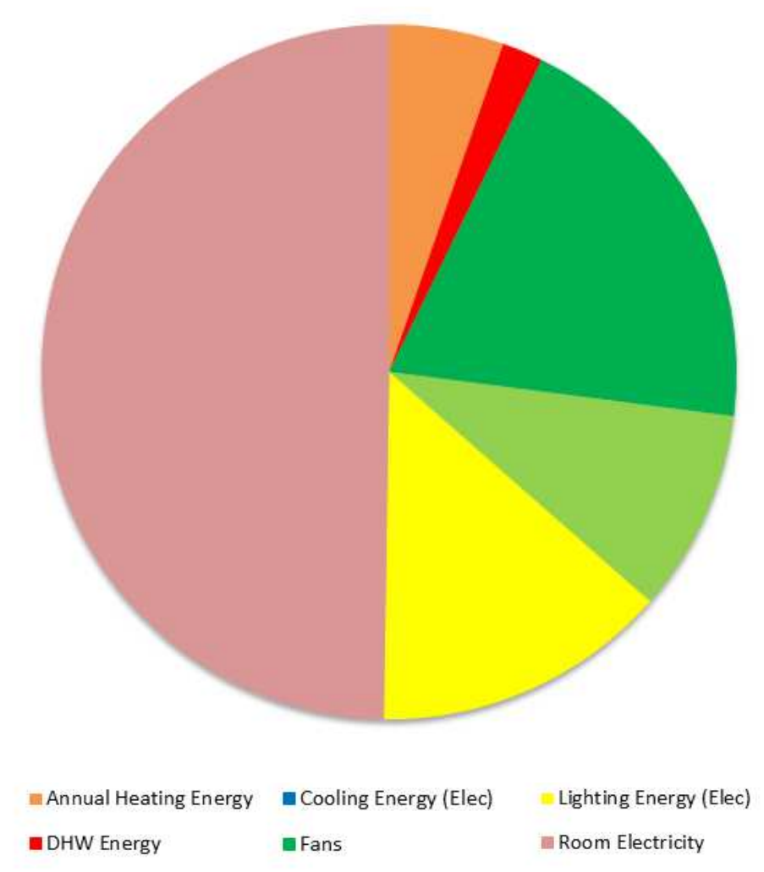


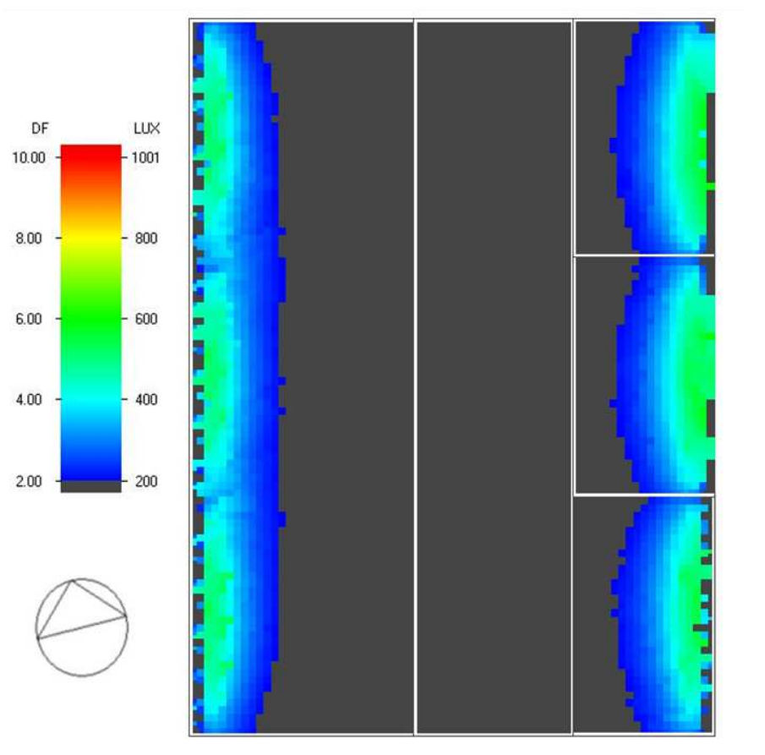
## Existing Baseline Building

Existing Typical Section through HOB (Above Left) & Existing Second Floor Plan (Above)

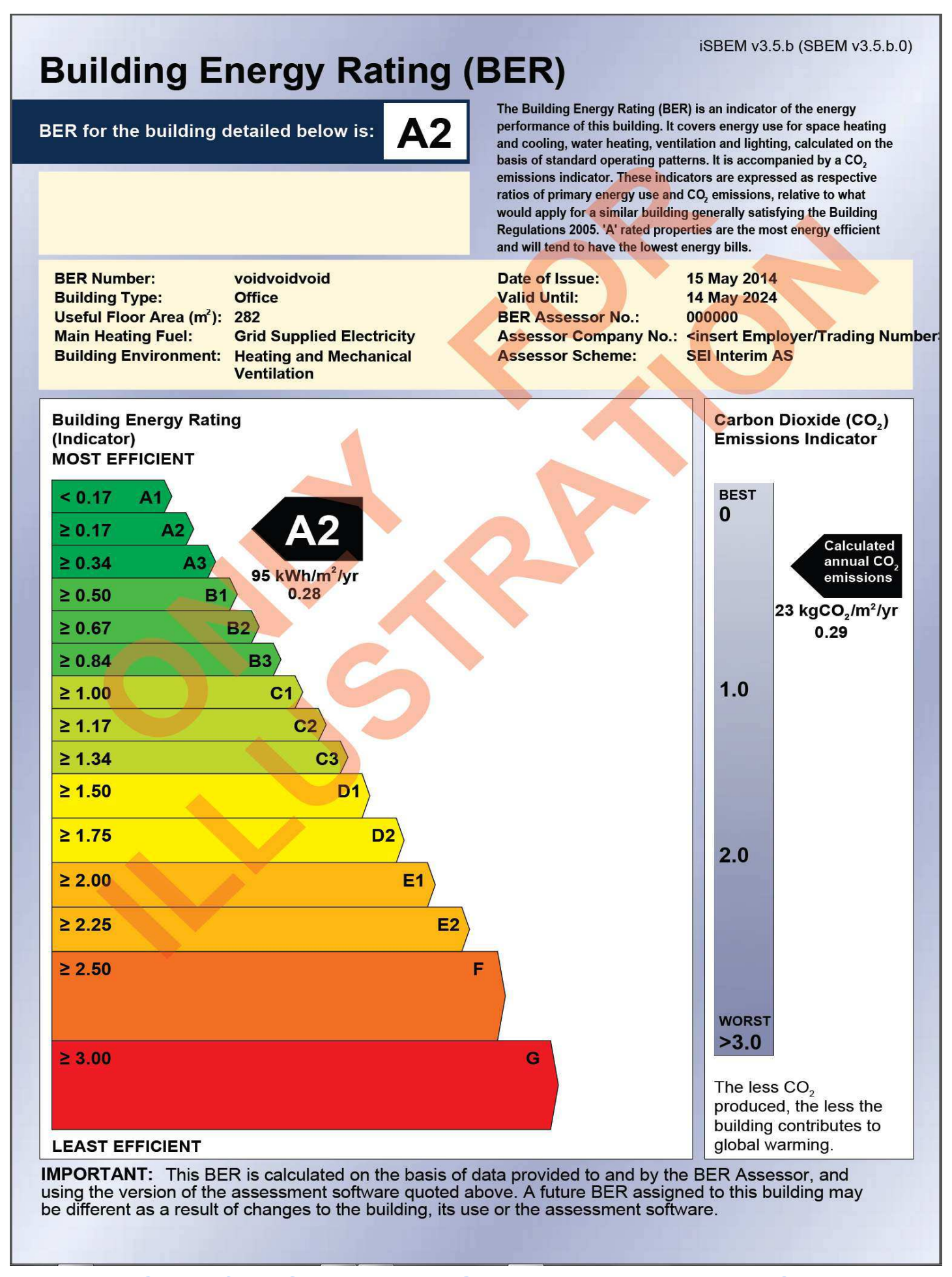
Proposed Optimum:
A holistic optimum strategy for the HOB bringing the building energy loads to the minimum practical level was required prior to the application of renewable energy inputs. The optimum strategy was developed as described in Section 2. The main measures introduced to the 3-Bay model were:

- Upgrade of thermal fabric
- Improved air-tightness
- Introduction / Modification of Natural Ventilation Strategies
- Introduction / Modification of Mechanical Ventilation Strategies
- Lighting control & efficiencies.
- Increasing Efficiencies of Systems.
- Increasing / reducing glazing areas
- Exposure of internal thermal mass.
- Introduction of shading to façade
- Reduction of equipment loads in line with benchmark data.





Optimum Proportional Energy Use Diagram (Left) and Daylighting Map (Above)



**Building Energy Rating (BER)**

iSBEM v3.5.b (SBEM v3.5.b.0)

BER for the building detailed below is: **A2**

The Building Energy Rating (BER) is an indicator of the energy performance of this building. It covers energy use for space heating and cooling, water heating, ventilation and lighting, calculated on the basis of standard operating patterns. It is accompanied by a $CO_2$ emissions indicator. These indicators are expressed as respective ratios of primary energy use and $CO_2$ emissions, relative to what would apply for a similar building generally satisfying the Building Regulations 2005. 'A' rated properties are the most energy efficient and will tend to have the lowest energy bills.

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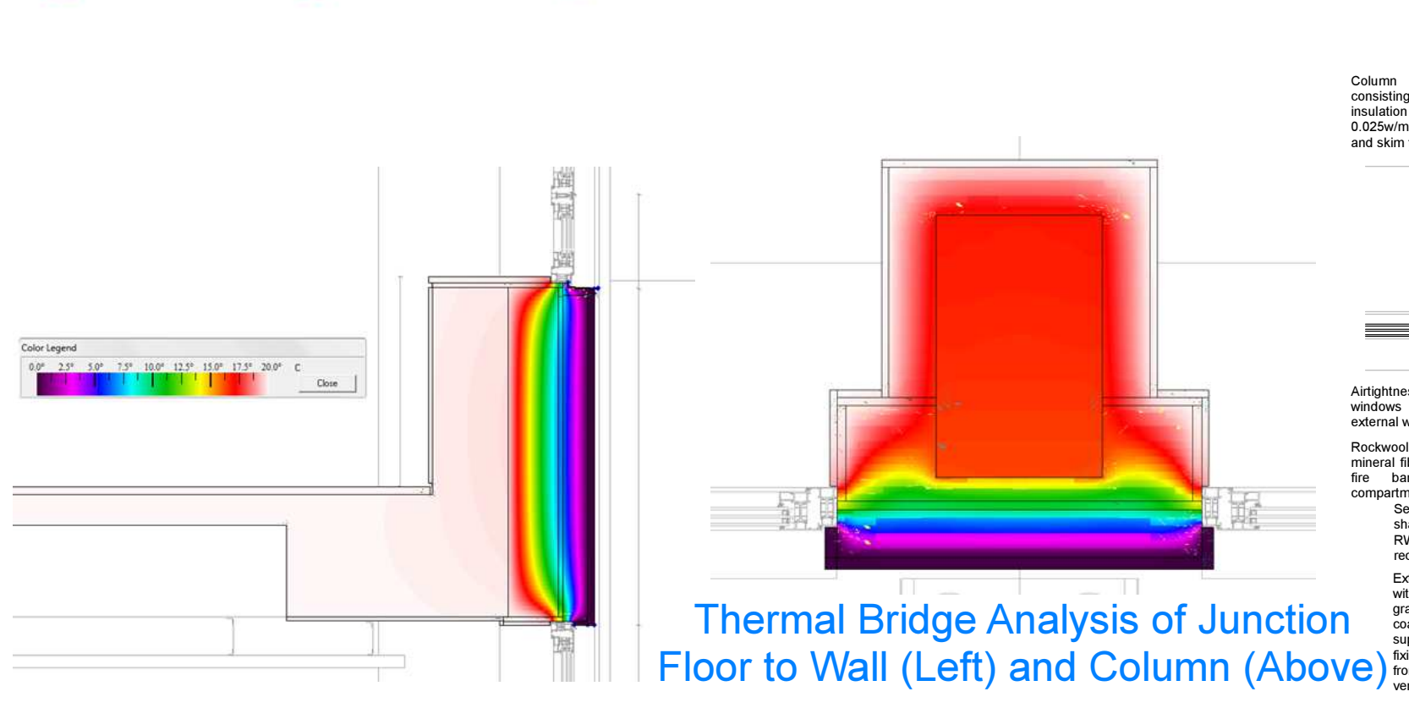
BER Cert for Optimum Generated Using iSBEM



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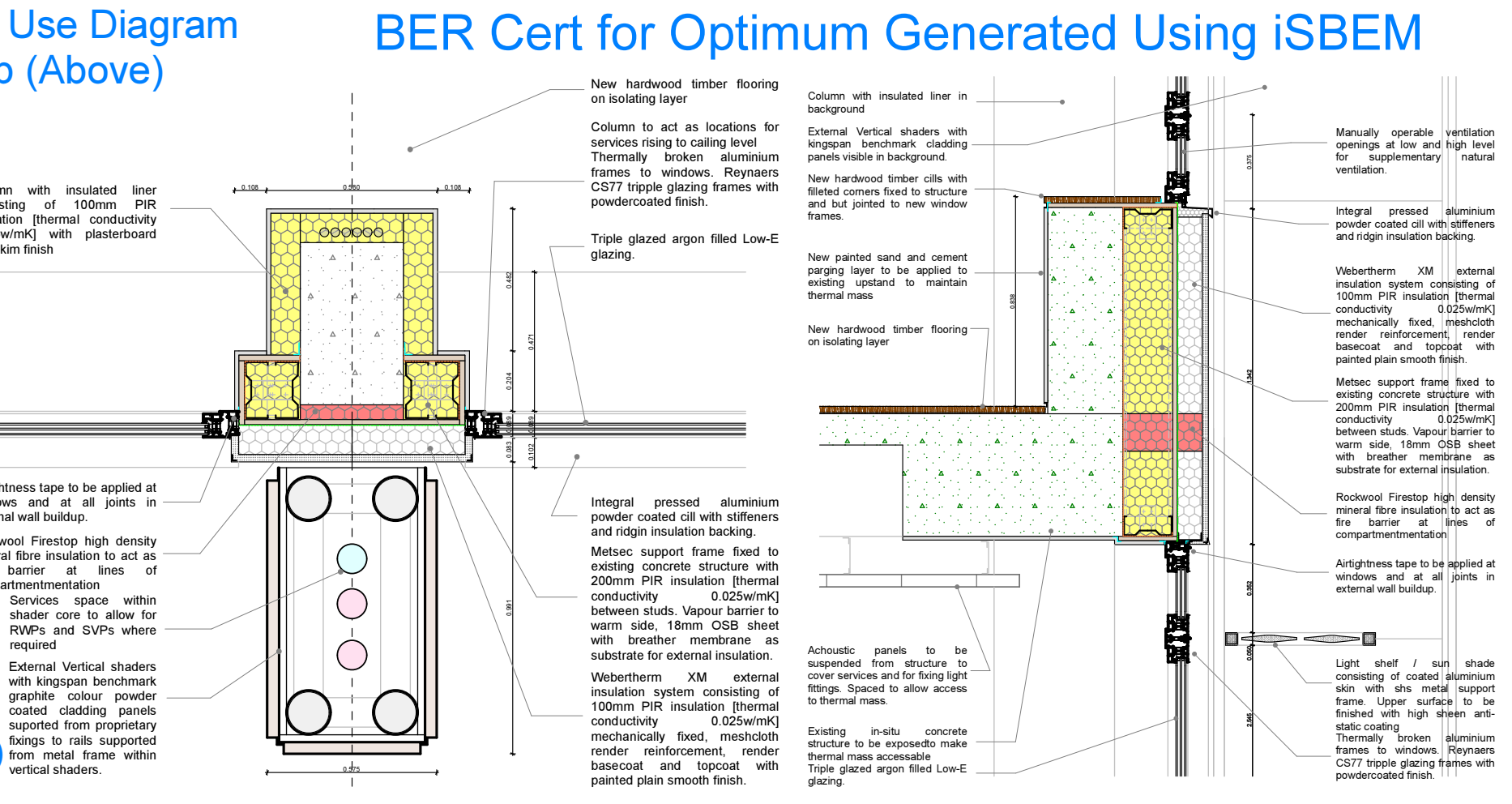

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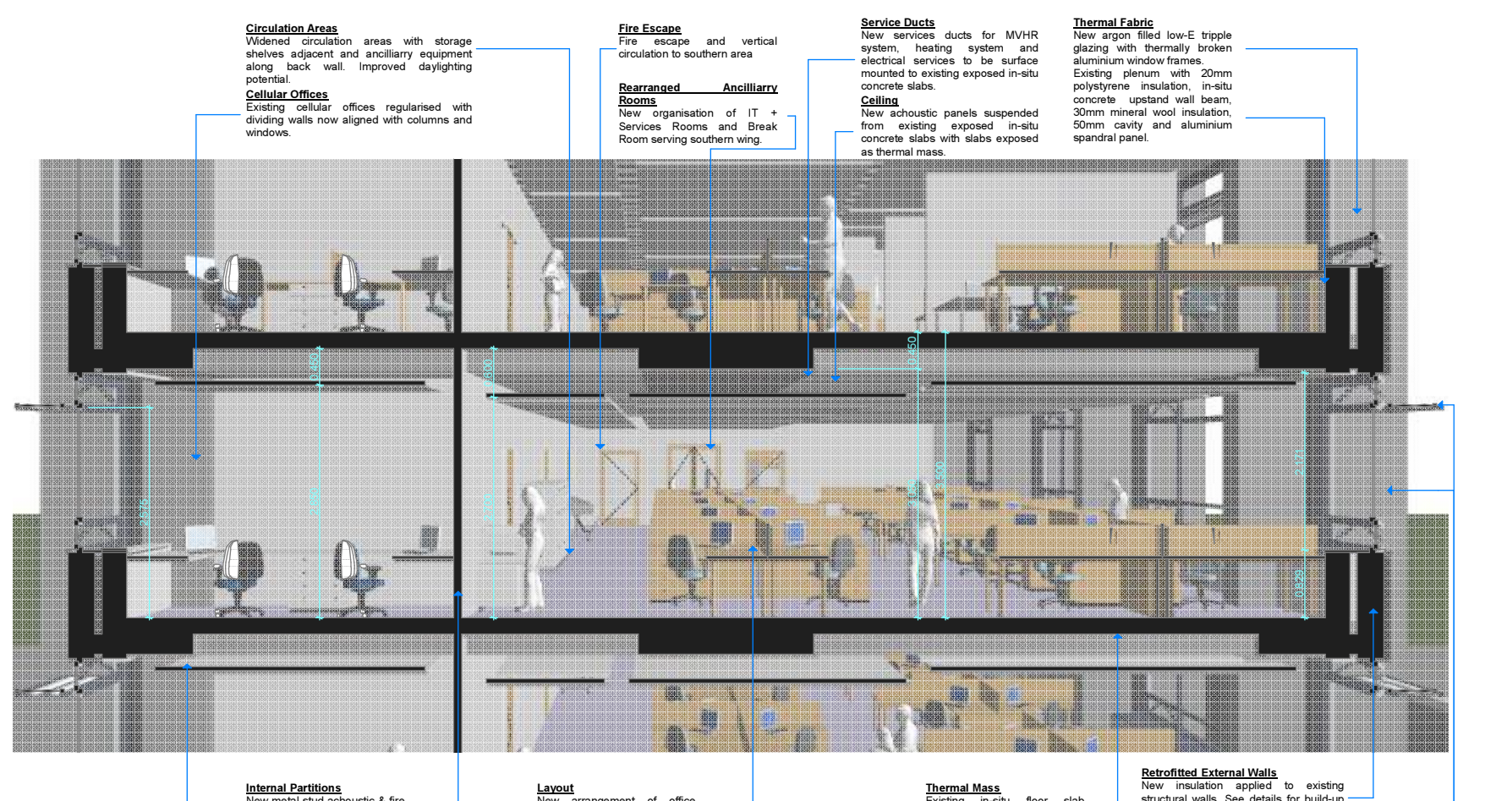
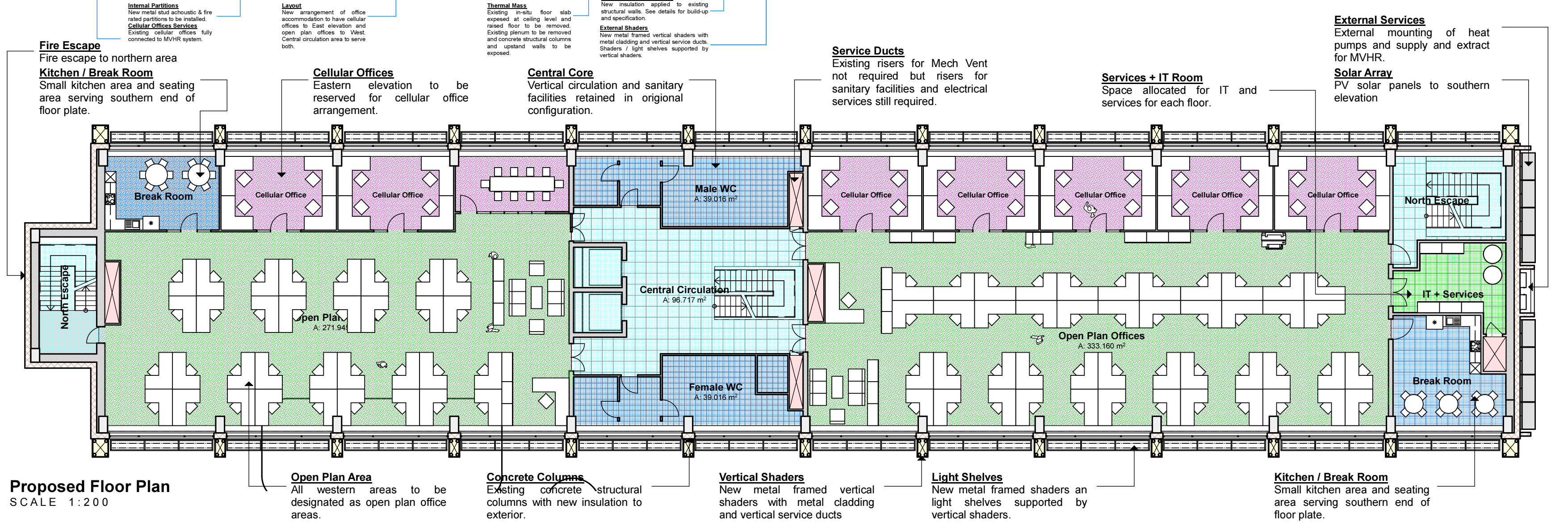


Upon implementing these measures into the baseline energy model an optimum model was established and simulations performed. The total energy loads for this model were 14.9W/m², 14.47W/m² and 16.27W/m² for the annual, summer and winter simulations respectively. Annual Internal gains from solar (8.83W/m²), lighting (1.94W/m²) and equipment (7.01W/m²) were greatly reduced and the annual heating demand cut to 0.75W/m². The low heating The overheating and discomfort hours present in the baseline have been eliminated in the optimum simulation. Average daylighting provision generally reduced; 0.5%, 1.91% and 2.78% for the central, west and east areas respectively but the uniformity of daylight spread increased.



## Proposed Optimum Strategy

Optimum Typical Section through HOB (Above Left) & Second Floor Plan (Above)

Comparison:
The energy balance of the simulated HOB has changed to an equipment dominant energy expenditure from the lighting dominated model that formed the baseline.

In the graph directly comparing the baseline and optimum for the different time periods examined (right), the baseline energy use is greater and in different proportions to the optimum strategy. There is also a large swing in energy use across the year on the baseline model whereas the optimum model remains quite consistent throughout.

This is also true for the graph plotting the gains data (far right). The internal gains are constantly high in the baseline results with the greatest variable being the solar gain. In the optimum model the gains are lower and at a more controlled level.

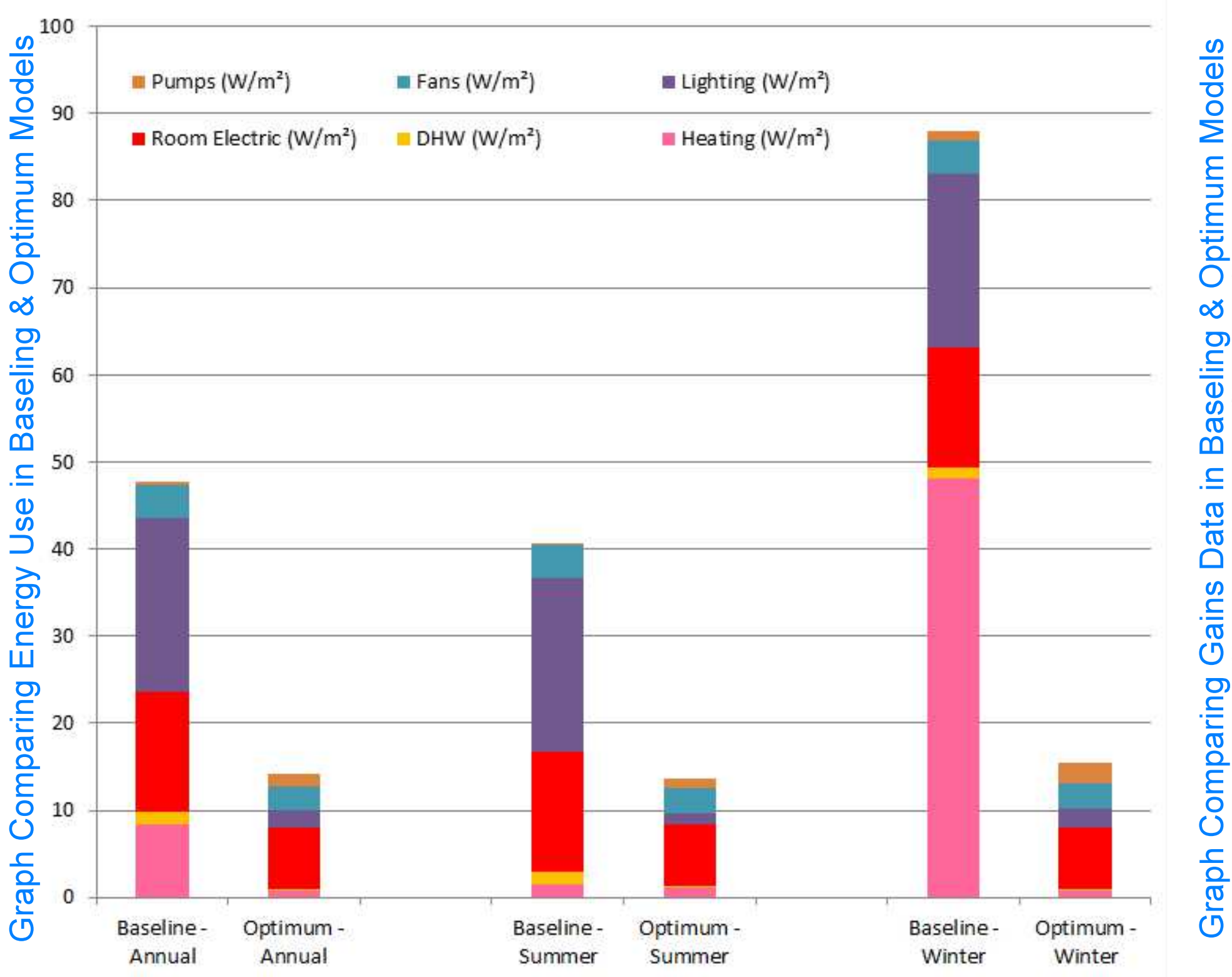
These diagrams are useful demonstrative tools and can illustrate the results in a clear and concise manner. The actual numerical savings are also vital to understanding the simulated performance of the proposed retrofit design. See table below left.

As can be seen from the results in the comparison table, the optimum retrofit strategy has reduced energy expenditure on an annual basis by 68.6%. The gains to the spaces have also been reduced by approximately 50% on an annual basis. This combined with MVHR allow for a more controlled internal space removing occupant discomfort and overheating. The heating energy required for the optimum solution to be 91% lower than the baseline due to reduced demand and greater efficiency.

The modeled MVHR system also provided a high rate of air changes with the economiser (bypass) in operation. This in conjunction with some natural ventilation and the reduction in gains effectively eliminated overheating to the spaces. The results are compared in the table and show no hours above 28 degrees and over 90% reduction in discomfort hours.

The reduction of the average daylighting provision is the only negative effect of the retrofit strategy (see graph right middle). However, the uniformity ratio of daylighting provision has increased but some supplementary artificial lighting will be required in the central area. With lighting control and efficiencies specified the predicted total lighting energy reduced by 90% in the optimum strategy.

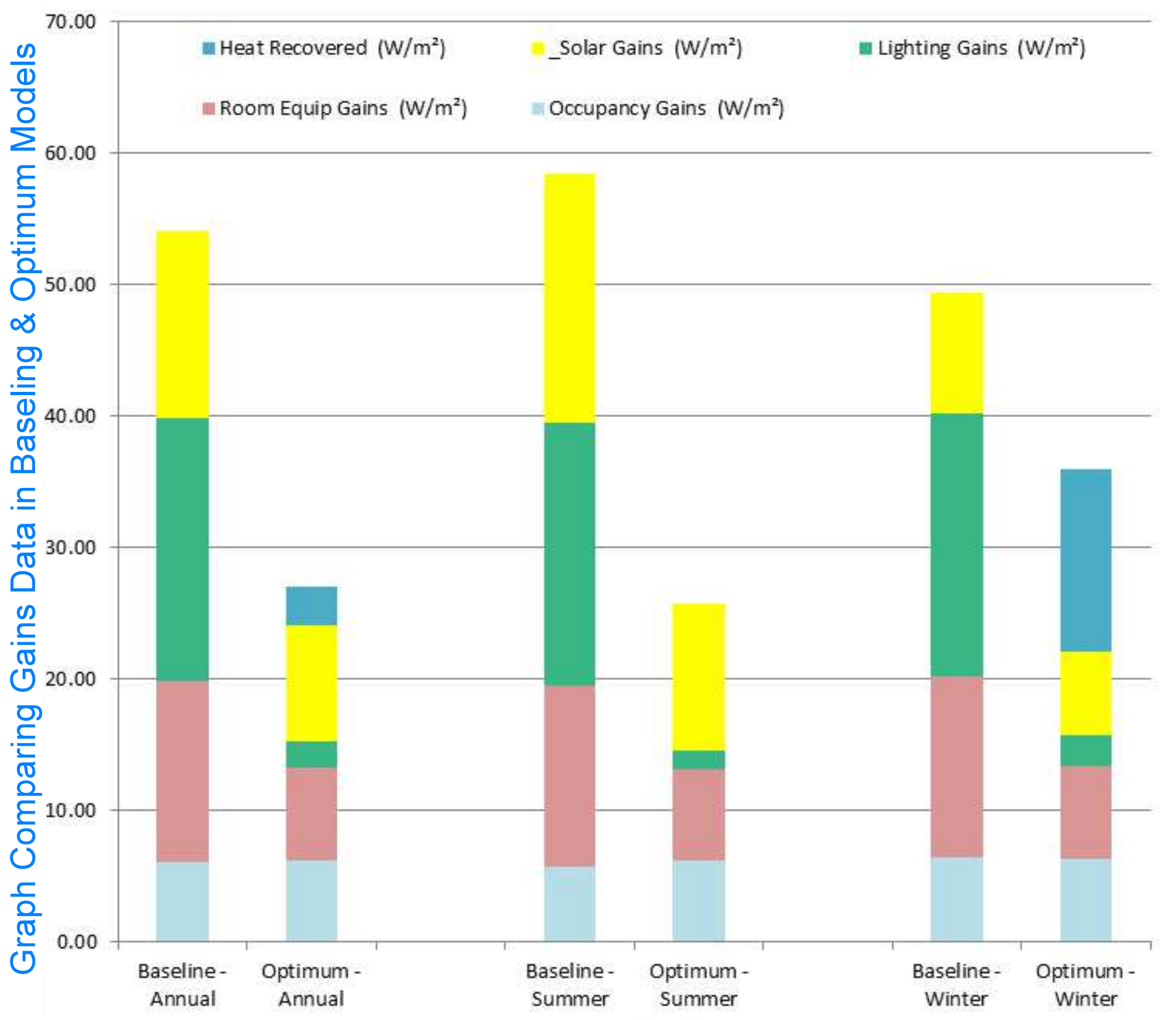
The Building Energy Rating achieved by the baseline 3-Bay assessment of the HOB was a C1 rating and the optimum solution attained an A2 BER. iSBEM produces an illustrative BER certificate (see sections above), and advisory reports and a calculation output document, an example of which is included (far right).



Graph Comparing Energy Use in Baseling & Optimum Models

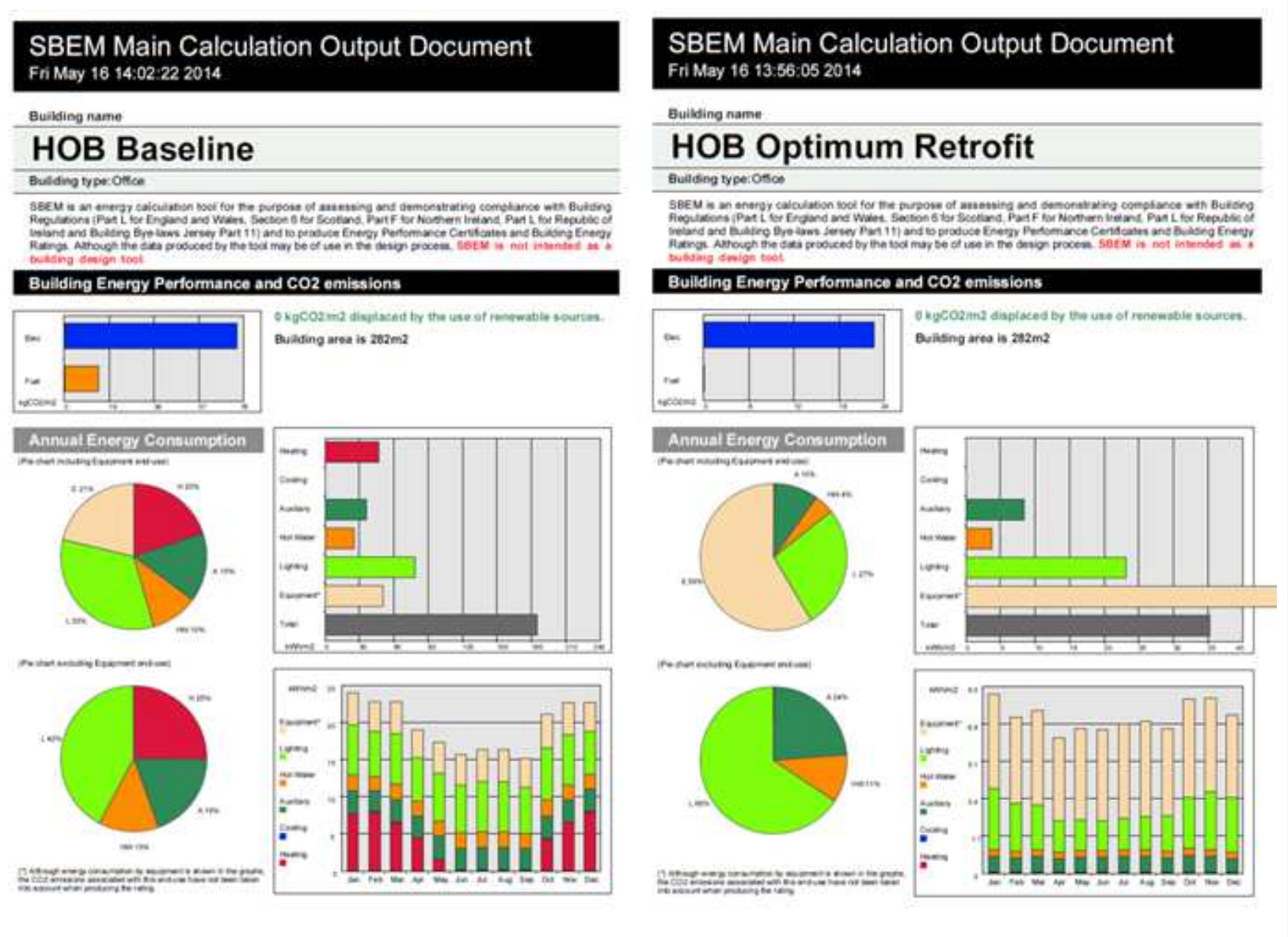
Table Comparing Simulation Results for Baseling & Optimum Models

| Category | Baseline Annual Simulation | Optimum Annual Simulation | Percentage Difference |
|---|---|---|---|
| Total Site Energy | 47.57W/m² | 14.9W/m² | -68.6% |
| Total Less Room Equipment | 33.81 W/m² | 7.89W/m² | -76.6% |
| Heating Energy | 8.43W/m² | 0.75W/m² | -91.1% |
| DHW Energy | 1.39 | 0.27W/m² | -80.6% |
| Cooling Energy | 0W/m² | 0W/m² | N/A |
| Auxiliary Pumps | 0.39W/m² | 1.33W/m² | +243% |
| Auxiliary Fans | 3.79W/m² | 2.79W/m² | -26.3% |
| Lighting Energy and Gains | 20W/m² | 1.94W/m² | -90.3% |
| Room Electricity and Gains | 13.76W/m² | 7.01W/m² | -49.1% |
| Solar Gains | 14.25W/m² | 8.83W/m² | -38% |
| Occupancy Gains | 6.04W/m² | 6.26W/m² | +3.6% |
| Heat recovered | 0W/m² | 3.01W/m² | N/A |
| Infiltration and Ventilation Losses | 33.22W/m² | 6.72W/m² | -79.8% |
| Average Fresh Air | 1.90 ac/h | 1.05 ac/h | -44.8% |
| Overheating - East | 162 Hours (5.2%) | 0 | -100% |
| Discomfort - East | 155 Hours | 14.5 Hours | -90.7% |
| Overheating - Central | 300 Hours (9.5%) | 0 | -100% |
| Discomfort - Central | 170 Hours | 13.5 Hours | -92.1% |
| Overheating - West | 310 Hours (9.9%) | 0 | -100% |
| Discomfort - West | 187.5 Hours | 12 Hours | -93.6% |



Graph Comparing Gains Data in Baseling & Optimum Models

| Description | East Optimum | East Baseline | East Difference | Central Optimum | Central Baseline | Central Difference | West Optimum | West Baseline | West Difference |
|---|---|---|---|---|---|---|---|---|---|
| Average Daylight Factor | 2.78% | 5.03% | -45% | 0.50% | 0.886% | -44% | 1.91% | 3.952% | -52% |
| Minimum Daylight Factor | 0.64% | 1.07% | -40% | 0.32% | 0.454% | -29% | 0.50% | 0.812% | -38% |
| Maximum Daylight Factor | 5.93% | 15.87% | -63% | 0.96% | 1.613% | -40% | 5.44% | 15.878% | -66% |
| Uniformity Ratio (Minimum/Average) | 0.25 | 0.21 | +19% | 0.64 | 0.513 | +25% | 0.27 | 0.205 | +35% |



SBEM Main Calculation Output Document
Fri May 16 14:02:22 2014

Building name
**HOB Baseline**
Building type: Office

SBEM Main Calculation Output Document
Fri May 16 13:56:05 2014

Building name
**HOB Optimum Retrofit**
Building type: Office

SBEM is an energy calculation tool for the purpose of assessing and demonstrating compliance with Building Regulations (Part L for England and Wales, Section 6 for Scotland, Part F for Northern Ireland, Part L for Republic of Ireland and Building Bye-laws Jersey Part 11) and to produce Energy Performance Certificates and Building Energy Ratings. Although the data produced by the tool may be of use in the design process, SBEM is not intended as a building design tool.

Building Energy Performance and CO2 emissions

0 kgCO2/m2 displaced by the use of renewable sources.
Building area is 282m2

Annual Energy Consumption

Calculation Document Produced by iSBEM for Baseling & Optimum Assessments

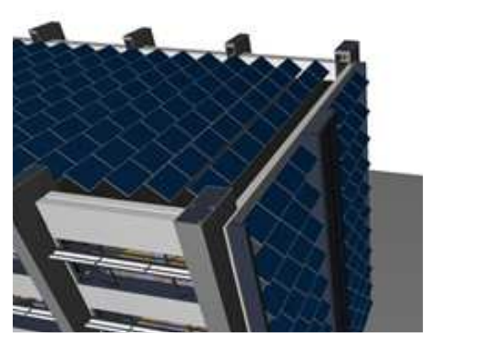
## Comparison of Results: Baseline & Optimum

NZEB:
The optimum strategy attempted to achieve the maximum practicable energy efficiency for the proposed HOB simulation. However there is still an inherent energy usage associated with the building; 14.9W/m²/annum (46kWh/m²/annum). To meet the NZEB standards renewable technologies will have to be introduced.

It is proposed to mount photovoltaic (PV) solar panels to the southern wall and roof of the retrofitted HOB with a total collector area of approximately 750m². This would provide approximately 96480 kWh /annum of electrical energy. This is approximately a quarter of the required energy demand but there is approximately 363520kWh/annum still required to achieve NZEB standards. Ideally the remainder of the renewable energy could be provided as part of a campus wide renewable energy generation strategy by, for example, a biomass CHP system. Failing the implementation of a campus wide strategy a single large wind turbine, providing approximately 0.46MWh located on the campus could fulfil the renewable energy targets for the entire HOB.

Table Showing Calculation for Possible Energy From Solar Array

| | |
|---|---|
| Calculation Formula | $0.80 \times kWp \times S \times Z_{PV}$<br>kWp = installed peak power<br>S = annual solar radiation<br>$Z_{PV}$ = overshading factor |
| kWp/m² of PV panel | 0.15kWp/m² |
| Area of Panels | 750 m² |
| Total kWp | 112.5 kWp |
| S (annual solar radiation) from Table H2 | 1072 kWh/m² |
| $Z_{PV}$ (overshading factor) from Table H3 | 1.0 |
| Calculation | 0.80 x 112.5kWp x 1072kWh/m² x 1.0 |
| Amount of Electrical Energy Produced | 96480 kWh /annum |



Conclusions:
The learning curve in developing skills in simulation tools, specifically DesignBuilder, is quite steep and a large amount of investigation and trial and error is required. The application of single retrofit measures to the baseline model was an interesting exercise as some of the results had counterintuitive outcomes. The process was quite slow but the insight into the procedure was beneficial overall. Predictive software can be an invaluable tool in identifying possible problem areas and areas for improvement within the building design prior to construction.

The investigation provided insight into passive architectural solutions, sealed mechanically ventilated systems and the holistic approach required for the optimum solution.

The single measure that had the largest impact was the lighting control, which is incidentally is the measure that could most easily be introduced in isolation and that does not have a negative impact (e.g. on overheating).Lighting control and greater efficiencies, as such, should be the first item considered for all office buildings as a priority.

The internal gains present in an office building provide the greatest challenge when strategizing a retrofit solution. The levels of equipment use and occupancy gains mean that the application of a strategy that has not been considered holistically could have large negative impacts on the occupants.

## NZEB & Conclusion