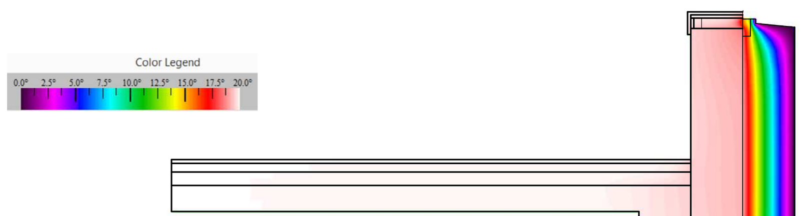
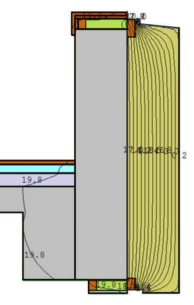
Linear Thermal Bridge Analysis



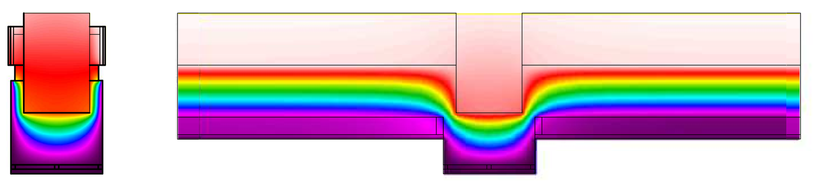
ψ - factor

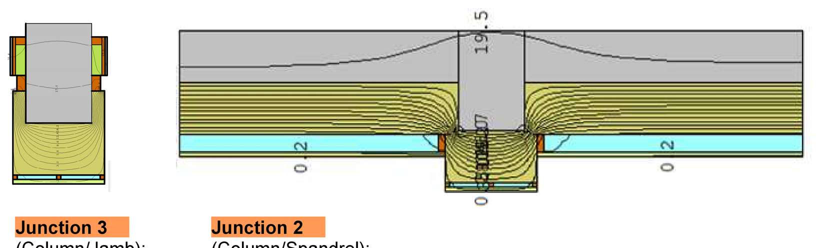
Detail	Psi ψ (W/mK)	Length (m)	Psi ψ x L (W/K)
Junction 1	0.06	38.4	2.3
Junction 2	0.053	9.4	0.5
Junction 3	0.275	11.8	3.3
Total			6.1

y factor = ∑(Psi ψ x L)/∑ (Area Exposed)
y factor = 6.1/135.7
y factor = **0.045W/m²K**



Junction 1
(Intermediate Floor Slab/Spandrel Wall):
Psi Ψ = 0.06W/mK





Junction 3
(Column/Jamb):
Psi Ψ = 0.275W/mK

Junction 2
(Column/Spandrel):
Psi Ψ = 0.053W/mK

Specification

Activity

Baseline

Heating Setpoint 22ºC
Heating Setback 12ºC

Cooling Setpoint 24ºC
Cooling Setback 28ºC

Indoor Min Temp Control: **OFF**
Min Fresh Air: **10L/s-person**
Target Illuminance: **300 Lux**

Optimal

All same as baseline except:

Indoor Min Temp Control: **ON**

Target Illuminance: **300 lux**
(Provided by:
background lighting of **100 lux**;
task lighting of **500 lux**)

Construction

Baseline

Main External Wall: **0.509W/m²K**
1. Aluminium (2mm)
2. Fibreboard (12mm)
3. Air Gap (105mm)
4. Rockwool (35mm)
5. Concrete 2% Steel (300mm)
6. Polystyrene (22mm)

Columns: **1.592W/m²K**
1. Aluminium (2mm)
2. Concrete 2% Steel (300mm)
3. Air Gap (200mm)
4. Plasterboard (12.5mm)

Intermediate Floor: **0.821W/m²K**
1. Ceiling Tiles (18mm)
2. Air Gap (400mm)
3. Concrete 2% Steel (200mm)
4. Air Gap (128mm)
5. Plywood (20mm)

Airtightness: **0.4ach**

Optimal

Main External Wall: **0.13W/m²K**
1. Aluminium (1mm)
2. XPS core (25mm) (λ = 0.027W/mK)
3. Aluminium (1mm)
4. Air Gap (100mm)
5. Brillux Mineral Wool (300mm) (λ = 0.027W/mK)
6. Concrete 2% Steel (300mm)

Columns: **0.13W/m²K**
(Same as wall)

Intermediate Floor: **0.24W/m²K**
1. Concrete 2% Steel (200mm)
2. EPS (78mm)
3. Air Gap (50mm)
4. Plywood (20mm)
(ceiling tiles removed and underside of concrete exposed, insulation placed above slab within raised access floor void)

Airtightness: Very Good

Glazing

Baseline

Double glazed outer skin
Single glazed inner secondary skin

External Windows: **1.923W/m2K**
6mm Clear Glass/ 6mm Air
Aluminium window frame,
no thermal break

Glazing to wall ratio 49%

Optimal

Triple glazed single skin facade.
0.78W/m2K
3mm Clear Glass/ 13mm Argon
Trp LoE (e2=e5=.1)
Wooden Frame

External: reduce glazing to wall ratio: 40%, 5% of which opens
Internal: 20% of which opens.

Lighting

Baseline

Energy: 5W/m²-100lux
(15W/m²-300lux)

Recessed Fittings

No Controls

Optimal

Generally: 3.3W/m²-100lux
Task Lighting: 4.92 W/m²K

Suspended Fittings

Controls: Linear, daylight sensors

HVAC

Baseline

Mechanical Ventilation - VAV units

Heating/DHW: natural gas boiler, COP 0.86

Natural Ventilation: no temp control

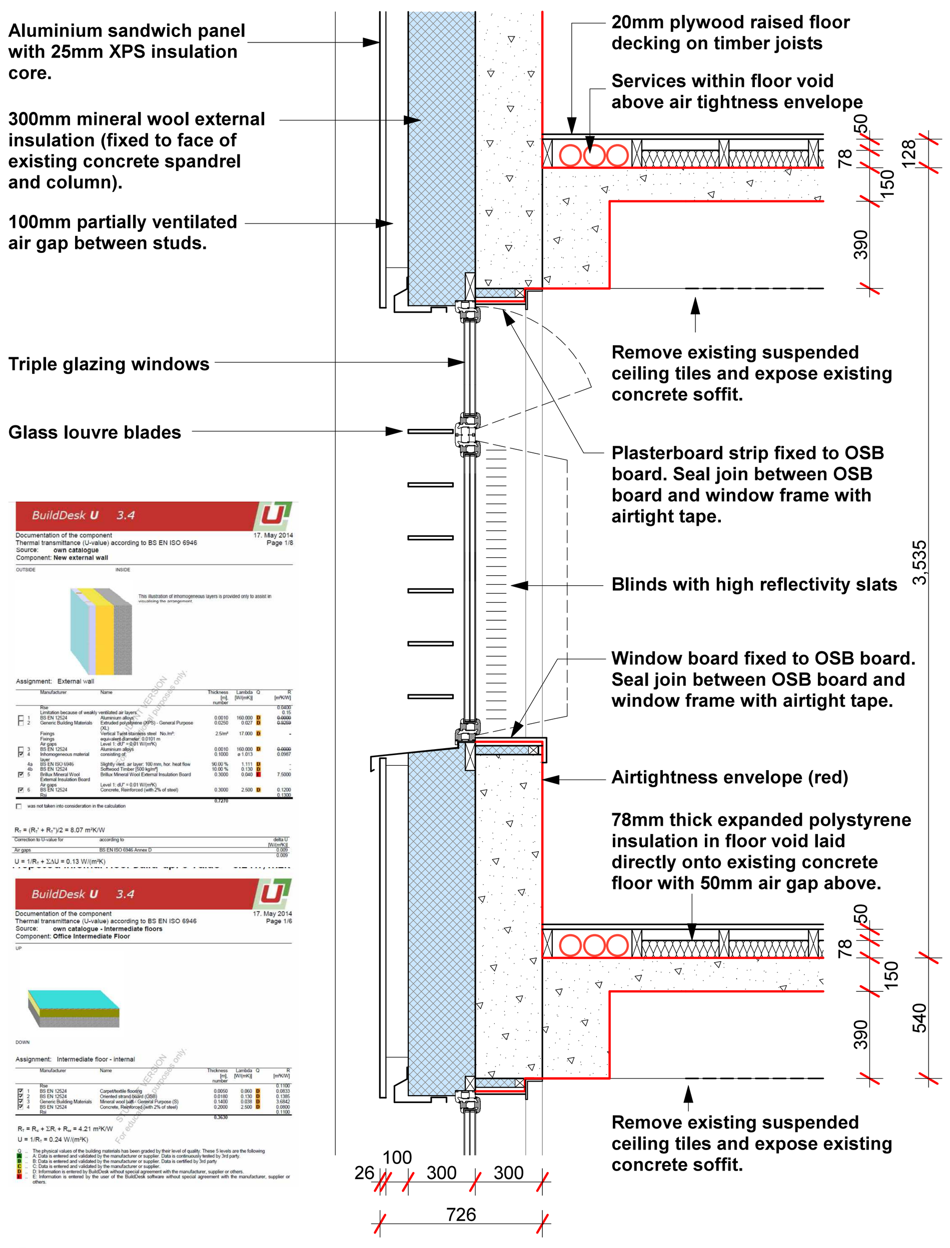
Optimal

Summer Ventilation : Nat Vent

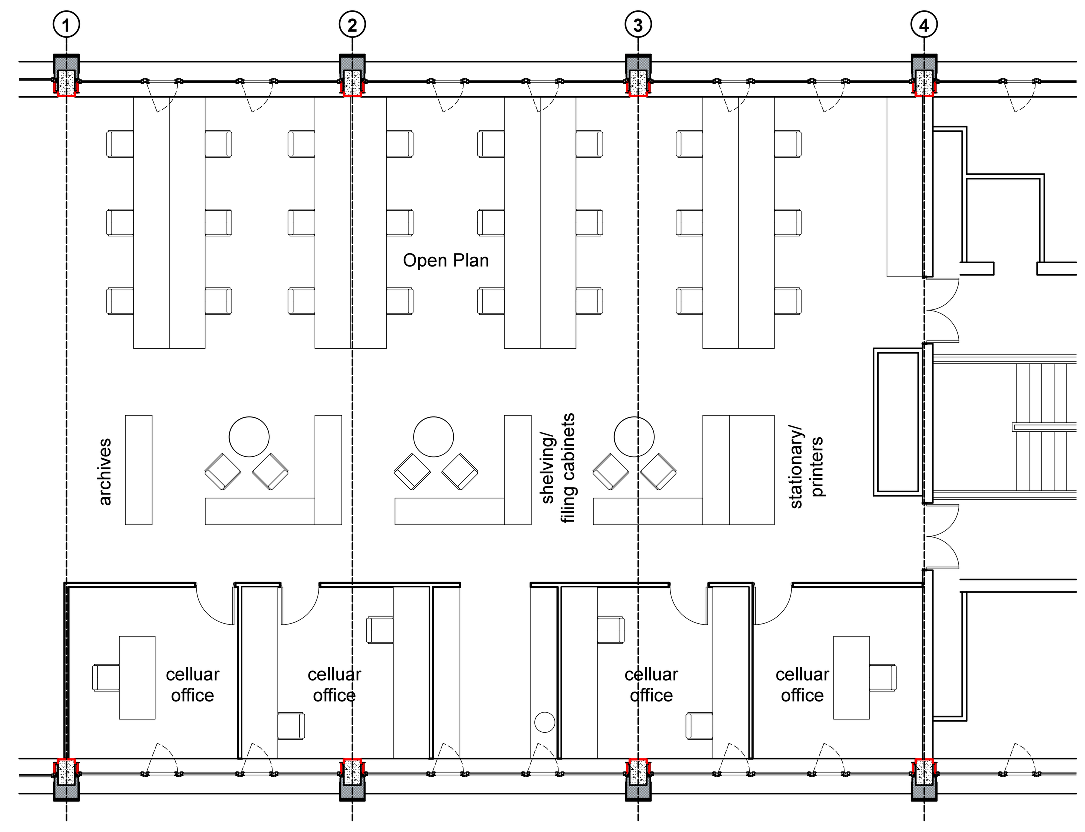
Winter Ventilation: Natural Vent with min temp controls. Mechanical ventilation with heat recovery to provide minimum fresh air when nat vent shut off by controls.

Heating/DHW: nat gas boiler, COP 0.86

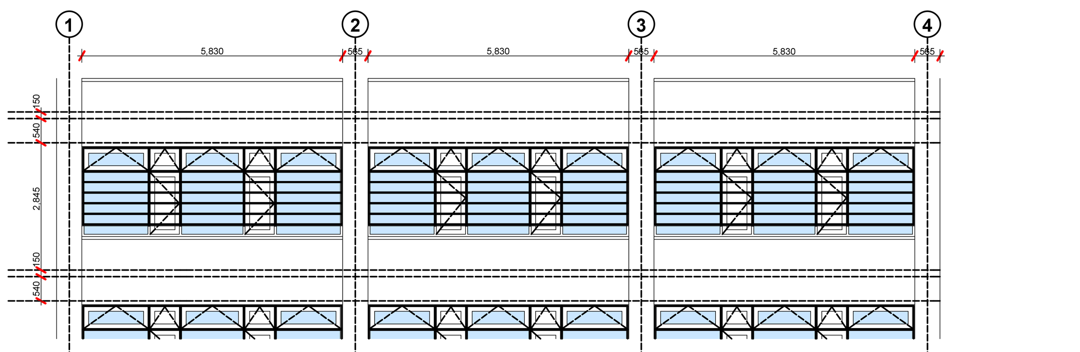
Construction Detail 1:20



3 Bay Plan Layout 1:100

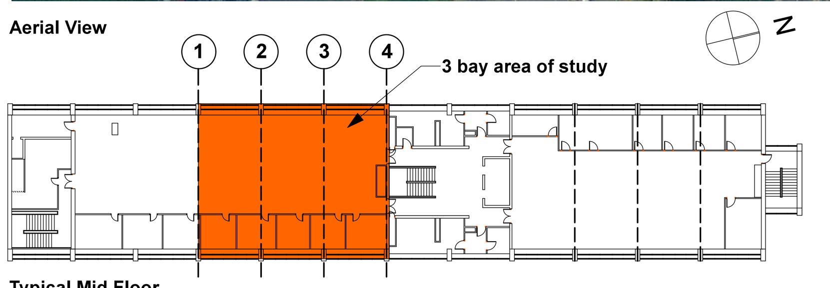


Elevation 1:100

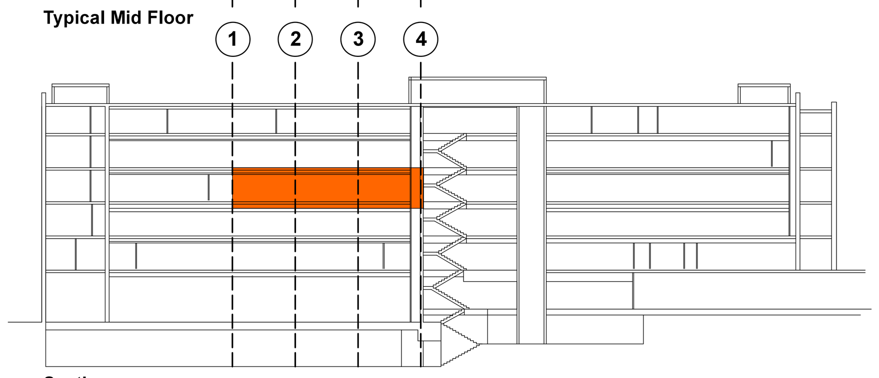


Context

Aerial View



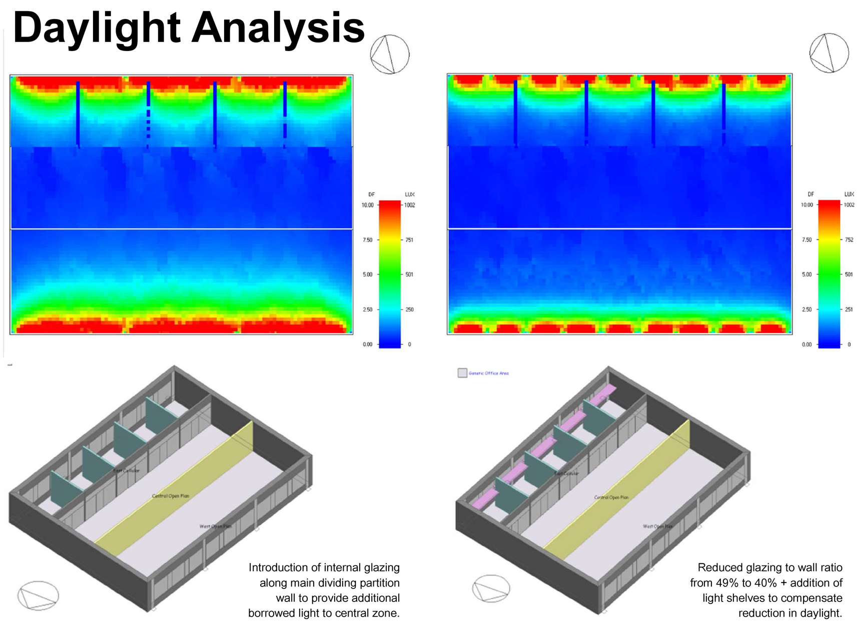
Typical Mid Floor



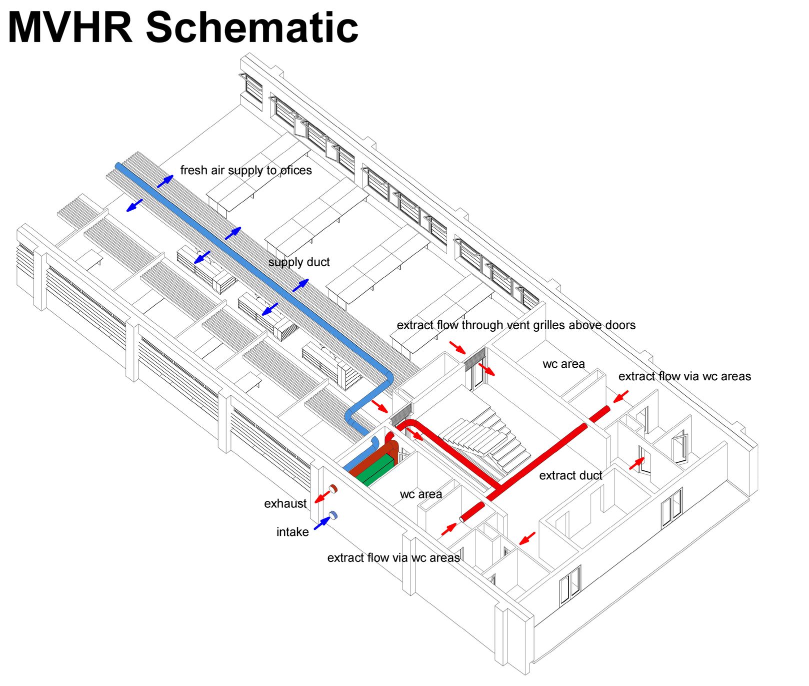
Section

Whole Building

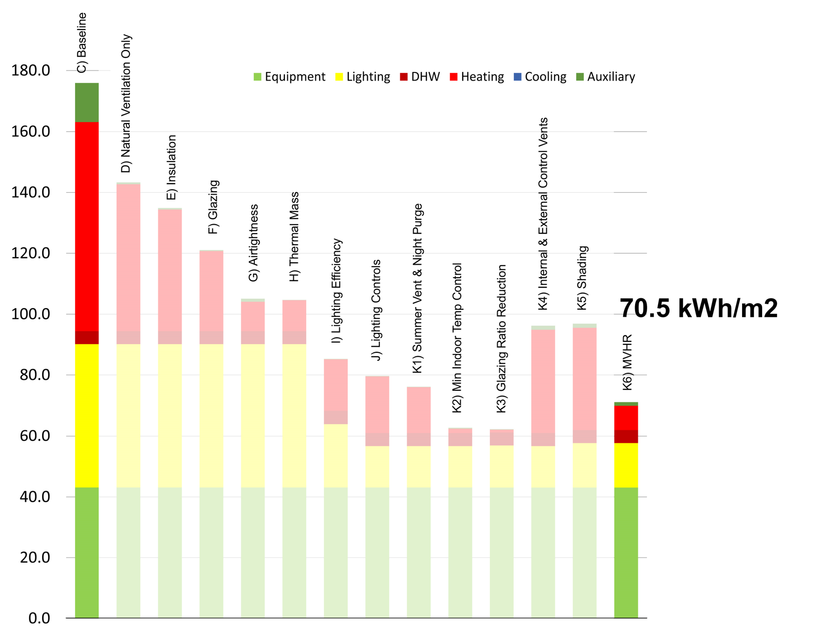
Daylight Analysis



MVHR Schematic



Cumulative Energy Reduction



Design Process

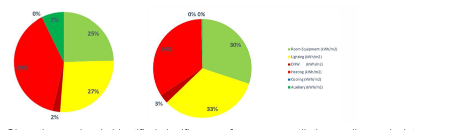
A) Auxiliary Loads

Baseline

	Results						
Units	Annual Energy (kWh/m2)	Room Equipment (kWh/m2)	Lighting (kWh/m2)	DHW (kWh/m2)	Heating (kWh/m2)	Cooling (kWh/m2)	Auxiliary (kWh/m2)
kWh/m2	175.3	43.1	47.0	4.4	68.7	0.0	12.8
W/m2	48.7	12.0	13.1	1.2	19.1	0.0	3.5

Nat Vent Only

	Results						
Units	Annual Energy (kWh/m2)	Room Equipment (kWh/m2)	Lighting (kWh/m2)	DHW (kWh/m2)	Heating (kWh/m2)	Cooling (kWh/m2)	Auxiliary (kWh/m2)
kWh/m2	142.7	43.1	47.0	4.4	48.2	0.0	0.6
W/m2	39.6	12.0	13.1	1.2	13.4	0.0	0.2



Given the previously identified significance of summer ventilation cooling and winter ventilation heat loss together with the emphasis on passive strategies, the first strategy was to eliminate as much of the auxiliary loads as possible by introducing natural ventilation and removing all mechanical ventilation.

B) Heating Loads

Insulation, Glazing, Airtightness, Thermal Mass

	Results						
Units	Annual Energy (kWh/m2)	Room Equipment (kWh/m2)	Lighting (kWh/m2)	DHW (kWh/m2)	Heating (kWh/m2)	Cooling (kWh/m2)	Auxiliary (kWh/m2)
kWh/m2	104.0	43.1	47.0	4.4	10.1	0.0	0.1
W/m2	28.9	12.0	13.1	1.2	2.8	0.0	0.0

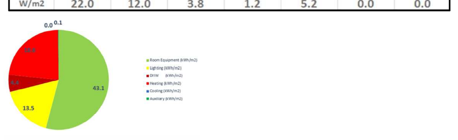
The external walls were insulated externally with 300mm mineral wool to achieve a U-value of 0.13 W/m2K. The windows were upgraded to triple glazing with a U-value of 0.78 W/m2K, a low g-value of 0.470 and a moderately high light transmission value of 0.661 to minimise solar heat gains in summer while maximising daylight levels. The airtightness was also upgraded to "excellent" to minimise infiltration losses.

The suspended ceiling tiles were removed to expose the concrete slab to provide thermal mass to help regulate internal temperatures. An additional layer of 75mm EPS insulation was applied on top of the slab to allow the full depth of the concrete ceiling to be dedicated to the one floor.

C) Lighting Loads

Lighting Efficiency & Controls

	Results						
Units	Annual Energy (kWh/m2)	Room Equipment (kWh/m2)	Lighting (kWh/m2)	DHW (kWh/m2)	Heating (kWh/m2)	Cooling (kWh/m2)	Auxiliary (kWh/m2)
kWh/m2	79.1	43.1	13.5	4.4	18.6	0.0	0.1
W/m2	22.0	12.0	3.8	1.2	5.2	0.0	0.0



Strategic targeting of higher lux levels over task areas with lower levels provided generally as background lighting. CIBSE Guidelines indicate the following recommendations:
- Task lighting (over individual desk workspaces) - 500 lux
- General office space – 300 lux
- Ancillary spaces (eg toilets) – 200 lux
- Circulation -100 lux

A "Dialux" simulation demonstrated that suspended task lighting providing 500 lux will also lift the surrounding radius to 300 lux if supplemented with 100 lux backgroung lighting.

Additional efficiency is achieved by providing daylight responsive lighting controls so that natural daylight is utilised wherever possible.

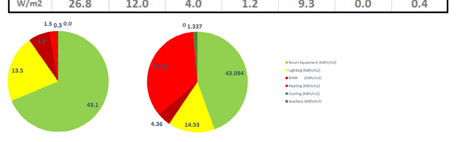
D) Overcooling & Overheating

Summer Vent, Night Purge, Indoor Temp Controls

	Results						
Units	Annual Energy (kWh/m2)	Room Equipment (kWh/m2)	Lighting (kWh/m2)	DHW (kWh/m2)	Heating (kWh/m2)	Cooling (kWh/m2)	Auxiliary (kWh/m2)
kWh/m2	62.1	43.1	13.5	4.4	1.5	0.0	0.3
W/m2	17.3	12.0	3.8	1.2	0.4	0.0	0.1

Glazing Ratio, External/Internal Vents, Shading

	Results						
Units	Annual Energy (kWh/m2)	Room Equipment (kWh/m2)	Lighting (kWh/m2)	DHW (kWh/m2)	Heating (kWh/m2)	Cooling (kWh/m2)	Auxiliary (kWh/m2)
kWh/m2	96.3	43.094	14.53	4.36	33.58	0	1.337
W/m2	26.8	12.0	4.0	1.2	9.3	0.0	0.4



There is excessive overcooling due to natural ventilation in winter with the supply of fresh but very cold winter air. Min indoor temperature controls were introduced and all external vents and opening windows were scheduled to operate during the summer only for both day vent cooling and night purge ventilation.

However, whenever natural ventilation was shut off, overheating began to rise and minimum fresh air supply was inhibited.

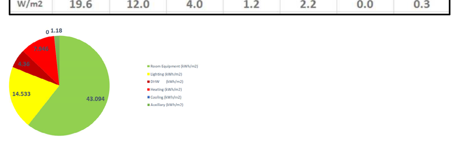
To reduce overheating the glazing to wall % ratio was lowered to reduce solar gains.The windows were broken into smaller sections with panels placed in between. This however, inreased overheating with the reduced area of glazing also reducing the area of window that could be opened thus restricting the capacity for cross-ventilation.The panels were therefore turned into venting openings to facilitate ventilation while limiting solar gain. This significantly reduced overheating but the previous problem of overcooling due to increased ventilation began to increase again.

Two contradicting problems are now in conflict:
1. Increased heat demand due to over-ventilation with cold external air.
2. Insufficient fresh air & increased overheating due to under-ventilation.

E) Minimum Fresh Air

MVHR

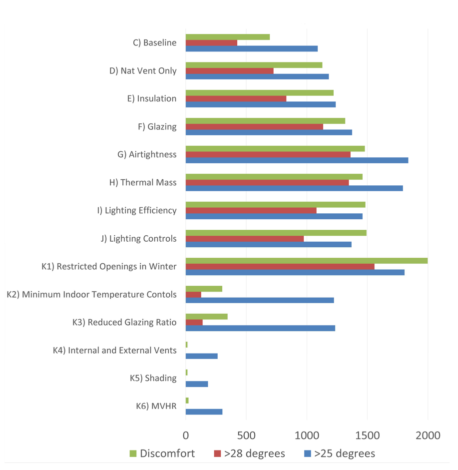
	Results						
Units	Annual Energy (kWh/m2)	Room Equipment (kWh/m2)	Lighting (kWh/m2)	DHW (kWh/m2)	Heating (kWh/m2)	Cooling (kWh/m2)	Auxiliary (kWh/m2)
kWh/m2	70.5	43.094	14.533	4.36	7.946	0	1.18
W/m2	19.6	12.0	4.0	1.2	2.2	0.0	0.3



At this point, natural ventilation appears to have reached its practical limit. While comfort levels are good and overheating kept to a minimum, fresh air on the other hand is massively compromised whenever natural ventilation is shut off in response to minimum indoor temperature controls. This is compounded by the additional effect of increasing overheat risk. Any attempt to counter this by increasing natural ventilation quickly results in over cooling due to excessive ventilation loss.

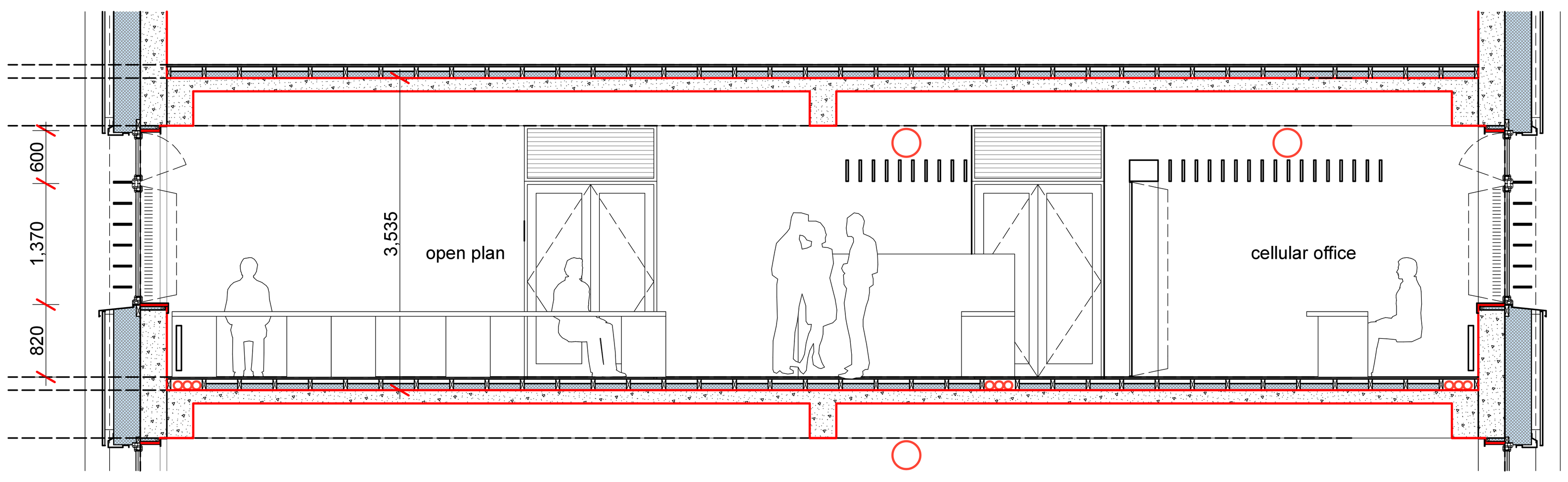
MVHR was introduced resulting in a reduction in total energy from 96.3kWh/m2 to 70.5 kWh/m2. Overheating was reduced to 292hrs (9.1%) above 25°C and eliminated entirely for temperatures above 28°C.

Overheating & Discomfort

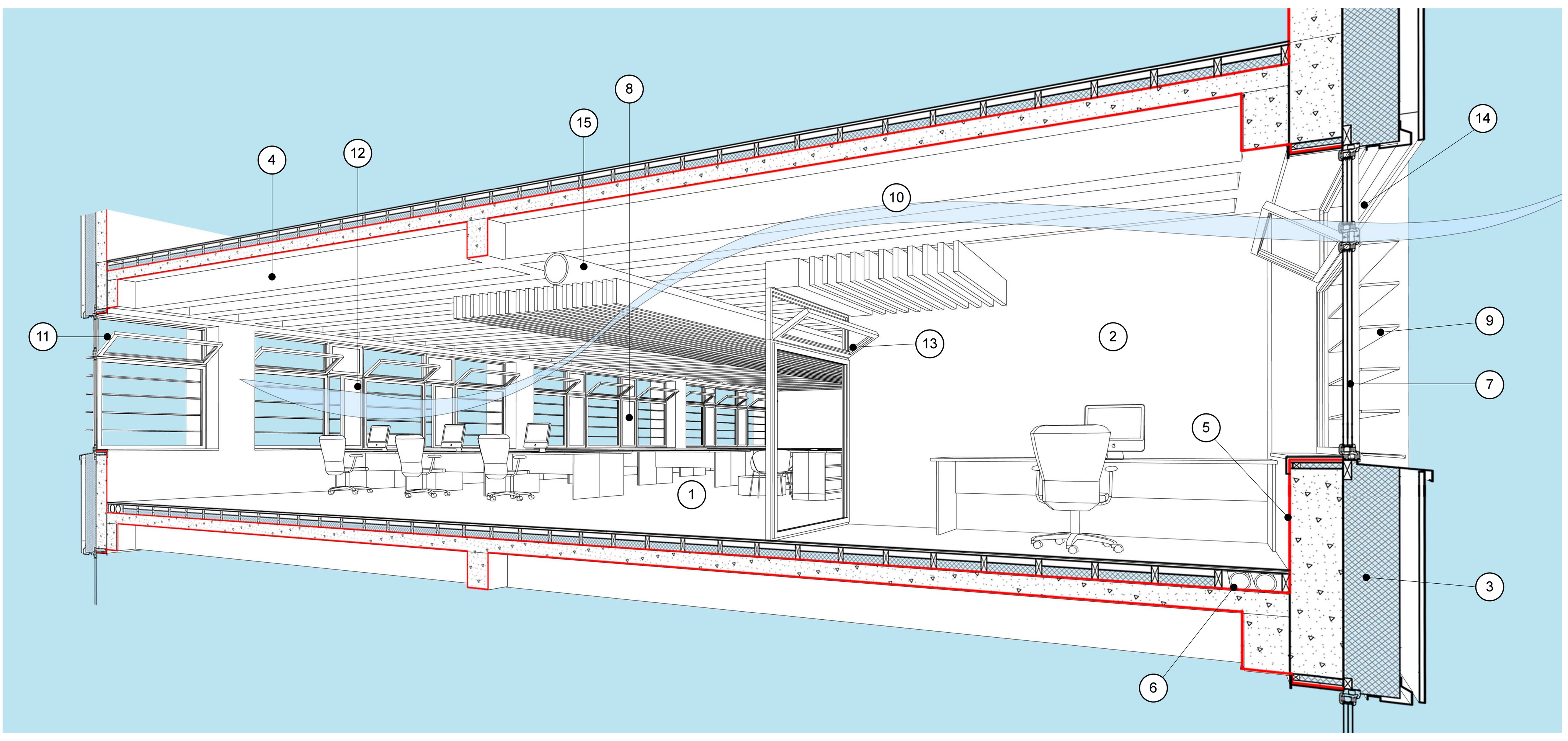


Progressive reduction in hours of overheat and discomfort during occupied periods (figures relate to open plan west zone)

Section 1:50



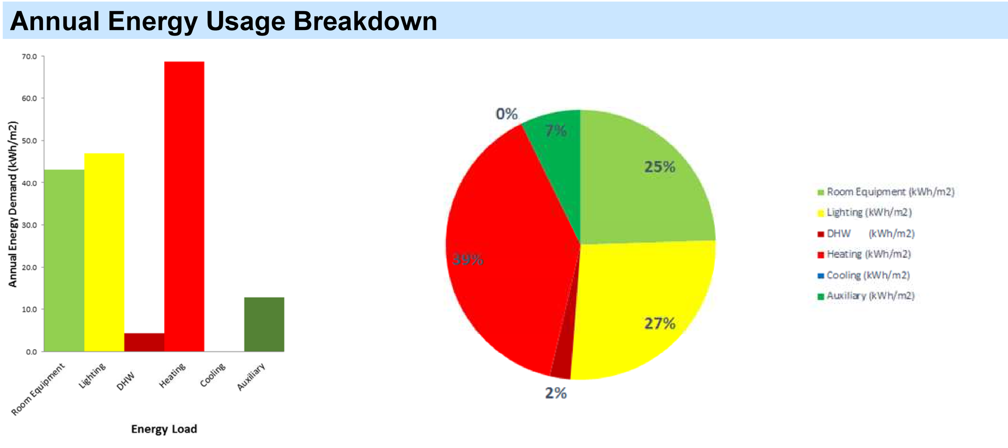
1 Open Plan Office
2 Cellular Office
3 External Insulation
4 Thermal Mass - exposed concrete slab
5 Airtightness Envelope
6 Services inside airtightness envelope
7 Triple Glazing
8 Reduced Glazing Ratio
9 Shading
10 Cross Ventilation
11 Natural Ventilation - Opening Windows
12 Venting opening panels
13 Internal Venting
14 Summer Night Purge
15 MVHR Fresh Air Supply Duct



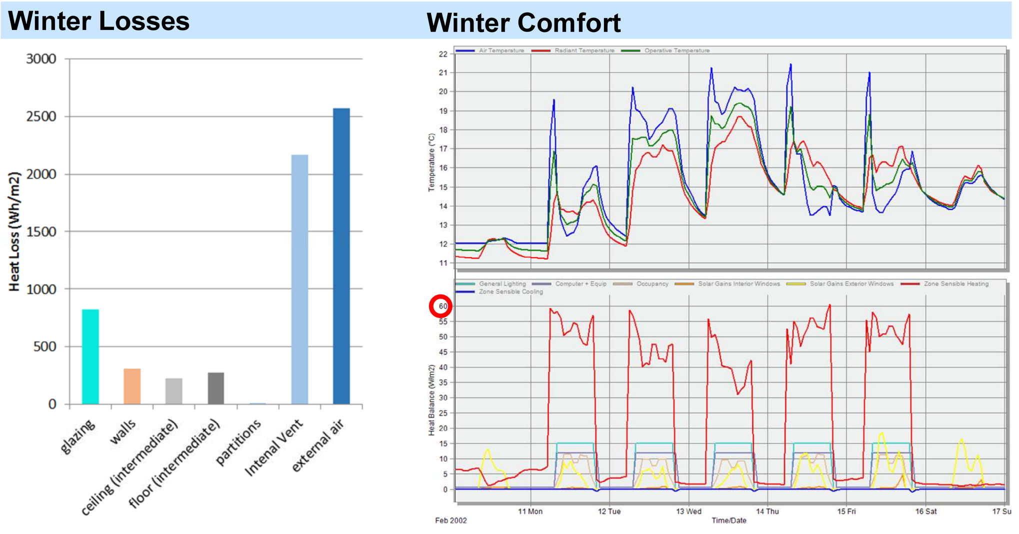
Baseline Model Analysis

	Results							Comfort		
Units	Annual Energy (kWh/m2)	Room Equipment (kWh/m2)	Lighting (kWh/m2)	DHW (kWh/m2)	Heating (kWh/m2)	Cooling (kWh/m2)	Auxiliary (kWh/m2)	Overheat Hrs (temp > 25°)	Overheat Hrs (temp > 28°)	Discomfort Hrs
kWh/m2	175.3	43.1	47.0	4.4	68.7	0.0	12.8	34.90%	13.60%	22.20%
W/m2	48.7	12.0	13.1	1.2	19.1	0.0	3.5			

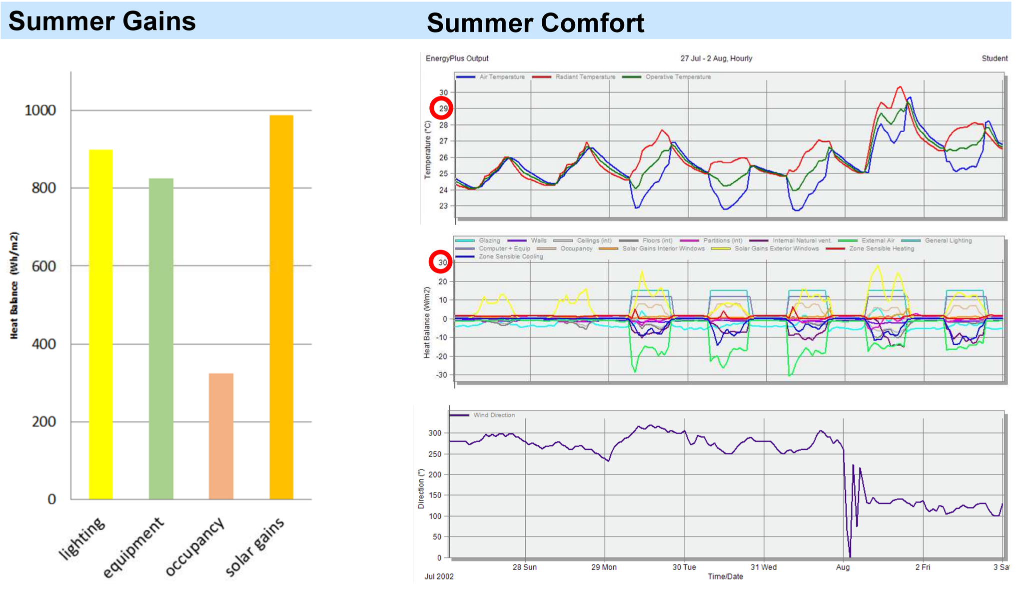
Annual Energy Usage Breakdown



Winter Losses / Winter Comfort



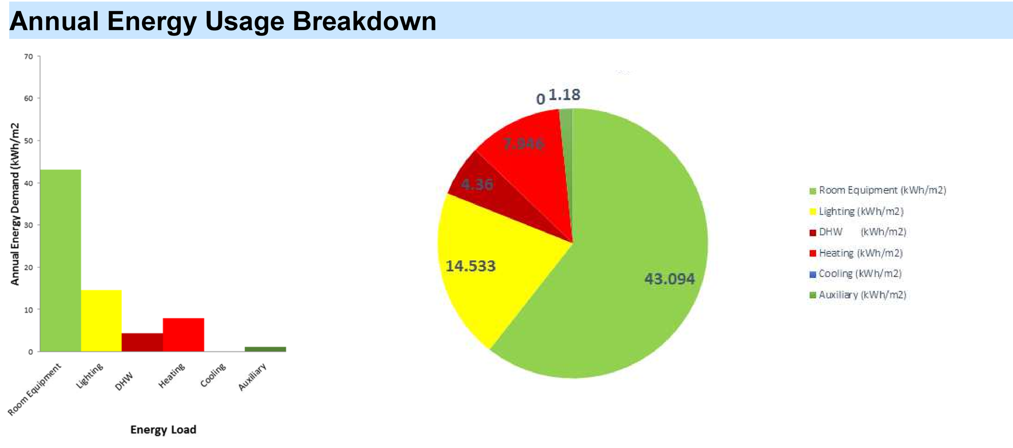
Summer Gains / Summer Comfort



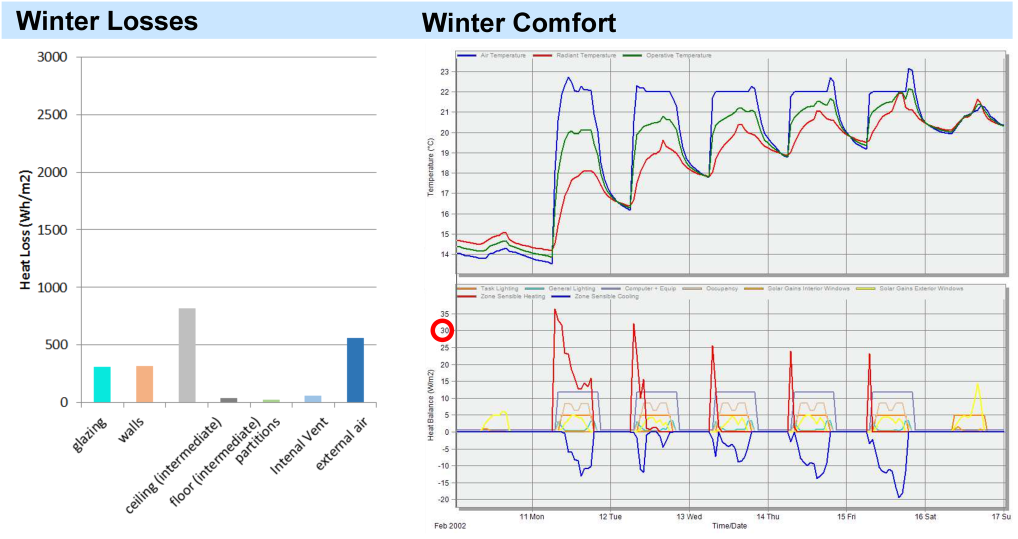
Optimal Model Analysis

	Results							Comfort		
Units	Annual Energy (kWh/m2)	Room Equipment (kWh/m2)	Lighting (kWh/m2)	DHW (kWh/m2)	Heating (kWh/m2)	Cooling (kWh/m2)	Auxiliary (kWh/m2)	Overheat Hrs (temp > 25°)	Overheat Hrs (temp > 28°)	Discomfort Hrs
kWh/m2	70.5	43.094	14.533	4.36	7.946	0	1.18	9.10%	0%	0.80%
W/m2	19.6	12.0	4.0	1.2	2.2	0.0	0.3			

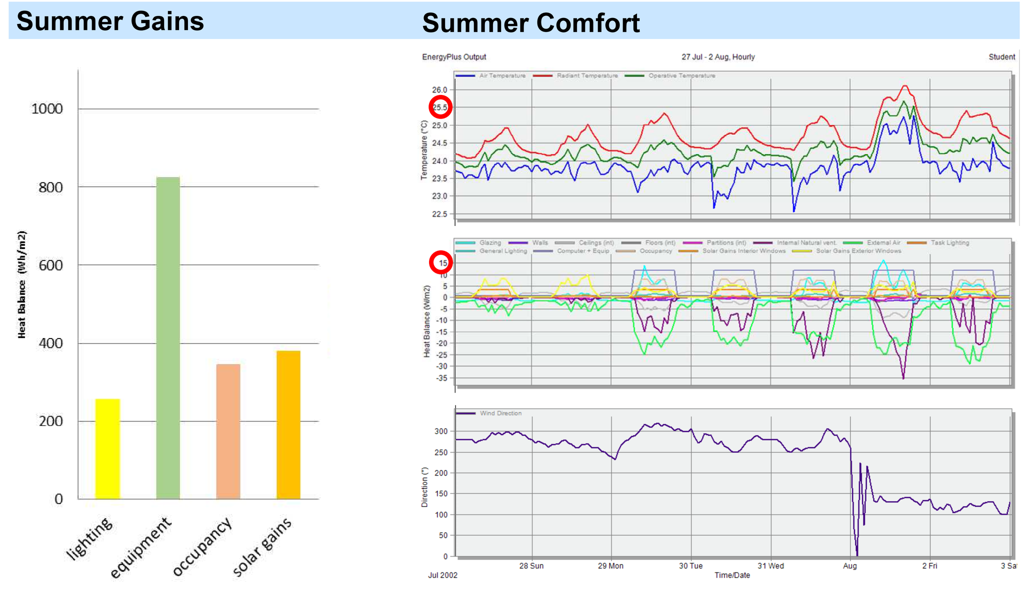
Annual Energy Usage Breakdown



Winter Losses / Winter Comfort



Summer Gains / Summer Comfort



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DT774b Energy Retrofit Technology

Office Retrofit - HOB Dublin Airport