nZEB OFFICE RETROFIT PROJECT

F i n a l   D e s i g n   S u b m i s s i o n

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Semester 2
Office Project

nZEB OFFICE RETROFIT - LIBERTY TOWER

Arising from the Recast European Performance of Buildings Directive 2010/30/EU, from January 1st 2021 every new building in Ireland will have to be designed to near zero energy building standards (nZEB).

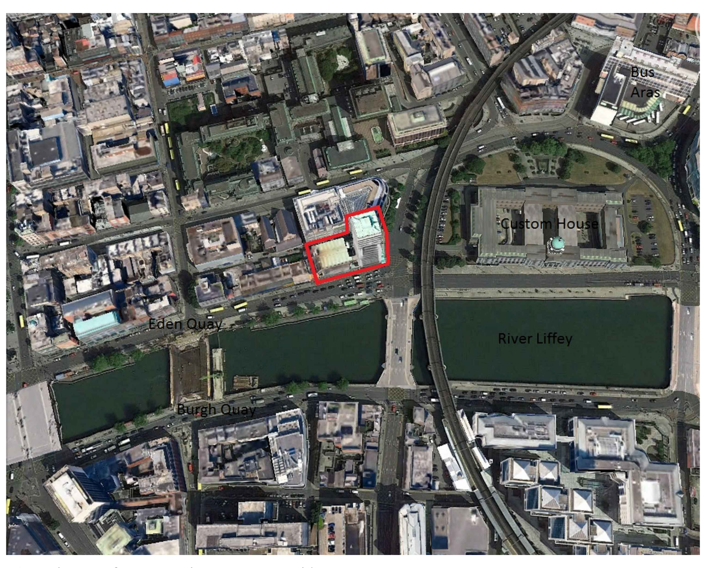
This project investigates a range of low energy retrofit measures for the upgrade and refurbishment of an existing multi-storey office building to nZEB standard, located in Dublin City centre.

The study was carried out using a range of energy analysis performance tools including Design Builder Dynamic Simulation software, Therm software for linear thermal bridge analysis and BuildDesk U for U-value and condensation risk assessment.

The bulk of analysis was performed using Design Builder in which a typical floor plan was modelled for the baseline assessment and the proposed retrofit solution.

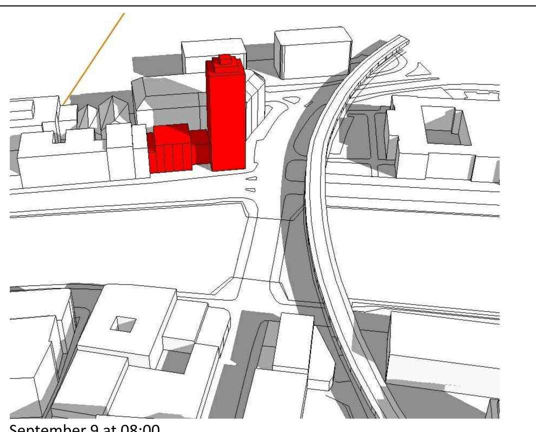
The subject building is of historical and symbolic importance to Dublin and it was decided to maintain the current building aesthetic and elevation proportions. The design solution was predominantly a fabric first approach with the focus on driving down energy loads and exploiting passive heating, cooling, ventilation and light sources. Occupant comfort was paramount to resolving the building with a delicate balance necessary to maintain optimum temperatures in a 75% glazed building. The study explored solutions offering 'optimal' load reductions with a focus on comfort as well as energy.

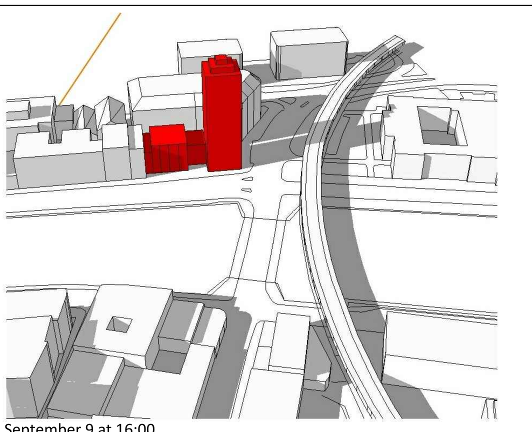
The total Delivered Energy demand for the building can be reduced by 85%, Primary Energy demand by 80%, annual space heating demand by 95% and comfort conditions maintained without the need for air conditioning.


3D Ariel View of existing Liberty Tower Building


Existing photographs - Liberty Tower Building

EXISTING SUN SHADOW STUDY

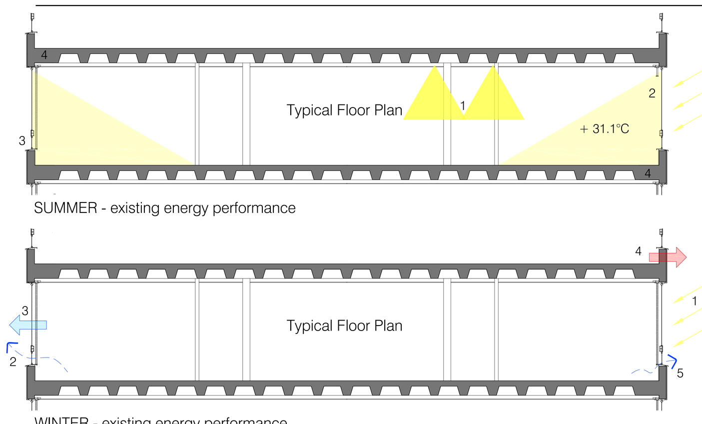

September 9 at 08:00


September 9 at 16:00

November 15 at 13:00


November 15 at 16:00

EXISTING BUILDING ENERGY ANALYSIS - TYPICAL FLOOR



SUMMER - existing energy performance

WINTER - existing energy performance

(1) High electrical lighting (uncontrolled) and room equipment (always on) loads resulting in internal gains

(2) High solar heat gains in East, West & South spaces due to high glazing ratio (75%)

(3) Limited scope for Nat Vent cooling (limited opening windows, no cross ventilation or stack effect, low floor to ceiling height

(4) Thermal mass of structure hidden behind finishes and not used to help modulate cooling loads

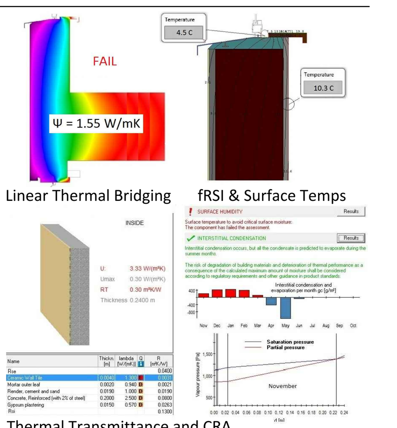
(1) Blinds down to prevent glare reduce availability of passive solar gains

(2) Large ventilation heat losses (Nat Vent without heat recovery)

(3) Glazing heat losses (single glazing with thermally unbroken aluminium frame)

(4) Fabric heat losses (poor external wall U-Value with no insulation, thermal bridging throughout)

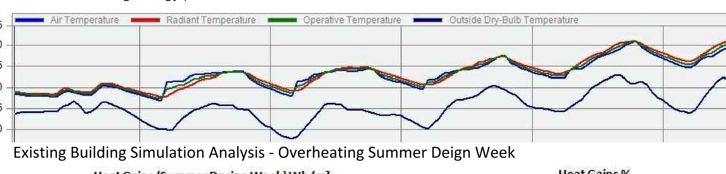
(5) Infiltration heat losses (very leaky building envelope)



Linear Thermal Bridging

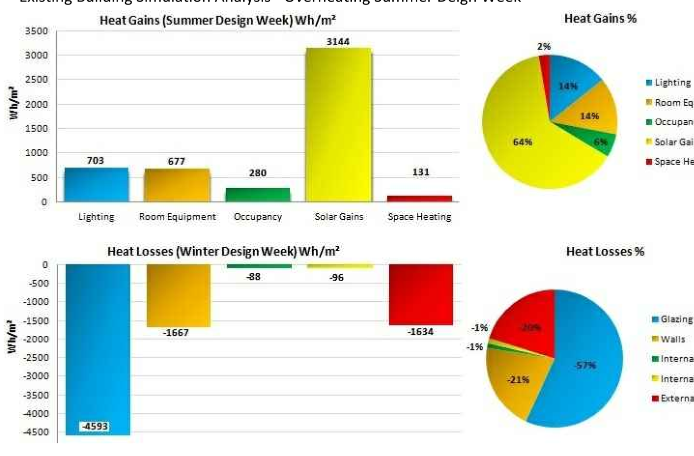
fRSI & Surface Temps

Thermal Transmittance and CRA

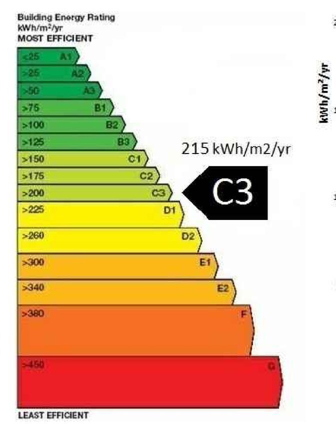


Existing Building Simulation Analysis - Overheating Summer Design Week

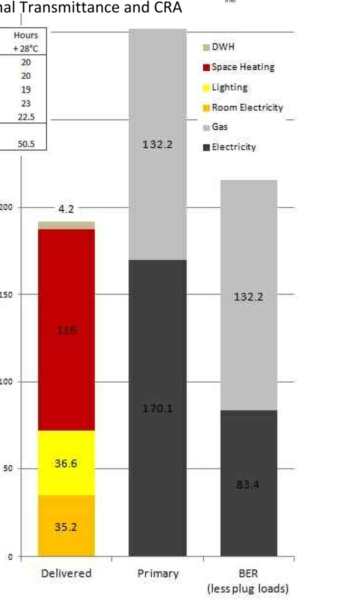
Overheating Hours (Summer DW)	Hours + 25°C	Hours + 28°C
Office (West)	33.5	20
Office (South West)	27	20
Office (South)	30.5	19
Office (South East)	39.5	23
Office (East)	43.5	22.5
Open Plan Total Annual OH Hours	252	50.5



Existing Building Simulation Analysis - Heat Gains & Losses



Existing Building BER



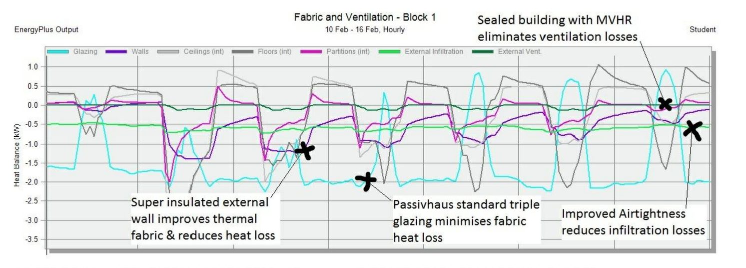
Existing Annual Energy Use & BER

nZEB OFFICE RETROFIT STRATEGY

1. Load Reduction	2. Passive Heat & Cooling	3. Building Services	4. Renewable Energy
Fabric Losses Air Infiltration Glazing Lighting Daylight Equipment	Winter: Passive Heat Gains Summer: Solar Control Thermal Mass Night Purge	Efficiency (CoP) Fuel Comfort Air Quality MVHR Controls (BMS)	PV District Heat Biomass Solar HW

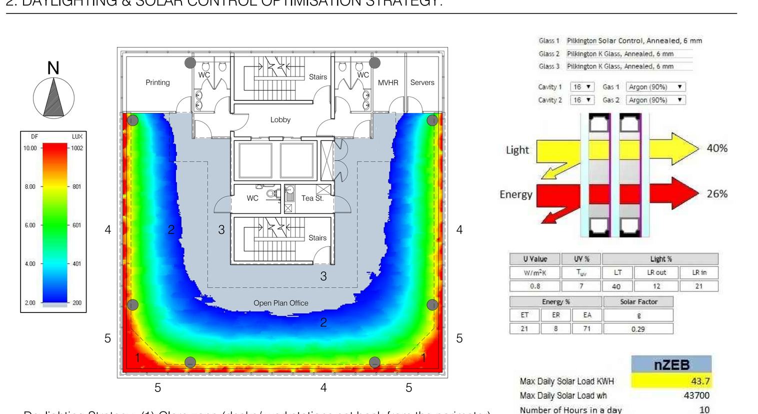
1. FABRIC AND GLAZING UPGRADES (PASIVHAUS ENERPHIT STANDARD):

Fabric Element	Existing	Retrofit
External Wall U-Value	3.3 (W/m²k)	0.15 (W/m²k)
Window U-Value (Ug)	5.8 (W/m²k)	0.8 (W/m²k)
Spandrel Panel U-Value	2.3 (W/m²k)	0.8 (W/m²k)
Airtightness (Infiltration Rate)	10 ac/h at 50 Pa	1 ac/h at 50 Pa



WINTER DESIGN WEEK FABRIC LOSSES FEBRUARY 10 - 16 (EXTRACT GRAPH FROM DESIGN BUILDER)

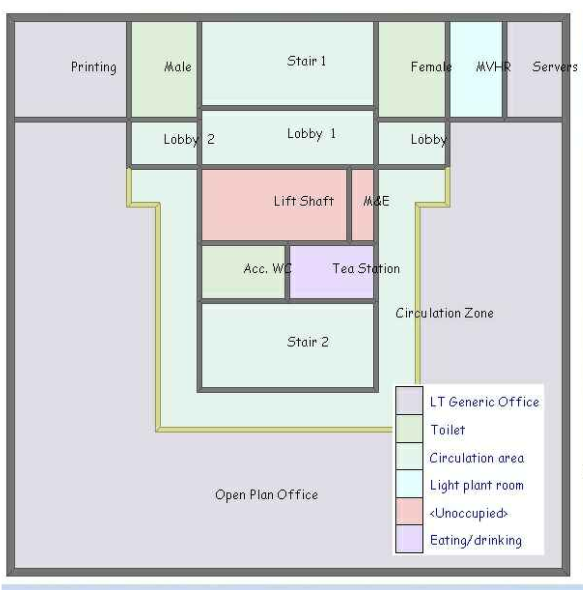
2. DAYLIGHTING & SOLAR CONTROL OPTIMISATION STRATEGY:

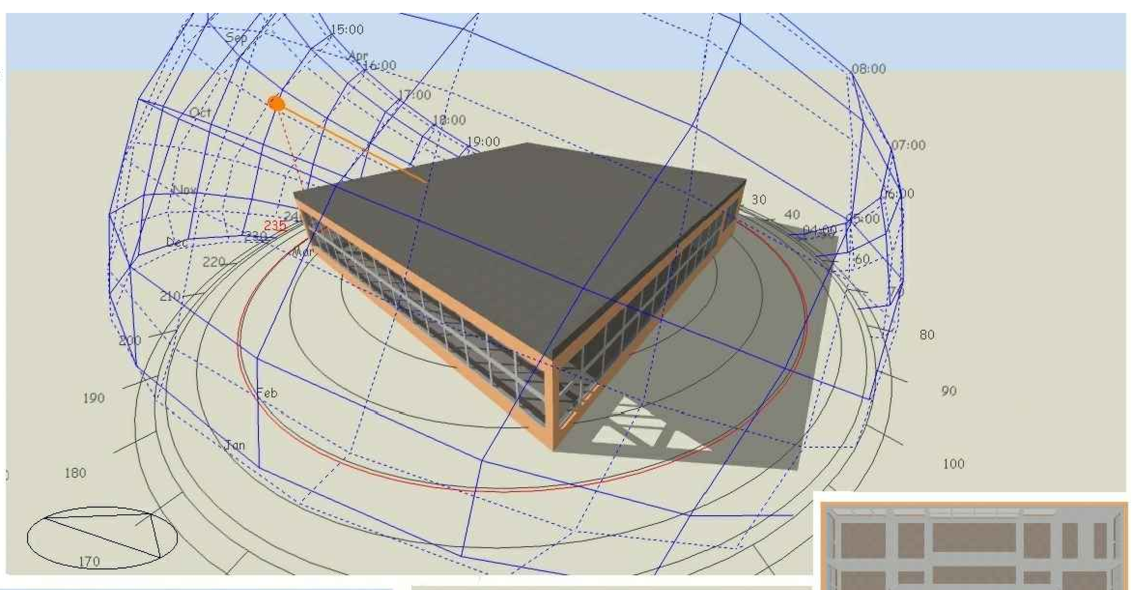


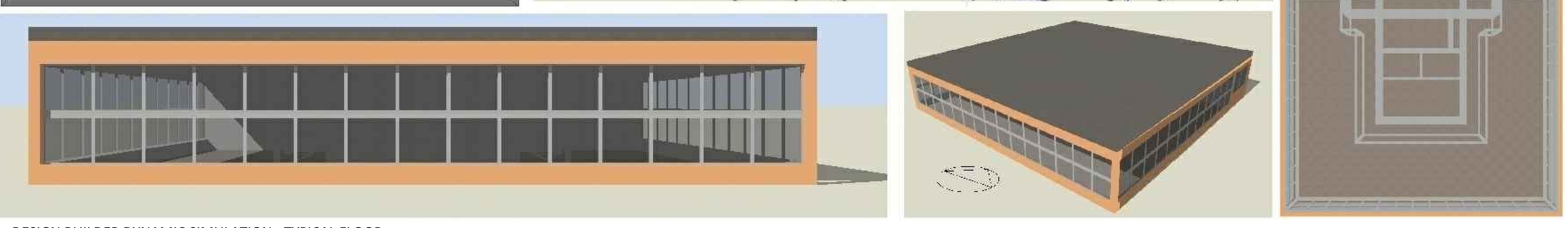
Daylighting Strategy: (1) Glare zone (desks/ workstations set back from the perimeter) (2) Office working areas with good daylight distribution (300 - 500 lux) (3) Circulation zone with lower daylighting levels (<200 lux) (4) Glazing light transmission ratio of 40% to minimise glare (5) Glazing with solar control 26% in SW and SE rooms

Solar Load < 25 W/m²

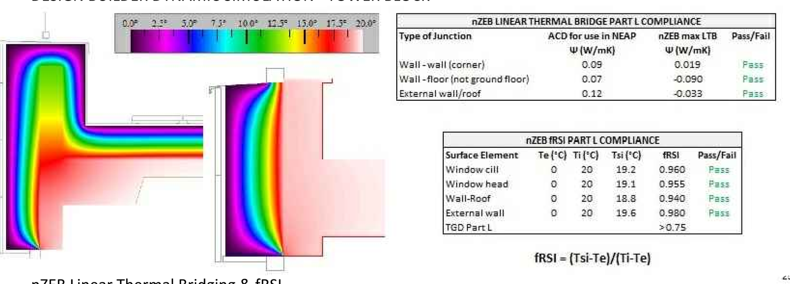
nZEB BUILDING DESIGN, DETAIL & ENERGY ANALYSIS

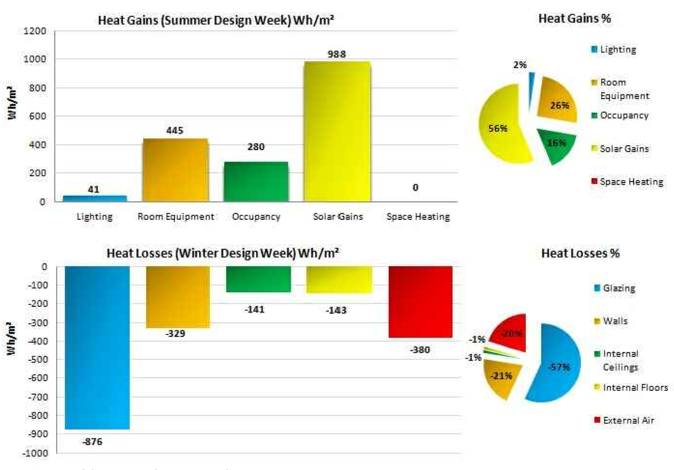





DESIGN BUILDER DYNAMIC SIMULATION - TYPICAL FLOOR


DESIGN BUILDER DYNAMIC SIMULATION - TOWER BLOCK


nZEB Linear Thermal Bridging & fRSI



nZEB Building Simulation Analysis - Heat Gains & Losses

SIMULATION RESULTS: ANNUAL ENERGY USE - kWh/m²

	Room Electricity	Lighting Electricity	Space Heating	DHW	Aux Energy	Total DE	Total PE	Hours + 25°C	Hours + 28°C
Baseline	35.2	36.6	116.0	4.2	0.0	192.0	301.9	8.0%	1.6%
Optimal Design	22.1	5.0	5.1	1.4	3.2	36.8	79.0	1.6%	0.0%
Reduction (%)	37%	88%	96%	67%	N/A	80%	74%	81%	100%

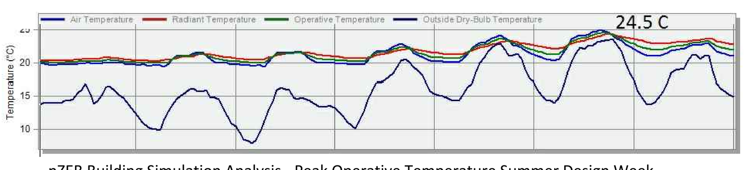
SIMULATION RESULTS: AVERAGE LOADS - W/m²

	Room Electricity	Lighting Electricity	Space Heating	DHW	Aux Energy	Total Loads
Baseline	11.2	11.7	37.0	1.3	0.0	61.3
Optimal Design	7.1	1.6	1.6	0.4	1.0	11.7
Reduction (%)	37%	88%	96%	67%	N/A	80%

HEAT GAINS (SUMMER DESIGN WEEK) - W/m²

	Equipment Gains	Lighting Gains	Occupancy Gains	Solar Gains	Heating Gains	Total Gains
Baseline	11.2	11.2	4.5	52.0	2.2	81.2
Optimal Design	7.0	0.6	4.5	15.7	0.0	27.8
Reduction (%)	38%	95%	0%	70%	100%	80%

Dynamic Simulation Results - Annual Energy Use, Loads & Heat Gains



nZEB Building Simulation Analysis - Peak Operative Temperature Summer Design Week

ROOF MOUNTED INCLINED SOLAR PV CALCULATOR

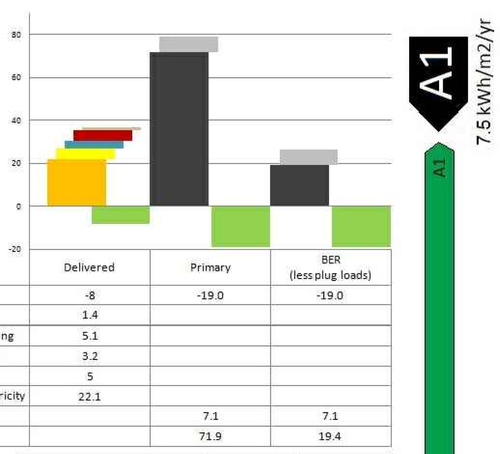
Orientation	South Facing	1074	30°	
Overshading	0%	1		
Collector Area 1 (m²)	1.65mx5m	8.25		
Collector Area 2 (m²)	1.65mx16mx3	79.2		
Total South PV (m²)		87.45	53	panels
Collector PP	Sunpower X-Series	345	18.3	
	0.80 x kWp x S x ZPV			
Annual output - South	15,710 kWh/yr			

Orientation	East/West Facing	929	15°	
Overshading	0%	1		
Collector Area 1 (m²)	1.65mx5mx2	16.5		
Collector Area 2 (m²)	1.65mx10mx6	99		
Total East/West PV (m²)		115.5	70	panels
Collector PP	Sunpower X-Series	345	24.2	
	0.80 x kWp x S x ZPV			
Annual output E/W	17,948 kWh/yr			

Orientation	North Facing	813	15°	
Overshading	0%	1		
Collector Area (m²)	1.65mx5.5mx3	27.23	16.5	panels
Collector PP	Sunpower X-Series	345	5.7	
	0.80 x kWp x S x ZPV			
Annual output - North	3,702 kWh/yr			

Annual PV electrical output for Building	37,361 kWh/yr
Approximate Annual Electric Demand for Building	141,360 kWh/yr
Annual PV electrical output for Typical Floor	2,335 kWh/yr
Approximate Annual Electric Demand for Typical Floor	8,835 kWh/yr
% of Electrical demand met by PV	26.43%

nZEB Building Solar Array PV Calculation

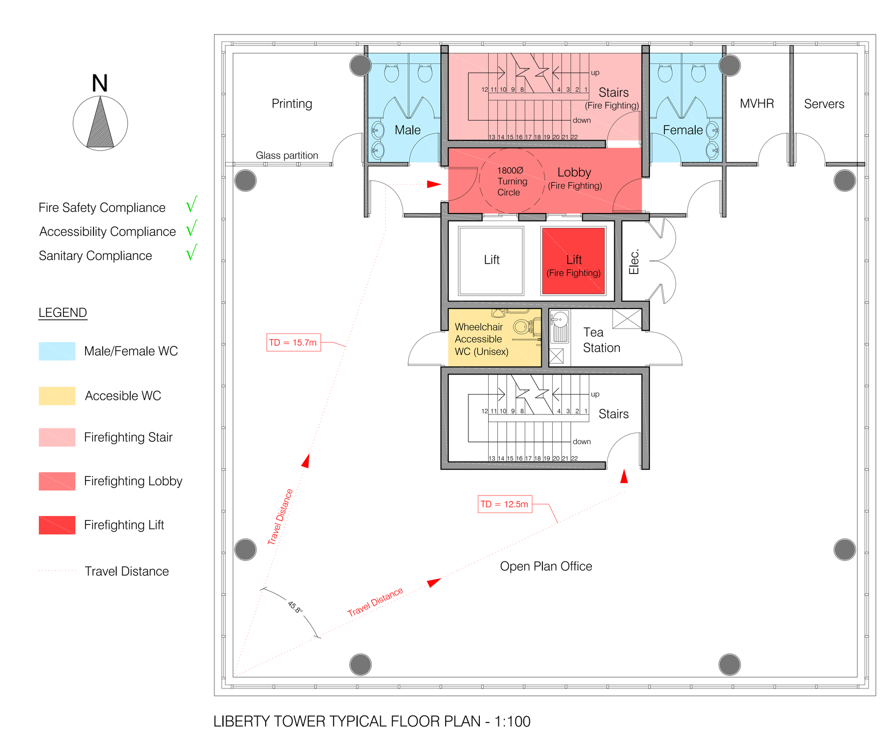


	Delivered	Primary	BER (less plug loads)
PV	-8	-19.0	-19.0
DWH	1.4		
Space Heating	5.1		
Aux Energy	3.2		
Lighting	5		
Room Electricity	22.1		
Gas		7.1	7.1
Electricity		71.9	19.4

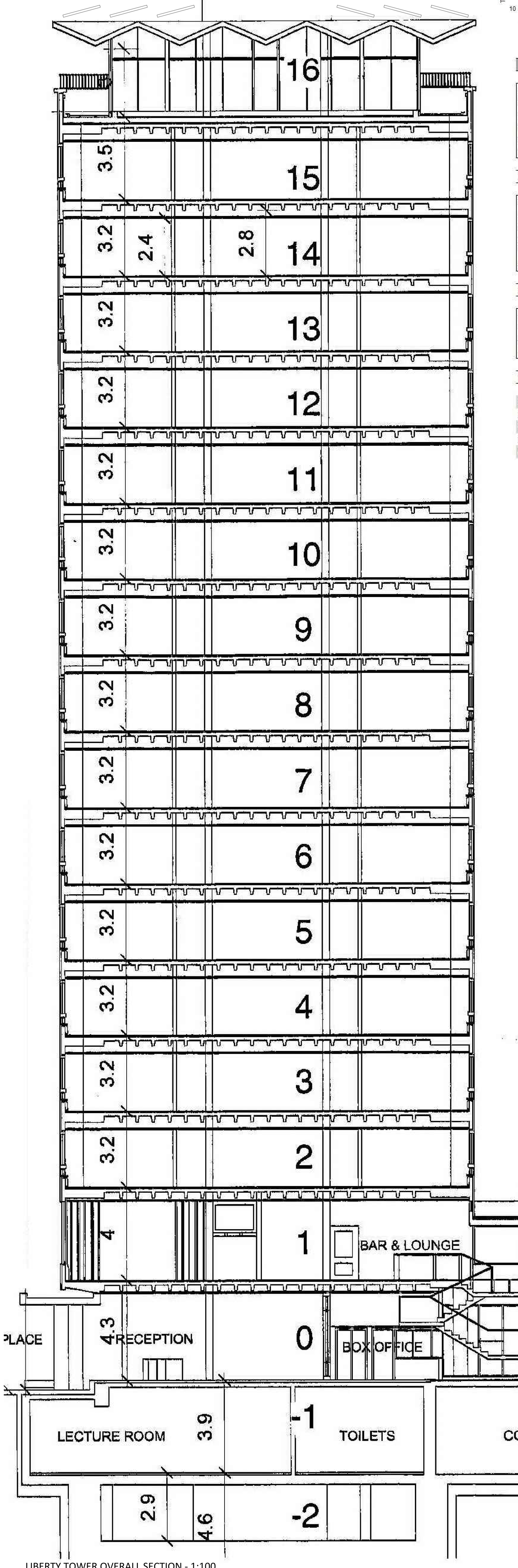
Fuel Coversion Factors	Gas	Electricity
	1.1	2.37

ANNUAL ENERGY SUMMARY	Delivered (kWh/m²/y)	Primary (kWh/m²/y)
Baseline Annual Energy	192	302.3
nZEB Annual Energy	28.8	60.1
% Reduction	85.2%	80.2%

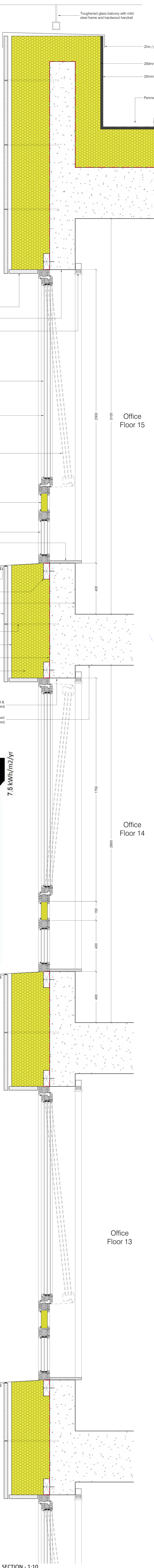
nZEB Annual Energy Use - Typical Floor & Total Building



LIBERTY TOWER TYPICAL FLOOR PLAN - 1:100

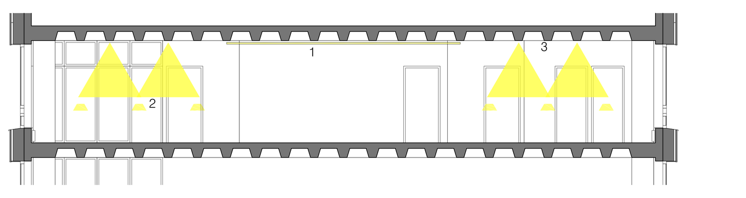


LIBERTY TOWER OVERALL SECTION - 1:100



SECTION - 1:10

3. LOW ENERGY LIGHTING STRATEGY (1.5 W/m² per 100 lux)



Low Energy Lighting Strategy: (1) Strip LED lighting to circulations area (2) Combined task and background lighting (300 lux), user controlled from individual workstations with daylight sensors and dimming controls (3) Reflective ceiling surface providing ambient background light

4. ROOM EQUIPMENT PLUG LOAD REDUCTIONS (9.44 W/m²)

OPEN PLAN OFFICE	Office Equipment	Quantity	Plug load each (W)	Plug load (W)
	Computers - desktop	25	40	1000
	Computers - laptop	10	17	170
	Monitors - desktop -LCD	25	17	425
	Portable HVAC (heaters, fans)	5	30	150
	Other small appliances, chargers	25	4	100
	Total plug load (W)			1945
	Plug load density (W/m²)			**9.44**

Low energy PCs and equipment

Plug loads control (time/occupancy)

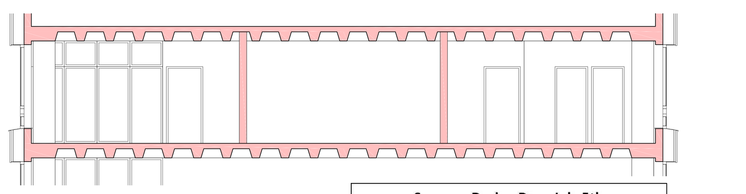
Reduce 'Phantom loads'

Server/printing room with localised cooling

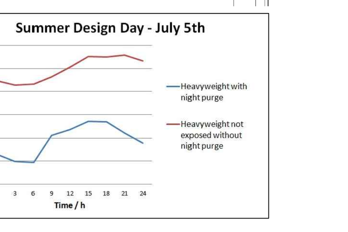
Post occupancy monitoring

Reduction in internal heat gains

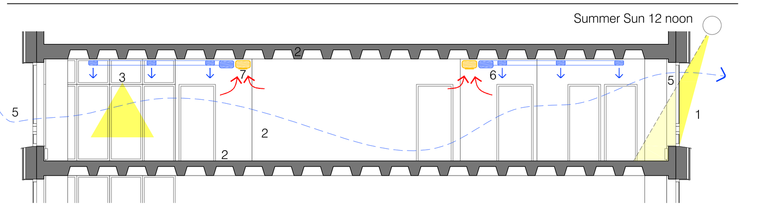
5. THERMAL MASS (SUMMER COOLING):



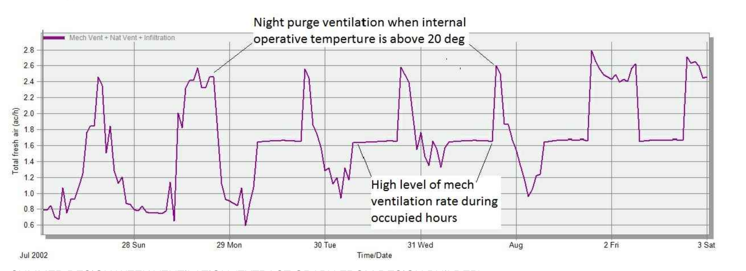
Exposing the existing concrete thermal mass (floor, ceilings & core) in conjunction with night time purge ventilation can help passively cool the building during summer, reducing the peak operative temperature on the typical floor plate by 5.2°C. In the open plan office area the annual hours at/above 28°C are reduced from 110.5 (3.5%) to 0 and hours at/above 25°C are reduced from 875.5 (27.9%) to 49 (1.5%).



6. PASSIVE COOLING STRATEGY (SUMMER):

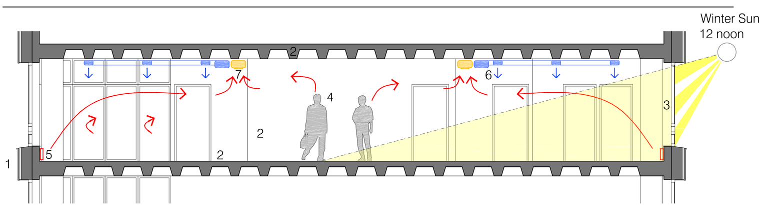


Passive Cooling Strategy (Summer): (1) Solar gains minimised with deep reveal and low solar transmission glass (2) Exposed thermal mass absorbs heat and modulates cooling loads (3) Lighting loads minimised with efficient LED light fittings, with daylight and occupancy responsiveness (4) Room equipment heat gains minimised by low energy equipment and "plug load" management (5) High and low opening windows automatically opened at night to provide night purge cooling (6) MVHR system supplies constant fresh air at high rate, with CO^2 monitoring and control (7) MVHR operating in summer bypass mode

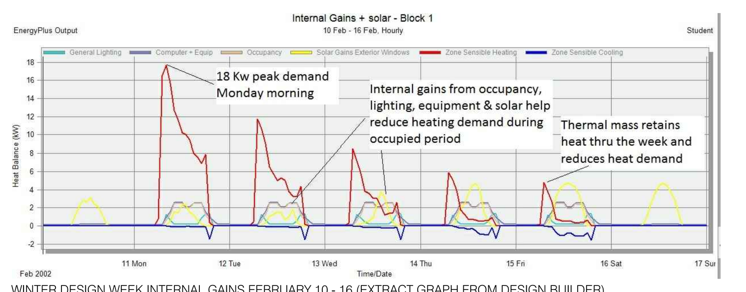


SUMMER DESIGN WEEK VENTILATION (EXTRACT GRAPH FROM DESIGN BUILDER)

7. PASSIVE HEATING STRATEGY (WINTER):

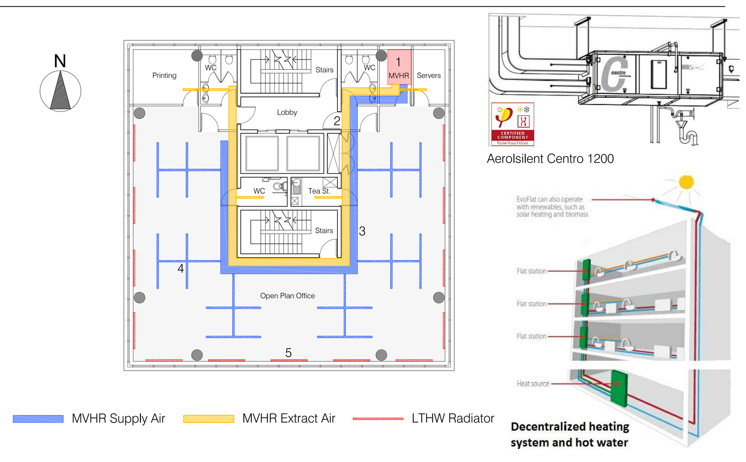


Passive Heating Strategy (Winter): (1) Airtight and super insulated building to minimise heat losses (2) Thermal mass stores passive heat gains which helps reduce the preheat demand from the heating system (3) High glazing ratio and no external shading maximise solar gains (4) Space heating mainly from passive internal gains from occupants, lighting, equipment and solar (5) Supplemented when required by heating system and delivered by low temperature hot water radiators (6) MVHR system supplies constant fresh air at low level based on occupant demand, warmed via a heat exchanger by the extract air, with CO^2 monitoring and control (7) Ceiling mounted extract ducts return air to the MVHR units on each floor



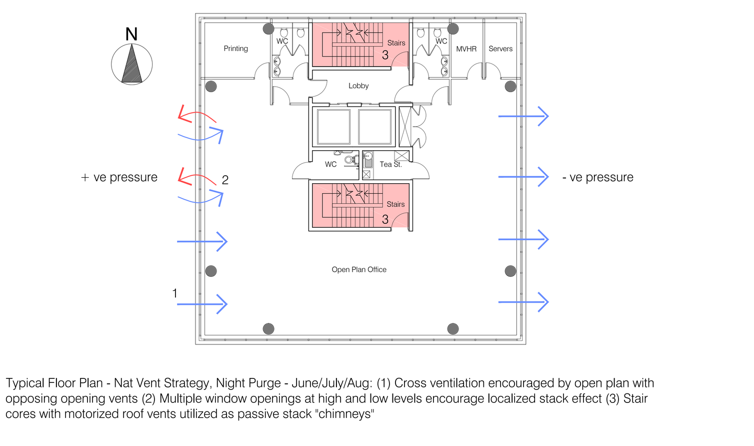
WINTER DESIGN WEEK INTERNAL GAINS FEBRUARY 10 - 16 (EXTRACT GRAPH FROM DESIGN BUILDER)

8. MECHANICAL SERVICES STRATEGY:



Mechanical Services Strategy: (1) MVHR Unit (83% efficient heat recovery. Electric power consumption 0.45 Wh/m³) (2) 400x200mm ceiling extract duct, (3) 400x200mm ceiling supply air duct (4) Supply air diffusers at ceiling level (5) Low temperature hot water panel radiators with TRV's, served by decentralised gas condensing boiler (92% efficient), meter station provided at each floor.

9. NAT VENT STRATEGY, NIGHT PURGE (SUMMER COOLING):



Typical Floor Plan - Nat Vent Strategy, Night Purge - June/July/Aug: (1) Cross ventilation encouraged by open plan with opposing opening vents (2) Multiple window openings at high and low levels encourage localized stack effect (3) Stair cores with motorized roof vents utilized as passive stack "chimneys"

10. RENEWABLE STRATEGY (ROOF MOUNTED PV ARRAY & FUTURE CONNECTION TO DISTRICT HEATING)