BILD 321: SUSTAINABLE ENGINEERING SYSTEMS DESIGN

NET ZERO ENERGY BUILDING

DESIGN OPPORTUNITIES AND CONSTRAINTS FOR 75 THORNDON QUAY, PIPITEA, WELLINGTON

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BACKGROUND & PURPOSE

The New Zealand Government has committed to being carbon zero by 2050, therefore new buildings must use as little energy as possible.[1] New Zealand currently has low carbon electricity, with 81% being produced by renewable sources in 2020, however, as buildings transition away from non-renewable sources, there will be an overwhelming demand for electricity.[1,2] It is necessary to design efficient buildings which minimise the need for heating, cooling, artificial lighting and plug loads which make up a large portion of the operational energy use.

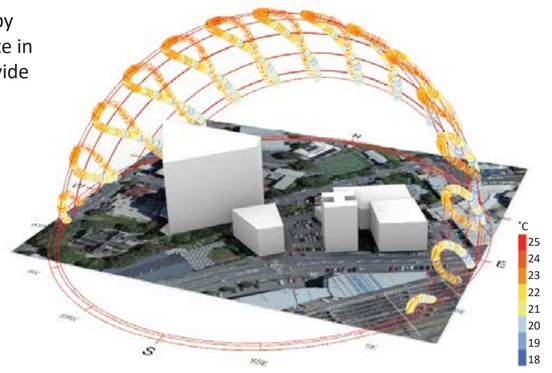
A Net Zero Energy Building is **"an energy-efficient building where, on a source energy basis, the actual annual delivered energy is less than or equal to the on-site renewable exported energy"[3]**

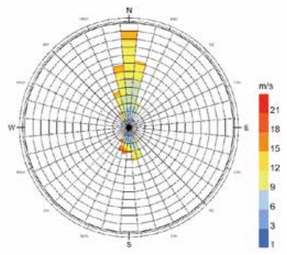
SITE

Energy efficiency and occupant comfort can be significantly increased by incorporating passive design features which respond to the local climate in order to exploit natural sources of energy such as sun and wind to provide heating, cooling, ventilation, and lighting.

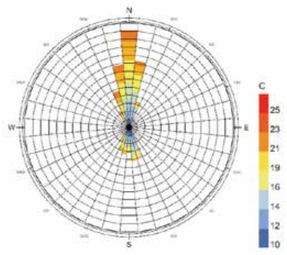
The sun path diagram identified:

- Direct sunlight was obstructed by the neighbouring buildings , especially during the winter months,
- Daylighting on the lower floors of any proposed building would therefore be reduced,
- A building approximately 28m high would achieve 4181 direct sun hours per year, suggesting solar energy would be a suitable source of renewable energy.





Wind Rose: Wind Speed and Direction



Wind Rose: Wind Temperature and Direction

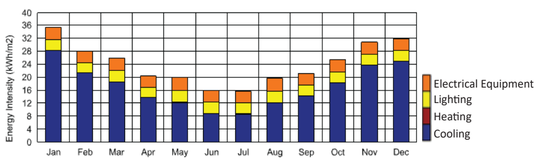
The wind rose diagrams identified:

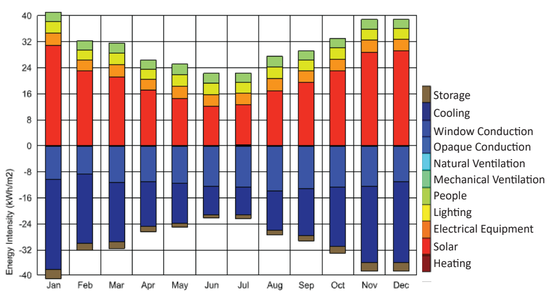
- Northerly winds are predominant, suggesting cross ventilation in the north to south direction for passive cooling would be effective,
- The average wind temperature, frequency and speed varies considerably contributing to heat loss, draughts, and conduction heat loss through glass.

BASELINE BUILDING

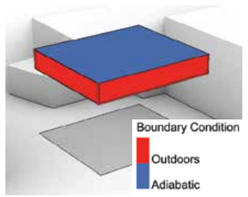
A base model was created in accordance with the New Zealand Building Code performance requirements for H1/AS2, Climate Zone 3.[4] This was mainly glass, typical of modern buildings in Wellington, like the pictured Deloitte Building. A building performance sketch (BPS) determined an approximate end use intensity (EUI) of 289kWh/m² for a building on this site.

EUI 289kWh/m²

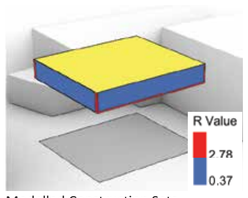




Energy Balance Graph



Modelled Boundary Conditions

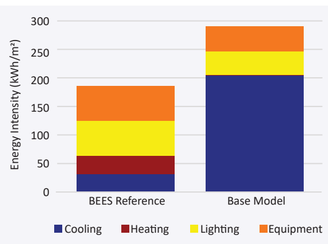


Modelled Construction Sets



Deloitte Building, Wellington[5]

QUALITY ASSURANCE
A typical New Zealand office building uses approximately 186kWh/m², however the base model can be considered accurate due to the high window to wall ratio and the subsequent energy required for cooling.[6]



The BPS identified:

- EUI of 289kWh/m²,
- Minimal heating required,
- Solar gains caused overheating,
- Cooling demanded the most energy,
- Heat loss through window conduction.

PERFORMANCE GOALS

Temperature should remain between **18-24˚C** during the hours of 08:00 to 18:00.[7]

Useful Daylight Index: **UDI300-2000**, 50% of the time, for 75% of the area.[8]
Spatial Daylight Autonomy: **sDA300**, 50% of the time, for 50% of the area.[3,9]

End use intensity should be less than **29kWh/m²**.

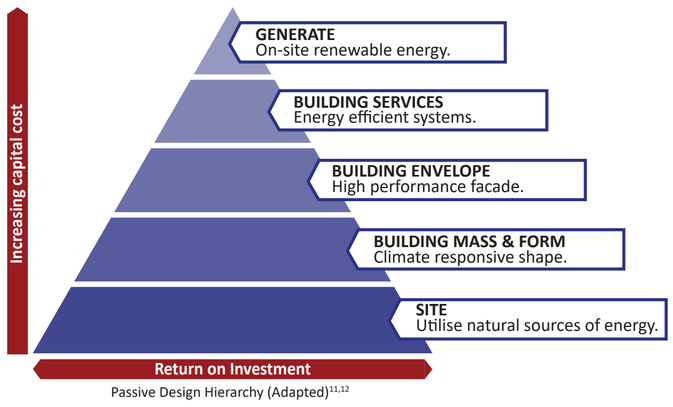
ENERGY GENERATION

Monocrystalline photovoltaic solar panels with an efficiency of 20% could cover 80% of the roof space, enabling **29kWh/m²** of energy to be generated on-site.

PROPOSED STRATEGIES

Literature suggested the following strategies would be advantageous:

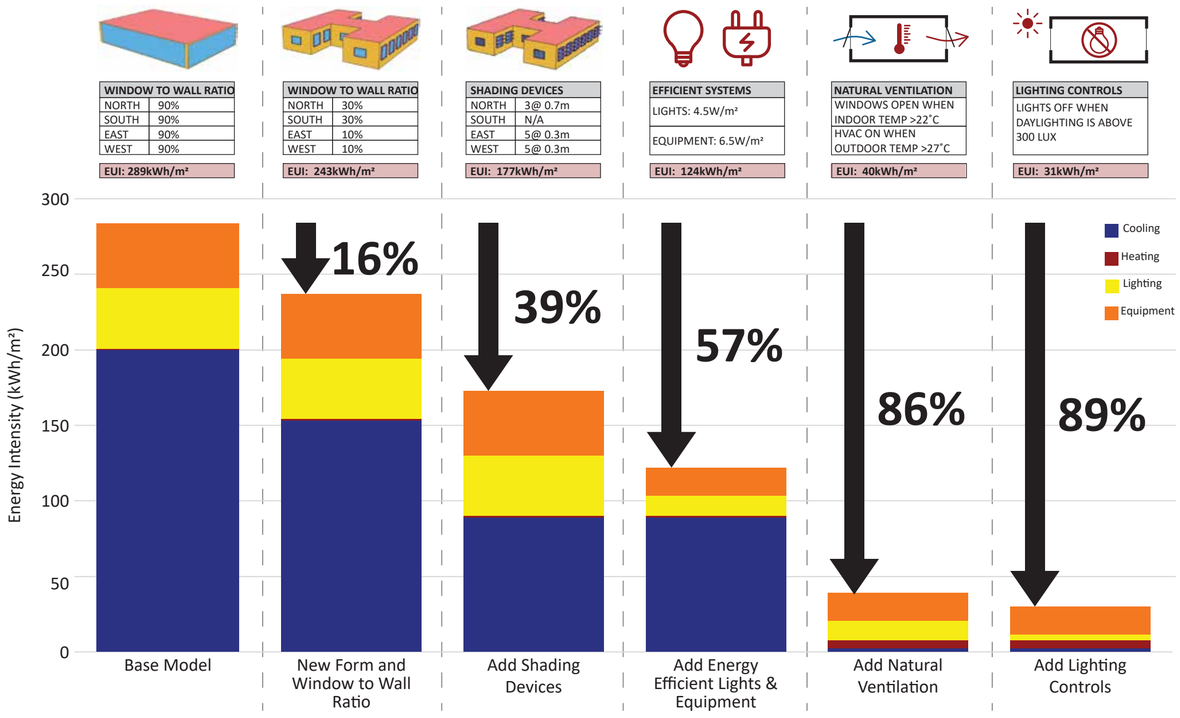
- Climate responsive shapes,
- Window to wall ratio,
- Fenestration shading,
- Natural ventilation,
- High performance glazing,
- Increased insulation,
- Lighting controls.



Passive Design Hierarchy (Adapted)[11,12]

RESULTS & KEY FINDINGS

The proposed strategies were modelled with the most effective being combined and included in the final design as detailed below. The effects of increased insulation and high-performance glazing were either minimal, or ineffective providing little benefit for the additional cost.



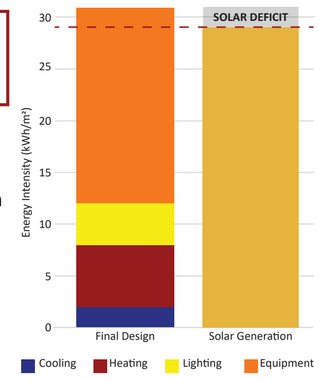
FINAL DESIGN



The Final Design in Context

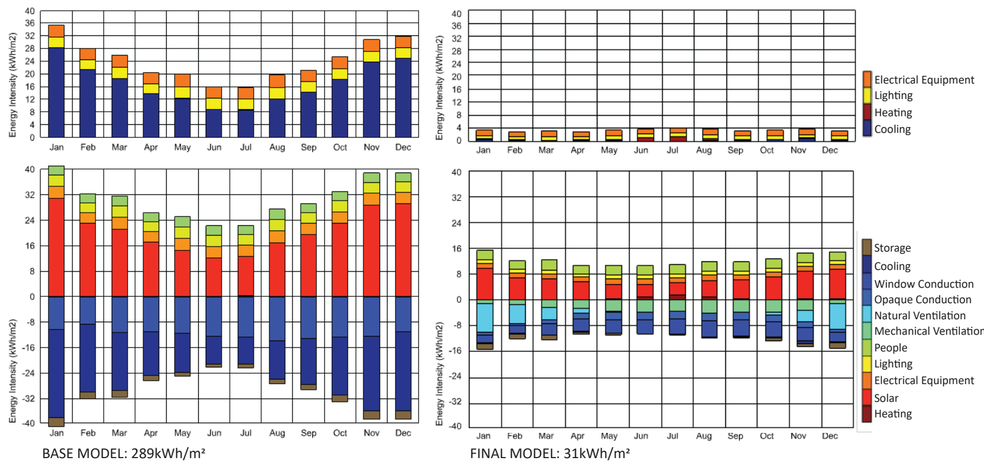
EUI 31kWh/m²

SOLAR ENERGY DEFICIT
It was not possible to generate enough renewable energy through PV panels alone to achieve net-zero status. Therefore, additional methods of energy generation such as a PV facade on the North elevation or scale-jumping would be required.



ENERGY BALANCE COMPARISON

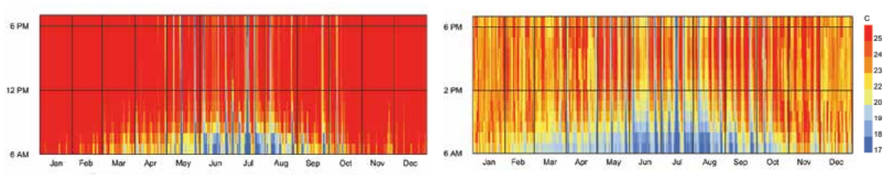
89%
decrease in operational energy use



BASE MODEL: 289kWh/m²
FINAL MODEL: 31kWh/m²

THERMAL COMFORT COMPARISON

13%
increase in thermal comfort

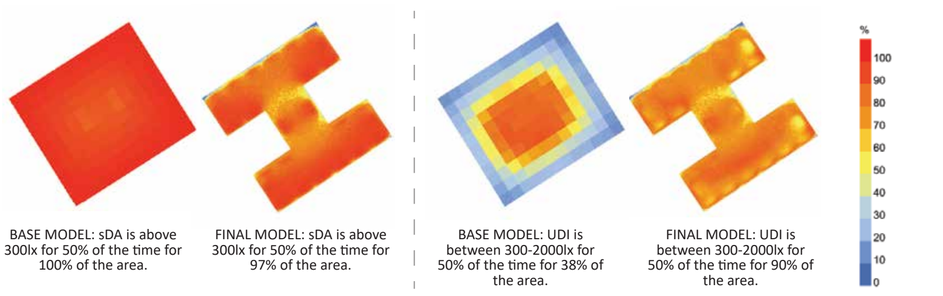


BASE MODEL: Comfortable 31% without heating or cooling

FINAL MODEL: Comfortable 44% without heating or cooling

VISUAL COMFORT COMPARISON

52%
increased area that is visually comfortable



BASE MODEL: sDA is above 300lx for 50% of the time for 100% of the area.

FINAL MODEL: sDA is above 300lx for 50% of the time for 97% of the area.

BASE MODEL: UDI is between 300-2000lx for 50% of the time for 38% of the area.

FINAL MODEL: UDI is between 300-2000lx for 50% of the time for 90% of the area.

CONCLUSION

The principles that facilitate a near net zero energy office building in Wellington, while increasing thermal and visual comfort, were:

- A climate responsive building shape,
- Optimised window to wall ratio of:
  - 30-40% on the North and South façades,
  - 10-20% on the East and West facades,
- An even distribution of glazing across each façade,
- Add shading devices to windows:
  - Approximately 3, 0.7m deep, horizontal shades to the North Façade,
  - Approximately 5, 0.3m deep, vertical shades to the East and West Facades,
- Incorporate natural ventilation,
- Incorporate lighting controls.

These strategies reduced solar gain and glare while retaining views and natural daylighting which increased thermal comfort and provided a uniform distribution of useful daylight within the building.

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