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# Achieving a Six-Star Rated Tall Building In Sydney's Central Business District



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The ANZ Tower in central Sydney not only represents the commercial office sector's recovery from the 2008 financial crisis; it is also a strong example of a high-performance tall building. This was the culmination of an ongoing partnership from the early design development stage onwards. An enlightened owner wanted to differentiate the building through green efficiency, and a design team committed to extensive modeling and testing of multiple, interrelated building services and architectural elements, in the interest of reducing overall carbon impact.

**Background**

Rising 212.6 meters above the street, the ANZ Tower at 161 Castlereagh Street, part of the precinct known as Liberty Place, was one of the first buildings to emerge from the 2008 global financial crisis in the central business district (CBD) of Sydney. The development reinvigorates a previously run-down site with a design that emphasizes the public domain and a richness of activity.

Located in the retail district between the business and legal precincts, the site provides competitive leasing rates and is easily accessible to public transport. Once inside, above the low-level floors, the northeasterly views of Sydney's magnificent harbor become apparent. The building form responds well to this view, its shape focused on the eastern harbor with a prominent northeast façade designed to maximize daylight and views. The

tower takes advantage of the site's particular planning constraints to develop its distinctive form, which also ensures that nearby Hyde Park is protected from shadows at key times of the day.

Originally conceived prior to the 2008 crisis, the site was acquired by Grocon as part owner, developer, and builder in April 2010; the design resolution commenced with anchor tenants ANZ Bank and the Freehills law firm.

**Design Evolution**

The environmental targets of the original design were set to achieve a five-star Green Star Design & As Built development rating, along with a five-star National Australian Built Environment Rating System (NABERS) energy target.

The developer secured a major bank and a legal firm to occupy up to 75% of the building's Property Council of Australia office premium-grade space prior to financial close in April 2010.

The team charged with designing the building included architect Francis-Jones Morehen Thorp (FJMT); building services design including mechanical, electrical, communications, security, specialist lighting, sustainability, and building façade services by AECOM; and Aurecon on structural engineering.

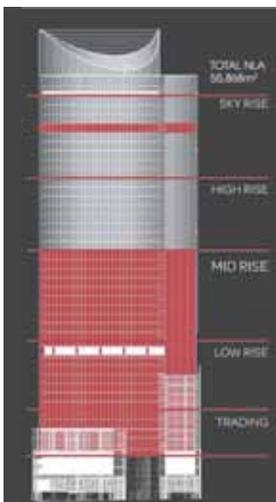


Figure 1. Liberty Place development stacking diagram



Figure 2. Typical floor plate – demonstrating access to views. © FJMT

Towards the end of the design development stage, the developer recognized an opportunity to differentiate this building from many of its competitors by raising the environmental standard to a six-star Green Star World Leadership rating. The building services engineer provided Green Star and energy performance consultancy and designed the building services to meet target during the early design stage. The building services engineer was then charged with continual refinement of the energy model, with the inputs generated by the development team, along with the services and façade design and construction subcontractors during the construction documentation stage.

### Architecture

The final arrangement of the building provides a 44-story, premium-grade office tower containing 55,963 square meters of office and 2,800 square meters of retail space. On the northeastern part of Levels 43 and 44, there is a single residential luxury apartment which is owned by the site's previous owner; the remaining floor area on these levels is plant room.

The building is divided into four groups, consisting of low-rise (Levels 5–14), mid-rise (16–25), high-rise (26–33), and sky-rise (34–42) floors (see Figure 1). Each group is served by dedicated elevators. Major air-handling plant rooms are located on the podium levels (1–3), Levels 14–15, and Levels 43–45.

The lower levels of the building comprise:

- Basements 1: Loading area, service rooms, and short-term parking
- Basements 2, 3, and 4: Long-term car parking, tenant facilities, and service rooms
- Pitt Street Level: Retail, foyer lobby, and vehicular access
- Castlereagh Street Level: Retail and foyer lobby

The floor plates are arranged to take advantage of the spectacular views across eastern Sydney harbor towards the open ocean. The architect achieved this by developing a triangular floor

plate, with the hypotenuse directed towards the harbor (see Figure 2). The remaining façades are separately articulated with rational rectilinear forms and align to the city's orthogonal grid (see Figure 3). The elevator shaft, amenities, and services risers are located on the southern façade.

A triangular structural element is located centrally on the floor and encloses the internal fire stairs and additional services riser space. The center core also accommodates the freight elevators. The building has been designed with a floor-to-floor height of just 3,700 millimeters for typical levels and 4,675 millimeters on the lower-level trading floors. The structural slab on each floor is designed to accommodate a 200-square-meter inter-floor void, should tenants require the construction of a communicating stair.

A key component of the development involved the enhancement of the public domain and provision of a new "pedestrian street," which provides a mid-block city link to connect to the wider city environs.

The site is an amalgamation of five sites, with frontages to both Castlereagh and Pitt streets. The Castlereagh Street frontage included Legion House and the adjacent Angus & Son Building, dating from 1902. Legion House was retained and refurbished, while the Angus & Son Building was demolished to allow for the through-site link.



Figure 3. Liberty Place development, Sydney. © Grocon Group

The planning of the foyer resolves a number of conflicting requirements, including negotiating level changes between the two streets without creating onerous access conditions, and differing tenant requirements for security control.

At the base of the tower is a retail complex of sunlit, public open spaces, with the new plaza and pedestrian lane connecting Castlereagh Street and Pitt Street. These landscaped spaces, ringed with café, restaurant, and bar opportunities, create an extension of the city into the heart of the development.

The floor plates are designed to maximize daylight, and accordingly the majority of the occupied space is no more than 12.5 meters from a glazed façade.

“As the Sydney electricity supply is primarily generated from black-coal-powered thermal power stations, the carbon content of the mains grid is high. The strategy to reduce carbon emissions substantially for this building was to minimize the consumption of mains electricity and, where possible, replace it with gas-fired equipment.”

Location	Glass Type/ Manufacturer	Visual Light Transmission	U-value (incl. Frame) (W/m <sup>2</sup> k) <sup>†</sup>	SHGC* (incl. frame)
Northeast façade	VNE 1-63 (Viracon): 6 / 12 Ar/ 10	62%	1.8	0.28
North & west elevations incl. the east & south reveals	CSG 6CET73-65: 6 / 12 Ar/ 10C	45%	1.7	0.22
South and east elevations	CSG 6CET73-65: 6 / 12 Ar/ 10C	45%	1.7	0.22
Recessed east, south & west elevation	CSG 6CED32-78: 6 / 12 Ar/ 10C	33%	1.8	0.25
Podium façade	CSG 6CET73-65: 6 / 12 Ar/ 10C	45%	1.7	0.22

\* Solar Heat Gain Coefficient (SHGC): Percentage of solar heat gain transmission through glass  
<sup>†</sup> Summer U-value

Table 1. Façade glazing performance.

### Thermal and Lighting Performance

High-performance façade design is a critical element of the green building design. Designed to maximize daylight while minimizing heat gain in summer, the façade consists of a curtain wall structure with full-height glazing on the east, northeast, north, and western orientations. The northeastern façade was provided with a deliberately higher visual light transmittance than the other façades, so as to accentuate the harbor vistas. This includes a 1,000-millimeter glazed insulated shadow box (spandrel zone) to the front of the slab edge, with a stack joint 250 millimeters above the finished floor level.

The façade incorporates thermal breaks to improve U-values, and reduce heat gain through the aluminum frames. Although this is standard practice in cold northern climates, this is not normal practice in the milder Sydney climate. The façade glazing performance is shown in Table 1.

Category	Available Points	Five-Star Strategy	Six-Star Strategy
Management	12	12	12
Indoor environmental quality	27	19	19
Energy	24	17	20
Transport	11	7	7
Water	13	10	11
Materials	14	8	12
Land use & ecology	8	2	4
Emissions	14	9	9
Innovation	5	0	2
<b>Total Weighted Points</b>	<b>100</b>	<b>68</b>	<b>77</b>
Target Points		60	75

Table 2. Green Star categories and rating strategy

Automatic internal blinds are provided to all elevations. The control strategy involves lowering the blinds when the incident solar radiation on glazing is higher than 400 W/m<sup>2</sup>, and raising them when the incident solar radiation on the glazing is lower than 400 W/m<sup>2</sup>.

The northeast façade is provided with two rows of external sunshades projecting 600 millimeters from the face of the glass, to address orientation, and which facilitate higher solar heat gain coefficient (SHGC) values.

### Green Building Response

The green building brief for the development was to achieve both a six-star Green Star rating and a five-star NABERS rating. The Green Star rating system for commercial buildings is based on achieving points under nine strategies. To achieve a five-star rating, a minimum of 60 points is required. To achieve a six-star rating, a minimum of 75 points is required (see Table 2).

The additional points needed to achieve World Leadership class (above a five-star rating) for this building were derived by implementing design strategies in the categories of energy, water, materials, and land use. Specifically, these additional points were from

- *Energy*: improving carbon emissions from 57 to 42 kgCO<sub>2</sub>/m<sup>2</sup>
- *Water*: improving water efficiency through increased rainwater harvesting potential
- *Materials*: implementation of an integrated

fit-out strategy for all new tenants, increasing the recycled content of concrete by an additional 20% to 40% of in-situ cement, plus the reduction of PVC by 60%.

- During the course of the demolition, the site was found to be contaminated with traces of lead, Polycyclic Aromatic Hydrocarbons, and Petroleum Hydrocarbons, which required remediation.

By far the biggest challenge was reducing the carbon emissions by a further 25%. This was mainly achieved through the implementation of low-static air handling systems, perimeter chilled beams, and the provision of a dedicated building tri-generation system.

As the Sydney electricity supply is primarily generated from black-coal-powered thermal power stations, the carbon content of the mains grid is high. The strategy to reduce carbon emissions substantially for this building was to minimize the consumption of mains electricity and, where possible, replace it with gas-fired equipment.

### Heating Ventilation and Air Conditioning

The Heating Ventilation and Air Conditioning (HVA) system consists of central chilled water and low-temperature hot-water systems serving variable volume air handling units and perimeter active chilled beams. The central base building chilled water HVAC system services the lobby, retail, and all the office tenancies from Level 5 to Level 42. The low-temperature Variable Air Volume system supplies 10°C air to the floors, allowing a reduced airflow to the central zones, while the active chilled beams on the perimeter provide higher-capacity cooling without the need to supply vast quantities of air to the façades. The air-handling systems are designed to overcome maximum total resistances of no more than 1,000 Pa at peak load, which includes losses in the air handling units, and the supply and return air paths. This reduced resistance has a consequence of larger air handling units and ductwork; however, as fans constitute one of the highest energy-consuming items in the Sydney climate; they provide an effective energy reduction strategy.

Dedicated water-cooled packaged air conditioning units serve areas that require air conditioning 24/7, such as communications rooms, control rooms, security room, elevator machine room, etc. By serving these units on a dedicated condenser water circuit, the necessity to operate the main central chilled water plant inefficiently during out-of-hours periods is avoided.

There are five water-cooled chillers serving the building. These consist of three high-efficiency electric chillers and two absorption chillers. The electrical chillers include one low-load chiller with a cooling capacity of 1,000 kW and two high-load chillers, each with a cooling capacity of 2,690 kW. The fourth and fifth chillers are each 319-kW absorption chillers, and are powered by the heat rejection of two gas-fired generators.

Each chiller is served by a dedicated primary chilled water pump and primary condenser water pump. Open-circuit cooling towers reject heat to the atmosphere and control return water temperature to maximize the chiller efficiency at all times. Cooling towers are controlled to operate on depressed wet bulbs, driving the condenser water temperature down and increasing the efficiency of the chiller units.

Heating is provided by means of two gas-fired boilers of 1,260 kW capacity and 85% efficiency each.

The air-conditioning system for the commercial offices consists of six Air-Handling Units (AHU) in the Level 43 plant room, serving high-rise floors, and six AHUs in the Level 14 plant room, serving low-, and mid-rise floors. Each of the AHUs serves a dedicated center or a dedicated perimeter zone, with the exception that east and south perimeter zones are served by one common AHU. The center zones are served by low-temperature VAV systems; perimeter zones are served by Active Chilled Beam systems. With each AHU serving a dedicated façade zone, the likelihood of any one AHU having to serve differing solar loads at any one time is minimized, thereby reducing the likelihood of a simultaneous heating/cooling requirement.

Each AHU is equipped with full outdoor-air economy-cycle operation and variable-speed drives. Motorized outside air dampers on each AHU are linked to a CO<sub>2</sub> monitoring and control system through the Building Management System (BMS). The minimum position of the outside air dampers corresponds to the minimum outside airflow rate of 11.25 L/s/person (a 50% improvement above Australian Standard AS1668.2-1991 requirements).

Sensors are located in each return air duct on every office floor to monitor the CO<sub>2</sub> concentration levels. A sample of all return air CO<sub>2</sub> sensor readings is used to control the AHUs' minimum outside air-damper position.

All HVAC pumps and cooling tower fans are equipped with variable-speed drives to respond to variations in load.

### Energy Generation

The tri-generation system uses gas to generate electricity, and then captures the excess heat for use as space heating, and for powering the absorption chillers. A tri-generation system can deliver an overall production energy efficiency of around 80%, compared to approximately 30% for grid-delivered electricity (see Figure 4). In addition, the

carbon emissions of the energy consumed are reduced by approximately 50%, due to the reduced carbon content of natural gas (0.23 kg CO<sub>2</sub>/kWh) when compared with thermal coal-powered power stations (0.94 kg CO<sub>2</sub>/kWh).

The generators and absorption chillers need to be carefully sized for commercial buildings. The capital cost of these assets is high, and so it is good business sense for them to operate for extended periods of time during any given year. Tri-generation systems need to be sized to meet not only the thermal demand but also the continuous electrical demand of the base building. The continuous electrical demand of the base building in this case was estimated to be in the order of only 800 kVA; when operating a tri-generator of this size, it was found that it would not provide the necessary carbon-emission reduction savings to achieve 42 kg CO<sub>2</sub>/m<sup>2</sup> for the NABERS five-star + 40% requirement and gain the 15 points for a Green Star six-star rating.

Two smaller 525 kVA tri-generation units were selected. However, as this selection of generators was larger than the minimum continuous electrical load, a control strategy was designed to sequence the generators so they could operate to include the load of some of the electrical chillers simultaneously.

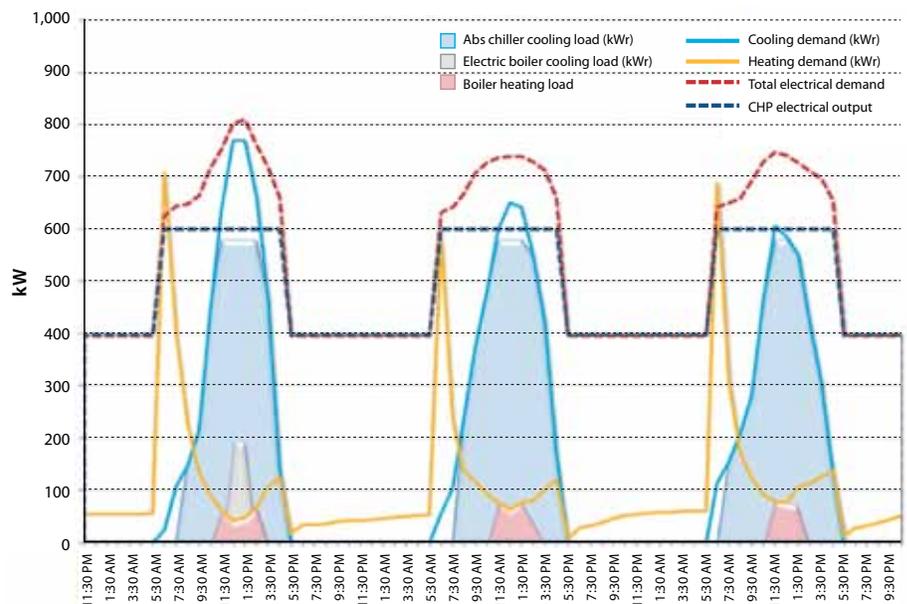


Figure 4. Tri-generation operation – typical August (winter) days.

**Electrical Design**

The mains utility power is obtained from the mains grid. Substations are located at Levels 1 and 14, supplying low-voltage power to their respective main switchboards.

Sufficient energy sub-metering is provided for calibrating substantive loads and tenancies to provide for a comprehensive energy metering system. All meters are connected to the BMS to provide an energy consumption monitoring system.

The BMS continually monitors and provides usable records of operational energy consumption by way of energy meters installed in key locations.

**Lighting**

The lighting power density across the tenant office floors is designed such that it does not exceed 2.0 W/m<sup>2</sup> per 100 Lux. In addition it is designed to achieve a lighting level of no less than 320 Lux and no more than 400 Lux at the working plane. To achieve these criteria and provide good uniformity, the lighting in the office areas generally consists of luminaires consisting of 1 x 35 WT5 linear fluorescent bulbs with high-frequency electronic ballasts.

An intelligent lighting control system is installed for both the base building house and tenant commercial areas. The intelligent lighting control system communicates via a high-level interface to the BMS.

The system incorporates manual-override push buttons within the core areas to switch individual zones of lighting. All individual or enclosed spaces will have individual light switches. Individually switched lighting zones do not exceed 100 square meters in area.

**Hydraulic Services**

The rainwater collection and reuse system collects water from roof areas, the plaza level, and fire flow-test into a central tank. The recycled water tank has a capacity of 382,200 L, with 150,000 L reserved for rainwater collection and reuse and 34,400 L for overflow rainwater. In addition, there are two reserve volumes of 123,000 L and 74,800 L for the collection of annual fire-flow test water and on-site detention (OSD) respectively.

The rainwater from the roof (1,900 square meters) and podium levels (1,900 square meters) is fed into the rainwater tank through a “first-flush” system for reuse. All subsoil drainage is pumped directly into the OSD component of the tank.

When the rainwater component of the tank fills, the water then cascades into the OSD component of the tank. The OSD is a walled section of the overall combined tank that is designed to cope with 1-in-100-year storm water events, without taking into consideration the rainwater tank. In other words, if the rainwater tank is full when a 1-in-100 storm event occurs, the OSD is capable of detaining the required amount of water.

The rainwater tank is also designed to receive the discharge water for the fire system as follows:

- Rainwater is collected and stored on-site, and is used to flush WCs and urinals from Level 25 and below. Potable water is used to flush the toilets from Level 26 to the roof. This constitutes 53% of WC and urinal usage within the building.
- Low-flow tapware is used throughout to minimize consumption.

**Building Energy Modelling**

Early in the design stage of the project, the building was modeled using IESVE software to determine the thermal and energy performance. The modeling simulated the building design, including all HVAC, electrical, hydraulic, and fire services within the building.

The energy modeling was undertaken and loads calculated on an hourly basis, which provided the ability to simulate the hourly performance of the building and the proposed tri-generation system (see Table 3). This method of hourly simulation analysis was used to optimize the tri-generation design and ultimately resulted in the selection of the two 525 kVA units and determined their control strategy.

When compared to the average building performance of many existing buildings of only 2.5 stars (equivalent benchmarking factor 150 kgCO<sub>2</sub>/m<sup>2</sup>/yr), the new Liberty Place develop-

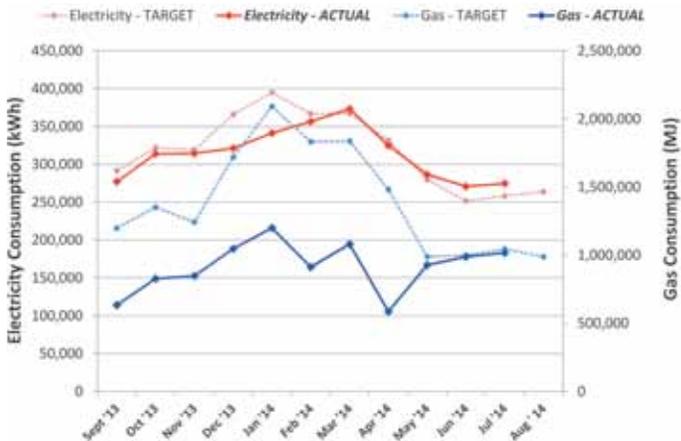


Figure 5. Actual vs. simulated monthly electricity and gas energy consumption



Figure 6. Actual monthly benchmark emissions vs. simulated NABERS benchmark emissions.

ment provides a clear example of how building engineering has improved in the last decade.

### Building Monitoring

As of August 2014, the building has been operating for just over 11 months, and monthly monitoring of the building's energy is being compared with the simulation modeling (see Figure 5).

The NABERS Energy rating scheme utilizes the Benchmark Factor as the indicator for performance. This Benchmark Factor is analogous to a benchmark greenhouse gas emission (normalized against occupancy hours, non-occupancy hours, and office area). Benchmark emissions have been used for this assessment, but are reported without units due to the measure not being representative of carbon equivalent emissions.

The simulated energy consumption used to calculate the benchmark emissions have been

End Energy Use	Total Electricity Use (kWh/year)	Total Gas Use (MJ/year)	Total Oil Use (L/year)
Space heating boilers	0	1,080,518	0
Chillers	535,861	0	0
AHU distribution fans	653,738	0	0
Chilled + Hot water pumps	322,858	0	0
Cooling tower fans & condenser water pumps	202,720	0	0
Auxiliary ventilation fans (car park, exhaust)	164,773	0	0
Common area lighting (including car park, outdoor)	388,224	0	0
Lifts	279,815	0	0
Domestic hot water	0	443,227	0
Tenant condenser water loop	122,807	0	0
Package unit	62,400	0	0
Gas and diesel generator testing & auxiliary power	70,080	0	11,135
Hydraulic and fire pumps	127,379	0	0
Miscellaneous non-tenant loads	55,963	0	0
Tri-generation plant	-1,399,143	13,952,302	0
<b>Total Energy Use</b>	<b>1,587,474</b>	<b>15,476,047</b>	<b>11,135</b>

Table 3. Energy consumption distribution.

adjusted based on the actual building net leased area, the after-hours air-conditioning use and the percentage of building occupancy (vacancy). The adjustment has been historically applied to the data for previous months of assessment.

Figure 6 demonstrates the monthly benchmark emissions calculated for the actual electricity and gas consumption, with the benchmark emissions calculated from the simulated NABERS energy consumption.

### Conclusion

The successful completion of the Liberty Place commercial development has demonstrated that there is a sound business case to design, build and operate a World Leadership-rated high-rise Green Building. This can be achieved without the necessity of incorporating expensive and/or complicated green initiatives, such as photovoltaic arrays, wind turbines, sewage recycling plants, etc.

Even though the installation of a tri-generation system increases the energy consumption significantly by up to 73%, the overall best-case simulated target greenhouse gas consumption of the development can be demonstrated to be significantly reduced by 14%. This is mainly due to the efficiency of the tri-generation process and the cleanliness of the fuel when compared that used to power the Sydney electricity grid.

Figure 7 demonstrates the actual performance of the building when compared to 135 other NABERS energy-rated buildings in Sydney. Performance values of these 135 buildings do not include the purchase of Green Power, which owners may choose to do to improve their buildings' NABERS ratings. Out of all of the NABERS energy-rated buildings listed in the Sydney CBD, Liberty Place is one of the six lowest carbon-emitting buildings currently operating. This exercise demonstrates that tall buildings are not necessarily higher in energy consumption than lower-rise buildings.

The up-scaling of the ANZ Tower's environmental Green Star performance from five to six stars has resulted in a better building for all concerned, not least for the tenants and the building owner. The building is not only demonstrating significantly more carbon-efficient operation; the strategy to achieve a six-star rating has also resulted in improved water efficiency and promoted the use of construction materials that have a lower impact on the environment. ■

*Unless otherwise noted, all photography credits in this paper are to AECOM.*

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Grocon Group  
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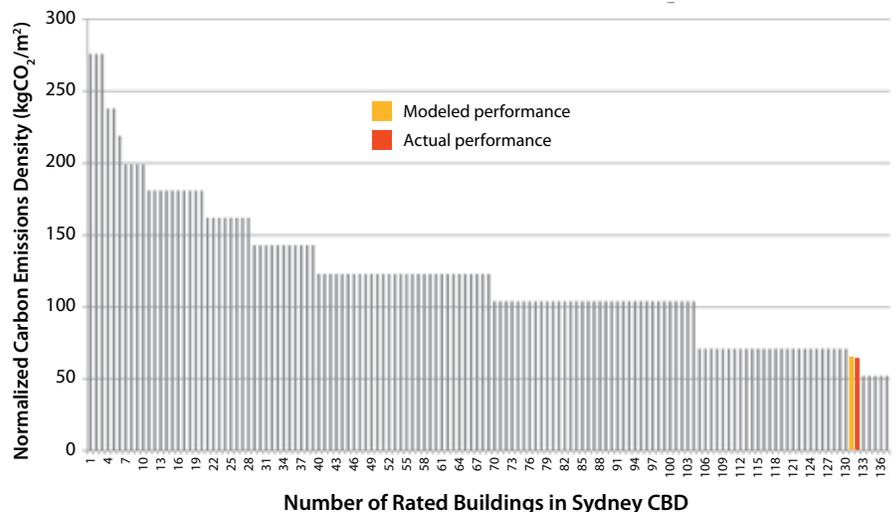


Figure 7. Carbon emissions for 136 officially rated commercial office buildings in Sydney including Liberty Place.